Prepared for the Committee by the Agricultural Research Service

United States Department of Agriculture

United States Department of Health and Human Services

May 2010

Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans, 2010

To the Secretary of Agriculture and the Secretary of Health and Human Services

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May 2010

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DEPARTMENT OF AGRICULTURE **DEPARTMENT OF HEALTH AND HUMAN SERVICES**

May 28, 2010

The Honorable Thomas J. Vilsack
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Washington DC, 20250

The Honorable Kathleen Sebelius
Secretary of Health and Human Services
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Washington DC, 20201

Dear Secretaries Vilsack and Sebelius,

It is my privilege to present to you on behalf of the entire 2010 U.S. Dietary Guidelines Advisory Committee the full Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans, 2010. In the initial charge to this panel, we were asked to "provide science-based advice for Americans, in order to promote health and to reduce the risk for major chronic diseases through diet and physical activity." More specifically, this involved, among other tasks, that we base our Report upon "the preponderance of the most current scientific and medical knowledge, and determine what issues for change need to be addressed," with a "primary focus on the review of scientific evidence published since the last DGAC deliberations" and place "primary emphasis on the development of food-based recommendations." We attended to each of these objectives and much more during the past 20 months and we are in consensus and committed to the content and recommendations delineated in the enclosed Report.

It has been a remarkable journey, filled with extensive investigation and critical evidence-based review, covering relevant aspects of diet and health. Just under 200 specific questions related to dietary guidance were initially identified and most were addressed. With assistance from the USDA Nutrition Evidence Library (NEL), and additional hand searches involving other extensive databases, the Committee formulated answers to the questions that it believes reflect the most current scientific evidence. In addition to the expertise represented by our members, we had the outstanding and able assistance of Dietary Guidelines Management Team staff members from both USDA and HHS, without whom this task would have been impossible. We also appreciate crucial input from the Federal staff from both USDA and HHS who each deserve recognition for their invaluable contributions.

The single most sobering aspect of this Report is the recognition that we are addressing an overweight and obese American population. Across all age, gender and ethnic groups, it is clear that urgent and systems-wide efforts are needed to address America's obesity epidemic as top priority. Everything within this Report is presented through the filter of an obesegenic environment in critical need of change. This is especially true in regard to American children whose incidence of obesity has tripled in the past five years. This desperately requires an all out effort to improve diet and physical activity behaviors across the country. The Committee is united in its resolve to provide recommendations that halt and reverse this rampant epidemic. This will require extensive collaboration and implementation of a unified effort to help reduce calorie intake, increase physical activity output and enhance the overall nutrient density of dietary intake. While the research evidence is now substantial and detailed in most cases, there remain gaps in the science that required us to use clinical judgment to help reconcile some of these missing pieces in order to provide reasonable recommendations on the basis of combined knowledge and data. In these cases, the assistance of food pattern modeling, contributed specifically by the highly capable team at the Center for Nutrition Policy and Promotion, provided those necessary translational linkages when epidemiologic data were unavailable.

In this regard, we encourage you to do everything possible to increase funding for greatly needed research studies on numerous, important and highly strategic nutrition issues raised throughout this Report. Specifically, in ultimately drafting our conclusion statements, the DGAC was struck by the number of questions that simply could not be addressed due to the absence of data or limitations due to inconclusive findings. Likewise, we urge you to further emphasize the importance of keeping current with the ongoing National Health and Nutrition Examination Survey (NHANES) data. The 2015 DGAC should be provided with the opportunity to study the impact of the 2010 Report by having access to the most current, accurate and detailed NHANES nutrient data available at that time. Steps should be taken to update these data as quickly as possible in order to maintain an accurate and ongoing view of America's dietary intake. In addition, the time has come to consider including all Americans, from birth on, as part of these results since research increasingly points to the importance of diet, even in utero, in shaping future health. Subsequent reports should include a focus on pregnancy, breastfeeding behavior and early diet from birth on.

In summary, every member of this Committee has worked diligently, collaboratively and tirelessly to produce this landmark Report. When differences of interpretation were debated from time to time, the mutual respect and admiration expressed for each and every member of this group has been nothing short of inspirational. The Committee looks forward to seeing the final Report become available online, as well as the subsequent documents, discussion and translational tools that will surely be generated. Thank you for your steadfast support, enthusiasm and recognition. We remain encouraged and hopeful that the American public will take these recommendations to heart and benefit extensively from their implementation.

Sincerely,

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Part A: Executive Summary

The 2010 Dietary Guidelines Advisory Committee (DGAC) was established jointly by the Secretaries of U.S. Department of Agriculture (USDA) and the U.S. Department of Health and Human Services (HHS). The Committee's task was to advise the Secretaries of USDA and HHS on whether revisions to the 2005 *Dietary Guidelines* were warranted, and if so, to recommend updates to the Guidelines. The DGAC immediately recognized that, on the basis of the vast amount of published research and emerging science on numerous relevant topics, an updated report was indeed needed.

The 2010 DGAC Report is distinctly different from previous reports in several ways. First, it addresses an American public of whom the majority are overweight or obese and yet under-nourished in several key nutrients. Second, the Committee used a newly developed, state-of-the-art, web-based electronic system and methodology, known as the Nutrition Evidence Library (NEL), to answer the majority of the scientific questions it posed. The remaining questions were answered by data analyses, food pattern modeling analyses, and consideration of other evidence-based reviews or existing reports, including the 2008 *Physical Activity Guidelines for Americans*. The 2005 *Dietary Guidelines* for Americans were the starting place for most reviews. If little or no scientific literature had been published on a specific topic since the 2005 Report was presented, the DGAC indicated this and established the conclusions accordingly.

A third distinctive feature of this Report is the introduction of two newly developed chapters. The first of these chapters considers the total diet and how to integrate all of the Report's nutrient and energy recommendations into practical terms that encourage personal choice but result in an eating pattern that is nutrient dense and calorie balanced. The second chapter complements this total diet approach by integrating and translating the scientific conclusions reached at the individual level to encompass the broader environmental and societal aspects that are crucial to full adoption and successful implementation of these recommendations.

The remainder of this Executive Summary provides brief synopses of these and all of the other chapters, which review current evidence related to specific topics and present the resulting highlights that comprise the fundamental essence of this report.

Major Cross-cutting Findings and Recommendations

Total Diet: Combining Nutrients, Consuming Foods

The 2010 DGAC Report concludes that good health and optimal functionality across the lifespan are achievable goals but require a lifestyle approach including a total diet that is energy balanced and nutrient dense. Now, as in the past, a disconnect exists between dietary recommendations and what Americans actually consume. On average, Americans of all ages consume too few vegetables, fruits, high-fiber whole grains, low-fat milk and milk products, and seafood and they eat too much added sugars, solid fats, refined grains, and sodium. SoFAS (added sugars and solid fats) contribute approximately 35 percent of calories to the American diet. This is true for children, adolescents, adults, and older adults and for both males and females. Reducing the intake of SoFAS can lead to a badly needed reduction in energy intake and inclusion of more healthful foods into the total diet.

The diet recommended in this Report is not a rigid prescription. Rather, it is a flexible approach that incorporates a wide range of individual tastes and food preferences. Accumulating evidence documents that certain dietary patterns consumed around the world are associated with beneficial health outcomes. Patterns of eating that have been shown to be healthful include the Dietary Approaches to Stop Hypertension (DASH)-style dietary patterns and certain Mediterranean-style dietary patterns. Similarly, the USDA Food Patterns illustrate that both nutrient adequacy and moderation goals can be met in a variety of ways. The daunting public health challenge is to accomplish population-wide adoption of healthful dietary patterns within the context of powerful influences that currently promote unhealthy consumer choices, behaviors, and lifestyles.

Translating and Integrating the Evidence: A Call to Action

Complementing the Total Diet chapter, this chapter describes the four major findings that emerged from the DGAC's review of the scientific evidence and articulates steps that can be taken to help all Americans adopt health-promoting nutrition and physical activity guidelines:

- Reduce the incidence and prevalence of overweight and obesity of the U.S. population by reducing overall calorie intake and increasing physical activity.
- Shift food intake patterns to a more plant-based diet that emphasizes vegetables, cooked dry beans and peas, fruits, whole grains, nuts, and seeds. In addition, increase the intake of seafood and fat-free and low-fat milk and milk products and consume only moderate amounts of lean meats, poultry, and eggs.
- Significantly reduce intake of foods containing added sugars and solid fats because these dietary components contribute excess calories and few, if any, nutrients. In addition, reduce sodium intake and lower intake of refined grains, especially refined grains that are coupled with added sugar, solid fat, and sodium.
- Meet the 2008 *Physical Activity Guidelines for Americans*.

The 2010 DGAC recognizes that substantial barriers make it difficult for Americans to accomplish these goals. Ensuring that all Americans consume a health-promoting dietary pattern and achieve and maintain energy balance requires far more than individual behavior change. A multi-sectoral strategy is imperative. For this reason, the 2010 DGAC strongly recommends that USDA and HHS convene appropriate committees, potentially through the Institute of Medicine (IOM), to develop strategic plans focusing on the actions needed to successfully implement key 2010 DGAC recommendations. Separate committees may be necessary because the actions needed to implement key recommendations likely differ by goal.

A coordinated strategic plan that includes all sectors of society, including individuals, families, educators, communities, physicians and allied health professionals, public health advocates, policy makers, scientists, and small and large businesses (e.g., farmers, agricultural producers, food scientists, food manufacturers, and food retailers of all kinds), should be engaged in the development and ultimate implementation of a plan to help all Americans eat well, be physically active, and maintain good health and function. It is important that any strategic plan is evidence-informed, action-oriented, and focused on changes in systems in these sectors.

Any and all systems-based strategies must include a focus on children. Primary prevention of obesity must begin in childhood. This is the single most powerful public health approach to combating and reversing America's obesity epidemic over the long term.

Strategies to help Americans change their dietary intake patterns and be physically active also will go a long way to ameliorating the disparities in health among racial and ethnic minorities and among different socioeconomic groups, which have been recognized as a significant concern for decades. While the reasons for these differences are complex and multifactorial, this Report addresses research indicating that certain dietary changes can provide a means to reduce health disparities.

Change is needed in the overall food environment to support the efforts of all Americans to meet the key recommendations of the 2010 DGAC. To meet these challenges, the following sustainable changes must occur:

- Improve nutrition literacy and cooking skills, including safe food handling skills, and empower and motivate the population, especially families with children, to prepare and consume healthy foods at home.
- Increase comprehensive health, nutrition, and physical education programs and curricula in U.S. schools and preschools, including food preparation, food safety, cooking, and physical education classes and improved quality of recess.
- For all Americans, especially those of low income, create greater financial incentives to purchase, prepare, and consume vegetables and fruit, whole grains, seafood, fat-free and low-fat milk and milk products, lean meats, and other healthy foods.
- Improve the availability of affordable fresh produce through greater access to grocery stores, produce trucks, and farmers' markets.
- Increase environmentally sustainable production of vegetables, fruits, and fiber-rich whole grains.
- Ensure household food security through measures that provide access to adequate amounts of foods that are nutritious and safe to eat.

- Develop safe, effective, and sustainable practices to expand aquaculture and increase the availability of seafood to all segments of the population. Enhance access to publicly available, user-friendly benefit/risk information that helps consumers make informed seafood choices.
- Encourage restaurants and the food industry to offer health-promoting foods that are low in sodium; limited in added sugars, refined grains, and solid fats; and served in smaller portions.
- Implement the U.S. National Physical Activity Plan, a private-public sector collaborative promoting local, state, and national programs and policies to increase physical activity and reduce sedentary activity (http://www.physicalactivityplan.org/index.htm). Through the Plan and other initiatives, develop efforts across all sectors of society, including health care and public health; education; business and industry; mass media; parks, recreation, fitness, and sports; transportation; land use; community design; and volunteer and non-profit. Reducing screen time, especially television, for all Americans also will be important.

Topic-specific Findings and Conclusions

Energy Balance and Weight Management

The prevalence of overweight and obesity in the U.S. has increased dramatically in the past three decades. This is true of children, adolescents, and adults and is more severe in minority groups. The American environment is conducive to this epidemic, presenting temptation to the populace in the form of tasty, energy-dense, micronutrient-poor foods and beverages. The macronutrient distribution of a person's diet is not the driving force behind the current obesity epidemic. Rather, it is the over-consumption of total calories coupled with very low physical activity and too much sedentary time. The energy density of foods eaten is an important factor in overeating. Americans eat too many calories from foods high in SoFAS that offer few or no other nutrients besides calories. This is true not only for adults but also for children, who consume energy-dense SoFAS, especially in the form of sugar-sweetened beverages, at levels substantially higher than required to maintain themselves at a normal weight as they grow.

With regard to special subgroups, maternal obesity before pregnancy and excessive weight gain during pregnancy are deleterious for the mother and the fetus. One-fifth of American women are obese when they become pregnant, often put on much more weight than is healthy during pregnancy, and have trouble losing it after delivery, placing their offspring at increased risk of obesity and type 2 diabetes (T2D) later in life. Breastfeeding has no sustained impact on maternal weight gain or loss, but has numerous benefits for mother and infant and should be encouraged.

Older overweight or obese adults can derive as much benefit from losing weight and keeping it off as do younger persons, with resulting improvements in quality of life, including diminished disabilities and lower risks of chronic diseases.

Selected behaviors that lead to a greater propensity to gain weight include too much TV watching, too little physical activity, eating out frequently (especially at quick service restaurants [i.e., fast food restaurants]), snacking on energy-dense food and drinks, skipping breakfast, and consuming large portions. Self-monitoring, including knowing one's own calorie requirement and the calorie content of foods, helps make individuals conscious of what, when, and how much they eat. Mindful, or conscious, eating is an important lifestyle habit that can help to prevent inappropriate weight gain, enhance weight loss in those who should lose weight, and assist others in maintaining a healthy weight.

Nutrient Adequacy

Americans are encouraged to lower overall energy intakes to match their energy needs. Energy-dense forms of foods, especially foods high in SoFAS, should be replaced with nutrient-dense forms of vegetables, fruits, whole grains, and fluid milk and milk products to increase intakes of shortfall nutrients and nutrients of concern—vitamin D, calcium, potassium, and dietary fiber. Women of reproductive capacity should consume foods rich in folate and iron, and older individuals should consume fortified foods rich in vitamin B_{12} or B_{12} supplements, if needs cannot be met through whole foods. Nutritious breakfast consumption and in some cases nutrient-dense snacking may assist in meeting nutrient recommendations, especially in certain subgroups.

A daily multivitamin/mineral supplement does not offer health benefits to healthy Americans. Individual mineral/vitamin supplements can benefit some population groups with known deficiencies, such as calcium and vitamin D supplements to reduce risk of osteoporosis or iron supplements among those with deficient iron intakes. However, in some settings, mineral/vitamin supplements have been associated with harmful effects and should be pursued cautiously.

Fatty Acids and Cholesterol

Intakes of dietary fatty acids and cholesterol are major determinants of cardiovascular disease (CVD) and T2D, two major causes of morbidity and mortality in Americans. Fats contribute 9 calories per gram. The health impacts of dietary fats and cholesterol are mediated through levels of serum lipids, lipoproteins, and other intermediate markers. The U.S. consumption of harmful types and amounts of fatty acids and cholesterol has not changed appreciably since 1990.

In order to reduce the population's burden from CVD and T2D and their risk factors, the preponderance of the evidence indicates beneficial health effects are associated with several changes in consumption of dietary fats and cholesterol. These include limiting saturated fatty acid intake to less than 7 percent of total calories and substituting instead food sources of mono- or polyunsaturated fatty acids. As an interim step toward achieving this goal, individuals should first aim to consume less than 10 percent of energy as saturated fats and gradually reduce intake over time, while increasing polyunsaturated and monounsaturated sources. Other beneficial changes include limiting dietary cholesterol to less than 300 milligrams per day, but aiming at further reductions of dietary cholesterol to less than 200 milligrams per day in persons with or at high risk for CVD or T2D, and limiting cholesterol-raising fats (saturated fats exclusive of stearic acid and *trans* fatty acids) to less than 5 to 7 percent of energy.

Beneficial changes also include avoiding *trans* fatty acids from industrial sources in the American diet, leaving small amounts (<0.5% of calories) from *trans* fatty acids from natural (ruminant) sources, and consuming two servings of seafood per week (4 oz cooked, edible seafood per serving) that provide an average of 250 milligrams per day of *n*-3 fatty acids from marine sources (i.e., docosahexaenoic acid [DHA] and eicosapentaenoic acid [EPA]). Ensuring maternal dietary intake of long chain *n*-3 fatty acids, in particular DHA, during pregnancy and lactation through two or more servings of seafood per week also has benefits for the infant, especially when women emphasize types of seafood high in *n*-3 fatty acids and with low methyl mercury content.

Protein

Proteins are unique because they provide both essential amino acids to build body proteins and are a calorie source. Protein contributes 4 calories per gram. Because protein requirements are based on ideal body weight (0.8 g protein/kg body weight/day for ages 19 years and older), lower-calorie diets result in a higher percentage of protein intake. Animal sources of protein, including meat, poultry, seafood, milk, and eggs, are the highest quality proteins. Plant proteins can be combined to form complete proteins if combinations of legumes and grains are consumed. Plant-based diets are able to meet protein requirements for essential amino acids through planning and offer other potential benefits, such as sources of fiber and nutrients important in a health-promoting diet.

Carbohydrates

Carbohydrates contribute 4 calories per gram and are the primary energy source for active people. Sedentary people, including most Americans, should decrease consumption of energy-dense carbohydrates, especially refined, sugar-dense sources, to balance energy needs and attain and maintain ideal weight. Americans should choose fiber-rich carbohydrate foods such as whole grains, vegetables, fruits, and cooked dry beans and peas as staples in the diet. Low-fat and fat-free milk and milk products are also nutrient-dense sources of carbohydrates in the diet and provide high-quality protein, vitamins, and minerals. High-energy, non-nutrient-dense carbohydrate sources that should be reduced to aid in calorie control include sugar-sweetened beverages; desserts, including grain-based desserts; and grain products and other carbohydrate foods and drinks that are low in nutrients.

Sodium, Potassium, and Water

At present, Americans consume excessive amounts of sodium and insufficient amounts of potassium. The health consequences of excessive sodium and insufficient potassium are substantial and include increased levels of blood pressure and its consequences (heart disease and stroke). In 2005, the DGAC recommended a daily sodium intake of less than 2300 milligrams for the general adult population and stated that hypertensive individuals, Blacks, and middle-aged and older adults would benefit from reducing their sodium intake even further to 1500 milligrams per day. Because these latter groups together now comprise nearly 70 percent of U.S. adults, the goal should be

1500 milligrams per day for the general population. Given the current U.S. marketplace and the resulting excessively high sodium intake, it will be challenging to achieve the lower level. In addition, time is required to adjust taste perception in the general population. Thus, the reduction from 2300 milligrams to 1500 milligrams per day should occur gradually over time. Because early stages of blood pressure-related atherosclerotic disease begin during childhood, both children and adults should reduce their sodium intake.

Individuals also should increase their consumption of dietary potassium because increased potassium intake helps to attenuate the effects of sodium on blood pressure. Water is needed to sustain life. However, there is no evidence, except under unusual circumstances, that water intake among Americans is either excessive or insufficient.

Alcohol

An average daily intake of one to two alcoholic beverages is associated with the lowest all-cause mortality and a low risk of diabetes and coronary heart disease among middle-aged and older adults. Despite this overall benefit of moderate alcohol consumption, the DGAC recommends that if alcohol is consumed, it should be consumed in moderation, and only by adults. Moderate alcohol consumption is defined as average daily consumption of up to one drink per day for women and up to two drinks per day for men, with no more than three drinks in any single day for women and no more than four drinks in any single day for men. One drink is defined as 12 fluid ounces of regular beer, 5 fluid ounces of wine, or 1.5 fluid ounces of distilled spirits.

The DGAC found strong evidence that heavy consumption of four or more drinks a day for women and five or more drinks a day for men has harmful health effects. A number of situations and conditions call for the complete avoidance of alcoholic beverages.

Food Safety and Technology

Since the release of the 2005 *Dietary Guidelines*, food safety concerns have escalated, with the apparent increase in voluntary recalls of foods contaminated with disease-causing bacteria and adulterated with non-food substances. These food safety issues affect commercial food products and food preparation in the home.

The basic four food safety principles identified to reduce the risk of foodborne illnesses remain unchanged. These principles are Clean, Separate, Cook, and Chill. Consumers must take more responsibility for carrying out these essential food safety practices. These actions, in tandem with sound government policies and responsible food industry practices, can help prevent foodborne illness. Even with current and future introductions of food safety technologies, food safety fundamentals in the home remain foundational.

The health benefits from consuming a variety of cooked seafood outweigh the risks associated with exposure to methyl mercury and persistent organic pollutants, provided that the types and sources of seafood to be avoided by some consumers are clearly communicated to consumers. Overall, consumers can safely eat at least 12 ounces of a variety of cooked seafood per week provided they pay attention to local seafood advisories and limit their intake of large, predatory fish. Women who may become or who are pregnant, nursing mothers, and children ages 12 and younger can safely consume a variety of cooked seafood in amounts recommended by this Committee while following Federal and local advisories.

Conclusion

The 2010 DGAC recognizes the significant challenges involved in implementing the goals outlined in this Report. The challenges go beyond cost, economic interests, technological and societal changes, and agricultural limitations, but together, stakeholders and the public can make a difference. We must value preparing and enjoying healthy food and the practices of good nutrition, physical activity, and a healthy lifestyle. The DGAC encourages all stakeholders to take actions to make every choice available to Americans a healthy choice. To move toward this vision, all segments of society—from parents to policy makers and everyone else in between—must now take responsibility and play a leadership role in creating gradual and steady change to help current and future generations live healthy and productive lives. A measure of success will be evidence that meaningful change has occurred when the 2015 DGAC convenes.

Part B: Section 1: Introduction

Since first published in 1980, the *Dietary Guidelines for Americans* have provided science-based advice to promote health and reduce risk of major chronic diseases through optimal diet and regular physical activity. The *Dietary Guidelines* have traditionally targeted the healthy general public older than age 2 years, but as data continue to accumulate regarding the importance of dietary intake during gestation and from birth on, it also will become important to consider those younger than age 2 years in future Guidelines. Because of their focus on health promotion and risk reduction, the *Dietary Guidelines* form the basis of Federal food, nutrition education, and information programs.

By law (Public Law 101-445, Title III, 7 U.S.C. 5301 et seq.), the most recent edition of the *Dietary Guidelines* is reviewed by a committee of experts, updated if necessary, and published every 5 years. The legislation also requires that the Secretaries of the U.S. Department of Agriculture (USDA) and U.S. Department of Health and Human Services (HHS) review all Federal publications for the general public containing dietary guidance information for consistency with the *Dietary Guidelines for Americans*. This Report presents the recommendations of the 2010 Dietary Guidelines Advisory Committee (DGAC) to the Secretaries of USDA and HHS for use in updating the Guidelines.

The 2010 DGAC Report is unprecedented in addressing an American public, two-thirds of whom are overweight or obese. Americans are making dietary choices in a highly obesogenic environment and at a time of burgeoning diet-related chronic diseases affecting people of all ages, ethnic backgrounds, and socioeconomic levels. The DGAC considers the obesity epidemic to be the single greatest threat to public health in this century. This Report is therefore focused on evidence-based guidelines and recommendations that are considered effective and useful in halting and reversing the obesity problem through primary prevention and changes in behavior, the environment, and the food supply.

The Role of Diet and Physical Activity in Health Promotion: Attenuating Chronic Disease Risks

A large proportion of deaths each year in the United States (U.S.) result from a limited number of preventable and modifiable factors. The leading causes of death for the past two decades have been tobacco use and poor diet and physical inactivity (McGinnis, 1993; Mokdad, 2004). The number of deaths related to poor diet and physical inactivity is increasing and may soon overtake tobacco as the leading cause of death. As discussed in this Report, poor dietary intake has been linked to excess body weight and numerous diseases and conditions, such as cardiovascular disease (CVD) and type 2 diabetes (T2D) and their related risk factors. Even if the overweight/obesity epidemic resolves, the problems of chronic disease would continue to be a major health problem because poor-quality diets, even in the absence of overweight/obesity, increase the risk some of our most common chronic diseases.

The reduction of chronic disease risk merits strong emphasis in our Nation for many reasons, especially because some groups in the population bear a disproportionate burden of chronic disease and attendant risk factors. The present Report highlights the evidence that links diet and different chronic diseases. It also summarizes and synthesizes knowledge regarding many individual nutrients and food components into recommendations for an overall total pattern of eating that can be adopted by the public. Although adherence to the *Dietary Guidelines* is low among the U.S. population, evidence is accumulating that selecting diets that comply with the Guidelines reduces the risk of chronic disease and promotes health. Ultimately, individuals choose the types and amount of food they eat and the amount of physical activity they perform, but the current environment significantly enhances the overconsumption of calories and discourages the expenditure of energy. Both sides of this equation are discussed in greater detail throughout the Report.

Population Groups of Particular Concern

The *Dietary Guidelines for Americans* has traditionally provided guidance to healthy Americans. However, the 2010 DGAC recognizes that a large percentage of the American population now has diet-related chronic diseases or risk factors for them, and has accommodated this reality in its review of the evidence. Much of the evidence the Committee reviewed pertains to adults. However, given the importance of nutrition across the lifespan and the rapidly growing scientific literature on diet and children's health, several sections of the Report focus particular attention on this important population group. In addition, the Committee presents reviews of evidence on several questions pertaining to pregnant and lactating women and to older adults.

Children

Increasingly, studies are addressing the role of nutrition and physical activity in promoting health in children. A nutrient-dense, high-quality diet, sufficient but not excessive in calories, and regular daily physical activity are integral to promoting the optimal health, growth, and development of children. For example, the rapid rates of growth occurring during adolescence increase the need for dietary sources of iron and calcium during that period to higher amounts per 1000 calories than required at any other stage of life.

Evidence documents the importance of optimal nutrition starting during the fetal period through childhood and adolescence because this has a substantial influence on the risk of chronic disease with age (Warner, 2010). Eating patterns established during childhood often are carried into adulthood (Aggett, 1994). For example, those who consume fruits and vegetables or milk regularly as children are more likely to do so as adults (Aggett, 1994).

Today, too many children are consuming diets with too many calories and not enough nutrients, and they are not getting enough physical activity (less than half of children age 12 to 21 years exercise on a daily basis [HHS, 1996]). As a result, chronic disease risk factors, such as glucose intolerance and hypertension, which were once unheard of in childhood, are now increasingly common. T2D now accounts for up to 50 percent of new cases of diabetes among youths. One in 400 youths will have T2D by age 20 years. Excess weight, particularly around the abdomen, as well as too little physical activity, appears to be the basis for developing this disease early in life.

Pregnant and Lactating Women

Both pregnancy and lactation are critical periods during which maternal nutrition is a key factor influencing the health of both child and mother. Energy as well as protein and several mineral and vitamin requirements increase substantially during pregnancy, making the pregnant woman's dietary choices critically important (Christian, 2010; Institute of Medicine [IOM], 1991; IOM, 2002; Picciano, 2003).

However, excess energy intake during pregnancy has become a major concern. Growing evidence indicates that overnutrition leading to unhealthy weight gain during pregnancy may greatly predispose the child to obesity. Insufficient micronutrient intake also continues to be a concern. For example, sufficient intake of folic acid, which is especially important for normal development of the embryo and fetus, is critical during the entire periconceptional period. Dietary factors also may contribute to impaired glucose tolerance, a common disorder of pregnancy that influences fetal growth and outcomes (Clapp, 1998; Saldana, 2004). Dietary contaminants, such as methyl mercury, may adversely affect fetal growth. Maternal diet, especially the intake of certain vitamins and alcoholic beverages, also may influence breast milk composition (Dewey, 1999; IOM, 1991).

Older Adults

The *65+ in the United States: 2005 Report* noted that the U.S. population aged 65 years and older is expected to double in size within the next 25 years (He, 2005). By 2030, it is projected that one in five people will be older than age 65 years. Individuals age 85 years and older are the fastest growing segment of the older population. In 2011, the "baby boom" generation will begin to turn 65. As the number of older Americans increases, the role of diet quality and physical activity in reducing the progression of chronic disease will become increasingly important. The health of older Americans is improving, but many are disabled and suffer from chronic conditions. The proportion with a disability fell significantly from 26.2 percent in 1982 to 19.7 percent in 1999 (Manton, 2001), yet 14 million people age 65 years and older reported some level of disability in Census 2000, mostly linked to a high prevalence of chronic conditions, such as CVD, T2D, hypertension, or arthritis.

The process of aging can influence how nutrients are used and can exacerbate the effect of poor diet quality on health. For example, aging may reduce nutrient absorption, increase urinary nutrient loss, and alter normal pathways of nutrient metabolism. These changes associated with aging can be compensated to some extent by a nutrient-dense diet that remains within calorie needs. Most important, modifications of diet and increases in physical activity have tremendous potential as a means to prevent or delay chronic disease in older persons. Older individuals achieve, in many instances, greater benefit from a given improvement in diet than do younger individuals (e.g., older individuals tend to be more responsive to the blood pressure-lowering effects of reducing salt intake) or from an increase in physical activity. As with children, adolescents, and younger adults, data comparing people aged 65 to 74 years in 1988-1994 and 1999-2000 show a startling rise in the percentage of obese older adults. In men, the proportion grew from about 24 to 33 percent and in women from about 27 percent to 39 percent (He, 2005). Furthermore, available data have repeatedly documented that older-aged persons can make and sustain behavior change, more so than their younger counterparts (The Diabetes Prevention Program [DPP], 2002, 2009; Whelton, 1997). Such results highlight the importance of encouraging dietary changes throughout the lifespan, including older-aged persons.

Changes in Diet and Physical Activity as a Means to Reduce Health Disparities

Of substantial concern are disparities in health among racial and ethnic minorities and among different socioeconomic groups. For example, Blacks have a higher prevalence of elevated blood pressure and a greater incidence of blood pressure-related diseases, such as stroke and kidney failure, than do non-Blacks (DGAC, 2004). Also, several subgroups of the population (e.g., Mexican-Americans, American Indians, and Blacks) have a strikingly high prevalence of overweight and obesity, even beyond that of the already high prevalence rates observed in the general population. Furthermore, it is well-recognized that individuals of lower socioeconomic status have a higher incidence of adverse health outcomes than do individuals of higher socioeconomic status. Dietary patterns differ among different groups, with individuals of lower education and income consuming fewer servings of vegetables and fruit than those with more education and higher income (USDA, 2004). While the reasons for such disparities are complex and multi-factorial, available research is sufficient to advocate certain dietary changes and increased physical activity as a means to reduce disparities.

The effects on blood pressure of a reduced sodium intake, increased potassium intake, and an overall healthy dietary pattern provide an example of how dietary changes could reduce health disparities. Although both Blacks and non-Blacks consume excess sodium, Blacks tend to be more sensitive to the effects of sodium than are non-Blacks. Likewise, Blacks tend to be more sensitive to the blood pressure-lowering effects of increased potassium intake. Ironically, the average potassium intake of Blacks is less than that of non-Blacks. The Dietary Approaches to Stop Hypertension (DASH) diet, an example of a healthy dietary pattern that emphasizes vegetables and fruits, has been shown in clinical trials to lower blood pressure to a greater extent in Blacks than in non-Blacks. Yet, Blacks tend to consume fewer fruits and vegetables than do non-Blacks.

Such evidence exemplifies important, yet underappreciated, opportunities to reduce health disparities through dietary changes.

From the 2010 DGAC Report to the Dietary Guidelines for Americans

A major goal of the 2010 DGAC is to summarize and synthesize the evidence to support USDA and HHS in developing nutrition recommendations that reduce the risk of chronic disease while meeting nutrient requirements and promoting health for all Americans.

The U.S. Government uses the *Dietary Guidelines* as the basis of its food assistance programs, nutrition education efforts, and decisions about national health objectives. For example, the National School Lunch Program and the Elderly Nutrition Program incorporate the *Dietary Guidelines* in menu planning; the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) applies the *Dietary Guidelines* in its educational materials; and the Healthy People 2010 Objectives for the Nation include objectives based on the *Dietary Guidelines*. The evidence described here in the 2010 DGAC Report, which will be used to develop the 2010 *Dietary Guidelines for Americans*, will help policymakers, educators, clinicians, and others speak with one voice on nutrition and health and reduce the confusion caused by mixed messages in the media. The DGAC also hopes that the 2010 *Dietary Guidelines for Americans* will encourage the food industry to grow, manufacture, and sell foods that promote health and contribute to appropriate energy balance.

A Guide to the 2010 DGAC Report

This report contains several major components. Part A provides an Executive Summary to the Report. Part B sets the stage for the Report through this Introduction. It also provides a synthesis of major findings in two complementary chapters. The first chapter describes a health-promoting total diet approach that combines the intake of foods, calories, and nutrients. The second chapter integrates the Report's major cross-cutting findings and provides specific recommendations for how Americans and different sectors throughout the Nation can put the Report's evidence-based dietary recommendations into action.

Part C describes the methodology the DGAC used to conduct its work and review the evidence on diet and health. Part D is the Science Base. In this Part, the DGAC's subcommittees present their specific findings in chapters focused on energy balance and weight management; nutrient adequacy; fatty acids and cholesterol; protein; carbohydrates; sodium, potassium, and water; alcohol; and food safety and technology.

The Report concludes with several Appendices, including a compilation of the Committee's scientific conclusions, a glossary, a brief history of the *Dietary Guidelines for Americans*, a listing of the food pattern analyses conducted for the 2010 DGAC, a summary of the process used to collect public comments, biographical sketches of DGAC members, and acknowledgments.

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Part B. Section 2: The Total Diet Combining Nutrients, Consuming Food

Introduction

The 2010 Dietary Guidelines Advisory Committee (DGAC) supports a total diet approach to achieving dietary goals. The purpose of this chapter is to demonstrate how the scientific evidence presented in each of the topic-specific chapters in *Part D: The Science Base*—Energy Balance and Weight Management; Nutrient Adequacy; Fatty Acids and Cholesterol; Protein; Carbohydrates; Sodium, Potassium, and Water; Alcohol; and Food Safety and Technology—can be incorporated into an overall eating pattern that optimizes health outcomes.

Until recently, data were insufficient to document the impact of whole diets and eating patterns on health outcomes. The state of the evidence and the methodologic rigor regarding such questions have improved tremendously and the data can now be incorporated into this Report.

This chapter synthesizes the evidence on dietary components that contribute to excess energy and inadequate nutrient intakes in the United States (U.S.), and the foods that can provide these missing essential nutrients and other health benefits. It presents a brief, evidence-based comparison of worldwide eating patterns, including the Dietary Approaches to Stop Hypertension (DASH), Mediterranean, and other patterns, along with a description of the U.S. Department of Agriculture (USDA) Food Patterns with vegetarian variations.

A nutrient-dense total diet has multiple health benefits and can be implemented in various ways. The U.S. is comprised of individuals of all ages who come from many cultures and have a variety of food and taste preferences. All of these factors were considered in developing a recommended total diet that is flexible while meeting nutrient needs without exceeding energy requirements.

The Catalyst for the Total Diet Approach

Although there is no single “American” or “Western” diet, average American food patterns currently bear little resemblance to the diet recommended in the 2005 *Dietary Guidelines for Americans*. As documented by the latest data from the National Health and Nutrition Examination Survey (NHANES), Americans eat too many calories and too much solid fats, added sugars, refined grains, and sodium. Americans also eat too little dietary fiber, vitamin D, calcium, potassium, and unsaturated fatty acids (specifically omega-3s), and other important nutrients that are mostly found in vegetables, fruits, whole grains, low-fat milk and milk products, and seafood (see *Part D. Section 2: Nutrient Adequacy*).

Overweight and obesity are highly prevalent in the U.S. in both adults and children. This is of great public health concern because excess body fat is associated with a much higher risk of premature death and many serious disorders, as identified in *Part D. Section 1: Energy Balance and Weight Management*. Preventing overweight is highly preferable to initiating weight loss treatment after weight gain occurs, because the failure rate in achieving and maintaining weight loss is very high. Furthermore, the behaviors required to prevent overweight are less daunting than the behaviors necessary to lose and sustain weight loss. Currently, the average American gains about a pound a year between the ages of 20 to 60 years. Some persons gain much more. Remaining conscious of one’s body weight throughout life and adopting a lifestyle early on that will achieve and sustain weight control across the lifespan are paramount to maintaining good health and quality of life.

A Special Focus on Children and Adolescents

The single most significant adverse health trend among U.S. children in the past 40 years has been the dramatic increase in overweight and obesity (see *Part D. Section 1: Energy Balance and Weight Management*). Since the early 1970s, the prevalence of overweight and obesity has approximately doubled among children ages 2 to 11 years, and tripled among adolescents ages 12 to 19 years. Not only is obesity associated with adverse health effects during childhood, but evidence documents increased risk of future chronic disease in adult life.

Childhood obesity results from poorly regulated energy balance. Ideally, children and adolescents should consume foods that provide an adequate intake of all essential nutrients needed for normal growth and development, metabolism, immunity, and cognitive function, without exceeding caloric requirements. Factors associated with preventing excess adiposity in children are incorporated into the total diet described here, and include:

- Energy intake balanced with expenditure
- Greatly reduced intake of sugar-sweetened beverages
- Increased intake of vegetables and fruits
- Smaller amounts of fruit juice, especially for overweight children
- Smaller portions of foods and beverages
- Infrequent consumption of meals from quick service (i.e., fast food) restaurants
- Habitual consumption of breakfast
- Fewer hours of screen time (e.g., television, computer)
- More hours of active play

Blending Science-based Recommendations into a Healthful Total Diet

The DGAC defines "total diet" as the combination of foods and beverages that provide energy and nutrients and constitute an individual's complete dietary intake, on average, over time. This encompasses various foods and food groups, their recommended amounts and frequency, and the resulting eating pattern. To achieve dietary goals and energy balance, Americans must become mindful, or "conscious," eaters, that is, attentively choosing what and how much they eat. Since the mid-1980s, the USDA has provided recommended food patterns that represent a total diet approach to dietary guidance (Britten, 2006). The most recent USDA Food Patterns have been visually conveyed as the MyPyramid Food Guidance System (Haven, 2006). This approach was intended to help people personalize dietary recommendations and offer flexibility based on individual preferences. The key core components of a nutrient-dense total diet for all Americans are presented below.

Moderate Energy Intake

The DGAC encourages Americans to achieve their recommended nutrient intakes by consuming foods within a total diet that meets but does not exceed energy needs. Overweight and obesity result from energy imbalance (intake exceeding expenditure) (see *Part D. Section 1: Energy Balance and Weight Management*). The increased incidence and current high proportion of overweight and obesity in the U.S. illustrates an energy imbalance across virtually all subgroups of the population. People consume too many calories (i.e., energy) relative to the calories they expend. As a start, all Americans are encouraged to know their energy needs in order to avoid inappropriate weight gain. Table B2.1 (see the end of this chapter) can help individuals identify their energy needs based on their age, sex, and level of activity. Self-monitoring of both calorie intake and time spent in physical activity is one of the most useful tools a person can use to engage in and maintain behaviors that sustain a healthy weight.

Because levels of leisure time physical activity in U.S. adults have remained stable or increased only slightly between 1990 and 2004, it is clear that an increased calorie intake has been the primary cause of the obesity problem. Hence, even though one can achieve a calorie deficit by increasing physical activity, the primary focus should be on reducing excessive calorie intake.

Overall, the top food sources of energy, and mean energy intake from each, for the U.S. population, as reported in the National Health and Nutrition Examination Survey (NHANES) 2005-2006, are (National Cancer Institute [NCI], 2010a):

- Grain-based desserts (cakes, cookies, doughnuts, pies, crisps, cobblers, and granola bars; 139 calories per day)
- Yeast breads (129 calories per day)
- Chicken and chicken mixed dishes (121 calories per day)
- Soda/energy/sports drinks (114 calories per day)
- Pizza (98 calories per day)

While the top sources of energy intake vary by age group, many of these sources are foods and beverages that are not in nutrient-dense forms. For example, the top energy source for adults ages 19 years and older and for children ages 4 to 13 years is grain-based desserts. These desserts are also among the top five sources of energy for teens and younger children. For teens ages 14 to 18 years, the top energy source is soda/energy/sports drinks, and these beverages are also among the top five energy sources for adults ages 19 years and older and for children ages 9 to 13 years. For children ages 2 to 3 years only, the top energy source is whole milk (rather than low-fat milk). Other foods that are among the top five sources of energy for various age groups are yeast breads, chicken and chicken mixed dishes, pizza, and, for adults only, alcoholic beverages (NCI, 2010a; see Table B2.2 at the end of this chapter for the top five sources of energy for each age group, and Tables D1.1, D1.6, and D1.7 in *Part D. Section 1: Energy Balance and Weight Management* for more detailed lists of food sources of energy).

Total diets that are high in energy but low in nutrients can paradoxically leave a person overweight but undernourished and thus, at higher risk of cardiovascular disease (CVD), type 2 diabetes (T2D), and certain types of cancers. Of urgent concern is America's youth, most of whom currently fit this pattern. Many children consume nutrient-poor sources of energy at the highest end of their respective energy ranges (see Figure D1.1 in *Part D. Section 1: Energy Balance and Weight Management*) and they are increasingly sedentary.

Beverages also contribute substantially to overall dietary and energy intake. Although they provide needed fluid, beverages often add calories to the diet without providing nutrients. Their consumption should be planned in the context of total calorie intake and how they can fit into the total diet of each individual. Currently, U.S. adults ages 19 years and older consume an average of 394 calories per day as beverages. The major types of beverages consumed, and the mean caloric intake from each, are (NCI, 2010b):

- Soda (112 calories per day)
- Coffee and tea (26 calories per day)
- Fluid milk (83 calories per day)
- 100 percent fruit juice and fruit drinks (66 calories per day)
- Alcoholic beverages (106 calories per day)

Children (ages 2 to 18 years) consume an average of 400 calories per day as beverages. The major beverages for children and calories from each are somewhat different:

- Fluid milk (160 calories per day)
- Soda (118 calories per day)
- 100 percent fruit juices and fruit drinks (108 calories per day)

In children, the amount and source of calories from beverages differs by age. For example, 100 percent fruit juice is a prominent source of energy in children ages 2 to 3 years, while soda/sports/energy drinks are the most common source of energy among beverages (and energy overall) in children ages 14 to 18 years.

Portion control and the quantity of foods and beverages consumed within the total diet also are important considerations in moderating energy intake (see *Part D. Section 1: Energy Balance and Weight Management*). Excessive portion sizes are very common in the U.S. and are linked to higher energy intakes and weight gain over time. This is particularly true when large portions of foods high in solid fats and added sugars (SoFAS) and refined grains are consumed.

Reduce Solid Fats and Added Sugars (SoFAS)

SoFAS contribute substantially (approximately 35% of calories) to total energy intakes of Americans, thereby leading to excessive saturated fat and cholesterol intakes and insufficient intake of dietary fiber and other nutrients (see *Part D. Section 2: Nutrient Adequacy; Part D. Section 3: Fatty Acids and Cholesterol; and Part D. Section 5: Carbohydrates*).

The 2005 DGAC defined the term "discretionary calorie allowance" as "the difference between total energy requirements and the energy consumed to meet recommended nutrient intakes" (DGAC, 2004). Discretionary calories were intended to represent the calories available for consumption *only* after meeting nutrient recommendations and without exceeding total energy needs. Unfortunately, this concept has been difficult to translate into meaningful consumer education. To clarify translation, the 2010 DGAC focused specifically on reducing the intake of SoFAS which provide most of the non-essential or extra calories that Americans consume. Major food sources of the two components of SoFAS are (Bachman, 2008):

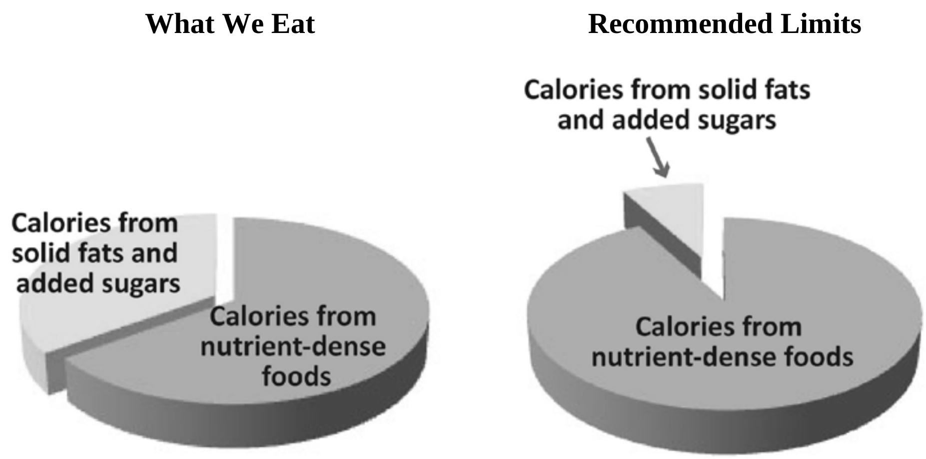
- Solid fats (percent of solid fat intake)
  - — Grain-based desserts, including cakes, cookies, pies, doughnuts, and granola bars (10.9%)
  - — Regular cheese (7.7%)
  - — Sausage, franks, bacon, and ribs (7.1%)
  - — Pizza (5.9%)
  - — Fried white potatoes, including French fries and hash browns (5.5%)

— Dairy-based desserts, such as ice cream (5.1%)

- Added sugars (percent of added sugars intake)
  - — Soda (36.6%)
  - — Grain-based desserts (11.7%)
  - — Fruit drinks (11.5%)
  - — Dairy-based desserts (6.4%)
  - — Candy (6.2%)

Maximum limits on SoFAS are meant to be estimates and not necessarily daily targets (see limits from USDA Food Patterns, Table B2.3, end of this chapter). These foods should constitute a very small proportion of total energy intake in the total diet. Figure B2.1 contrasts the current disproportionately high intake of SoFAS with what is more appropriate from a healthy eating pattern.

Figure B2.1. What we eat versus recommended limits: calories from solid fats and added sugars (SoFAS)



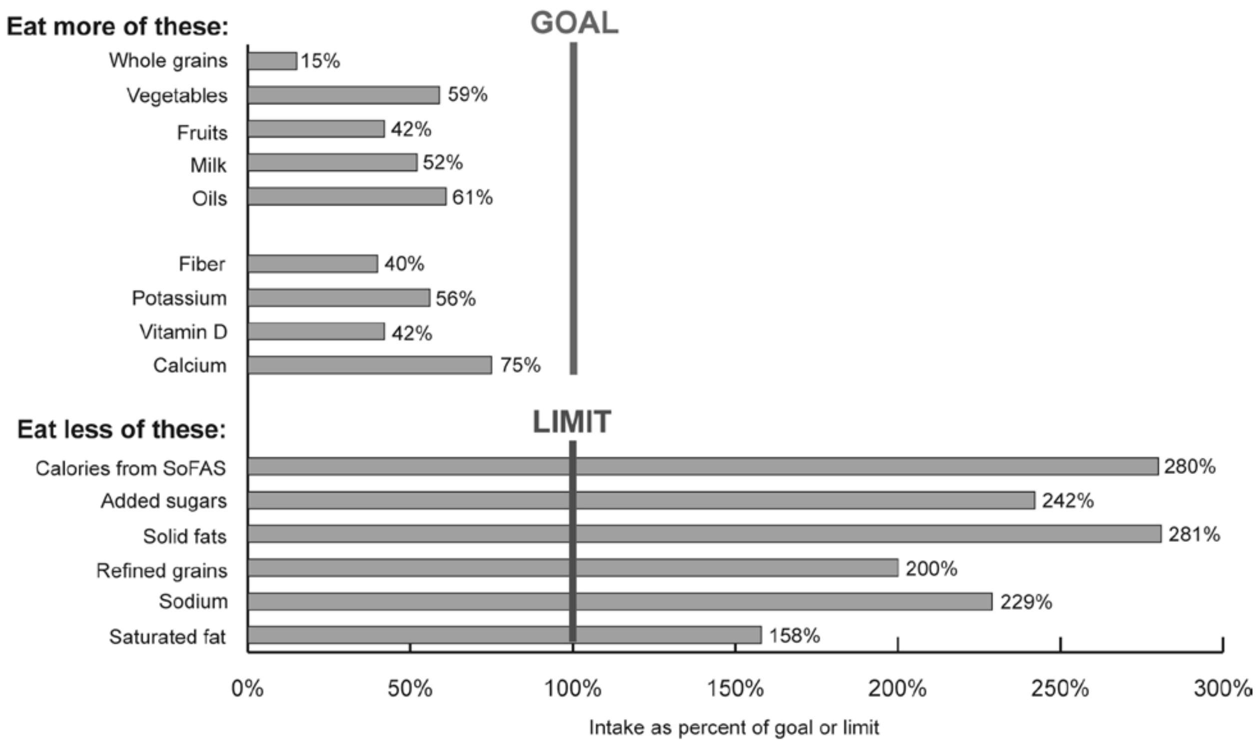
Note: The depiction of the proportionate amounts of total calories consumed and the recommended limits are illustrative only. The figure illustrates about 35 percent of total calories consumed as SoFAS, on average, in contrast to a recommended limit of no more than about 5 to 15 percent of total calories for most individuals.

Americans currently consume 35 percent of their total calories from SoFAS. This is too high. They should reduce intake of calories from SoFAS by 20 to 30 percent. This means that no more than 5 to 15 percent of total calories should be derived from SoFAS. For example, the USDA Food Patterns limit SoFAS to about 120 calories in the 1600-calorie pattern, 160 calories in the 1800-calorie pattern, and 260 calories in the 2000-calorie pattern (Table B2.3, at the end of the chapter, lists SoFAS limits for all calorie levels). Reduction of calories from SoFAS to these amounts allows for increased intakes of nutrient-dense foods such as vegetables (including cooked dry beans and peas), fruits, whole grains, and fat-free and low-fat fluid milk and milk products, without exceeding overall calorie needs.

Consume Nutrient-dense Foods (But Not Too Much of Them)

Currently, Americans consume less than 20 percent of the recommended intakes for whole grains, less than 60 percent for vegetables, less than 50 percent for fruits, and less than 60 percent for milk and milk products (Figure B2.2). Inadequate intakes of nutrient-dense foods from these basic food groups place individuals at risk for lower than recommended levels of specific nutrients, namely vitamin D, calcium, potassium, and dietary fiber.

Figure B2.2. Dietary intakes in comparison to recommended intake levels or limits



Note: Bars show average intakes for all individuals (ages 1 or 2 years or older) as a percent of the recommended intake level or limit. Recommended intakes for food groups and limits for refined grains, SoFAS, solid fats, and added sugars are based on the USDA 2000-calorie food patterns. Recommended intakes for fiber, potassium, vitamin D, and calcium are based on the highest Adequate Intakes (AI) for ages 14 to 70 years. Limits for sodium are based on the AI and for saturated fat on 7 percent of calories.

Data source: What We Eat in America, National Health and Nutrition Examination Survey (WWEIA, NHANES) 2001-2004 or 2005-2006.

Food from all food groups are composed of a combination of the macronutrients carbohydrates, fats, and protein in varying proportions. These are the major sources of energy in any food or diet. Understanding their role in the diet will help Americans make appropriate food choices.

Carbohydrates (4 kcal/g) are the primary source of energy intake, and higher intakes of carbohydrates, especially complex sources, are recommended for active people. Sedentary individuals, and thus most Americans, should lower their intakes of refined carbohydrates, greatly reducing intakes of sugar and sugar-sweetened beverages and refined grains that are high in calories, but relatively low in certain nutrients. Whole-grain versions of many grain products (such as plain white bread, rolls, bagels, muffins, pasta, breakfast cereals) should be substituted to meet the recommendation that half of grains consumed be whole grains, also assisting in meeting dietary fiber recommendations (see *Part D. Section 5: Carbohydrates*).

Dietary fats (both solid fats and oils) are high in calories (9 kcal/g). Unsaturated fats, including omega-3 from seafood sources, should be increased and saturated fat and *trans* fatty acid intake should be minimized. Given typical patterns of consumption in the U.S., dietary saturated fat intake is highly correlated with total fat intake. Consuming the recommended intake of saturated fat (less than 10% of calories immediately as an interim step toward an eventual goal of less than 7% of calories) is more likely achievable when total fat intake is less than 30 percent of total calories. It is recommended that total fat should be in the range of 20 to 35 percent of total calories but derived mostly from oils within a nutrient-rich, energy-balanced dietary pattern. These oils should replace solid fats and not add calories to the total diet (see Part *D. Section 3: Fatty Acids and Cholesterol*).

Dietary protein (4 kcal/g) provides essential amino acids and energy, and assists in building and preserving body proteins. Both plant-based sources of protein (i.e., cooked dry beans and peas, nuts, seeds, and soy products) and animal-based sources (i.e., meat, poultry, seafood, eggs, and low-fat and fat-free milk) can be incorporated into the total diet, with further emphasis on increasing seafood (rich in omega-3 fatty acids as well as protein) and cooked dry beans and peas (rich in dietary fiber as well as vegetable protein) (see *Part D. Section 4: Protein*).

Consumption of alcoholic beverages also contributes to calories (7 kcal/g), from the alcohol itself as well as accompanying mixers (e.g., soda, juice, or sweetened mixer). In many cases, the accompanying mixer (see Table D1.9 in *Part D. Section 1: Energy Balance and Weight Management*) has more calories than the alcohol itself, so careful attention to portion size is important for alcoholic beverages. Based on individual preferences among adults, a moderate amount of alcohol may be included in the total diet if calorie allowances are not exceeded and essential nutrient needs are met. For adults who are attempting to reduce calorie intake, alcohol could be one of the energy sources that is reduced to lower total calorie intake. Pregnant women or individuals with certain medical conditions or on certain medications as well as individuals who will take part in activities that require attention or skill should not consume alcohol (see *Part D. Section 7: Alcohol*).

Vegetables, fruits, high-fiber whole grains, seafood, eggs, and nuts prepared without added SoFAS are considered "nutrient-dense foods," as are low-fat forms of milk and lean meat and poultry prepared without added SoFAS. Nutrient-dense foods are found in a variety of forms but ideally are minimally processed and minimize or exclude added SoFAS, starches, and sodium. Combined into a total diet, these foods should provide a full range of essential nutrients, including those of special concern (e.g., vitamin D, calcium, potassium, and dietary fiber).

Finally, the nutrient-dense total diet should be prepared using best practices for food safety to ensure that foods consumed do not induce foodborne illnesses (see *Part D. Section 8: Food Safety and Technology*). A balanced grouping of a variety of foods among all the food groups, consumed in moderation, that are culturally appealing will offer pleasurable eating experiences and promote health among Americans.

Reduce Sodium Intake

Even a nutrient-dense total diet that remains excessive in sodium can lead to health consequences such as elevated blood pressure. Excessive sodium intake raises blood pressure, a well-documented and extraordinarily common risk factor for heart disease, stroke, and kidney disease. Although most research has been conducted in adults, the adverse effects of sodium on blood pressure begin early in life, and reducing sodium intake has substantial health benefits. Given the fact that a higher potassium intake attenuates the adverse effects of sodium on blood pressure, ensuring increased intakes of dietary potassium also would have health benefits.
The current food supply is replete with excess sodium. In this setting, virtually all Americans exceed the recommended upper limit of sodium intake. Because approximately 75 percent of dietary sodium is added during food processing, food manufacturers and restaurant industries have a critically important role in reducing the sodium intake. In addition, individuals should choose and prepare foods with little or no sodium (see *Part D. Section 6: Sodium, Potassium, and Water*).

A Flexible Approach to Applying Total Diet Recommendations

A healthful total diet is not a rigid prescription, but rather is a flexible approach that incorporates a wide range of individual tastes and preferences. Just as there is no one "American" or "Western" diet, there is no one recommendation for a healthful diet. As is evident in the following sections, data are accumulating that certain dietary patterns consumed around the world are associated with beneficial health outcomes. Likewise, the Food Patterns developed by the USDA illustrate that both nutrient and moderation goals can be met in a variety of ways.

Worldwide Dietary Patterns Provide Support for a Nutrient-dense Total Diet

Across the world and within the U.S., there are striking differences in diets and also in diet-related health outcomes. Although research on dietary patterns is complex, and many methodological issues remain in synthesizing data across studies, a consensus is emerging that consumption of certain dietary patterns is associated with a reduced risk of several major chronic diseases. The 2010 DGAC focused on the effects of dietary patterns on total mortality, CVD, and blood pressure (a major diet-related cardiovascular risk factor). The World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR, 2007) recently reviewed the available evidence of the relationship of cancer with specific dietary factors and overall dietary patterns. While several dietary factors were associated with specific types of cancer, it concluded that no firm judgment can be made on the relationship of dietary patterns with cancer.

The 2010 DGAC focused on the DASH-style dietary patterns and Mediterranean-style dietary patterns because considerable research exists on health outcomes as well as information on nutrient and food group composition. It also examined traditional Asian dietary patterns and vegetarian diets. Traditional Asian dietary patterns (e.g., Japanese and Okinawan dietary patterns) have been associated with a reduced risk of coronary heart disease, but documentation using contemporary research methods is scant. Most traditional dietary patterns provide for health at least moderately well, and their variety demonstrates that a person can eat healthfully in a number of ways. Vegetarian diets have been associated with a reduced risk of CVD, but information on nutrient content and food group composition is sparse.

Dietary patterns with health benefits are summarized below. An Appendix at the end of this chapter provides further detail on these dietary patterns as well as several summary tables.

DASH-style Dietary Patterns

DASH-style dietary patterns emphasize vegetables, fruits, and low-fat milk and milk products; include whole grains, poultry, seafood, and nuts; and are reduced in red meat, sweets, sodium, and sugar-containing beverages. As originally tested, the DASH diet is reduced in total fat (27% of kcal) with total protein intake of 18 percent of calories and carbohydrate intake of 55 percent of calories. However, other versions of the DASH diet are available, in which carbohydrate is partially replaced with protein (about half from plant sources) or unsaturated fat (predominantly monounsaturated fat). The latter version is noteworthy because nutrient adequacy and a reduced saturated fat intake (6% of kcal) were both achieved in the setting of high monounsaturated fat (21% of kcal) and total fat (37% of kcal) intake. In a free-living setting, care is needed to meet but not exceed energy needs in order to avoid weight gain.

Each of these DASH style diets lowers blood pressure, improves blood lipids, and reduces CVD risk. Blood pressure reduction is the greatest when the DASH diet is consumed with reduced sodium intake. At present, few adults, even those with hypertension, eat a diet that is consistent with the DASH dietary pattern.

Mediterranean-style Dietary Patterns

In view of the large number of cultures and agricultural patterns of countries that border the Mediterranean Sea, the “Mediterranean” diet is not a single dietary pattern. Although no well-accepted set of criteria exist, a traditional Mediterranean diet can be described as one that emphasizes breads and other cereal foods usually made from wheat, vegetables, fruits, nuts, unrefined cereals, and olive oil; includes fish and wine with meals (in non-Islamic countries); and is reduced in saturated fat, meat, and full-fat dairy products. Results from observational studies and clinical trials suggest that consumption of a traditional Mediterranean diet, similar to that of Crete in the 1960s, is associated with one of the lowest risks of coronary heart disease in the world. Over time, the diet of Crete has changed remarkably and is now characterized by higher intake of saturated fat and cholesterol, and reduced intake of monounsaturated fats. At the same time, total fat consumption has fallen. These trends have been accompanied by a steady rise in heart disease risk.

Vegetarian Dietary Patterns

In some observational studies, vegetarian diets and lifestyle have been associated with improved health outcomes. The types of vegetarian diets consumed in the U.S. vary widely. Vegans do not consume any animal products, while lacto-ovo vegetarians consume milk and eggs. Although not strict vegetarians, many individuals consume small or minimal amounts of animal products. On average, vegetarians consume fewer calories from fat than non-vegetarians, particularly saturated fat, and have a higher consumption of carbohydrates than non-vegetarians. In addition, vegetarians tend to consume fewer overall calories and have a lower body mass index than non-vegetarians. These characteristics, in addition to the dietary pattern per se, may contribute to the improved health outcomes of vegetarians (see the Appendix at the end of this chapter and *Part D. Section 4: Protein* for additional information on vegetarian diets).

Other Dietary Patterns

In view of the increasing diversity of the U.S. population, interest in the health effects of non-Western diets is substantial. One group of diets with potential health benefits are those traditionally consumed in Asia, which has experienced some of the lowest rates of coronary heart disease in the world. Both traditional Japanese and Okinawan dietary patterns have been associated with a low risk of coronary heart disease. Nonetheless, compared to the evidence supporting DASH and Mediterranean diets, detailed information on diet composition as well as epidemiologic and clinical trial evidence on health benefits, similar to that available for the other types of diets, is sparse. Also, over time, dietary intakes in these countries have changed and may no longer reflect the healthiest choices.

USDA Food Patterns Provide Guidance for Meeting Dietary Guideline Recommendations

Applying results from carefully conducted studies of nutrition and health, the USDA has developed a number of different food guides over the past century. These guides have identified eating patterns that meet known nutrient needs and balance intake from various food groups. Based upon the Nation's dietary intake at the time, early USDA food guides focused on nutrient adequacy only. Due to the health risks associated with overconsumption of specific dietary components, including the increasing obesity problem, recent guides have encompassed moderation goals while meeting nutrient adequacy goals. The current USDA Food Patterns also are aimed at primary disease prevention. For example, Table B2.4 (see end of chapter) compares the 2000-calorie USDA food pattern with the DASH diet and with current consumption patterns. The types and amounts of foods recommended in the USDA patterns are very similar to the DASH diet, and both are very different from current intakes.

The USDA Food Patterns recommend the amounts of foods to eat each day from the five major food groups and subgroups, specifically in nutrient-dense forms. The Patterns allow for oils and limit the maximum number of calories that should be consumed from SoFAS. Table B2.3 (see end of chapter) shows recommended amounts and limits in the USDA Food Patterns at all 12 energy levels (*Part D. Section 2: Nutrient Adequacy*, Table D2.1 provides the specific nutritional goals for each pattern).

The USDA Food Patterns incorporate several important assumptions:

- A variety of foods are used to meet recommended intakes from each food group or subgroup, in amounts proportionate to current consumption by the population.
- Food choices selected for use in the analysis are in nutrient-dense forms, that is, with little or no SoFAS, and in most cases without added salt.
- For each age-sex group, the pattern developed to meet nutrient needs is at a caloric level that meets but does not exceed energy needs for sedentary individuals.

The online *Appendix E3.1: Adequacy of the USDA Food Patterns*, available at www.dietaryguidelines.gov, provides details of the analysis conducted for the DGAC to determine whether the USDA Food Patterns meet nutritional goals for adequacy and moderation while staying within established calorie targets.

Recommended intake amounts in the USDA Food Patterns remain unchanged from 2005 with the exception of the vegetable subgroups. Several changes were made to decrease the wide discrepancy in number and amounts of vegetables consumed between the largest and the smallest subgroups. This resulted in moving tomatoes and red peppers from "other vegetables" to a new "red-orange vegetable" subgroup, which provided a greater focus on tomatoes without compromising the nutrient adequacy of the patterns (see the online *Appendix E3.2: Realigning Vegetable Subgroups* report at www.dietaryguidelines.gov, for details). The USDA Food Patterns meet almost all of their nutritional goals for adequacy and moderation, when evaluated using current food composition and consumption data.

USDA also developed and evaluated several variations on the base patterns, applying the same principles but modifying food choices to accommodate those wanting to eat a plant-based or vegetarian diet. An additional analysis investigated a possible modification of the patterns for those tracking carbohydrate intake, such as people with diabetes. The results of these analyses are presented below (see *Part C: Methodology* for a description of the methods used and a list of all food pattern modeling analyses).

Vegetarian Patterns Based on USDA Food Patterns

The USDA Food Patterns include two animal-based food groups: the “meat, poultry, seafood, eggs, soy products, nuts, and seeds” group and the “milk, yogurt, and cheese” group. Although the groups contain some plant foods, the majority of consumption from them is from animal products. As is true in American diets, these two food groups in the Food Patterns are the major sources of protein, calcium, vitamin D, vitamin B_{12}, riboflavin, choline, selenium, zinc, and the omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaeonic acid (DHA).

The USDA Food Patterns were modified to replace some or all animal products with plant products (see the online *Appendix E3.3: Vegetarian Food Patterns* report at www.dietaryguidelines.gov for details). The plant-based (at least 50% of all protein from plant sources), lacto-ovo vegetarian (no meat, poultry, or seafood), and vegan (no meat, poultry, seafood, eggs, fluid milk or milk products) food patterns, collectively referred to as the “vegetarian patterns,” meet almost all goals for nutrient adequacy. Amounts of protein, including all essential amino acids, were adequate in all vegetarian patterns. Amounts of calcium and vitamins D and B_{12} were adequate because fortified sources of these nutrients were selected to replace milk and meat products. The estimated bioavailable iron in the vegan patterns was less than the RDA for some children and women. While no dietary standards exist for omega-3 fatty acids, levels of EPA and DHA are substantially lower than the base Food Patterns, especially in the vegan patterns. All moderation goals are met in the vegetarian patterns. If only plant foods are consumed, choices should include foods fortified with vitamin B_{12}, vitamin D, and calcium. Other nutrients of potential concern include iron, choline, EPA, and DHA.

Considering an Alternative Placement for Starchy Vegetables

To offer flexibility in selecting a food pattern that meets nutrient needs and accommodates food preferences, USDA evaluated a nutritionally adequate option that considers starchy vegetables as a grain alternative (see the online *Appendix E3.4: Starchy Vegetables* report at www.dietaryguidelines.gov for details). This pattern may be useful for individuals who wish to track the amount of carbohydrates they consume, who prefer a dietary pattern that groups all major sources of starch together, or who wish to integrate the USDA recommendations with other diet plans. In this pattern, individuals can substitute starchy vegetables for a portion of the recommended grains, as long as they eat additional vegetables from other subgroups to replace the starchy vegetables. As with all of the modeling analyses, the vegetables and grains selected should be nutrient-dense forms, not forms with added fats, sugars, or salt. Although starchy vegetables remain part of the vegetable group in the USDA Food Patterns, this analysis identified an option for flexibility to help some individuals integrate the USDA recommendations with other dietary plans.

The Importance of Nutrient-dense Choices

The USDA Food Patterns assume that foods in each food group will be consumed in the same relative proportions as they appear in the average American diet, but that most will be in nutrient-dense forms. Nutrient-dense choices are available to consumers, but they are not the forms most typically consumed. Consuming recommended amounts of foods, but in forms that represent typical food choices rather than the “ideal” nutrient-dense choices, has a major impact on energy and nutrient intake. Excess intake of energy, sodium, saturated fat, and cholesterol results from using typical food choices in the recommended amounts for the patterns. For example, assuming typical food choices, the calorie intake in the 2000-calorie pattern is almost 400 calories more per day than the target (see the online *Appendix E3.5: “Typical Choices” Food Patterns* report at www.dietaryguidelines.gov for details of an analysis of the effect of typical versus ideal choices). If consumers act on the message about quantities to eat from each food group or subgroup, but fail to implement the moderation messages about choosing most foods in low-fat, no-added-sugars, and low-sodium forms, they will not meet the important moderation goals.

Chapter Summary

Good health and vitality across the lifespan are what Americans desire. The 2010 DGAC Report concludes that this is achievable but requires a lifestyle approach that includes a total diet that is:

- Energy balanced, limited in total calories, and portion controlled
- Nutrient-dense and includes:
  - Vegetables, fruits, high-fiber whole grains
  - Fat-free or low-fat fluid milk and milk products
  - Seafood, lean meat and poultry, eggs, soy products, nuts, seeds, and oils

- Very low in solid fats and added sugars (SoFAS)
- Reduced in sodium

Physical activity will assist in the helping to achieve a balance between calorie intake and expenditure, leading to body weight maintenance. Children and adolescents are of particular concern because the dietary habits that they form during their youth will set the foundation for their choices and behaviors as adults.

Several distinct dietary patterns are associated with health benefits, including lower blood pressure and a reduced risk of CVD and total mortality. A common feature of these diets is an emphasis on plant foods. Accordingly, fiber intake is high and saturated fat is typically low. When total fat intake is high, that is, more than 30 percent of calories, the predominant fats are monounsaturated and polyunsaturated fats. Carbohydrate intake is typically in the range of 50 to 60 percent of calories, but these often include whole grain products with minimal processing, as well as cooked dry beans and peas. The totality of evidence documenting a beneficial impact of plant-based dietary patterns on CVD risk is remarkable and worthy of recommendation.

Americans have considerable flexibility in selecting a diet that includes foods they enjoy, meets nutrient requirements, reduces risk of preventable disease, and controls weight. No one specific dietary pattern provides the only way to incorporate the principles listed above into a total diet. The daunting public health challenge is to accomplish population-wide adoption of healthful dietary patterns within the setting of powerful influences that currently promote unhealthy lifestyles. The 2010 DGAC is united in advocating that policy makers, stakeholders, and health-care providers embrace and support these important, evidence-based guidelines for the benefit of all Americans.

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Table B2.1. Estimated energy needs[1] in calories per day, for reference-sized individuals by age, sex, and activity level

Sex/Activity Level	Male/ Sedentary	Male/ Moderately Active	Male/ Active	Female/ Sedentary	Female/ Moderately Active	Female/ Active
Age						
2	1000	1000	1000	1000	1000	1000
3	1000	1400	1400	1000	1200	1400
4	1200	1400	1600	1200	1400	1400
5	1200	1400	1600	1200	1400	1600
6	1400	1600	1800	1200	1400	1600
7	1400	1600	1800	1200	1600	1800
8	1400	1600	2000	1400	1600	1800
9	1600	1800	2000	1400	1600	1800
10	1600	1800	2200	1400	1800	2000
11	1800	2000	2200	1600	1800	2000
12	1800	2200	2400	1600	2000	2200
13	2000	2200	2600	1600	2000	2200
14	2000	2400	2800	1800	2000	2400
15	2200	2600	3000	1800	2000	2400
16	2400	2800	3200	1800	2000	2400
17	2400	2800	3200	1800	2000	2400
18	2400	2800	3200	1800	2000	2400
19-20	2600	2800	3000	2000	2200	2400
21-25	2400	2800	3000	2000	2200	2400
26-30	2400	2600	3000	1800	2000	2400
31-35	2400	2600	3000	1800	2000	2200
36-40	2400	2600	2800	1800	2000	2200
41-45	2200	2600	2800	1800	2000	2200
46-50	2200	2400	2800	1800	2000	2200
51-55	2200	2400	2800	1600	1800	2200
56-60	2200	2400	2600	1600	1800	2200
61-65	2000	2400	2600	1600	1800	2000
66-70	2000	2200	2600	1600	1800	2000
71-75	2000	2200	2600	1600	1800	2000
76 and up	2000	2200	2400	1600	1800	2000

[1]Based on Estimated Energy Requirements (EER) equations, using reference heights (average) and reference weights (healthy) for each age/sex group, rounded to the nearest 200 calories. EER equations are from the Institute of Medicine. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. Washington DC: National Academies Press, 2002.
Source: Britten et al., 2006.

Table B2.2. Top five sources of energy among U.S. children, adolescents, and adults by age, NHANES 2005-06[1]

Mean Energy Intake (kcal)	Overall, Ages 2+ years 2157	Ages 2-18 years 2027	Ages 2-3 years 1471	Ages 4-8 years 1802	Ages 9-13 years 2035	Ages 14-18 years 2427	Ages 19+ years 2199
Rank							
1	Grain-based desserts[1] (138 kcal)	Grain-based desserts (138 kcal)	Whole milk (104 kcal)	Grain-based desserts (136 kcal)	Grain-based desserts (145 kcal)	Soda/energy /sports drinks[2] (226 kcal)	Grain-based desserts (138 kcal)
2	Yeast breads (129 kcal)	Pizza (136 kcal)	100% fruit juice (not orange or grapefruit) (93 kcal)	Yeast breads (98 kcal)	Pizza (128 kcal)	Pizza (213 kcal)	Yeast breads (134 kcal)
3	Chicken and chicken mixed dishes (121 kcal)	Soda/energy/ sports drinks (118 kcal)	Reduced fat milk (91 kcal)	Pasta and pasta dishes (97 kcal)	Chicken and chicken mixed dishes (122 kcal)	Grain-based desserts (157 kcal)	Chicken and chicken mixed dishes (123 kcal)
4	Soda/energy/ sports drinks (114 kcal)	Yeast breads (114 kcal)	Pasta and pasta dishes (86 kcal)	Pizza (95 kcal)	Yeast breads (109 kcal)	Yeast breads (151 kcal)	Soda/energy /sports drinks[2] (112 kcal)
5	Pizza (98 kcal)	Chicken and chicken mixed dishes (113 kcal)	Grain-based desserts (68 kcal)	Reduced fat milk (95 kcal)	Soda/energy/ sports drinks (105 kcal)	Chicken and chicken mixed dishes (143 kcal)	Alcoholic beverages (106 kcal)

[1]Foods ranked by mean contribution to overall energy intake. Table shows each food category and its mean caloric contribution for each age group.
[2]Includes cakes, cookies, doughnuts, pies, crisps, cobblers, granola bars.
[3]Includes sodas, energy drinks, sports drinks, and sweetened bottled water including vitamin water.
Note: For a more detailed listing of food sources of energy, see *Part D. Section 1. Energy Balance*, Tables D1.1, D1.6, and D1.7.
Source: National Cancer Institute (NCI). *Food Sources of Energy Among U.S. Population*, 2005-06. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute, 2010a. http://riskfactor.cancer.gov/diet/foodsources/. Updated May 21, 2010. Accessed May 21, 2010.

Table B2.3. USDA Food Patterns—recommended daily intake amounts[1] from each food group or subgroup at all calorie levels. Recommended intakes from vegetable subgroups are per week

Energy Level of Pattern[2]	**1000**	**1200**	**1400**	**1600**	**1800**	**2000**	**2200**	**2400**	**2600**	**2800**	**3000**	**3200**
Fruits	1 c	1 c	1½ c	1½ c	1½ c	2 c	2 c	2 c	2 c	2½ c	2½ c	2½ c
Vegetables	1 c	1½ c	1½ c	2 c	2½ c	2½ c	3 c	3 c	3½ c	3½ c	4 c	4 c
Dark green vegetables	½ c/wk	1 c/wk	1 c/wk	1 ½ c/wk	1 ½ c/wk	1 ½ c/wk	2 c/wk	2 c/wk	2 ½ c/wk	2 ½ c/wk	2 ½ c/wk	2 ½ c/wk
Red/Orange vegetables	2½ c/wk	3 c/wk	3 c/wk	4 c/wk	5 ½ c/wk	5 ½ c/wk	6 c/wk	6 c/wk	7 c/wk	7 c/wk	7½ c/wk	7½ c/wk
Cooked dry beans and peas	½ c/wk	½ c/wk	½ c/wk	1 c/wk	1 ½ c/wk	1 ½ c/wk	2 c/wk	2 c/wk	2 ½ c/wk	2 ½ c/wk	3 c/wk	3 c/wk
Starchy vegetables	2 c/wk	3½ c/wk	3½ c/wk	4 c/wk	5 c/wk	5 c/wk	6 c/wk	6 c/wk	7 c/wk	7 c/wk	8 c/wk	8 c/wk
Other vegetables	1½ c/wk	2½ c/wk	2½ c/wk	3½ c/wk	4 c/wk	4 c/wk	5 c/wk	5 c/wk	5½ c/wk	5½ c/wk	7 c/wk	7 c/wk
Grains	3 oz eq	4 oz eq	5 oz eq	5 oz eq	6 oz eq	6 oz eq	7 oz eq	8 oz eq	9 oz eq	10 oz eq	10 oz eq	10 oz eq
Whole grains	1½ oz eq	2 oz eq	2½ oz eq	3 oz eq	3 oz eq	3 oz eq	3½ oz eq	4 oz eq	4½ oz eq	5 oz eq	5 oz eq	5 oz eq
Other grains	1½ oz eq	2 oz eq	2½ oz eq	2 oz eq	3 oz eq	3 oz eq	3½ oz eq	4 oz eq	4½ oz eq	5 oz eq	5 oz eq	5 oz eq
Meat and beans	2 oz eq	3 oz eq	4 oz eq	5 oz eq	5 oz eq	5½ oz eq	6 oz eq	6 ½ oz eq	6 ½ oz eq	7 oz eq	7 oz eq	7 oz eq
Milk	2 c	2 c	2 c	3 c	3 c	3 c	3 c	3 c	3 c	3 c	3 c	3 c
Oils	15 g	17 g	17 g	22 g	24 g	27 g	29 g	31 g	34 g	36 g	44 g	51g
Maximum SoFAS[3] limit, calories (%total calories)	137 (14%)	137 (11%)	137 (10%)	121(8%)	161(9%)	258 (13%)	266 (12%)	330 (14%)	362 (14%)	395 (14%)	459 (15%)	596 (19%)

[1]Food group amounts shown in cup (c) or ounce equivalents (oz eq). Oils are shown in grams (g). Quantity equivalents for each food group are:

- Grains, 1 ounce equivalent is: ½ cup cooked rice, pasta, or cooked cereal; 1 ounce dry pasta or rice; 1 slice bread; 1 small muffin (1 oz); 1 ounce ready-to-eat cereal.
- Fruits and vegetables, 1 cup equivalent is: 1 cup raw or cooked fruit or vegetable, 1 cup fruit or vegetable juice, 2 cups leafy salad greens.
- Meat and beans, 1 ounce equivalent is: 1 ounce lean meat, poultry, fish; 1 egg; ¼ cup cooked dry beans; 1 Tbsp peanut butter; ½ ounce nuts/ seeds.
- Milk, 1 cup equivalent is: 1 cup milk or yogurt, 1½ ounces natural cheese such as Cheddar cheese or 2 ounces of processed cheese.

[2]Food intake patterns at 1000, 1200, and 1400 calories meet the nutritional needs of children ages 2 to 8 years. Patterns from 1600 to 3200 calories meet the nutritional needs of children 9 years of age and older and adults. If a child ages 2 to 8 years needs more calories and, therefore, is following a pattern at 1600 calories or more, the recommended amount from the milk group should be 2 cups per day. Children ages 9 years and older and adults should not use the 1000, 1200, or 1400 calorie patterns.

[3]SoFAS are calories from solid fats and added sugars.

Table B2.4. Dietary Pattern Comparison: Current U.S. intake, DASH-sodium diet, and USDA Food Patterns. Description, nutrient composition, and food group amounts (adjusted to 2000 calories)

Dietary Pattern	**Usual U.S. Intake Adults**	**DASH with Reduced Sodium**	**USDA Base Pattern[1]**	**USDA Plant-based**	**USDA Lacto-ovo Vegetarian**	**USDA Vegan**
Citation	NHANES 2001-04; 2005-06; Ages 19+	Karanja et al., 1999 and Lin et al., 2003	Britten et al., 2006; Online Appendix E-3.1	Online Appendix E-3.3	Online Appendix E-3.3	Online Appendix E-3.3
Qualitative Description						
Emphasizes		Potassium-rich vegetables, fruits, and low-fat milk products	Vegetables, fruits, and whole grains, low-fat milk products	Plant foods - vegetables, fruits, whole grains, legumes, low-fat milk products	Plant foods - vegetables, fruits, whole grains, legumes, nuts, seeds, soy foods, milk products	Plant foods - vegetables, fruits, whole grains, legumes, nuts, seeds, soy foods
Includes		Whole grains, poultry, fish, and nuts	Enriched grains, lean meat, fish, and oils	Lean meat, eggs, fish, and oils	Eggs, oils	Non-dairy milk alternatives
Limits (small amount)		Red meats, sweets, and sugar-containing beverages	Solid fats Added sugars	Solid fats Added sugars	No meat, poultry, fish Added sugars	No animal products Added sugars
Nutrients						
Calories (kcal)	2000	2000	2000	2000	2000	2000
Carbohydrates (% total kcal)	48.4%	58%	56.7%	55.8%	56.7%	56.8%
Protein (% total kcal)	15.2%	18%	15.2%	16.3%	15.2%	13.3%
Total Fat (% total kcal)	33.5%	27%	32%	31%	31%	33%
Saturated Fat (% total kcal)	10.9%	6%	8.4%	7.8%	7.8%	6.8%
Monounsaturated (% total kcal)	12.5%	10%	12.0%	11.4%	11.8%	12.4%
Polyunsaturated (% total kcal)	6.8%	8%	9.0%	9.3%	9.4%	12.0%
Cholesterol (mg)	269	143	229	170	160	17

Table B2.4 (continued). Dietary Pattern Comparison: Current U.S. intake, DASH-sodium diet, and USDA Food Patterns. Description, nutrient composition, and food group amounts (adjusted to 2000 calories)

Dietary Pattern	**Usual U.S. Intake Adults 19 year+**	**DASH with Reduced Sodium**	**USDA Base Pattern[1]**	**USDA Plant-based**	**USDA Lacto-ovo Vegetarian**	**USDA Vegan**
Fiber (g)	15	29	30	37	39	43
Potassium (mg)	2909	4371	3478	3611	3610	3645
Sodium (mg)	2846	1095	1722	1582	1595	1224
Food Groups						
Vegetables: total (c)	1.6	2.1	2.5	2.5	2.5	2.5
- Dark Green (c)	0.1	nd	0.2	0.2	0.2	0.2
- Legumes[2](c)	0.1	nd	0.2	0.2	0.2	0.2
- Red Orange (c)	0.4	nd	0.8	0.8	0.8	0.8
- Other Veg (c)	0.5	nd	0.6	0.6	0.6	0.6
- Starchy Veg (c)	0.5	nd	0.7	0.7	0.7	0.7
Calories (kcal)	2000	2000	2000	2000	2000	2000
Food Groups						
Fruit & juices (c)	1.0	2.5	2	2	2	2
Grains: total (oz)	6.4	7.3	6	6	6	6
- Whole grains (oz)	0.6	3.9	3	3	3	3
Milk & milk products incl whole fat (c)	1.5	0.7 (whole)	-	-	-	-
- Low-fat milk (c)	nd	1.9	3	3	3	3 (non-dairy)[3]
Animal Proteins:						
- Meat (oz)	2.5	1.4	2.5	0.6	-	-
- Poultry (oz)	1.2	1.7	1.5	0.4	-	-
- Eggs (oz)	0.4	nd	0.4	0.4	0.6	-
- Fish (total) (oz)	0.5	1.4	0.5	0.7	-	-
-- Hi *n*3 (oz)	0.1	nd	0.1	nd	-	-
-- Low *n*3 (oz)	0.4	nd	0.4	nd	-	-

Table B2.4 (continued). Dietary Pattern Comparison: Current U.S. intake, DASH-sodium diet, and USDA Food Patterns. Description, nutrient composition, and food group amounts (adjusted to 2000 calories)

Dietary Pattern	Usual U.S. Intake Adults 19 year+	DASH with Reduced Sodium	USDA Base Pattern[1]	USDA Plant-based	USDA Lacto-ovo Vegetarian	USDA Vegan
Plant Proteins:						
- Legumes (oz)	nd	0.4	See vegetables.	1.4	1.4	1.9
- Nuts & seeds (oz)	0.5	0.9	0.6	1.1	1.9	2.1
- Soy products (oz)	0.0	nd	0.05	0.9	1.7	1.4
Oils (g)	17.7	24.8	27	23	19	18
Solid Fats (g)	43.2	nd	16	16	16	16
Added Sugar (g)	79.0	12 (snacks/sweets)	32	32	32	32
Alcohol (g)	9.9	-	-	-	-	-

[1]The USDA Base Food Pattern is slightly adapted from the 2000-calorie pattern presented in the 2005 *Dietary Guidelines for Americans* (DGA). Vegetable subgroups were realigned to include a Red/Orange subgroup. The base pattern and the vegetarian variations are subject to change as the 2010 DGA are developed. The measures are cup and ounce equivalents (Britten, 2006; Marcoe, 2006). Nutrient distribution updated with 2010 composites.
[2]On USDA patterns, total recommended legume amount is the sum of amounts recommended in the Vegetable and the Meat & Beans groups. An ounce equivalent of legumes in the Meat & Beans group is ¼ cup. For example, in the 2000-calorie pattern, total weekly legume recommendation is (13 oz eq /4) + 1.5 cups = 5 cups.
[3]Non-dairy options in Vegan pattern are calcium-fortified soymilk, rice milk, and tofu. All USDA patterns contain a small amount of soy milk.
nd = Not described.
(-) = No recommendation.
Sources: Usual U.S. Intakes – WWEIA, NHANES 2001-2004 and WWEIA, NHANES 2005-2006, one-day mean intakes consumed per individual. Male and female intakes adjusted to 2000 calories, averaged, and rounded to one decimal point.

Part B. Section 2. Appendix: Dietary Patterns and Health Outcomes

Introduction

Across the world and within the United States, there are striking differences in diet. Concomitantly, there are substantial differences in health outcomes, many of which are related to diet. This section discusses several dietary patterns that are associated with desirable health outcomes. It focuses on total mortality, cardiovascular disease (CVD), and blood pressure, a major diet-related cardiovascular risk factor. The World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR), recently reviewed the available evidence of the relationship of cancer with specific dietary factors and overall dietary patterns (WCRF/AICR, 2007). Although several dietary factors were associated with specific types of cancer, it concluded that no firm judgment can be made on the relationship of dietary patterns with cancer, in large part, because variability in definitions precluded a formal synthesis of evidence.

The study of dietary patterns is complex. First, there is substantial heterogeneity even among diets that fall under a common rubric (e.g., Mediterranean diets). Second, dietary patterns are not static. Traditional diets known for their health benefits (e.g., Mediterranean and Okinawan diets) are being supplanted by versions that often reflect Western culture and that lead to worse not better health outcomes. For this reason, we focused on pre-transition dietary patterns. Third, with few exceptions, standardized assessment of diet is unavailable, making it difficult to compare diets. Fourth, health outcomes are often unavailable and, when available, are not directly comparable across studies. Fifth, dietary patterns, even with proven health benefits, may not be ideal and could be improved. For example, traditional Japanese diets are associated with a low risk of coronary heart disease but a high risk of stroke, likely because of excessive sodium intake. Sixth, describing dietary patterns and evaluating their health outcomes often requires scoring systems based on adherence to specific aspects of the diets. This approach commonly relies on researchers who exercise best judgment in selecting biologically relevant aspects of the diet and in developing a formula, which typically weights each dimension as of equivalent importance. Seventh, in the interpretation of observational data, particularly ecologic data, it is difficult to separate the effects of diet from other factors, such as smoking and physical inactivity, that likely account for part of the observed differences in health outcomes.

Despite these caveats, the 2010 Dietary Guidelines Advisory Committee (DGAC) was able to identify dietary patterns that are associated with substantial beneficial health benefits (Table B2.5). Specifically, the Committee focused on the following dietary patterns for which there was research on health outcomes as well as information on nutrient and food group composition: (1) Dietary Approaches to Stop Hypertension (DASH)-style dietary patterns, (2) Mediterranean-style dietary patterns, and (3) Vegetarian dietary patterns. The DASH dietary pattern is a Western-style dietary pattern for which a large and burgeoning literature documents its health benefits. The Committee also included Mediterranean and Japanese dietary patterns, which were associated with the lowest risk of coronary heart disease in the Seven Countries study (Keys, 1980). Subsequently, a substantial literature has documented the health benefits of Mediterranean-style diets. In contrast, while traditional Asian dietary patterns (e.g., Japanese and Okinawan dietary patterns) have also been associated with a reduced risk of coronary heart disease (Wilcox, 2007), documentation using contemporary research methods is scant. Finally, the Committee studied vegetarian diets, which have been associated with a reduced risk of coronary heart disease (Key, 1999).

DASH-style Dietary Patterns

DASH-style dietary patterns emphasize fruits, vegetables, and low-fat dairy products; include whole grains, poultry, fish and nuts; and are reduced in red meat, sweets, and sugar-containing beverages (Karanja, 1999; Craddick, 2003). The diets are rich in potassium, magnesium, calcium and fiber, and reduced in saturated fat and cholesterol. As originally tested, the DASH diet is reduced in total fat (27% kcal) with total protein intake of 18 percent of calories and carbohydrate intake of 55 percent of calories. However, other versions of the DASH diet are available, in which carbohydrate is partially replaced with protein (about half from plant sources) or unsaturated fat (predominantly monounsaturated fat) (Appel, 2005; Swain, 2008). The latter version is noteworthy because nutrient adequacy and a reduced saturated fat intake (6% kcal) were both achieved in the setting of high monounsaturated fat intake (21% kcal). Each of these DASH-style diets lowers blood pressure, improves blood lipids, and reduces CVD risk. Blood pressure reduction is the greatest when the DASH diet is consumed with reduced sodium intake (Sacks, 2001).

As originally developed, the DASH diet was designed to provide a nutrient profile that might lower blood pressure. As such, it is a derived dietary pattern. Nonetheless, it is based on foods that are routinely available in U.S. and was studied using foods purchased at local stores. At present, few adults, even those with hypertension, eat a diet that is consistent with the DASH dietary pattern (Mellen, 2008).

Mediterranean-style Dietary Patterns

In view of the large number of cultures and agricultural patterns of countries that border the Mediterranean Sea, the "Mediterranean" diet is not a single dietary pattern. Countries included those of southern-most Europe, the Middle East, and northern-most Africa. Interest in traditional Mediterranean-style diets is substantial because such diets have been associated with considerable health benefits. Because of the multiplicity of dietary patterns termed "Mediterranean," it has been challenging to characterize these diets. Although a traditional Mediterranean diet has no well-accepted set of criteria, it can be described as one that emphasizes breads and other cereal foods usually made from wheat, vegetables, fruits, nuts, unrefined cereals, and olive oil; includes fish and wine with meals (in non-Islamic countries); and is reduced in saturated fat, meat, and full-fat dairy products (Kris-Etherton, 2001; Trichopoulou, 2003; WCRF/AICR, 2007). Table B2.5 displays the nutrient profile and food group composition of Mediterranean-style diets, as reported in three cohort studies (one from Greece, one from Spain, and one from the U.S.) (Fung, 2009; Karanja, 1999; Lin, 2003; Nunez-Cordoba, 2008; Trichopoulou, 2003; Wilcox, 2007).

Results from observational studies and clinical trials suggest that consumption of a traditional Mediterranean diet, similar to that of Crete in the 1960s, is associated with one of the lowest risks of coronary heart disease in the world. Over time, the diet of Crete has changed remarkably and is now characterized by higher intake of saturated fat and cholesterol, and reduced intake of monounsaturated fats. At the same time, total fat consumption has fallen. These trends have been accompanied by a steady rise in coronary heart disease risk (Menotti, 1999).

Vegetarian Dietary Patterns

In many observational studies, vegetarian diets and lifestyle have been associated with improved health outcomes. The types of vegetarian diets consumed in the U.S. vary considerably. Strict vegetarians (i.e., vegans), do not consume any animal products, while other types of vegetarians, such as lacto-ovo vegetarians, consume milk and eggs. Although not strict vegetarians, many individuals consume small or minimal amounts of animal products. On average, vegetarians consume fewer calories from fat than non-vegetarians, particularly saturated fat, and have a higher consumption of carbohydrates than non-vegetarians. In addition, vegetarians tend to consume fewer overall calories and have a lower body mass index than non-vegetarians. These characteristics, in addition to the dietary pattern per se, may contribute to the improved health outcomes of vegetarians.

Although no or minimal consumption of animal products is a hallmark of vegetarian diets, these diets have a clear potential for confounding, particularly from other dietary and non-dietary factors. Hence, the improved health experience of vegetarians may not only result from reduced consumption of saturated fats but also from greater consumption of vegetables, fruit, nuts, and grains or from other health attributes, such as not smoking cigarettes.

Other Dietary Patterns

In view of the increasing diversity of the U.S. population, interest in the health effects of non-Western diets is substantial. One group of diets with potential health benefits are those consumed in Asia. It is well-documented that in Southeast Asia, coronary heart disease rates have been among the lowest in the world.

Lifestyle factors, especially diet, appear to be a major reason. However, contemporary evidence (e.g., prospective cohort studies and clinical trials) similar to the evidence available for the other types of diets is sparse.

Traditional Japanese dietary patterns emphasize soybean products, fish, seaweeds, vegetables, fruit, and green tea, and are reduced in meats (Shimazu, 2007). Nonetheless, it should be recognized that this diet is high in salt, likely accounting for the high incidence of stroke in this population. Similar to other dietary patterns, Japanese dietary patterns have evolved over time.

The longevity of Okinawans is among the highest in the world. Researchers attribute the longevity and health of Okinawans, in large part, to diet composition or some other aspect of their diet, such as energy restriction (Willcox, 2007). The indigenous Satsamu sweet potato, which is rich in nutrients, is the food staple that provides the bulk of energy intake. Other prominent foods are a wide variety of seaweeds, Okinawan tofu, and herbaceous plants. Okinawan food culture also includes a modest amount of fish and pork. The estimated carbohydrate content of this diet is extremely high, at more than 80 percent of calories. Salt intake is the lowest of all Japan. However, the traditional Okinawan diet has changed such that fast foods and processed foods are increasingly consumed.

What is the Effect of Different Dietary Patterns (DASH, Mediterranean, Vegetarian, and Other) on Blood Pressure in Adults?

The 2010 DGAC performed a literature search to identify research, with no date limits, on the effect of the above dietary patterns on blood pressure in adults. Some articles were reviewed that included dietary patterns that were characterized using dietary cluster or factor analysis. The NEL search identified 146 potential articles (11 reviews/meta-analyses and 135 primary studies). Of these, 126 were excluded. A total of 20 articles, all of them primary studies, met the eligibility criteria and were reviewed (Table B2.6).

Of the 12 studies that evaluated a DASH-style dietary pattern (Appel, 2005, 1997, 2003; Azadbakht, 2005; Dauchet, 2007; Forman, 2009; Miller, 2002; Nowson, 2009, 2005, 2004; Sacks, 2001; Schulze, 2003), nine were randomized controlled trials (Appel, 2005, 1997, 2003; Azadbakht, 2005; Miller, 2002; Nowson, 2009, 2005, 2004; Sacks, 2001), and three were prospective cohort studies (Dauchet, 2007; Forman, 2009; Schulze, 2003). In aggregate, the DASH diet lowered systolic blood pressure in 12 studies (Appel, 2005, 1997, 2003; Azadbakht, 2005; Dauchet, 2007; Forman, 2009; Miller, 2002; Nowson, 2009, 2005, 2004; Sacks, 2001; Schulze, 2003) and diastolic blood pressure in 10 of the 12 studies that reported diastolic blood pressure (Appel, 2005, 1997, 2003; Azadbakht, 2005; Dauchet, 2007; Forman, 2009; Miller, 2002; Nowson, 2005, 2004; Schulze, 2003). In several instances, blood pressure reduction occurred as part of a multi-factorial intervention that tested the DASH dietary pattern concomitantly with other interventions (Appel, 2003; Miller, 2002; Sacks, 2001).

Few studies examined the effects of a Mediterranean-style diet on blood pressure. In the one available study (Núñez-Córdoba, 2009) a cohort study, a Mediterranean-style diet lowered systolic and diastolic blood pressure.

Four trials tested the effects of vegetarian diets on blood pressure (Hakala and Karvetti, 1989; Margetts, 1986; Rouse, 1983; Sciarrone 1993). Vegetarian-style dietary patterns lowered systolic blood pressure in all four trials and diastolic blood pressure in three trials (Hakala and Karvetti, 1989; Rouse, 1983; Sciarrone, 1993).

One randomized, cross-over trial found that, within the context of a traditional Japanese diet, increased vegetables and fruit intake and decreased sodium intake significantly reduced systolic blood pressure in normotensive and hypertensive free-living rural Japanese (Takahashi, 2006).

What is the Effect of Different Dietary Patterns (DASH, Mediterranean, Vegetarian, and Other) on Cardiovascular Disease, Stroke, and Total Mortality in Adults?

The 2010 DGAC performed a literature search to identify research, with no date limits, on the effect of these dietary patterns on cardiovascular disease, stroke, and total mortality in adults. Some articles were reviewed that included dietary patterns that were characterized using dietary clusters or factor analysis. The search identified 197 potential articles (11 reviews/meta-analyses and 186 primary studies). Of these, 168 were excluded. A total of 29 articles (27 primary studies, one systematic review/meta-analysis, and one systematic review), met the eligibility criteria and were reviewed. Of the 27 primary studies, two were randomized controlled trials, 20 were prospective cohort studies (two were follow-up of RCTs and one was non-concurrent), three were case-control studies, one was a med adherence analysis, and one was a time series (Table B2.7).

Of the 10 studies that evaluated a DASH-style dietary pattern, nine were prospective cohort studies (Folsom, 2007; Fung, 2001, 2008; Heidemann, 2008; Hu, 2000; Levitan, 2009; Osler, 2001; Parikh, 2009; Singman, 1980) and one was a randomized trial in which estimated coronary heart disease risk was the outcome (Appel, 2005). Of the 10 that evaluated a relationship of a DASH-style dietary pattern with CVD, nine studies documented that consumption of a DASH-style diet was associated with a reduced risk of CVD (Appel, 2005; Fung, 2001, 2008; Heidemann, 2008; Hu, 2000; Levitan, 2009; Osler, 2001; Parikh, 2009; Singman, 1980), and one (Folsom, 2007) found no such relationship. For total mortality, six of seven studies that reported data on mortality documented an inverse relation (Fung, 2008; Heidemann, 2008; Hu, 2000; Levitan, 2009; Osler, 2001; Parikh, 2009) and one (Folsom, 2007) found no such relationship. In the two available studies with stroke (Fung, 2008; Parikh, 2009), consumption of a DASH-style pattern prevented stroke.

Several studies examined the effects of a Mediterranean style diet on CVD and total mortality. Of the 13 studies, one was a systematic review/meta-analysis (Mente, 2009), one was a meta-analysis (Sofi, 2008), nine were prospective cohort studies (Fidanza, 2004; Fung, 2009; Harriss, 2007; Knoops, 2004; Mitrou, 2007; Panagiotakos, 2009; Trichopoulou, 2003, 2009; Waijers, 2006), one was an adherence analysis (Alberti, 2008), and one was a case-control study (Panagiotakos, 2005). Of the 10 studies that evaluated a relationship of a Mediterranean-style dietary pattern with CVD, each documented a beneficial effect (Fidanza, 2004; Fung, 2009; Harriss, 2007; Knoops, 2004; Mente, 2009; Mitrou, 2007; Panagiotakos, 2009, 2005; Sofi, 2008; Trichopoulou, 2003). Likewise, of the 10 studies with data on total mortality, each documented an inverse relation (Alberti, 2008; Fidanza, 2004; Fung, 2009; Harriss, 2007; Knoops, 2004; Mitrou, 2007; Sofi, 2008; Trichopoulou, 2003, 2009; Waijers, 2006). In the one available study with stroke, consumption of a Mediterranean-style pattern prevented stroke (Fung, 2009).

Five studies examined the effects of a vegetarian diet on CVD and total mortality. Of the five studies, three were prospective cohort studies (Chang-Claude, 2005; Key, 1996; Mann, 1997), one was a meta-analysis (Key, 1998), and one was a time series analysis (Fraser, 2005). Of the five studies with CVD as the study outcome, all found that vegetarian diets were associated with a reduced risk of CVD compared to non-vegetarian diets (Chang-Claude, 2005; Fraser, 2005; Key, 1998, 1996; Mann, 1997). For total mortality, four studies (Fraser, 2005; Key, 1998, 1996; Mann, 1997) documented that a vegetarian diet was associated with a reduced risk of death, and one study (Chang-Claude, 2005) did not detect an association.

One prospective cohort study (Shimazu, 2007) assessed the association between dietary patterns among the Japanese and CVD mortality. Three diet patterns were identified: (1) Japanese pattern including soybean products, fish, seaweed, vegetables, fruit and green tea, (2) animal food pattern, and (3) high-dairy, high-fruit and vegetable, low alcohol (DFA) pattern. The Japanese pattern was associated with a decreased risk of CVD mortality, while the animal food pattern was associated with increased risk. The DFA pattern was not significantly associated with a change in CVD risk.

Conclusion

The totality of evidence documenting a beneficial impact of plant-based, lower-sodium dietary patterns on CVD risk is remarkable. Indeed, several distinct dietary patterns are associated with lower blood pressure and a reduced risk of CVD and total mortality. When explicitly tested, a reduced sodium intake further lowers blood pressure. A common feature of these diets is an emphasis on plant-based foods. Accordingly, fiber intake is high while saturated fat typically low. When total fat intake is high, that is, over 30 percent of calories, the predominant fat is monounsaturated or polyunsaturated fat. Carbohydrate intake is often, but not necessarily high; the predominant forms appear to be complex carbohydrates, often from whole grain products with minimal processing.

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Table B2.5. Selected dietary patterns with documented cardiovascular health benefits (adjusted to 2000 calories)

Dietary Pattern	**DASH with Reduced Sodium**	**Mediterranean Diet (Greece)**	**Mediterranean Diet (Spain)**	**Mediterranean Diet (U.S.)**	**Japanese**	**Okinawan**
Citation	Karanja et al, 1999 and Lin et al, 2003	Trichopoulou et al, NEJM 2003	Nunez-Cordoba 2008 (SUN Study; MAI high score)	Fung et al, 2009	Wilcox et al, 2007 (Circa 1950)	Wilcox et al, 2007 (Circa 1949)
Qualitative Description						
Emphasizes	Potassium-rich vegetables, fruits, and low-fat dairy products	Plant- foods, vegetables, fruits, grains, beans, nuts and seeds, olive oil, and fish	Plant- foods, vegetables, fruits, breads, other cereals potatoes, beans, nuts and seeds, olive oil, and fish	Plant foods, vegetables, fruits, whole grains, legumes, fish	Rice, legumes, soy foods, vegetables, seaweed, and fish	Plant-foods, primarily Okinawan sweet potatoes, rice, legumes, soy foods, other vegetables, and nutrient rich foods of low energy density
Includes	Whole grains, poultry, fish, and nuts	Lean meat Red wine	Cheese, yogurt Red wine	Lean meat	Fruit Meat and eggs	
Limits (small amount)	Red meats, sweets, and sugar-containing beverages		Red meat Sweets	Potatoes	Milk products	Fruit Meat, eggs Milk products
Nutrients						
Calories (kcal)	2000	2000	2000	2000	2000	2000
Carbohydrates (% total kcal)	58%	nd	47%	39.1%	79%	85%
Protein (% total kcal)	18%	nd	18%	15.1%	13%	9%
Total Fat (% total kcal)	27%	~42.7 (summed)	33%	nd	8%	6%
Saturated Fat (% total kcal)	7%	13.1 %	10%	10% (Incl. trans)	2.0%	1.9%
Monounsaturated (% total kcal)	10%	22.7%	15 %	9.5%	2.3%	1.8%

Table B2.5 (continued). Selected dietary patterns with documented cardiovascular health benefits (adjusted to 2000 calories)

Dietary Pattern	DASH with Reduced Sodium	Mediterranean Diet (Greece)	Mediterranean Diet (Spain)	Mediterranean Diet (U.S.)	Japanese	Okinawan
Polyunsaturated (% total kcal)	8%	6.9%	5.1 %	nd	3.5%	2.4%
Cholesterol (mg)	143	nd	nd	nd	nd	nd
Fiber (g)	29	nd	29	20	22	26
Potassium (mg)	4371	nd	4589	nd	2623	5826
Sodium (mg)	1095	nd	2532	nd	2370	1269
Food Groups						
Vegetables: total (c)	2.1	4.1	1.2	2.2	nd	nd
- Dark Green (c)	nd	nd	nd	nd	<0.1 (seaweed)	<0.1 (sea weed)
- Legumes[2](c)	nd	<0.1	0.4	0.3	0.3	0.5
- Red Orange (c)	nd	nd	nd	nd	0.5 (Asian sweet potatoes)	6.6 (Asian sweet potatoes)
- Other Veg (c)	nd	nd	nd	nd	1.3; + 0.3 (pickled veg)	0.9
- Starchy Veg (c)	nd	0.6	nd	No potatoes	0.3 (other potatoes)	<0.1 (other potatoes)
Fruit & juices (c)	2.5	1.0 (fruit & nuts) 1.5 (juice & other bev)	1.3 (fruit & juice) 0.1 (dried fruit & nuts)	1.6	0.2 (papaya & tomato = veg)	<0.1 (papaya & tomato = veg)
Grains: total (oz)	7.3	5.4	2.0	nd	2.4; 1.7 (rice)	1.1; 0.9 (rice)
- Whole grains (oz)	3.9	nd	nd	1.6	nd	nd
Milk & milk products, Whole	0.7	1.0	0.8	nd	<0.1	<0.1
- Low-fat (c)	1.9	nd	1.3	nd	nd	nd

Table B2.5 (continued). Selected dietary patterns with documented cardiovascular health benefits (adjusted to 2000 calories)

Dietary Pattern	**DASH with Reduced Sodium**	**Mediterranean Diet (Greece)**	**Mediterranean Diet (Spain)**	**Mediterranean Diet (U.S.)**	**Japanese**	**Okinawan**
Animal Proteins:						
- Meat (oz)	1.4	3.5	3.6	2.4	0.4	0.1
- Poultry (oz)	1.7	nd	nd	nd	nd	nd
- Eggs (oz)	nd	nd	1.9	nd	0.3	<0.1
- Fish (total) (oz)	1.4	0.8	2.4	1.5	2.1	0.6
-- Hi *n*3 (oz)	nd	nd	nd	nd	nd	nd
-- Low *n*3 (oz)	nd	nd	nd	nd	nd	nd
Plant Proteins:						
- Legumes (oz)	0.4	nd	0.4	nd	0.4 (Incl soy)	0.3 (Incl soy)
- Nuts & seeds (oz)	0.9	See fruit above.	See fruit above.	0.5	< 1 g	<0.1
- Soy products (oz)	nd	nd		nd	See legumes.	See legumes.
Oils (g)	24.8	40.3 (olive oil)	19.0 (olive oil)	nd	nd	nd
Solid Fats (g)	nd	nd	nd	nd	nd	nd
Added Sugar (g)	12	24.3	nd	nd	7.7	3.4
Alcohol (g)	Nd	7.9[2]	7.1 (red wine)	7.3	30.0 (flavors and alcohol)	7.8 (flavors and alcohol)

Table B2.6. Dietary patterns and blood pressure in adults

Author and Year	Study Type	Quality	Population/Location	Sig SBP Reduction	Sig DBP Reduction	Caveats
DASH	**N = 12** (9 RCT, 3 prospective cohort)	12 Positive 2 Neutral		12 +	10 + 1 Ø 1 n/d	
Appel LJ et al., 2005	RCT (OmniHeart)	Positive	N = 164 adult with prehypertension or stage 1 hypertension U.S.	+	+	Overall Between Diet Differences - SBP: Pro vs.Cho diet: P =0.002; Unsat Fat vs. Cho: P = 0.005 DBP: Pro vs.Cho diet: P <0.001; Unsat Fat vs. Cho: P = 0.02
Appel LJ et al., 1997	RCT	Positive	N = 459; 234 males; 225 females Normo and hypertensive subjects U.S.	+	+	SBP: P< 0.001 DBP: Males P <0.001; Females P = 0.003
Appel LJ et al., 2003	RCT	Positive	N = 810 free living adults Normo and Hypertensive U.S.	+	+	SBP and DBP: P <0.001
Azadbakht L et al., 2005	RCT	Neutral	N =116 subjects with metabolic syndrome BP > 130/85 Iran	+	+	For both men and women P<0.001
Dauchet L et al., 2007	Longitudinal and cross-sectional analysis	Positive	N= 6,119 (2596 men, 3523 women); free living France	+	+	SBP: P <0.05 DBP: P < 0.01 Longitudinal results: DASH score: SBP: P<0.002; DBP: P<0.02

Table B2.6 (continued). Dietary patterns and blood pressure in adults

Author and Year	Study Type	Quality	Population/Location	Sig SBP Reduction	Sig DBP Reduction	Caveats
Forman JP et al., 2009	Prospective cohort study	Positive	N = 83,882 females; Nurse's Health Study II Normotensive U.S.	+	+	Outcome in multivariate HR (95% CI) for incident HTN
Miller ER et al., 2002	RCT	Positive	N = 43 U.S.	+	+	SBP, DBP: P <0.001
Nowson CA et al., 2009	RCT	Positive	N = 111 females (menopausal) Australia	+ + **	Ø +**	SBP: P = 0.38, 0.21** DBP: P = 0.61, 0.27** ** With HTN meds
DASH	**N = 12** (9 RCT, 3 prospective cohort)	12 Positive 2 Neutral		12 +	10 + 1 Ø 1 n/d	
Nowson CA et al., 2004	RCT	Positive	N = 94 males and females Australia	+	+	SBP: P = 0.001 DBP: P = 0.05
Sacks FM et al., 2001	RCT (cross-over)	Positive	N = 390 (males, females; black and white) U.S.	+	n/d	SBP: P < 0.001
Schulze MB et al., 2003	Prospective cohort study	Positive	N = 8,552 females Normotensive Germany	+	+	HR (95% CI) for incident HTN

Table B2.6 (continued). Dietary patterns and blood pressure in adults

Author and Year	Study Type	Quality	Population/Location	Sig SBP Reduction	Sig DBP Reduction	Caveats
MEDITERRANEAN	N = 1 cohort	1 Positive		1+	1+	
Núñez-Córdoba JM et al., AJE 2009	Prospective cohort study (6 yr f/u)	Positive	N = 9,408 adults; 3,583 males, 5,825 females Spain	+	+	SBP: P = 0.01 DBP: P = 0.05
VEGETARIAN	N = 4 RCT	3Positive 1 Neutral		4+	3 + 1 Ø	
Hakala P and Karvetti RL, 1989	RCT	Positive	N = 110 adults Finland	+	+	SBP: P = 0.05 DBP: P = 0.01
Margetts BM et al., 1986	RCT (cross-over)	Neutral	N = 58; 42 males, 16 females Untreated mild hypertensives Australia	+	Ø	SBP: P , 0.05
Rouse IL et al., 1983	RCT (cross-over)	Positive	N = 59 males and females Australia	+	+	SBP, DBP: P <0.01
Sciarrone SE et al., 1993	RCT	Positive	N = 21 males Australia	+	+	Ovo-lacto vegetarian
JAPANESE/OKINAWAN	N = 1 RCT	1 Positive		1+	1 Ø	
Takahashi Y 2006	RCT	Positive	N = 550 (202 males, 348 females) Japan	+	Ø	SBP: P = 0.007 Japanese diet with ↑Vitamin C, carotene, Fruits and vegetables ↓ Sodium intake

Table B2.7. Dietary patterns, cardiovascular disease (CVD), and mortality in adults

Author and Year/ Quality/Study Type	Population/ Location	CVD	Mortality	Outcomes	Comments/Caveats
DASH and DASH Variations	**N=10** 1 RCT 9 Cohort				
Appel et al., 2005 Randomized, 3-period Crossover Trial Positive	N=164 (mean age = 53.6 yr; 45% women) Omni-Heart U.S.	+	nd	Compared with baseline, all diets lowered estimated CHD risk. Compared with the high carbohydrate diet, estimated 10-yr CHD risk was lower and similar on the high protein and high unsaturated fat diets. Compared to high carbohydrate diet, high UFA diet decreased SBP; increased HDL-C; decreased TG, no change in LDL-C	Addresses **total fat question:** High UFA diet replaced 10% energy from CHO (total fat=37% E; 21% MUFA; 10% PUFA; 6% SFA). High UFA improved CHD risk, BP, and serum lipids, compared to high CHO (SFA constant).
Folsom et al., 2007 Prospective Cohort Study Neutral	N = 20,993, 55-69 yrs at baseline Iowa Women's Health Study Non-hypertensive	**Ø**	**Ø**	Incidence of hypertension inversely associated w/ degree of concordance with DASH diet (P for trend = 0.02), After adjustment for additional risk factors, little evidence that any endpoint assoc w/ DASH score	DASH diet concordance score calculated w/ baseline FFQ in 1986, subjects followed through 2002.
Fung et al., 2001 Prospective Cohort Study Positive	N = 69,017, 38 – 63 yrs at baseline Nurses' Health Study U.S.	+	nd	Higher **Prudent-pattern** score assoc w/ lower risk total CHD (RR Q5 vs Q1=0.61, 95% CI: 0.49-0.76, P for trend <0.001); after adjustment for BMI, smoking, caloric intake, supplemental use, hormone replacement therapy, and other coronary risk factors (RR=0.76, 95% CI: 0.60-0.98, P for trend = 0.03). Higher **Western-pattern** score assoc w/ higher risk total MI after adjusting for age (RR Q5 versus Q1= 1.44, 95% CI: 1.16-1.78, P for trend <.001); remained sig. after multivariate adjustment (RR=1.46, 95% CI: 1.07-1.99).	12 y follow-up: 1984-1996 Baseline=1984 All FQQs using 1984 format (116 item)

Table B2.7 (continued). Dietary patterns, cardiovascular disease (CVD), and mortality in adults

Author and Year/ Quality/Study Type	**Population/ Location**	**CVD**	**Mortality**	**Outcomes**	**Comments/Caveats**
Fung et al., 2008 Prospective Cohort Study Positive	N = 88,517, 34 - 59 yrs at baseline Nurses' Health Study U.S.	+ **and Stroke**	+	RR of CHD across quintiles of DASH score = 1.0, 0.99, 0.86, 0.87 and 0.76 (95% CI: 0.67 - 0.85, P for trend <0.001) Magnitude of risk difference was similar for nonfatal MI and fatal CHD DASH score assoc w/ ↓ risk of stroke	24y follow-up: 1980-2004 Baseline=1980 Included data from older 1980 FFQ (61 item) and 1984 FFQ
Heidemann et al., 2008 Prospective Cohort Study Positive	N = 72,113 Nurses' Health Study U.S.	+	+	**Prudent** pattern assoc w/ 28% lower risk of cardiovascular mortality and 17% lower risk of all-cause mortality, **Western** pattern assoc w/ 22% higher risk of cardiovascular mortality, 16% higher risk of cancer, and 21% higher risk of all-cause mortality.	18 y follow-up: 1984-2002 Baseline=1984 All FQQs using 1984 format (116 item)
DASH and DASH Variations	**N=10** 1 RCT 9 Cohort				
Hu et al., 2000 Prospective Cohort Study Positive	N=44,875 men, 40-75 y at baseline Health Professionals Follow-up Study	+	+	Two patterns explaining < 20% of the variance identified by factor analysis: **Prudent and Western** Higher **Prudent score** assoc w/ monotonic lower risk of CHD (RR across quintiles: 1.0, 0.84, 0.76, 0.71, 0.66 (95% CI: 0.54-0.80, P for trend < 0.0001 For fatal CHD after adjustment for age, smoking, BMI, and other CHD risk factors (RR across increasing quintiles: 1.0, 0.83, 0.78, 0.81, 0.70 (95% CI: 0.54, 0.91, P for trend=0.03 Higher **Western score** assoc w/ monotonic higher risk of CHD (RR across quintiles (P<0.0001) CHD RR (highest Prudent vs lowest Western) = 0.50 (95% CI: 0.34, 0.74).	8 y follow-up from 1986 Authors conclude dietary patterns derived from their FFQ predict CHD risk independent of other lifestyle factors.

Table B2.7 (continued). Dietary patterns, cardiovascular disease (CVD), and mortality in adults

Author and Year/ Quality/Study Type	Population/ Location	CVD	Mortality	Outcomes	Comments/Caveats
Levitan et al., 2009 Prospective Cohort Study Neutral	36,019 women, 48-83 y at baseline Swedish Mammography Cohort	+	+	Top quartile of DASH score had 37% lower rate of heart failure (HF); rate ratios across quartiles = 1 (ref), 0.85 (95% CI: 0.66-1.11), 0.69 (95% CI: 0.54-0.88), and 0.63 (95% CI: 0.48-0.81), P for trend <0.001. Both HF-assoc hospitalization and death were determined	7 y follow-up; dietary intake only measured at baseline Hypertension was based on self-report.
Osler et al., 2001 Prospective Cohort Study Neutral	N= 5,872 (2,994 men, 2,878 women) Random equal-sized samples 30,40,50, 60-y at baseline Danish World Health Organization MONICA survey	+	+	**Prudent** pattern inversely assoc w/ all-cause (hazard ratios =0.63 in women =0.75 in men) and cardiovascular mortality **Western** pattern not associated w/ mortality	
Parikh et al., 2009 Prospective Cohort Study Neutral	N=5532 adults w/ hypertension NHANES III (1988-1994) U.S.	+	+ **and Stroke**	DASH-like group had lower unadjusted mortality rates per 1,000 person-yrs for all-cause mortality (P=0.02), stroke mortality (P<0.001), and cancer mortality (P=0.05). DASH-like group, after adjusting for multiple confounders, assoc w/ lower mortality from all causes (HR=0.69, 95% CI 0.52-0.92, P=0.01) and stroke (HR=0.11, 95% CI 0.03-0.47, P=0.003). CVD mortality risk (HR=0.92, 95% CI 0.63-1.35, P=0.67), IHD (HR=0.77, 95% CI 0.47-1.14, P=0.28), and cancer (HR=0.51, 95% CI 0.23-1.10, P=0.09) not stat significant	8.2 person-years follow-up Secondary outcomes included specific causes of mortality CVD, ischemic heart disease, stroke, and cancer

Table B2.7 (continued). Dietary patterns, cardiovascular disease (CVD), and mortality in adults

Author and Year/ Quality/Study Type	**Population/ Location**	**CVD**	**Mortality**	**Outcomes**	**Comments/Caveats**
DASH and DASH Variations	**N=10** 1 RCT 9 Cohort				
Singman et al., 1980 Prospective Cohort Study Neutral	N=1,113 men experimental and 467 men control U.S.	+	nd	**Prudent** diet group in both age categories (40-49 y & 50-59 y) had lower CHD incidence rates	
MEDITERRANEAN	N=13 1 Index 1 Systematic Rev 1 Meta Analysis 9 Cohort 1 Case Control				
Alberti et al., 2008 Analysis of Mediterranean Adequacy Index (MAI) Neutral	5 data sets on 23 populations	ND	+	Inverse correlation between MAI and 25 y CHD death rate and total mortality	MAI: divide the sum of the percentages of dietary energy from food groups typical of a healthy reference Mediterranean diet, by the sum of the percentages of dietary energy of food groups that are not characteristic of a healthy reference Mediterranean diet
Fidanza et al., 2004 Prospective Cohort Study Neutral	N=12,763 men, 40-59 yrs at baseline U.S.	+	+	The coefficient of linear correlation between the MAI and CHD death rates in the 16 cohorts was -0.72 (P=0.001)	MAI Index

Table B2.7 (continued). Dietary patterns, cardiovascular disease (CVD), and mortality in adults

Author and Year/ Quality/Study Type	Population/ Location	CVD	Mortality	Outcomes	Comments/Caveats
Fung et al., 2009 Prospective Cohort Study Neutral	N = 76,522 , 38 - 63 yrs at baseline Nurses' Health Study U.S.	+ **and Stroke**	+	Top aMed quintile ↓risk CHD and stroke: RR CHD = 0.71, 95% CI: 0.62-0.82, P for trend < 0.0001, RR stroke = 0.87, 95% CI: 0.73-1.02, P for trend = 0.03 CVD mortality ↓: top quintile RR=0.61, 95% CI:0.49-0.76, P for trend <0.0001	20 y follow-up: 1984-2004 Baseline=1984 All FQQs using 1984 format
Harriss et al., 2007 Prospective Cohort Study Neutral	N= 40,653 (16,673 men, 23,908 women) Melbourne Collaborative Study	+	+	Mediterranean dietary factor inversely assoc w/ CVD and IHD mortality IHD, HR (highest compared w/ lowest quartile) = 0.59 (95% CI: 0.39-0.89, P for trend=0.03) Excluding subjects w/ prior CVD (HR=0.51, 95% CI: 0.30-0.88, P for trend = 0.03)	Mean follow-up = 10.4 y Involved migrants to Australia from Mediterranean countries (24% of subjects were Mediterranean born)
MEDITERRANEAN	**N=13** 1 Index 1 Systematic Rev 1 Meta Analysis 9 Cohort 1 Case Control				
Knoops et al., 2004 Prospective Cohort Study Neutral	N= 40,653 (1,507 men, 832 women) HALE cohort Netherlands	+	+	Mediterranean diet (HR = 0.77, 95% CI: 0.68 - 0.88) assoc w/ ↓ risk all-cause mortality Similar results were observed for mortality from coronary heart disease, cardiovascular diseases, and cancer	10 y mortality from all causes (CVD, CHD, and Cancer)

Table B2.7 (continued). Dietary patterns, cardiovascular disease (CVD), and mortality in adults

Author and Year/ Quality/Study Type	**Population/ Location**	**CVD**	**Mortality**	**Outcomes**	**Comments/Caveats**
Mente et al., 2009 Systematic Review/ Meta-analysis Positive	146 prospective cohort studies + 43 RCTs (pub1950-2007) Europe, Asia, U.S.	+	nd	Among the dietary exposures with strong evidence of causation from cohort studies, only the Mediterranean dietary pattern is related to CHD in RCTs	Used Bradford Hill guidelines to derive causation score based on 4 criteria (strength, consistency, temporality, and coherence) for each dietary exposure in cohort studies and examined for consistency with the findings of RCTs.
Mitrou et al, 2007 Prospective Cohort Study Positive	N= 352,497 (196,158 men, 156,339 women) median age = 62 NIH-AARP Diet and Health Study U.S.	+	+	Men: multivariate HR all-cause mortality = 0.79 (95% CI: 0.76 - 0.83), CVD mortality = 0.78 (95% CI: 0.69 - 0.87), cancer mortality = 0.83 (95% CI: 0.76 - 0.91). Women: ↓ risks = 12% cancer mortality (P for trend = 0.04); = 20% all-cause mortality (P for trend < 0.001).	5 y follow-up Used 9-point score to assess conformity with Mediterranean dietary pattern (components included vegetables, legumes, fruits, nuts, whole grains, fish, monounsaturated fat-saturated fat ratio, alcohol, and meat)
Panagiotakos et al., 2005 Case-control Study Positive	N= 848 w/ 1st CHD event and 1,078 age- and sex-matched controls (aged 49 - 75) CARDIO2000 Study Greece	+	nd	10-unit increase in Mediterranean diet score assoc w/ 27% (95% CI: 0.66 - 0.89) decrease odds of non-fatal acute coronary syndromes	Secondary prevention

Table B2.7 (continued). Dietary patterns, cardiovascular disease (CVD), and mortality in adults

Author and Year/ Quality/Study Type	Population/ Location	CVD	Mortality	Outcomes	Comments/Caveats
Panagiotakos et al., 2009 Prospective Cohort Study Neutral	N = 2,101 ATTICA Study Greece	+	nd	Pattern characterized by cereals, small fish, and olive oil assoc w/ ↓ CVD risk (HR = 0.72, 95% CI: 0.52 - 1.00) Pattern characterized by fruit and vegetables using olive oil in cooking (HR = 0.80, 95% CI: 0.66 - 0.97) Patterns characterized by sweets, red meat, margarine, salty nuts, hard cheese and alcohol assoc w/ ↑ CVD risk	5 y follow-up Exclusion of CVD done by detailed clinical evaluation
Trichopoulou et al., 2003 Prospective Cohort Study Neutral	N = 22,043, 38-63 yrs at baseline EPIC Study Greece	+	+	Higher adherence to Med diet assoc w/ ↓ total mortality (adjusted HR =0.75, 95% CI: 0.64 - 0.87); inverse assoc w/ CHD death (adjusted HR = 0.67, 95% CI: 0.47 - 0.94) and cancer death (adjusted HR = 0.76, 95% CI: 0.59 - 0.98).	44 month follow-up
Trichopoulou et al., 2009 Prospective Cohort Study Neutral	N = 23,349 EPIC Study Greece	nd	+	Higher adherence to a Med diet assoc w/ ↓ total mortality (adjusted mortality ratio = 0.864, 95% CI: 0.802 - 0.932).	8.5 y follow-up
Waijers et al., 2006 Prospective Cohort Study Neutral	N = 5,427 women (aged >60 years) EPIC Study Netherlands	nd	+	Principal component analysis identified 3 diet patterns: Mediterranean, Traditional Dutch, and Healthy Dutch Healthy trad Dutch pattern assoc w/ ↓ mortality rate; women in highest tertile 30% ↓mortality risk	8.2 y follow-up

Table B2.7 (continued). Dietary patterns, cardiovascular disease (CVD), and mortality in adults

Author and Year/ Quality/Study Type	Population/ Location	CVD	Mortality	Outcomes	Comments/Caveats
VEGETARIAN	**N=5** 4 Cohort 1 Time series				
Chang-Claude et al., 2005 Prospective Cohort Study Neutral	N = 1,904 ; 858 males, 1,046 females 1,165 lacto-ovo, 679 non-veg, 60 vegans. Germany	+	**Ø**	↓ risk ischemic heart disease (RR = 0.70, 95% CI: 0.41 – 1.18) No effect on mortality (RR = 1.10, 95% CI: 0.89 – 1.36)	A cohort study of vegetarians and health-conscious persons in Germany was followed-up prospectively for 21 years, including 1,225 vegetarians and 679 health-conscious nonvegetarians
Fraser et al., 2005 Time series Neutral	(N=30,292 males, N=50,562 females) California Seventh Day Adventists (N=297,126 male, 344,401 female) Stanford Five-City Project U.S.	+	+	Rate ratio (RR) (Adventist/Stanford study) 1st event fatal CHD = 0.59 (95% CI, 0.43-0.80) men and 0.49 (0.32-0.76) women. Vegetarian Adventists, RR = 0.45 (0.24-0.84) and 0.20 (0.06-0.63) men and women, respectively. 1st event MI RR = 0.60 (0.47-0.78) and 0.46 (0.33-0.65). Vegetarian Adventists RR = 0.37 (0.20-0.66) and 0.62 (0.35-1.09) men and women, respectively.	Two concurrent California observational studies, one with unusual dietary habits, are compared. Similar diagnostic criteria were used in both the Adventist Health Study and the Stanford Five-City Project.
VEGETARIAN	**N=5** 4 Cohort 1 Time series				

Table B2.7 (continued). Dietary patterns, cardiovascular disease (CVD), and mortality in adults

Author and Year/ Quality/Study Type	Population/ Location	CVD	Mortality	Outcomes	Comments/Caveats
Key et al., 1996 Prospective Cohort Study Neutral	N = 10,771; 4,336 males, 6,435 females UK	+	+	Daily consumption of fresh fruit assoc w/ ↓ mortality ischemic heart disease (rate ratio = 0.76, 95% CI: 0.60 – 0.97), cerebrovascular disease (rate ratio = 0.68, 95% CI: 0.47 – 0.98), and all causes (rate ratio = 0.79, 95% CI: 0.70 – 0.90)	Mortality ratios measured for vegetarianism and for daily versus less than daily consumption of wholemeal bread, bran cereals, nuts or dried fruit, fresh fruit, and raw salad in relation to all cause mortality and mortality from ischemic heart disease, cerebrovascular disease, all malignant neoplasms, lung cancer, colorectal cancer, and breast cancer.
Key et al., 1998 Meta-analysis: 5 Prospective Cohort Studies Neutral	N = 76,172 men and women U.S.	+	+	Compared to non-vegetarians, vegetarians had 24% ↓ IHD mortality (rate ratio = 0.76, 95% CI:0.62-0.94) Reduction in mortality among vegetarians varied significantly with age at death. Regular meat consumers compared to semi-vegetarians (fish or meat <1X/wk), IHD rate ratios=0.78 (95% CI:0.68-0.89) in semi-vegetarians and 0.66 (95% CI:0.53-0.83) in vegetarians (P for trend <0.001).	Vegetarians were those who did not eat any meat or fish (n = 27,808). Non-vegetarians were from a similar background to the vegetarians within each study.
Mann et al., 1997 Prospective Cohort Study Neutral	N = 10,802; 4,102 males, 6,700 females Health conscious, mean age=33-34 United Kingdom	+	+	An increase in mortality for IHD was observed with increasing intakes of total and saturated animal fat and dietary cholesterol-death rate ratios in the third tertile compared with the first tertile: 329, 95% confidence interval (CI) 150 to 721; 277, 95% CI 125 to 613; 353, 95% CI 157 to 796, respectively. No protective effects for dietary fiber, fish or alcohol	13.3 y follow-up Prospective observation of vegetarians, semi-vegetarians, and meat eaters

Table B2.7 (continued). Dietary patterns, cardiovascular disease (CVD), and mortality in adults

Author and Year/ Quality/Study Type	Population/ Location	CVD	Mortality	Outcomes	Comments/Caveats
JAPANESE/ OKINAWAN	**N=1 Cohort**				
Shimazu et al., 2007 Prospective Cohort Study Neutral	N=40,547, 40-79 yrs at baseline Japan	+	+	3 patterns identified by principal components analysis: i) a Japanese dietary pattern highly correlated with soybean products, fish, seaweeds, vegetables, fruits and green tea, (ii) an 'animal food' dietary pattern and (iii) a high-dairy, high-fruit-and-vegetable, low-alcohol (DFA) dietary pattern. Japanese pattern assoc w/ ↓ risk CVD mortality (HR = 0.73, 95% CI 0.59-0.92, P for trend=0.003)	7 y follow-up

ND = Not determined.

Part B. Section 3: Translating and Integrating the Evidence: A Call to Action

The data clearly document that America is experiencing a public health crisis involving overweight and obesity. Particularly alarming is the further evidence that the obesity epidemic involves American children and youth, as nearly one in three are classified as overweight or obese. Childhood obesity and overweight is a serious health concern in the United States (U.S.) because of immediate health consequences, as well as because it places a child at increased risk of obesity in adulthood, with all its attendant health problems such as cardiovascular diseases (CVD) and type 2 diabetes (T2D). All adults—parents, educators, caregivers, teachers, policy makers, health care providers, and all other adults who work with and care about children and families—serve as role models in some capacity and share responsibility for helping the next generation prevent obesity by promoting healthy lifestyles at all ages. Primary prevention of obesity, starting in pregnancy and early childhood, is the single best strategy for combating and reversing America's obesity epidemic for current and future generations. While there is also an urgent need to improve the health and well-being of children and adults who are already overweight and obese, primary prevention offers the strongest universal benefits. Solving the obesity problem will take a coordinated system-wide, multi-sectoral approach that engages parents as well as those in education, government, healthcare, agriculture, business, advocacy, and the community. This approach must promote primary prevention among those who are not yet overweight and address weight loss and fitness among those who are overweight.

Disparities in health among racial and ethnic minorities and among different socioeconomic groups have been recognized as a significant concern for decades. Several subgroups of the population (Native Americans, Blacks, Hispanics, and segments of the population with low income) have a strikingly high prevalence of overweight and obesity. Dietary patterns vary among different ethnic and socioeconomic groups. Individuals of lower education and/or income levels tend to eat fewer servings of vegetables and fruits than do those with more education and/or higher income. According to national surveys, Blacks tend to have the lowest intakes of vegetables and fruits among ethnic groups, but also have a higher prevalence of hypertension and related diseases, such as stroke. Although the reasons for these differences are complex and multifactorial, this Report addresses research indicating that certain dietary changes can provide a means to reduce health disparities. If we are successful in changing dietary intake patterns of all Americans through a systematic approach, we will go a long way in narrowing the gap in health disparities.

Although obesity is related to many chronic health conditions, it is not the only diet-related public health problem confronting the Nation. Nutritionally suboptimal diets with or without obesity are etiologically related to many of the most common, costly, and yet preventable health problems in the U.S., particularly CVD (atherosclerosis, stroke) and related risk factors (T2D, hypertension, and hyperlipidemia), some cancers, and osteoporosis. Improved nutrition and appropriate eating behaviors have tremendous potential to enhance public health, prevent or reduce morbidity and mortality, and decrease health care costs.

The science is not perfect; evidence is strong in some areas and limited or inconsistent in other areas. Nevertheless, this Report is an urgent call to action to address a major public health crisis by focusing on helping all Americans achieve energy balance through adoption and adherence to current nutrition and physical activity guidelines.

After reviewing its entire Report, the Dietary Guidelines Advisory Committee (DGAC) recognized a need to not only document the evidence, but to translate and integrate major findings that have cross-cutting public health impact and provide guidance on how to implement the changes necessary to enhance the health and well being of the population. Below are the four major cross-cutting findings from the 2010 DGAC Report, followed by suggestions for implementation.

Four Main Integrated Findings to Be Used in Developing the 2010 Dietary Guidelines for Americans

1. Reduce the incidence and prevalence of overweight and obesity of the U.S. population by reducing overall calorie intake and increasing physical activity.

A focus on life-stage approaches (pregnant women, children, adolescents, adults, and older adults) is necessary nationwide to help Americans meet nutrient needs within appropriate calorie intake. To achieve this, Americans should:

- Know their calorie needs. In other words, individuals need to know how many calories they should consume each day based on their age, sex, and level of physical activity.
- Significantly lower excessive calorie intake from added sugars, solid fats, and some refined grain products.
- Increase their consumption of a variety of vegetables, fruits, and fiber-rich whole grains.
- Avoid sugar-sweetened beverages.
- Consume smaller portions, especially of high-calorie foods.
- Choose lower-calorie options, especially when eating foods away from home.
- Increase their overall physical activity.
- Have access to improved, easy-to-understand labels listing calorie content and portion size on packaged foods and for restaurant meals (especially quick service [i.e., fast food] restaurants, restaurant chains, and other places where standardized foods are served).

Collectively, these measures will help Americans manage their body weight and improve their overall health. In order to achieve this goal, the public and private sectors must be committed to assisting all Americans to know their calorie needs at each stage of life and help them recognize how to manage and/or lower their body weight. Simple but effective consumer-friendly tools for self-assessment of energy needs and self-monitoring of food and beverage intake are urgently needed and should be developed. These strategies will enable everyone to recognize and implement, both inside and outside the home, dietary recommendations that have been consistent for decades.

2. Shift food intake patterns to a more plant-based diet that emphasizes vegetables, cooked dry beans and peas, fruits, whole grains, nuts, and seeds. In addition, increase the intake of seafood and fat-free and low-fat milk and milk products, and consume only moderate amounts of lean meats, poultry, and eggs.

This approach will help Americans meet their nutrient needs while maintaining energy balance. Importantly, this will assist Americans to increase their intake of shortfall nutrients, such as potassium and fiber. These goals can be attained through a range of food patterns—from omnivore to vegan—that embrace cultural heritage, lifestyle, and food preferences. These flexible patterns of eating must encompass all foods and beverages that are consumed as meals and snacks throughout the day, regardless of whether they are eaten at home or away from home.

3. Significantly reduce intake of foods containing added sugars and solid fats because these dietary components contribute excess calories and few, if any, nutrients. In addition, reduce sodium intake and lower intake of refined grains, especially refined grains that are coupled with added sugar, solid fat, and sodium.

The components of the American diet that are consumed in excess are solid fats and added sugars (SoFAS), refined grains, and sodium. SoFAS alone contribute approximately 35 percent to total energy intake of Americans. Collectively, the consumption of foods containing SoFAS, refined grains, and sodium lead to excessive calorie intake, resulting in weight gain and health consequences such as hypertension, CVD, and T2D. Reducing the intake of these overconsumed components will require much more than individual behavior change. A comprehensive approach is needed. The food industry will need to act to help Americans achieve these goals. Every aspect of the industry, from research and development to production and retail, needs to contribute healthful food solutions to reduce the intake of SoFAS, certain refined grain products, and sodium. Sound health and wellness policies at the local, state, and national level also can help facilitate these changes.

4. Meet the 2008 Physical Activity Guidelines for Americans.

A comprehensive set of physical activity recommendations for people of all ages and physical conditions was released by the U.S. Department of Health and Human Services in 2008 (HHS, 2008). The 2008 *Physical Activity Guidelines for Americans* were developed to help Americans to become more physically active. By objective measures, large portions, indeed the majority, of the U.S. population are sedentary (Metzger, 2008). In fact, Americans spend most of their waking hours engaged in behaviors that expend very little energy (Matthews, 2008). To increase the public's participation in physical activity, compelling multi-sector approaches are needed to improve home, school, work, and community environments to promote physical activity. These changes need to surpass planned exercise and foster greater energy expenditure throughout the day. Improved exposure to recreational spaces, increased use of active transportation, and encouraging development of school and worksite policies that program physical activity throughout the day can help enable Americans to develop and maintain healthier lifestyle behaviors. Special attention and creative approaches also are needed to help Americans reduce sedentary behaviors, especially television viewing and video game use, among children and adolescents.

A Call to Action

Dietary Guidelines for Americans have been published since 1980. During this time obesity rates have escalated and dietary intake patterns have strayed from the ideal. The 2010 DGAC recognizes that several of its recommendations have been made repeatedly in prior reports with little or no demonstrable impact. For example, recommended intakes of vegetables and fruit remain woefully unchanged, despite continuing advice to markedly increase intake of these foods. Substantial, high-level barriers appear to impede achievement of these goals, including certain government regulations and policies. Chief among these are land use policy and economic incentives for food manufacturers. The food supply and access to it has changed dramatically over the past 40 years, contributing to an overall increased calorie intake by many individuals. Since the 1970s, the number of fast food restaurants has increased 147 percent. The portions that are served in restaurants and the serving sizes of foods sold in packages at stores have increased as well. Moreover, the number of food items at the supermarket has increased from 10,425 in 1978 to 46,852 in 2008, and most of these contribute SoFAS, refined grains, and sodium to the American diet (see *Part D. Section 1. Energy Balance and Weight Management* for a discussion of recent changes in the food environment). This has far-reaching effects such that the average child now consumes 365 calories per day of added sugars and 433 calories per day of solid fat for a combined total of 798 calories, or more than one-third of total calorie intake (HHS, 2010; see *Part D. Section 2. Nutrient Adequacy*). Conversely, Americans spend 45 percent less time preparing food at home (see *Part D. Section 1. Energy Balance and Weight Management*) or eating food at the family table than previously, and this behavioral trend is associated with increased risk of weight gain, overweight, and obesity. **In this context, the DGAC concluded that mere repetition of advice will not effectively help Americans achieve these evidence-based and often-repeated goals for a healthy diet.**

Ensuring that all Americans consume a health-promoting dietary pattern and achieve and maintain energy balance requires far more than individual behavior change. A multi-sectoral strategy is imperative. For this reason, the 2010 DGAC strongly recommends that HHS and USDA convene appropriate committees, potentially through the Institute of Medicine (IOM), to develop a strategic plan focusing on the behaviors and actions needed to successfully implement the four key 2010 DGAC recommendations highlighted above.

A coordinated strategic plan that includes all sectors of society, including individuals, families, educators, communities, allied health professionals, public health advocates, policy makers, scientists, and small and large businesses (e.g., farmers, agricultural producers, food scientists, food manufacturers, and food retailers of all kinds), should be engaged in developing and implementing the plan to help all Americans eat well, be physically active, and maintain good health. It is important that any strategic plan be evidence-informed, action-oriented, and focused on changes in systems (IOM, 2010a). This systems approach is already underway in countries such as the United Kingdom for obesity prevention (Butland, 2007) with promising results. Recent examples of this approach in the U.S. include an IOM committee convened by HHS and USDA and charged with developing strategies for gradually but dramatically reducing sodium intake, which remains persistently high even after more than 40 years of advice. This IOM committee recently issued its report (IOM, 2010b), providing a comprehensive strategy to reduce dietary sodium intake in the general population by focusing on the food supply and targeting industry to partner in systematic reductions in sodium content of foods. Already there is encouraging evidence that food manufacturers are responding positively and are committed to reducing the sodium content in their food products. Similarly, the U.S. National Physical Activity Plan, released in May 2010, was developed by multiple stakeholders and provides a comprehensive, realistic implementation framework intended to promote physical activity in the American population. Most recently, the May 2010, White House Task Force on Childhood Obesity Report, *Solving the Problem of Childhood Obesity Within a Generation*, also calls for a multi-sector, systems approach to solving this important public health issue.

An Urgent Need to Focus on Children

Any and all systems-based strategies must include a focus on children. Primary prevention of obesity must begin in childhood. This is the single most powerful public health approach to combating and reversing America's obesity epidemic over the long term. Trends for childhood overweight and obesity are alarming, with obesity prevalence rates tripling between 1980 and 2004. Although rates for children appear to be leveling off, they remain high, with one-third currently overweight or obese, defined as at or above the 85th percentile on body mass index (BMI)-for-age growth charts (Ogden, 2010). These numbers represent more than 25 million children in the U.S. In order to reverse this trend, we will need to work together as a Nation to improve the food environment to which children are exposed at home, school, and the community. Efforts to prevent childhood obesity need to start very early, even in utero. Increasing evidence indicates that maternal obesity before conception and excessive gestational weight gain represent a substantial risk of childhood obesity in the offspring (see *Part D. Section 2. Energy Balance and Weight Management* for a detailed discussion of this issue). Thus, addressing maternal nutrition, physical activity, and body weight before conception and during pregnancy as well as emphasizing early childhood nutrition is paramount for preventing the onset of childhood obesity. Areas targeting childhood obesity prevention that should be addressed include, but are not limited to:

- Improve foods sold and served in schools, including school breakfast, lunch, and after-school meals and competitive foods so that they meet the recommendations of the IOM report on school meals (IOM, 2009) and the key findings of the 2010 DGAC. This includes all age groups of children, from preschool through high school.
- Increase comprehensive health, nutrition, and physical education programs and curricula in U.S. schools and preschools, including food preparation, food safety, cooking, and physical education classes and improved quality of recess.
- Develop nationally standardized approaches for health care providers to track BMI-for-age and provide guidance to children and their families to effectively prevent, monitor, and/or treat childhood obesity.
- Develop nationally standardized approaches for health care providers to improve nutrition, physical activity participation, healthy weight gain during pregnancy, and the attainment of a healthy weight postpartum.
- Increase safe routes to schools and community recreational areas to encourage active transportation and physical activity.
- Remove sugar-sweetened beverages and high-calorie snacks from schools, recreation facilities, and other places where children gather.
- Develop and enforce responsible zoning policies for the location of fast food restaurants near schools and places where children play.
- Increase awareness and promote action around reducing screen time (television and computer or game modules) and removing televisions from children's bedrooms.
- Develop and enforce effective policies regarding marketing of food and beverage products to children. Efforts in this area are underway through a government interagency committee comprised of the Federal Trade Commission, Centers for Disease Control and Prevention, USDA, and Food and Drug Administration, as well as some self-regulation from industry (Omnibus Appropriations Act, 2009).
- Develop affordable summer programs that support children's health, as children gain the most weight during the out-of-school summer months (von Hippel, 2007).

Challenges and Opportunities for Change

Change is needed in the overall food environment to support the efforts of all Americans to meet the key recommendations of the 2010 DGAC (Story, 2009).

The 2010 DGAC recognizes that the current food environment does not adequately facilitate the ability of Americans to follow the evidence-based recommendations outlined in the 2010 DGAC Report. Population growth, availability of fresh water, arable land constraints, climate change, current policies, and business practices are among some of the major challenges that need to be addressed in order to ensure that these recommendations can be implemented nationally. For example, if every American were to meet the vegetable, fruit, and whole-grain recommendations, domestic crop acreage would need to increase by an estimated 7.4 million harvested acres (Buzby, 2006). Furthermore, the environment does not facilitate the ability of individuals to follow the 2008 *Physical Activity Guidelines for Americans*. Most home, school, work, and community environments do not promote engagement in a physically active lifestyle. To meet these challenges, the following sustainable changes must occur:

- Improve nutrition literacy and cooking skills, and empower and motivate the population to prepare and consume healthy foods at home, especially among families with children.
- For all Americans, especially those with low-income, create greater financial incentives to purchase, prepare, and consume vegetables and fruit, whole grains, seafood, fat-free and low-fat milk and milk products, lean meats, and other healthy foods. Currently, individuals have an economic disincentive to purchase healthy foods.
- Improve the availability of affordable fresh produce through greater access to grocery stores, produce trucks, and farmers' markets.
- Increase environmentally sustainable production of vegetables, fruits, and fiber-rich whole grains.
- Ensure household food security through measures that provide access to adequate amounts of foods that are nutritious and safe to eat.
- Develop safe, effective, and sustainable practices to expand aquaculture and increase the availability of seafood to all segments of the population. Ensure that consumers have access to user-friendly benefit/risk information to make informed seafood choices.
- Encourage restaurants and the food industry to offer health-promoting foods that are low in sodium; limited in SoFAS and refined grains; and served in smaller portions.
- Implement the U.S. National Physical Activity Plan, a private-public sector collaborative promoting local, state, and national programs and policies to increase physical activity and reduce sedentary activity (National Physical Activity Plan, 2010). Through the Plan and other initiatives, develop efforts across all sectors of society, including health care and public health; education; business and industry; mass media; parks, recreation, fitness, and sports; transportation, land use, and community design; and volunteer and non-profit. Reducing screen time, especially television, for all Americans also will be important.

The 2010 DGAC recognizes the significant challenges involved in implementing the goals outlined here. These challenges go beyond cost, economic interests, technological and societal changes, and agricultural limitations. Over the past several decades, the value of preparing and enjoying healthy food has eroded, leaving instead the practices of eating processed foods containing excessive sodium, solid fats, refined grains, and added sugars. As a Nation, we all need to value and adopt the practices of good nutrition, physical activity, and a healthy lifestyle. The DGAC encourages all stakeholders to take actions to make every choice available to Americans a healthy choice. To move toward this vision, all segments of society—from parents to policy makers and everyone else in between—must now take responsibility and play a leadership role in creating gradual and steady change to help current and future generations live healthy and productive lives. A measure of success will be evidence that meaningful change has occurred when the 2015 DGAC convenes.

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Part C. Methodology

Committee Appointment

Beginning with the 1985 edition, the U.S. Department of Agriculture (USDA) and U.S. Department of Health and Human Services (HHS) have appointed a Dietary Guidelines Advisory Committee (DGAC) of prominent experts in nutrition and health to assist in preparing the *Dietary Guidelines for Americans*. This Committee has been an effective mechanism for obtaining a comprehensive review of the science, recommendations from experts, and broad public acceptance of the *Dietary Guidelines*. The 2010 DGAC was established for the single, time-limited task of reviewing the 2005 edition of *Nutrition and Your Health: Dietary Guidelines for Americans* and determining whether, on the basis of current scientific and medical knowledge, revision was warranted. The Committee determined that a revision was needed and developed nutrition and health recommendations in this Advisory Report to the Secretaries of USDA and HHS. The Committee was dissolved upon delivery of this report.

Nominations were sought from the public through a *Federal Register* notice published on April 10, 2008. Prospective members of the DGAC were expected to be knowledgeable about current scientific research in human nutrition and chronic disease, and be respected and published experts in their fields. They would be familiar with the purpose, communication, and application of the *Dietary Guidelines* and have demonstrated interest in the public's health and well-being through their research and educational endeavors. Expertise was sought in specific specialty areas, including, but not limited to, the prevention of chronic diseases (e.g., cancer, cardiovascular disease, type 2 diabetes, obesity, and osteoporosis), energy balance (including physical activity), epidemiology, food safety and technology, general medicine, gerontology, nutrient bioavailability, nutrition biochemistry and physiology, nutrition education, pediatrics, public health, and evidence review methodology.

The Secretaries of USDA and HHS jointly selected individuals for membership to the 2010 DGAC. The chosen individuals are highly respected by their peers for the depth and breadth of their scientific knowledge of the relationship between dietary intake and health in all relevant areas of the current *Dietary Guidelines*.

To ensure that recommendations of the Committee took into account the needs of the diverse groups served by USDA and HHS, membership included, to the extent practicable, individuals with demonstrated ability to represent minorities, women, and persons with disabilities. Efforts were made to ensure equitable geographic distribution and racial, ethnic, and gender representation. Appointments were made without discrimination on the basis of age, race and ethnicity, gender, sexual orientation, disability, or cultural, religious, or socioeconomic status. Equal opportunity practices, in line with USDA and HHS policies, were followed in all membership appointments to the Committee.

Charge to the 2010 Dietary Guidelines Advisory Committee

The *Dietary Guidelines for Americans* provide science-based advice for Americans, ages 2 years and older, in order to promote health and to reduce the risk of major chronic diseases through diet and physical activity.

The *Dietary Guidelines* form the basis of Federal nutrition policy, nutrition standards, nutrition programs, and nutrition education for the general public and are published jointly by USDA and HHS every 5 years.

The charge to the Dietary Guidelines Advisory Committee, whose duties were time-limited and solely advisory in nature, was as follows:

- Inform the Secretaries of both Departments if no changes to the *Dietary Guidelines for Americans*, 2005 are warranted. This action will disband the DGAC.
- Inform the Secretaries of both Departments if changes are warranted, based on the preponderance of the most current scientific and medical knowledge, and determine what issues for change need to be addressed.

- Place their primary focus on the review of scientific evidence published since the last DGAC deliberations.
- Place their primary emphasis on the development of food-based recommendations.
- Prepare and submit a report of technical recommendations with rationales to the Secretaries. DGAC responsibilities do not include translating the recommendations into a policy or communications document.
- Disband upon the submittal of the Committee's recommendations via the *Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans, 2010*.

The Committee Process

The 13-member Committee served without pay and worked under the regulations of the Federal Advisory Committee Act (FACA). The Committee held six public meetings in Washington, DC over the course of 1½ years. Meetings were held in October 2008; January, April, and November 2009; and April and May 2010. Members of the general public were able to attend the Committee's first two meetings in person in Washington, DC. For the remaining meetings, members of the public were able to participate by webinar. All meetings were announced in the *Federal Register*. Meeting minutes and transcripts were posted for each meeting at www.dietaryguidelines.gov. Archived recordings of the third through sixth meetings were made available at www.dietaryguidelines.gov. All documents pertaining to Committee deliberations were made available for public viewing at the first two meetings, and thereafter, were made available through www.dietaryguidelines.gov and at the National Agricultural Library Reference Desk.

Written public comments were received throughout the Committee's deliberations through a newly developed electronic database designed for collecting public comments. This database allowed for the generation of public comment reports as a result of a query by key topic areas. Comments received on and before April 29, 2010, were compiled into these reports and shared with all Committee members. A general description of the types of comments received and the process used for collecting public comments is described in *Appendix E-5. Public Comments*. Comments can be viewed by the public at www.dietaryguidelines.gov. In response to a solicitation for oral comments, 51 of the 58 organizations or individuals who registered presented oral testimony during the January 29-30, 2009, meeting of the Committee. These comments are summarized in the January Public Meeting Minutes at www.dietaryguidelines.gov.

The Committee used a newly developed, state-of-the-art, web-based electronic system and methodology to address the majority of the science-based research questions posed by the Committee. These reviews are publicly available in the Nutrition Evidence Library (NEL) at www.NutritionEvidenceLibrary.gov. Remaining questions were answered by data analyses, modeling analyses, and consideration of other evidence-based reviews or existing reports, such as the 2008 edition of the *Physical Activity Guidelines for Americans*. Topic areas that were addressed for this Report were similar to those for the 2005 *Dietary Guidelines*, but this new methodology and web-based system allowed the Committee to ask and process more questions in a systematic, transparent, evidence-based manner. These research questions were developed and assessed by seven subcommittees: Energy Balance and Weight Management; Nutrient Adequacy; Fatty Acids and Cholesterol; Carbohydrates and Protein; Sodium, Potassium, and Water; Alcohol (initially called Ethanol); and Food Safety and Technology. One main difference from 2005 was that protein was added as a topic area, thus resulting in the Carbohydrates and Protein subcommittee. Food technology was also added as a topic area and was incorporated into the Food Safety and Technology subcommittee. Each subcommittee was made up of three to five Committee members, with one Committee member appointed as the lead. Although the lead member was responsible for communicating and coordinating all the work that needed to be accomplished within the subcommittees, draft conclusions reached on the scientific evidence reviewed ultimately reflected the consensus of the entire Committee.

Subcommittees met regularly and communicated by conference calls, webinars, e-mail, and face-to-face meetings. Each subcommittee was responsible for presenting the basis for its draft conclusions and recommendations to the full Committee within a public forum, responding to questions, and making changes if indicated. To gain perspective for interpreting the science, some subcommittees invited experts to respond to specific questions during conference calls. The full Committee also heard presentations at the public meetings from five invited outside experts. These experts addressed questions posed by the Committee in advance and responded to additional questions during the meetings.

The Committee members were supported by USDA's Designated Federal Officer, who led the administrative effort for this revision process and served as one of four Co-executive Secretaries (two from USDA and two from HHS). Support staff for managing Committee operations consisted of 12 USDA and HHS Dietary Guidelines Management Team members and 10 NEL Team members, including a research librarian. Each subcommittee included a primary and secondary Dietary Guidelines Management Team member as well as a primary and secondary NEL Team member.

In addition to the seven topical subcommittees, the DGAC included a Science Review subcommittee, similar to that formed for the 2005 DGAC. The main focus of this four-member subcommittee was to provide oversight to the whole DGAC process, an especially important function given the shift to a systematic and transparent evidence-based review process using the newly developed NEL. Additional roles included providing guidance on overlapping and cross-cutting issues and determining the final report structure and format. As the review of the science progressed, the Science Review subcommittee meetings were opened to subcommittee Chairs and eventually to other Committee members during times when cross-cutting topics were placed on the agenda. In order to adhere to FACA guidelines, full Committee participation was not allowed, except in cases where the meeting was strictly administrative in nature and was held for purposes of information sharing only.

Reflecting the DGAC subcommittee structure, the bulk of the report consists of eight science-based chapters that review the evidence on these major topic areas. In addition, throughout their deliberations, the Committee considered issues related to overall dietary patterns and the need for synthesizing and integrating findings from individual diet and nutrition topic areas. As a result, the Committee included two additional chapters—*Part B. Section 2. The Total Diet: Combining Nutrients, Consuming Food* and *Part B. Section 3. Translating and Integrating the Evidence: A Call to Action*.

Systematic Review of the Scientific Evidence

In 2005, USDA and HHS committed to using an evidence-based, systematic review methodology to support development of the 2010 DGAC Report. This rigorous, transparent methodology, designed to minimize bias, enables the Departments to comply with the Data Quality Act, which mandates that the government ensure the quality, objectivity, utility, and integrity of information used to form Federal guidance.

Science leaders from the Agency for Healthcare Research Quality (AHRQ), the U.S. Cochrane Collaboration, and the American Dietetic Association assisted in developing the NEL systematic review methodology. NEL nutritionists and systematic review methodologists helped Committee members execute the systematic review and synthesize the evidence in its DGAC Report.

DGAC members developed the NEL systematic review questions, created a literature search protocol (called the search and sort plan) for each question, and approved all completed search and sort lists. Trained Evidence Abstractors (National Service Volunteers) systematically abstracted published articles and evaluated the methodological rigor of each study. NEL staff conducted quality reviews of these materials and developed evidence portfolios with summary paragraphs and evidence tables to assist the committee in synthesizing the evidence. Based on the evidence portfolio, Committee members developed evidence summaries and conclusion statements, graded each conclusion, and described these findings in the DGAC Report. The complete evidence portfolio for each NEL systematic review question is available in the USDA NEL, which can be accessed at www.NutritionEvidenceLibrary.gov. These steps are described in greater detail in the following sections.

Question Development

Each DGAC subcommittee generated a list of topic areas to explore to update the 2005 *Dietary Guidelines*. These lists were based on the evolution of the science, public comment received, and whether controversy existed about a given topic or guideline. After developing an initial list of research questions, the subcommittees set priorities for questions to be answered using the NEL systematic review methodology. The wording and intent of specific questions evolved and additional questions were considered in an iterative process. Frequently, multiple questions were needed to fully address a topic of interest. This cluster of questions was referred to as a "family of questions." Limitations in time and resources prevented the review of all questions using the NEL systematic review methodology.

As needed, NEL staff conducted exploratory literature searches and developed analytical frameworks to assist Committee members in framing NEL systematic review questions. The scope of topic areas addressed was very broad, so subcommittee members were required to make critical decisions related to the comprehensiveness of reviews, such as determining literature search date ranges. Any available systematic reviews (e.g., 2009 AHRQ Report *Vitamin D and Calcium: A Systematic Review of Health Outcomes*) or reports based on systematic reviews (e.g., *Physical Activity Guidelines Advisory Committee Report, 2008*) that were deemed to be current and comprehensive representations of available literature were not duplicated by the NEL team. Results from the 2007 *World Cancer Research Fund/American Institute for Cancer Research; Food, Nutrition, Physical Activity, and the Prevention of Cancer: A Global Perspective* Report were used to substantiate recommendations related to food, nutrient, and diet intake and cancer-related outcomes.

Literature Search and Sort Plans

A method, referred to as PICO, was used to identify the **P**opulation or Participants, **I**ntervention (or Exposure in observational studies), **C**omparator, and **O**utcomes of interest to be addressed by a specific question or family of questions. The PICO method aided the generation of a literature search and sort plan, which defined the eligibility criteria for studies selected for inclusion in each systematic review. All searches were limited to human studies, developed countries, English language, and peer-reviewed publications. Unpublished data, including abstracts and conference proceedings, were not included. A brief explanation of the rationale behind the chosen search strategy for specific topics and questions is presented in the Methodology section in each chapter in *Part D. Science Base*. General eligibility criteria included factors, such as:

- Age
- Health status of subjects (inclusion of subjects with type 2 diabetes or other prevalent chronic diseases varied by topic)
- Study setting
- Number of subjects per study arm (typically a minimum of 10 subjects per study arm)
- Attrition rate (typically less than 20 percent; rate was modified for long-term studies)
- Characteristics of the intervention (e.g., dose or duration of intervention, food based nutrients)
- Outcome measures and timing of measures
- Study design

The subcommittees tailored inclusion and exclusion criteria by question or family of questions. Each subcommittee carefully considered the date range from which to extract the evidence, based upon whether the systematic review was designed to update 2005 *Dietary Guidelines*, update a comprehensive systematic review, or examine an area not previously addressed by the *Dietary Guidelines*. Many searches initially included all study designs. However, for a number of questions, cross-sectional studies were eventually excluded from review when sufficient evidence from studies with a stronger design was available.

Existing systematic reviews were frequently incorporated into the portfolio of evidence used to answer a question. Comprehensive systematic reviews (with well-documented methodology and rigorous criteria for judging methodological quality of included studies and grading the body of evidence), were occasionally selected to serve as a baseline for a review in cases where the seminal research on a question was considered to be "settled science." Numerous published systematic reviews conducted by the American Dietetic Association were updated for this report, using DGAC criteria.

The Committee used an iterative, step-wise process to determine which research designs were considered to examine a question. Study designs included intervention trials, observational studies, ecological studies, systematic reviews, and meta-analyses. If systematic reviews were used, primary studies included in these reviews were excluded. If multiple systematic reviews considered an overlapping body of primary studies, this was noted in the evidence summary.

Each search and sort plan specified the databases and search terms used to guide the search. PubMed/Medline and the Cochrane Database of Systematic Reviews were searched for all of the NEL systematic review questions, supplemented by BIOSIS, CAB Abstracts, Food Science & Technology Abstracts, Scopus, ScienceDirect, Embase, Aquatic Sciences and Fisheries Abstracts, Fish and Fisheries Worldwide, and AGRICOLA, as dictated by the question topics. A wide variety of search terms and key words were used, including subject headings such as MeSH and thesauri terms. Because some databases do not have full text search capabilities, key word/subject terms searches were limited to certain fields (e.g., titles and abstracts), which may have limited identification of potentially relevant articles.

Electronic searches were augmented by hand searches of references from primary and review articles, as well as articles identified for consideration by committee members. If new search terms were identified, the electronic searches were rerun to ensure completeness of the search. The Committee monitored the search process including review of the search terms and results. The search was expanded or modified based on their feedback and knowledge of the field.

Selecting the Evidence

The literature search plan was implemented collaboratively by the research librarian, the NEL nutrition scientist staff, and the DGAC members. The research librarian conducted a title screen and identified abstracts to be reviewed by the NEL staff. All abstracts identified by the research librarian were evaluated by the NEL staff, in accordance with criteria outlined in the search and sort plan. Articles that potentially met the eligibility criteria were reviewed in full-text version. Two lists were compiled for review by subcommittee members: a list of citations meeting the inclusion criteria and a list of citations recommended for exclusion (with the specific rationale for exclusion noted). When an article could not be clearly included or excluded based on the eligibility criteria, it was highlighted for subcommittee review.

Once the subcommittee reached agreement on the final list of articles to be included in the review, the NEL staff assigned each included manuscript to a National Service Volunteer to prepare an evidence worksheet. Information on the search terms used, search date, number of included and excluded citations identified by the search, final list of included citations, and a table with the excluded citations, including reason for exclusion, are provided in the NEL, at www.NutritionEvidenceLibrary.gov.

Critical Review of Studies

National Service Volunteers, a cadre of highly qualified nutrition and health professionals, were trained and served as evidence abstractors to support the systematic review process. They: (1) classified the study by design type; (2) extracted key evidence from each individual study into a comprehensive, templated evidence worksheet (made available to committee members and posted on the NEL); and (3) applied predefined criteria from Research Design and Implementation Checklists for each primary research study and review study to critically appraise the methodological quality of the study. Evidence abstractors received training on how to apply the criteria to studies differing in design.

Each study received a quality rating of positive, neutral, or negative, based upon a predefined scoring system (these quality grades are available for each article in the NEL). In the chapter text, for clarity, these ratings are described as studies which are methodologically strong (positive), methodologically neutral (neutral), and methodologically weak (negative). The appraisal of study quality is a critical component of the systematic review methodology because in a highly transparent manner, it indicates the Committee's judgment regarding the relevance (external validity/generalizability) and validity of each study's results. This rating, referred to as the "quality rating," indicates the extent to which the design and conduct of a study is shown to be protected from systematic bias, nonsystematic bias, and inferential error (Lohr, 2004). Studies were not excluded on the basis of quality rating. However, the quality rating was taken into consideration by the DGAC as they reviewed the literature and formed conclusions.

Summaries of the Evidence

NEL staff drafted evidence summary paragraphs and evidence tables for all included articles on a question or family of questions to aid analysis and synthesis of the complete body of evidence. These paragraphs and tables provided key information about the study design, quality rating, study subjects, the intervention or exposure, comparators, and key outcomes. Using this information, and going back to the original articles when necessary, Committee members then drafted an evidence overview summary, which included an overall summary statement, comparison of findings between studies, discussion of relevant issues related to methodologies used, and definitions.

Formulating and Grading the Conclusion Statement

The final step in the DGAC's systematic review process was writing and grading a Conclusion statement, based upon the body of scientific evidence evaluated. This step was characterized by careful consideration of the qualitative and quantitative findings. Each Conclusion statement briefly answered the research question, focusing on the general agreement among studies. When the evidence addressed only one sex, age group, ethnicity, or level of health risk (such as children or subjects without cardiovascular disease), this was reflected in the Conclusion statement. Conclusions also included a statement regarding distinct subgroups, if findings for that population were different than for the overall conclusion.

Developing and grading each Conclusion was a deliberative and time-consuming process that benefited from group interaction. The strength of the evidence supporting the conclusion statement was graded using the DGAC's predetermined criteria (outlined in Table C1), which assessed the quality (relevance and validity) and size of the studies, the quantity of studies, the consistency and agreement across studies, the generalizability to the population of interest, and the magnitude of the effect or public health impact. Each subcommittee deliberated on each Conclusion statement and grade, and proposed Conclusions and grades were then brought to the full Committee for consideration and discussion. Due to the challenge of grading such a broad range of conclusions within one report, the Committee decided to use the following qualitative word grades rather than numerical grades: Strong; Moderate; Limited; Expert Opinion; Grade Not Assignable.

For some research questions, the DGAC's systematic review generated recommendations for future research.

Table C1. 2010 DGAC Conclusion Grading Chart used to grade the strength of the body of evidence supporting conclusion statements

Elements	***Strong***	**Moderate**	**Limited**	**Expert Opinion Only**	**Grade Not Assignable**
Quality Scientific rigor and validity Study design and execution	Studies of strong design Free from design flaws, bias, and execution problems	Studies of strong design with minor methodological concerns OR only studies of weaker study design for question	Studies of weak design for answering the question OR inconclusive findings due to design flaws, bias, or execution problems	No studies available Conclusion based on usual practice, expert consensus, clinical experience, opinion, or extrapolation from basic research	No evidence that pertains to question being addressed
Consistency Consistency of findings across studies	Findings generally consistent in direction and size of effect or degree of association, and statistical significance with very minor exceptions	Inconsistency among results of studies with strong design, OR consistency with minor exceptions across studies of weaker design	Unexplained inconsistency among results from different studies, OR single study unconfirmed by other studies	Conclusion supported solely by statements of informed nutrition or medical commentators	NA

Table C1 (continued). 2010 DGAC Conclusion Grading Chart used to grade the strength of the body of evidence supporting conclusion statements

Elements	*Strong*	Moderate	Limited	Expert Opinion Only	Grade Not Assignable
Quantity Number of studies Number of study participants	One large study with a diverse population or several good quality studies Large number of subjects studied Studies with negative results have sufficiently large sample size for adequate statistical power	Several studies by independent investigators Doubts about adequacy of sample size to avoid Type I and Type II error	Limited number of studies Low number of subjects studied and/or inadequate sample size within studies	Unsubstantiated by published research studies	Relevant studies have not been done
Impact Importance of studied outcomes Magnitude of effect	Studied outcome relates directly to the question Size of effect is clinically meaningful Significant (statistical) difference is large	Some doubt about the statistical or clinical significance of the effect	Studied outcome is an intermediate outcome or surrogate for the true outcome of interest OR size of effect is small or lacks statistical and/or clinical significance	Objective data unavailable	Indicates area for future research
Generalizability Generalizability to population of interest	Studied population, intervention, and outcomes are free from serious doubts about generalizability	Minor doubts about generalizability	Serious doubts about generalizability due to narrow or different study population, intervention or outcomes studied	Generalizability limited to scope of experience	NA

Use of the USDA Food Patterns for Special Analyses

The 2010 DGAC identified specific questions that they felt could best be addressed through a food pattern modeling approach, using the USDA Food Patterns and the modeling process developed to address similar requests by the 2005 DGAC.

Briefly, the USDA Food Patterns describe types and amounts of food to consume that will provide a nutritionally satisfactory diet. They include recommended intakes for five major food groups and for subgroups within several of the groups. They also recommend an allowance for intake of oils and limits on intake of calories from solid fats and added sugars. The calories and nutrients that would be expected from consuming a specified amount from each component of the patterns are determined by calculating nutrient profiles. A nutrient profile is the consumption-weighted average nutrient content for nutrient-dense forms of foods within each group. These nutrient profiles can be modified based on the assumptions for each food pattern modeling analysis. Additional details on the USDA Food Patterns can be found in the report for the food pattern modeling analysis, *Adequacy of the USDA Food Patterns*, which is available at www.dietaryguidelines.gov.

The USDA Food Patterns were originally developed in the 1980s (Cronin, 1987; Welsh, 1993), and were substantially revised and updated in 2005, concurrent with the development of the 2005 *Dietary Guidelines* (Britten, 2006a). The 2005 updates included use of nutrient goals from the Institute of Medicine (IOM) *Dietary Reference Intakes* reports that were released from 1997 to 2004 (IOM, 1997, 1998, 2000, 2001, 2002, 2004). The developmental process and the food patterns resulting from the 2005 update have been documented in detail (Britten, 2006a; Marcoe, 2006).

A food pattern modeling process was developed for and used by the 2005 DGAC to determine the hypothetical impact on nutrients in and adequacy of the food patterns when specific changes are made. The structure of the USDA Food Patterns allows for modifications that test the overall impact on diet quality of various dietary recommendation scenarios. Most analyses involved identifying the impact of specific changes in amounts or types of foods that might be recommended by the Committee or selected by consumers. For example, subcommittees requested analyses to obtain information on the potential impact of consumers selecting only lacto-ovo vegetarian choices, eliminating legumes, or choosing varying levels of fat as a percent of calories (DGAC, 2004). The use of food pattern modeling analyses for the 2005 DGAC has been documented (Britten, 2006b; Nicklas, 2005; Weaver, 2005).

Five 2010 DGAC subcommittees identified a total of 18 questions that they felt could be addressed through food pattern modeling. Several questions were merged or dropped, resulting in 12 modeling analyses that were completed and provided as reports to the relevant subcommittees. For each question, a specific approach was drafted by USDA staff and provided to the subcommittee for comment. After the approach was discussed and accepted, USDA staff completed the analytical work and drafted a full report for the subcommittee's consideration. Each report was discussed by the relevant subcommittee, and the analysis and report were revised as needed. The food pattern modeling analyses conducted for the DGAC are listed in Table C2. Full reports for each analysis are available online at www.dietaryguidelines.gov; summary discussions are provided in relevant chapters of the DGAC Report, as shown in the Table.

Table C2. Food pattern modeling analyses conducted for the 2010 DGAC

Topic and Question	Addressed in
E3.1: Adequacy of the USDA Food Patterns How well do the USDA Food Patterns, using updated food intake and nutrient data, meet IOM and potential DG 2010 nutrient recommendations?	Part B.2: The Total Diet: Combining Nutrients, Consuming Foods
E3.2: Realigning Vegetable Subgroups What revisions to the vegetable subgroups may help to highlight vegetables of importance and allow recommendations for intake levels that are achievable, without compromising the nutrient adequacy of the patterns?	Part B.2: The Total Diet: Combining Nutrients, Consuming Foods
E3.3: Vegetarian Food Patterns How well do plant-based or vegetarian food patterns, adapted from the USDA Food Patterns, meet IOM and potential DG 2010 nutrient recommendations?	Part B.2: The Total Diet: Combining Nutrients, Consuming Foods
E3.4: Starchy Vegetables How do the nutrients provided by the starchy vegetable subgroup compare with those provided by grains and those provided by other vegetable subgroups? How would nutrient adequacy of the patterns be affected by considering starchy vegetables as a replacement for some grains rather than as a vegetable subgroup?	Part B.2: The Total Diet: Combining Nutrients, Consuming Foods
E3.5: "Typical Choices" Food Patterns What is the impact on caloric and nutrient intake if the USDA Food Patterns are followed but typical rather than nutrient-dense food choices are made?	Part B.2: The Total Diet: Combining Nutrients, Consuming Foods

Table C2 (continued). Food pattern modeling analyses conducted for the 2010 DGAC

Topic and Question	Addressed in
E3.6: Milk Group and Alternatives What is the impact on nutrient adequacy (1) if no milk or milk products were consumed, (2) if calcium was obtained from nondairy sources or fortified foods, and (3) if more fluid milk and less cheese were consumed?	Part D.2: Nutrient Adequacy
E.3.7: Replacing all Non-Whole Grains with Whole Grains What is the impact on intake of folate and other nutrients if all recommended grain amounts are selected as whole grains rather than half whole and half nonwhole grains?	Part D.2: Nutrient Adequacy
E3.8: Cholesterol What is the impact on food choices and overall nutrient adequacy of limiting cholesterol to less than 200 milligrams per day?	Part D.3: Fatty Acids and Cholesterol
E3.9: Reducing Cholesterol-Raising Fatty Acids What is the impact on food choices and overall nutrient adequacy of limiting cholesterol-raising (CR) fatty acids to less than 7 percent of total calories and to less than 5 percent of total calories, with CR fatty acids operationalized as total saturated fatty acids minus stearic acid?	Part D.3: Fatty Acids and Cholesterol
E3.10: Seafood What is the impact on nutrient adequacy of increasing seafood in the USDA Food Patterns to (1) 4 ounces per week of seafood high in *n*-3 fatty acids, (2) 8 ounces per week of seafood in proportions currently consumed, and (3) 12 ounces per week of seafood low in *n*-3 fatty acids?	Part D.3: Fatty Acids and Cholesterol
E3.11: Sodium What would the sodium levels of the USDA Food Patterns be (1) using current patterns, (2) using "typical choices" patterns, and (3) using only low sodium and no-salt-added foods?	Part D.6: Sodium, Potassium, and Water
E3.12: Potassium What are the potassium levels in the USDA Food Patterns, in comparison to current consumptions and DASH diet levels, in absolute amounts, adjusted for energy intake, and as a ratio of sodium to potassium? How would potassium levels of the USDA Food Patterns change if current levels of coffee and tea intake were included?	Part D.6: Sodium, Potassium, and Water

Chapter Summary

The Committee used conclusions from the NEL systematic review as the primary means to answer their research questions. These Conclusion statements were integrated with results from food modeling analyses, reviews of reports from expert groups, dietary intake analyses, presentations by expert consultants, established nutrition science knowledge, and/or expert opinion of the DGAC and the broader scientific community to inform the development of the Committee's Implications statements. The Implications statements are an extension of the NEL Conclusion statements that lay out the overarching conclusion that the Committee has drawn about the question.

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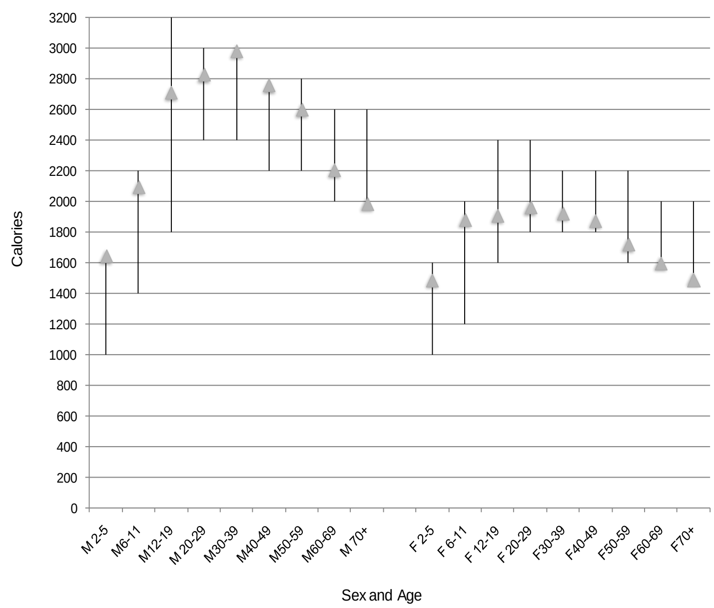
Part D. Section 1: Energy Balance and Weight Management

Introduction

Energy balance refers to the balance between calories consumed through eating and drinking and those calories expended through physical activity and metabolic processes. Energy consumed must equal energy expended for a person to remain at the same body weight. Overweight and obesity will result from excess calorie intake and/or inadequate physical activity. Weight loss will occur when a calorie deficit exists, which can be achieved by eating less, being more physically active, or a combination of the two. Recommendations for calorie intake to maintain weight will vary depending on a person's age, sex, size, and level of physical activity. Specific equations for estimating calorie needs are provided in the Dietary Reference Intakes (DRI) (Institute of Medicine [IOM], 2002/2005). Recommended total energy intakes range from 2000 to 3000 calories per day for men and 1600 to 2400 calories per day for women, depending on age and physical activity level (see *Part D. Section 2: Nutrient Adequacy* and Table B2.1 in *Part D. Section 2: The Total Diet: Combining Nutrients, Consuming Food* for additional information on energy intake). Although current mean energy intake seems to be in this range, as indicated in Figure D1.1, energy intake is only one part of the energy balance equation.

Figure D1.1. Mean total energy intake in comparison to recommended ranges for age and sex groups



Note: Vertical lines represent recommended ranges of calorie intake based on sex and age, with the triangle denoting mean energy intake for each group.

Source: What We Eat in America, National Health and Nutrition Examination Survey (WWEIA, NHANES), 2005-2006, individuals 2 years and older (excluding breast-fed children), Day 1 dietary intake data, weighted. Available at: www.ars.usda.gov/ba/bhnrc/fsrg. (USDA, 2008).

Recommendations for energy intake include consideration of the physical activity level of each individual, and strong evidence indicates that the current level of calorie intake is too high, given physical activity levels in the United States (U.S.).

Although the U.S. does not have a national surveillance system that captures total energy expended throughout the day, several national public health surveillance systems monitor physical activity in the U.S. population, including the Behavioral Risk Factor Surveillance System (BRFSS; http://www.cdc.gov/brfss), the Youth Risk Behavior Surveillance System (YRBSS; http://www.cdc.gov/HealthyYouth/yrbs), National Health and Nutrition Examination Survey (NHANES; http://www.cdc.gov/nchs/nhanes.htm), and the National Health Interview Survey (NHIS; http://www.cdc.gov/nchs/nhis.htm). These resources indicate that physical activity levels in the U.S. are insufficient. As indicated in the 2008 NHIS (Pleis, 2009), 36 percent of adults were considered inactive, 31 percent participated in some leisure-time physical activity, and only 33 percent engaged in leisure-time physical activity on a regular basis.

Recent literature has tried to quantify the energy gap that has led to the current obesity epidemic, with estimations ranging from 100 to 400 extra calories per day (Bouchard, 2008; Butte, 2003, 2007; Hill, 2003; Swinburn, 2006; Wang, 2006). Although the magnitude of this energy imbalance has been debated, there is consensus that weight gain occurs as a result of a positive energy balance—consuming more calories than are expended. As illustrated by the increase in the prevalence of overweight and obesity in the U.S., energy intakes are exceeding energy expenditure for many Americans. Moreover, recent data from the NHANES 2005-2006 (NCI, 2010) indicates that many of the top food sources of calories among the U.S. population are energy-dense and are not in nutrient-dense forms (see Tables D1.1, D1.6, and D1.7 for the top food sources of energy by age group, and see Questions 4 and 6 in this section for more information about the relationship between energy density and body weight).

Table D1.1. Mean intake of energy and mean contribution (kcal) of various U.S. foods among U.S. population, by age, NHANES 2005–2006

Age Group		All Persons	Age 2-18	Age 2-3	Age 4-8	Age 9-13	Age 14-18	Age 19+	Age 19-30	Age 31-50	Age 51-70	Age 71+
Sample Size		8549	3778	497	899	1047	1335	4771	1310	1537	1224	700
Mean Intake of Energy (kcal)		2157	2027	1471	1802	2035	2427	2199	2407	2354	2020	1691
Rank[a]	Food Group[b,c]											
1	Grain-based desserts	**138**	**138**	**68**	**136**	**145**	**157**	**138**	**128**	**145**	**134**	**141**
2	Yeast breads	**129**	**114**	**65**	**98**	**109**	**151**	**134**	120	**128**	**149**	**141**
3	Chicken and chicken mixed dishes	**121**	**113**	59	**92**	**122**	**143**	**123**	**154**	**141**	**97**	**67**
4	Soda/energy/sports drinks	**114**	**118**	23	50	**105**	**226**	**112**	**186**	**121**	**73**	33
5	Pizza	**98**	**136**	47	**95**	**128**	**213**	86	**129**	108	48	21
6	Alcoholic beverages	82	6	**-**	-	**-**	18	**106**	120	**135**	**82**	40
7	Pasta and pasta dishes	81	91	**86**	**97**	101	78	78	92	81	75	50
8	Mexican mixed dishes	80	63	26	40	76	86	85	**146**	99	48	9
9	Beef and beef mixed dishes	64	43	19	23	42	70	71	81	78	58	55
10	Dairy desserts	62	76	40	93	86	64	58	48	58	59	**78**
11	Potato/corn/other chips	56	70	37	60	72	88	51	62	61	41	23
12	Burgers	53	55	14	27	49	99	53	71	60	40	25
13	Reduced fat milk	51	86	**91**	**95**	92	69	39	43	39	35	48

Table D1.1 (continued). Mean intake of energy and mean contribution (kcal) of various U.S. foods among U.S. population, by age, NHANES 2005–2006

Age Group		All Persons	Age 2-18	Age 2-3	Age 4-8	Age 9-13	Age 14-18	Age 19+	Age 19-30	Age 31-50	Age 51-70	Age 71+
Sample Size		8549	3778	497	899	1047	1335	4771	1310	1537	1224	700
Mean Intake of Energy (kcal)		2157	2027	1471	1802	2035	2427	2199	2407	2354	2020	1691
Rank[a]	Food Group[b,c]											
14	Regular cheese	49	43	32	31	41	60	51	64	52	45	37
15	Ready-to-eat cereals	49	65	58	77	60	61	44	50	39	41	**57**
16	Sausage, franks, bacon, and ribs	49	47	43	44	53	46	49	47	53	51	39
17	Fried white potatoes	48	52	35	43	49	68	46	64	52	36	16
18	Candy	47	56	41	50	59	66	44	42	50	42	26
19	Nuts/seeds and nut/seed mixed dishes	42	27	22	26	30	26	47	28	50	60	43
20	*Eggs and egg mixed dishes*	*39*	*30*	*20*	*25*	*31*	*36*	*42*	*38*	*44*	*44*	*39*
21	*Rice and rice mixed dishes*	*36*	*24*	*19*	*20*	*28*	*24*	*41*	*49*	*49*	*30*	*20*
22	*Fruit drinks*	*36*	*55*	*46*	*51*	*51*	*65*	*29*	*45*	*33*	*18*	*13*
23	*Whole milk*	*33*	*60*	***104***	*76*	*42*	*45*	*25*	*30*	*28*	*17*	*22*
24	*Quick breads*	*32*	*19*	*17*	*13*	*17*	*28*	*36*	*34*	*34*	*42*	*33*
26	*Soups*	*26*	*20*	*18*	*23*	*19*	*18*	*28*	*25*	*22*	*37*	*36*
28	*Other white potatoes*	*25*	*14*	*11*	*11*	*16*	*18*	*29*	*24*	*25*	*33*	*38*
29	*Other fish and fish mixed dishes*	*25*	*10*	*9*	*10*	*11*	*11*	*30*	*22*	*29*	*34*	*35*
30	*Crackers*	*24*	*27*	*38*	*34*	*24*	*21*	*23*	*25*	*23*	*21*	*25*

[a] Rank for all persons only. Columns for other age groups are ordered by this ranking. The top five food groups for each age group are **bolded**.
[b] Specific foods contributing at least 2 percent of energy for all persons in descending order are listed. Specific foods contributing at least 2 percent of energy for any given subgroup are then also listed in *italics*.
[c] Specific foods contributing at least 1 percent of energy for all persons in descending order: eggs and egg mixed dishes, rice and rice mixed dishes, fruit drinks, whole milk, quick breads, cold cuts, soups, salad dressing, other white potatoes, other fish and fish mixed dishes, crackers, and 100 percent orange/grapefruit juice.

Source: National Cancer Institute (NCI). *Food Sources of Energy Among U.S. Population, 2005-06*. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute, 2010a.

The result of the continued energy imbalance has resulted in a very high prevalence of overweight and obesity in the U.S. in both adults (Flegal, 2010) and children (Ogden, 2010). In adults, the age-adjusted figures are 35.5 percent of women and 32.2 percent of men are obese. Combining overweight and obese adults, the figures are 72.3 percent of women and 64.1 percent of men. The prevalence is higher in Hispanic and Black women. In children, 9.5 percent of infants and toddlers are at or above the 95th percentile of the weight-for-recumbent-length growth charts. Among children and adolescents ages 2 through 19 years, 11.9 percent are at or above the 97th percentile of the body mass index (BMI)-for-age growth charts, 16.9 percent are at or above the 95th percentile, and 31.7 percent are at or above the 85th percentile. Again, minority children have a higher prevalence of both overweight and obesity.

Such a high prevalence of overweight and obesity across the U.S. population is of great public health concern because excess body fat leads to a much higher risk of premature death and many serious disorders, including type 2 diabetes (T2D), hypertension, dyslipidemia, cardiovascular disease (CVD), stroke, gall bladder disease, sleep apnea, osteoarthritis, and certain kinds of cancer (Pi-Sunyer, 2009). A sedentary lifestyle also poses risks of premature death, coronary artery disease, hypertension, T2D, overweight and obesity, osteoporosis, certain types of cancer, depression, decreased health-related quality of life, and decreased cardiorespiratory, metabolic, and musculoskeletal fitness (HHS, 2008).

The questions asked and discussed in this chapter deal with important issues related to the high prevalence of obesity in the U.S. For the first time, the Committee is examining how the food environment is associated with dietary intake and body weight. Additionally, behaviors associated with dietary intake and body weight are considered. The Committee also reviewed literature related to body weight during the life cycle, including maternal weight gain during pregnancy and the relationship between breastfeeding and maternal weight change. Because of the increase in childhood overweight and obesity, a series of questions addressing dietary intake and childhood adiposity was asked. For adults, the Committee reviewed literature related to two areas of recent interest in published literature: the effects of dietary macronutrient proportion and energy density on body weight. For older adults, the relationships between body weight and mortality and disease risk were reviewed. Finally, the Committee addressed the complementary aspect of energy balance, physical activity.

List of Questions

FOOD ENVIRONMENT AND DIETARY BEHAVIORS

1. What effects do the food environment and dietary behaviors have on body weight?

BODY WEIGHT AND THE LIFE CYCLE

2. What is the relationship between maternal weight gain during pregnancy and maternal-child health?
3. What is the relationship between breastfeeding and maternal postpartum weight change?
4. How is dietary intake associated with childhood adiposity?
5. What is the relationship between macronutrient proportion and body weight in adults?
6. Is dietary energy density associated with weight loss, weight maintenance, and type 2 diabetes among adults?
7. For older adults, what is the effect of weight loss versus weight maintenance on selected health outcomes?

PHYSICAL ACTIVITY

8. What is the relationship between physical activity, body weight, and other health outcomes?

Methodology

The methodology for discussing the questions listed above varied with the question. Aspects of Questions 5, 6, and 8 and a few dietary behaviors included in Question 1 were considered by the 2005 Dietary Guidelines Advisory Committee (DGAC). The remaining questions were not considered in previous iterations of the DGAC Report.

With the exception of Questions 2 and 8, the topics in this section were answered using a Nutrition Evidence Library (NEL) evidence-based systematic review. Question 2 was answered with the recent *IOM Weight Gain During Pregnancy: Reexamining the Guidelines Report* (IOM, 2009), and Question 8 was answered using the *2008 Physical Activity Guidelines for Americans* (HHS, 2008) and the associated *Physical Activity Guidelines Advisory Committee Report* (PAGAC, 2008).

A description of the NEL evidence-based systematic review process is provided in *Part C: Methodology*. Additional information about the search strategy and articles considered for each question can be found in the NEL at www.NutritionEvidenceLibrary.gov. To answer the overall question of how the environment and dietary behaviors affect body weight, the Committee conducted a series of NEL evidence-based systematic reviews. For the environment question, only systematic reviews published since 2000 were considered because the Committee felt that several recent reviews had been published that address the broad range of components that make up the food environment. Energy intake, body weight, and vegetable and fruit intake were selected as outcomes because they are frequent outcomes considered in this research. The methodology addressing dietary behaviors varied, but in general, the studies considered for these questions included children and adults, were published between January 2000 and December 2009, and were not cross-sectional in design.

Questions 5 and 6 were considered by the 2005 DGAC. The conclusions expressed in the 2005 DGAC Report were based on evidence gathered before that date. The present conclusions for the 2010 Report are based on a NEL review of publications after June 2004. For macronutrient proportions, the literature search included studies done in children and adults; however, after the search revealed few studies with children, it was decided that the review would be limited to studies done in adults older than age 19 years. Because Questions 3 and 7 were new questions considered by a DGAC, the searches for these questions were extended back to 2000 and 1995, respectively. The Committee focused their review of breastfeeding and maternal postpartum weight change to recent systematic reviews and excluded primary research citations.

Question 4 was answered using the NEL evidence-based systematic review. Eight research questions related to dietary intake in children were chosen. Several of the questions had previously been reviewed by the American Dietetic Association (ADA) Evidence Analysis Library, available at www.adaevidencelibrary.com, so that the NEL review process updated these reviews to incorporate the most recent five to six years that had not been covered in the ADA reviews. Two new questions, however, were added to the NEL review (energy density and dietary fiber), and for these new reviews, literature searches extended back to 1980. Cross-sectional studies were excluded from the reviews on childhood adiposity.

FOOD ENVIRONMENT AND DIETARY BEHAVIORS

Question 1: What Effects Do the Food Environment and Dietary Behaviors Have on Body Weight?

Conclusion

An emerging body of evidence has documented the impact of the food environment and select behaviors on body weight in both children and adults. Moderately strong evidence now indicates that the food environment is associated with dietary intake, especially less consumption of vegetables and fruits and higher body weight. The presence of supermarkets in local neighborhoods and other sources of vegetables and fruits are associated with lower body mass index, especially for low-income Americans, while lack of supermarkets and long distances to supermarkets are associated with higher body mass index. Finally, limited but consistent evidence suggests that increased geographic density of fast food restaurants and convenience stores is also related to increased body mass index.

Strong and consistent evidence indicates that children and adults who eat fast food are at increased risk of weight gain, overweight, and obesity. The strongest documented relationship between fast food and obesity is when one or more fast food meals are consumed per week. There is not enough evidence at this time to similarly evaluate eating out at other types of restaurants and risk of weight gain, overweight, and obesity. Strong evidence documents a positive relationship between portion size and body weight. Strong and consistent evidence in both children and adults shows that screen time is directly associated with increased overweight and obesity. The strongest association is with television screen time. Strong evidence shows that for adults who need or desire to lose weight, or who are maintaining body weight following weight loss, self-monitoring of food intake improves outcomes. Moderate evidence suggests that children who do not eat breakfast are at increased risk of overweight and obesity. The evidence is stronger for adolescents. There is inconsistent evidence that adults who skip breakfast are at increased risk for overweight and obesity. Limited and inconsistent evidence suggests that snacking is associated with increased body weight. Evidence is insufficient to determine whether frequency of eating has an effect on overweight and obesity in children and adults.

Implications

In order to reduce the obesity epidemic, actions must be taken to improve the food environment. Policy (local, state, and national) and private-sector efforts must be made to increase the availability of nutrient-dense foods for all Americans, especially for low-income Americans, through greater access to grocery stores, produce trucks, and farmers' markets, and greater financial incentives to purchase and prepare healthy foods. The restaurant and food industries are encouraged to offer foods in appropriate portion sizes that are low in calories, added sugars, and solid fat. Local zoning policies should be considered to reduce fast food restaurant placement near schools.

In addition, individuals can adopt a series of dietary behaviors:

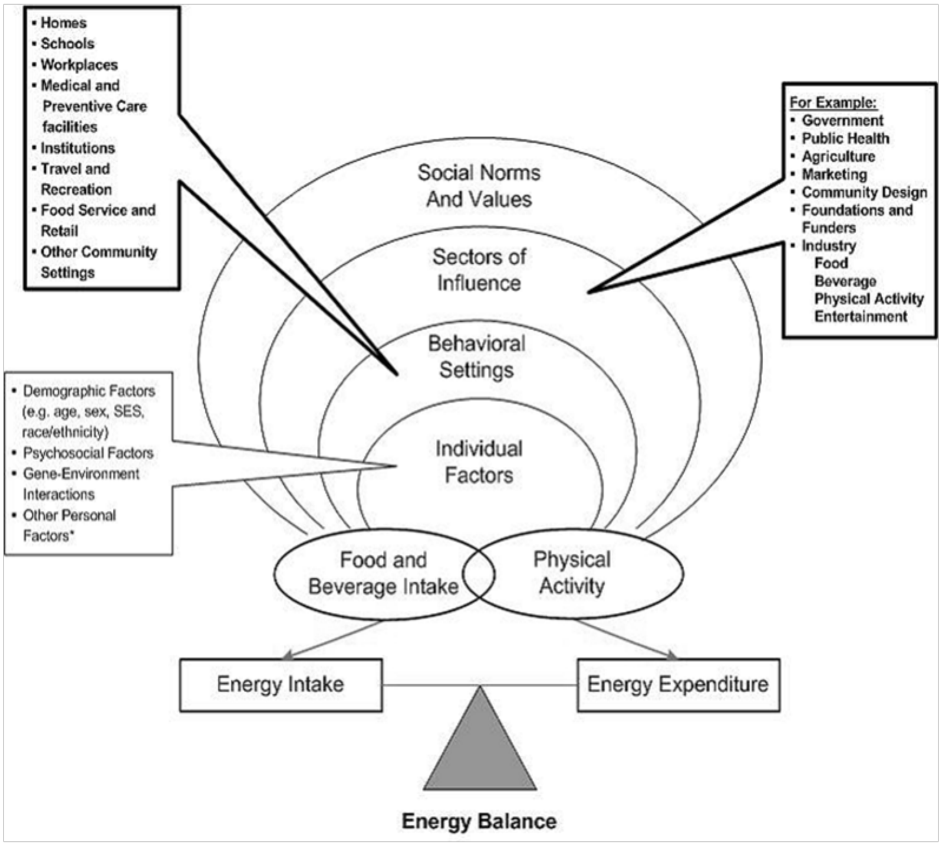
- Individuals are encouraged to prepare, serve, and consume smaller portions at home and choose smaller portions of food while eating foods away from home.
- Children and adults are also encouraged to eat a healthy breakfast and to choose nutrient-dense, minimally-processed foods whenever they snack.
- Children and adults should limit screen time, especially television viewing, and not eat food while watching television. The American Academy of Pediatrics (AAP) recommends no more than 1 to 2 hours of total media time for children and adolescents and discourages television viewing for children younger than age 2 years (AAP, 2001). A Healthy People 2010 objective is to increase the proportion of adolescents who view television 2 or fewer hours on a school day (HHS, 2000).
- Adults are encouraged to self-monitor body weight, food intake, and physical activity to improve outcomes when actively losing weight or maintaining body weight following weight loss. There is also evidence that self-monitoring of body weight and physical activity also improves outcomes when actively losing weight or maintaining body weight following weight loss (Butryn, 2007; Wing, 2006). In order to facilitate better self-monitoring of food intake, there needs to be increased availability of nutrition information at the point of purchase.
- Children and adults are encouraged to follow a frequency of eating that provides nutrient-dense foods within daily caloric requirements periodically through the day. Caution must be taken such that the frequency of eating does not lead to excess calorie intake but does meet nutrient needs.

Review of the Evidence

Background

Very few American children or adults currently follow the U.S. *Dietary Guidelines*. The reasons for this lack of overall compliance are numerous. Food intake is influenced by multiple factors ranging from individual behaviors; food preferences; family and peer influences; cultural norms; food availability at home, work, school, and in the community; food marketing; economic price structures; food production, manufacturing, and retail; and policies. These influences range from individual factors, the social environment, and the physical environment, to the macro-level environment and are outlined in the socioecological framework (Figure D1.2).

Figure D1.2. Socioecologic Framework

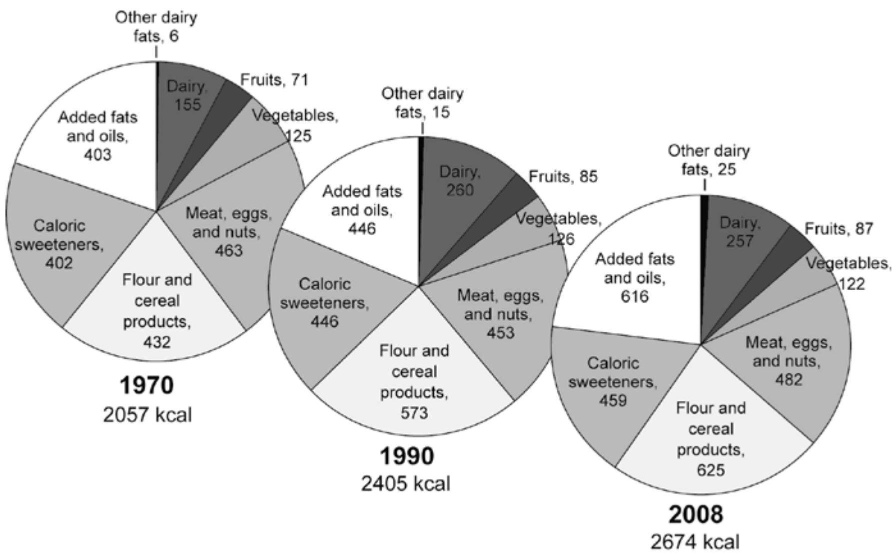


Source: Centers of Disease Control and Prevention. Division of Nutrition, Physical Activity, and Obesity. *State Nutrition, Physical Activity and Obesity (NPAO) Program: Technical Assistance Manual*. January 2008. Accessed April 21, 2010. http://www.cdc.gov/obesity/downloads/TA_Manual_1_31_08.pdf - pg 36 of the document.

Examining shifts in the food environment over the past 40 years is helpful in understanding why Americans have difficulty meeting the U.S. *Dietary Guidelines*. Tables D1.2 through D1.4 and Figures D1.3 and D1.4 provide an overview of shifts in our food environment and consumer behaviors from 1970 to 2008. Food available for consumption has increased in all major food categories (Figure D1.3) and is not in alignment with recommendations as outlined in the U.S. *Dietary Guidelines* (Figure D1.4). Average daily per capita calories, adjusted for spoilage and other waste, increased from 2057 in 1970 to 2674 in 2008. Added fats and oils (not including naturally occurring fats from meats and dairy) availability per person increased 56 percent, from 56 pounds in 1970 to 87 pounds in 2008. Availability of added sugars and sweeteners per person increased 15 percent, from 119 pounds per person in 1970 to 136 pounds in 2008.

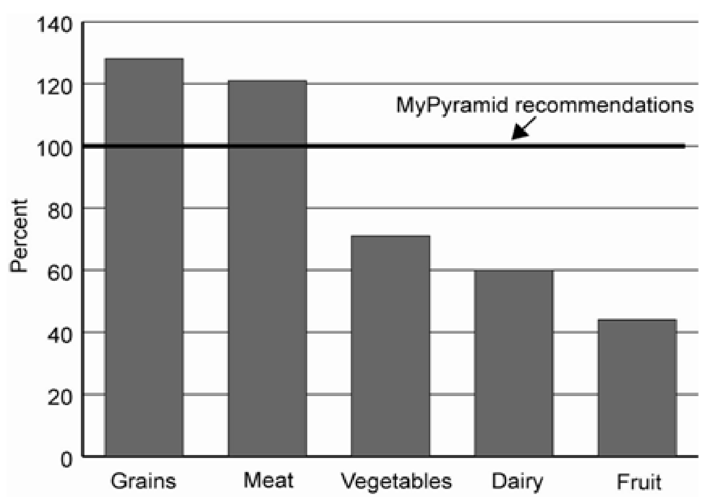
The amount and type of beverages available have changed over time. Total beverage milk declined 33 percent from 1970 to 2008 with a decrease in whole milk and increase in other beverage milk products. Fruit juice availability increased 25 percent from 1970 to 2008, while vegetable juice availability has remained constant since the data became available in 1999. In 2008, almost two times more fruit drinks, cocktails, and ades (12.9 gallons per person) were available than fruit juice (6.9 gallons). Among carbonated soft drinks, total availability increased from 39 gallons per person per year in 1984 to 47 gallons in 2008, a 20 percent increase. During this time, availability of diet soft drinks increased 58 percent from 9 to 15 gallons per person per year, and availability of regular soft drinks increased 9 percent from 30 to 32 gallons per person per year. In 2008, more than two times the amount of carbonated soft drink (46.9 gallons per person) was available than total beverage milk (20.8 gallons) (USDA, 2010). As indicated in Table D1.9 (see end of the chapter), the caloric content of beverages varies widely, and some of the beverages with the highest availability, including regular sodas and fruit drinks, add calories to the diet without providing nutrients. Other beverages, however, such as fat-free or low-fat milk and 100 percent fruit juice, provide a substantial amount of nutrients along with the calories they contain, while water and unsweetened coffee and tea can provide fluid needs without adding calories. Beverages, as an important component of the total diet, are discussed further in *Part B. Section 2: The Total Diet: Combining Nutrients, Consuming Food*.

Figure D1.3. Average daily per capita calories from the U.S. food availability in 1970, 1990, and 2008, adjusted for spoilage and other waste



Source: ERS Food Availability (Per Capita) Data System. Available at http://www.ers.usda.gov/Data/FoodConsumption/.

Figure D1.4. Loss-adjusted per capita food availability was out of balance with dietary recommendations in 2008



Note: Based on a 2000-calorie diet.
Source: USDA, Economic Research Service, Food Availability (Per Capita) Data System. Available at http://www.ers.usda.gov/AmberWaves/March10/PDF/TrackingACentury.pdf.

Not only has the availability of foods and food products increased, but so has the number of eating establishments (Table D1.2). The number of commercial eating places has increased 89 percent, with the number of fast food restaurants increasing 147 percent. The share of daily caloric intake from foods eaten away from home increased from 18 percent in 1977 to 77 percent in 1996. A recent USDA report found that overall, foods eaten away from home increases daily calorie intake, saturated and solid fat, alcohol, added sugars (SoFAAS), and sodium intake, and reduces vegetable consumption (Todd, 2010). Expenditures by families and individuals for foods eaten away from home as a share of disposable income increased 26 percent, while expenditures for foods eaten at home decreased 42 percent. Overall food expenditures by families and individuals decreased 24 percent. Forty-five percent of all food expenditures are for foods eaten away from home, up from 33 percent in 1970. The number of food items at the supermarket increased from 10,425 in 1978 to 46,852 in 2008. Where Americans buy their food has also shifted, with the greatest decrease in smaller grocery stores and the greatest increase in warehouse clubs and supercenters (Table D1.3). Almost all portion sizes have increased over the past half-century, with the largest increases in hamburgers, French fries, soda, and baked goods (Table D1.4). In 2002, the average serving of steak was 224 percent larger and a chocolate cookie was 700 percent larger than the 1996 USDA standard Food Guide Pyramid serving. Finally, the amount of time spent in food preparation activities among American women has decreased 45 percent between 1975 and 2006 from 92 minutes per day to 51 minutes per day (Zick, 2009).

Table D1.2. Changes over time in selected measures of the U.S. food retail and food service environment

Food Environment Measure	**Time Frame**	**Percent Change**
Number of commercial eating places[1]	1972 to 1995	89%
Number of fast food restaurants[1]	1972 to 1995	147%
Percentage of meals and snacks eaten at restaurants (non-fast food)[2]	1977 to 1995	150%
Percentage of meals and snacks eaten at fast food restaurants[2]	1977 to 1995	200%
Number of commercially prepared meals consumed per week[3]	1981 to 2000	14%
Food At Home expenditures by families and individuals as a share of disposable income (% of income)[4]	1970 to 2008	-42%
Food Away from Home expenditures by families and individuals as a share of disposable income (% of income)[4]	1970 to 2008	26%
Total Food expenditures by families and individuals as a share of disposable income (% of income)[4]	1970 to 2008	-24%
Food Away from Home as a share of food expenditures[5]	1970 to 2008	45%
Share of daily caloric intake from food away from home[6]	1977-78 to 1994-96	77%
Average number of items carried in a supermarket[7]	1978 to 2008	449%

[1]National Restaurant Association. 1998. *Restaurant Industry Members: 25 year History, 1970-1995*. Washington, DC: Natl Restaurant Assoc. 133 pp.
[2]National Restaurant Association. 2000. *Restaurant Industry Pocket Factbook.* http://www.restaurant.org/research/pocket/index.htm.
[3]National Restaurant Association. *Americans' dining-out habits: 2000*. http://www.restaurant.org/tools/magazines/rusa/magArchive/year/article/?ArticleID=138.
[4]USDA, ERS. Food CPI and Expenditures: Table 8. http://www.ers.usda.gov/Briefing/CPIFoodandExpenditures/Data.
[5]USDA, ERS. Food CPI and Expenditures: Table 10. http://www.ers.usda.gov/Briefing/CPIFoodandExpenditures/Data.
[6]Stewart H, et al. 2006. *Let's eat out: Americans weight taste, convenience, and nutrition*. USDA, Economic Research Service Economic Information Bulletin. http://www.ers.usda.gov/publications/eib19/eib19.pdf.
[7]Food Marketing Institute. *1979 Food Marketing Industry Speaks*; http://www.fmi.org/facts_figs/?fuseaction=superfact.

Table D1.3. Changes over time in where Americans purchase food

Location	1972	2008
Supermarket	55%	58%
Convenience Store	2%	3%
Other grocery store	25%	4%
Specialty food store	8%	3%
Warehouse clubs and super centers	<0.05%	18%
Mass merchandisers	N/A	2%
Other stores	5%	8%
Home deliveries, mail order	3%	4%
Farmers, processors, wholesalers, and other	2%	1%

Source: USDA, ERS. Food CPI and Expenditures: Table 14. Available at http://www.ers.usda.gov/Briefing/CPIFoodandExpenditures/Data.

Table D1.4. Changes over time in the average portion size of selected food items sold in the U.S. marketplace

Food Item	Portion Size (year)	Portion Size (year)	Percent Change
Beer, can	12 oz (1936)	8-24 oz (2002)	-33% - 100%
Beer, bottle	7 oz (1976)	7-40 oz (2002)	0% - 471%
Chocolate bar, milk chocolate	0.6 oz (1908)	1.6-8 oz (2002)	167% - 1233%
French fries	2.4 oz (1955)	2.4-7.1 oz (2002)	0% - 196%
Hamburger	3.9 oz (1954)	4.4-12.6 oz (2002)	13% - 223%
Soda, fountain	7 oz (1955)	12-42 oz (2002)	71% - 500%
Soda, bottle and can	6.5 oz (1916)	8-34 oz (2002)	23% - 423%

Source: Young LR, Nestle M. Expanding portion sizes in the U.S. marketplace: Implications for nutrition counseling. *J Am Diet Assoc*. 2003;103:231-234.

It appears that the food environment is not supporting Americans in consuming a healthy eating pattern. The solution will likely reside not only in consumer education and behavior but also in a change in our overall food system (Story, 2009).

Evidence on the Relationship Between the Food Environment and Body Weight and Vegetable and Fruit Intake

Evidence is growing that the food environment is associated with dietary intake, body weight, and the consumption of vegetables and fruits. Availability of healthy food, including vegetables and fruits, is associated with improved dietary intake and weight status, especially in economically disadvantaged areas. The presence of supermarkets and other sources of vegetables and fruits is associated with lower body mass index (BMI), while lack of supermarkets and long distances to supermarkets are associated with higher BMI. Increased density of fast food restaurants and convenience stores is related to increased BMI. More evidence is available regarding the relationship between the environment and vegetable and fruit intake than for body weight.

This conclusion is based on the review of 10 systematic reviews that investigated the relationship between the environment and body weight, energy intake, and vegetable and fruit intake (Black, 2008; Casagrande, 2009; Dunton, 2009; Ford, 2008; Giskes, 2007; Holsten, 2009; Jago, 2007; Kamphuis, 2006; Papas, 2007; van der Horst, 2007). All 10 studies suggested associations between the environment and body weight and/or dietary intake, but indicated that more research is still needed to better understand these linkages. Three studies found that neighborhood-level measures of economic disadvantage (unemployment, income, education) are associated with obesity and poor dietary intake (Black, 2008; Ford, 2008; Kamphuis, 2006). Eight studies found that the availability of healthy food, or lack thereof, through supermarkets and distance to a supermarket is associated with weight status and dietary intake (vegetable and fruit intake) (Casagrande, 2009; Ford, 2008; Giskes, 2007; Holsten, 2009; Jago, 2007; Kamphuis, 2006; Papas, 2007; van der Horst K, 2007). One study found that lack of access to outdoor space for physical activity, hazards (trash and noise), and number of locked school yards were positively associated with childhood obesity and access to recreational facilities and bicycling and walking trails were negatively associated with childhood obesity (Dunton, 2009). Two studies found that higher density of fast food restaurants and convenience stores is associated with higher rates of obesity (Holsten, 2009; Papas, 2007).

Evidence on the Relationship Between Dietary Behaviors and Body Weight

Eating Out—Strong and consistent evidence indicates that children and adults who eat fast food are at increased risk of weight gain, overweight, and obesity. The strongest documented relationship between fast food and obesity is when one or more fast food meals are consumed per week. There is not enough evidence at this time to similarly evaluate eating out at other restaurants and risk of weight gain, overweight, and obesity.

Evidence for Children. The literature review identified six studies: one systematic review (Rosenheck, 2008) and five cohort studies (Bisset, 2007; Haines, 2007; Niemeier, 2006; Taveras, 2005; Thompson, 2004). The studies were conducted in the U.S. and Canada. Studies ranged in sample size from 101 (Thompson, 2004) to 14,355 (Taveras, 2005), and one study included only girls (Thompson, 2004). All six studies looked specifically at fast food consumption. Five studies with strong methodology found a positive relationship between consumption of fast food and body weight in children (Rosenheck, 2008; Bisset, 2007; Niemeier, 2006; Taveras, 2005; Thompson, 2004). Two studies demonstrated the greatest gains in body weight were seen with fast food consumption greater than once a week (Taveras, 2005; Thompson, 2004). One study found a negative relationship between consumption of fast food and body weight in girls, and no relationship in boys (Haines, 2007).

Evidence for Adults. The literature review identified six studies: one systematic review (Rosenheck, 2008) and five prospective cohort studies (Duffey, 2007; French, 2000; Li, 2009; Niemeier, 2006; Pereira, 2005). All of the studies were conducted in the U.S. Studies ranged in sample size from 891 (French, 2000) to 9,919 (Niemeier, 2006), and one study included only women (French, 2000). All six studies looked specifically at fast food consumption, with one study also examining restaurant food consumption (Duffey, 2007). All six studies found a significant, positive relationship between consumption of fast food and body weight in adults. Similar to the research on children, more than one fast food meal consumed per week was associated with increases in BMI (Pereira, 2005). Only one study examined consumption of restaurant food and found that restaurant food consumption was not related to body weight (Duffey, 2007).

Portion Sizes—Strong evidence documents a positive relationship between portion size and body weight.

Evidence for Children. The 2010 DGAC conducted a search on this question but found no studies pertaining to children.

Evidence for Adults. The 2005 DGAC reviewed the evidence related to the effect of portion size (the amount of food served in one eating occasion) on energy intake, concluding that portion size influences how much a person eats; and, in general, more calories are consumed when a large portion is served rather than a small one (HHS/USDA, 2005). For this reason, we did not conduct a NEL review on the evidence related to portion size and energy intake. However, a NEL literature review on the effects of portion size on body weight was done, and four studies were identified: three randomized controlled trials (RCTs) (Gilhooly, 2007; Hannum, 2006, 2004) and one case-control study (Pearcey, 2002). The studies were conducted in the U.S. Studies ranged in sample size from 19 (Pearcey, 2002) to 53 (Hannum, 2004), and one study included only men (Hannum, 2006), two studies included only women (Gilhooley, 2007; Hannum, 2004), and one study included both men and women (Pearcey, 2002). The three RCTs focused on controlling portion sizes to aid in weight loss and all found a positive relationship between controlling portion size and weight loss in adults**.** The small case-controlled study of Pearcey et al. (2002) followed weight stable and weight gaining adults and found that consuming larger portion sizes was positively associated with weight gain.

Screen Time—Strong and consistent evidence in both children and adults shows that screen time is directly associated with increased overweight and obesity. The strongest association is with television screen time.

Evidence for Children. The 2005 DGAC reviewed this question and found a strong relationship between screen time and body weight in children (HHS/USDA, 2005). For this reason, the 2010 DGAC conducted a NEL review to examine only systematic reviews and/or meta-analyses. One 2004 meta-analysis (Marshall, 2004) was identified that examined the relationship between screen time (television viewing and video game/computer use) and body weight. This study found a significant relationship between screen time in the form of TV viewing and body fatness. However, much of the variance in body fatness could be explained by factors other than TV viewing. There was no association between body weight and video game/computer use.

Evidence for Adults. The literature review identified eight prospective cohort studies (Erik Landhuis, 2008; Hancox, 2004; Hu, 2003; Koh-Banerjee, 2003; Oken, 2007; Parsons, 2008; Raynor, 2006; Viner, 2005). All eight studies examined television viewing only and did not examine other types of screen time. The studies were conducted in the U.S., New Zealand, and the United Kingdom. Studies ranged in sample size from 902 (Oken, 2007) to 50,277 (Hu, 2003), one study included only men (Koh-Banerjee, 2003), and two studies included only women (Hu, 2003; Oken, 2007). All eight included studies found a positive relationship between television viewing and body weight in adults.

Breakfast Eating Behavior—Modest evidence suggests that children who do not eat breakfast are at increased risk of overweight and obesity. The evidence is stronger for adolescents. There is inconsistent evidence that adults who skip breakfast are at increased risk for overweight and obesity.

Evidence for Children. The literature review identified 15 studies: one randomized controlled trial (Rosado , 2008), one non-randomized controlled trial (Ask, 2006), and 13 prospective cohort studies (Affenito, 2005; Albertson, 2007, 2009; Barton, 2005; Berkey, 2003; Crossman, 2006; Elgar, 2005; Haines, 2007; Merten, 2009; Neumark-Sztainer, 2007; Niemeier, 2006; Timlin, 2008; Wengreen, 2009). The majority of studies defined breakfast as an eating occasion that occurred between 5 a.m. and 10 a.m. on weekdays and 5 a.m. and 11 a.m. on weekends. The studies were conducted in the U.S., Mexico, Norway, and the United Kingdom. Studies ranged in sample size from 54 (Ask, 2006) to 14,586 (Berkey, 2003), and three studies included only girls (Affenito, 2005; Albertson, 2007; Barton, 2005). Nine studies found an inverse relationship between breakfast consumption and body weight in children (Ask, 2006; Albertson, 2007; Barton, 2005; Crossman, 2006; Elgar, 2005; Haines, 2007; Merten, 2009; Niemeier, 2006; Timlin, 2008). One study found an inverse relationship only among children with a BMI >95th percentile (Albertson, 2007). Two studies found an inverse relationship in boys only, and no relationship in girls (Albertson, 2009; Crossman, 2006), and one study found an inverse relationship in girls only, and no relationship in boys (Neumark-Sztainer, 2007). Only one study found no relationship between breakfast consumption and body weight in children (Albertson, 2009). One study found no relationship with breakfast alone, but an inverse relationship with breakfast combined with a nutrition education program (Rosado, 2008). Two studies initially found an inverse relationship, but after adjusting for potential confounders, the relationship was no longer significant (Affenito, 2005; Timlin, 2008). One study found no relationship with breakfast, but found an inverse relationship between cereal consumption and adiposity (Barton, 2005). One study found a positive relationship between breakfast consumption and body weight in freshman college students (Wengreen, 2009). One study found a positive relationship between breakfast consumption and body weight in overweight children, and an inverse relationship in normal-weight children (Berkey, 2003).

Evidence for Adults. The literature review identified six prospective cohort studies (Crossman, 2006; Merten, 2009; Niemeier, 2006; Nooyens, 2005; Purslow, 2008; van der Heijden, 2007). The studies were conducted in the U.S., the United Kingdom, and the Netherlands. Studies ranged in sample size from 228 (Nooyens, 2005) to 20,064 (van der Heijden, 2007), and three studies included only men (Nooyens, 2005; Purslow, 2008; van der Heijden, 2007). Three studies found an inverse relationship between breakfast consumption and body weight in adults (Merten, 2009; Niemeier, 2006; Purslow, 2008). One study initially found an inverse relationship, but after adjusting for potential confounders the relationship was no longer significant (Nooyens, 2005). One study found an inverse relationship between breakfast intake and body weight in men, and no relationship in women (Crossman, 2006). We did not review the literature on the use of breakfast consumption as a tool for adults actively losing weight.

Snacking Behavior—Evidence suggesting that snacking is associated with increased body weight is inconsistent.

Evidence for Children. The literature review identified six studies: five cohort studies (Bisset, 2007; Black, 2006; Field, 2004; Francis, 2003; Phillips, 2004) and one case-control study (Novaes, 2008). The studies were conducted in the U.S., Canada, and Brazil. Studies ranged in sample size from 100 (Novaes, 2008) to 14,977 (Field, 2004), and three studies included only girls (Black, 2006; Francis, 2003; Phillips, 2004). Two studies found a positive relationship between snacking and body weight in children (Bisset, 2007; Novaes, 2008). Two studies found no relationship between snacking and body weight in children (Black, 2006; Phillips, 2004). One study initially found a negative relationship between snacking and adiposity in girls, but after adjusting for potential confounders, the relationship was no longer significant (Field, 2004). One study only found that snacking in front of the television was associated with development of overweight in children (Francis, 2003). One of the reasons for the inconsistency of findings is likely due to the variability in the design of studies and definitions for snacking.

Evidence for Adults. The literature review identified two prospective cohort studies (Halkjaer, 2009; Woo, 2008). The studies were conducted in Sweden and Hong Kong. Studies ranged in sample size from 1,010 (Woo, 2008) to 22,570 (Halkjaer, 2009). In the study of Halkjaer et al. (2009) diets high in snack food were associated with increased waist circumference over the 5-year follow-up period. Increased variety of snack food was associated with increased weight gain over a 5- to 9-year follow-up period in the study of Woo et al. (2008). The DGAC did not review the literature on the use of snacking as a tool for adults actively losing weight.

Eating Frequency—Evidence is insufficient to determine whether frequency of eating has an effect on overweight and obesity in children and adults.

Evidence for Children. The literature review identified one prospective cohort study (Franko, 2008). The study was conducted in the U.S. and had a sample of 2,379 girls. This study found that increased meal frequency, measured by number of days with more than three meals, was inversely associated with BMI in adolescent girls.

Evidence for Adults. The literature review identified one prospective cohort study (van der Heijden, 2007). The study investigated the association between food patterns and long-term weight gain in U.S. men over 10 years. An increased number of eating occasions in addition to three standard meals was associated with a higher risk of 5-kilogram weight gain over time. The Committee did not review the literature on the use of eating frequency as a tool for adults actively losing weight.

Self-monitoring Behavior—Strong evidence shows that for adults who need or desire to lose weight, or who are maintaining body weight following weight loss, self-monitoring of food intake improves outcomes.

The literature review identified seven studies: six randomized controlled trials (Adachi, 2007; Carels, 2008; Helsel, 2007; Lowe, 2008; Tate, 2001; Wylie-Rosett, 2001) and one non-randomized controlled trial (Yon, 2007). In the majority of studies, diet self-monitoring included keeping a daily record of food consumed, with a focus on monitoring calorie intake. The studies were conducted in the U.S. and Japan. Studies ranged in sample size from 42 (Helsel, 2007) to 588 (Wylie-Rosett, 2001), and all seven studies included both men and women. Six studies found a positive relationship between diet self-monitoring and weight loss in adults (Adachi, 2007; Carels, 2008; Helsel, 2007; Tate, 2001; Wylie-Rosett, 2001; Yon, 2007) only one study found no relationship between diet self-monitoring and weight loss in adults (Lowe, 2008).

BODY WEIGHT AND THE LIFE CYCLE

Question 2: What Is the Relationship Between Maternal Weight Gain During Pregnancy and Maternal-Child Health?

Conclusion

Maternal weight gain during pregnancy outside the recommended ranges is associated with suboptimal maternal and child health. Women who gain weight excessively during pregnancy retain more weight after delivery, are more likely to undergo a cesarean section and to deliver large-for-gestational age newborns, and their offspring may be at increased risk of becoming obese later on in life. Women who gain weight below recommendations are more likely to deliver small-for-gestational age newborns.

Implications

Women are encouraged to maintain a healthy weight before conception. Additionally, women are encouraged to practice sound dietary and physical activity practices to help them attain gestational weight gain within the guidelines outlined by the IOM.

Review of the Evidence

Maternal preconceptional weight and prenatal nutrition are increasingly recognized as important influences on the risk of obesity in the offspring and of associated comorbidities later in life (IOM, 2009). Similarly, maternal nutritional status before and during pregnancy affects a woman's shorter- and longer-term health outcomes. This is a cause for public health concern in the U.S., where more than half of women of reproductive age are overweight or obese and the proportion who are extremely obese (i.e., BMI $\geq$40) has reached 8 percent (IOM, 2009). In addition, the percent of women who have a gestational weight gain (GWG) outside current guidelines ranges from 50 percent among underweight to 73 percent among overweight women. Furthermore, excessive weight gain is more common in heavier than lighter women with over half of overweight/obese women gaining excessively (IOM, 2009).

Institute of Medicine Gestational Weight Gain Guidelines

The IOM recently revised its 1990 GWG guidelines, taking into account the trade-offs between maternal and child health outcomes associated with increased GWG in different prepregnancy BMI subgroups (IOM, 2009). This report forms the basis for the DGAC recommendations.

The IOM examined birth weight adjusted for gestational age, expressed as small-for-gestational age (SGA) and large-for-gestational age (LGA), as the primary short-term childbirth outcome. Childhood obesity risk was the longer-term child outcome examined. The key maternal outcomes examined were emergency cesarean section and maternal postpartum weight retention at 6 months. Findings from the 1996-2002 Danish National Birth Cohort Study were valuable in identifying the points where the SGA and postpartum weight retention GWG risk curves intersected among women classified into four different prepregnancy BMI subgroups.

The IOM also conducted a Quality-Adjusted Life Years (QALY) lost risk analysis to identify the "optimal" GWG ranges across prepregnancy BMI subgroups. GWG-related outcomes used in these analyses were morbidity and mortality associated with SGA, childhood obesity, and maternal postpartum weight retention. The IOM Committee used findings from the literature, together with the Danish study, the QALY analysis, other commissioned analyses, and its own expert judgment to develop the revised GWG recommendations (Table D1.5). The evidence examined by the Committee provided no support for issuing different GWG guidelines for women younger than age 20 years or for women who smoked, were primiparous, or who were of short stature (<160 cm). However, the Danish data suggest that primiparous women could benefit from having GWG toward the upper end of the recommended range, but these results need to be confirmed by others.

Table D1.5. 2009 IOM recommendations for total and rate of weight gain during pregnancy by prepregnancy BMI

Prepregnancy BMI	**Total Weight Gain Range in kg**	**Total Weight Gain Range in lbs**	**Rates of Weight Gain[1] 2nd and 3rd Trimester Mean (range) in kg/week**	**Rates of Weight Gain[1] 2nd and 3rd Trimester Mean (range) in lbs/week**
Underweight (< 18.5 kg/m^2)	12.5-18	28-40	0.51 (0.44-0.58)	1 (1-1.3)
Normal weight (18.5-24.9 kg/m^2)	11.5-16	25-35	0.42 (0.35-0.50)	1 (0.8-1)
Overweight (25.0-29.9 kg/m^2)	7-11.5	15-25	0.28 (0.23-0.33)	0.6 (0.5-0.7)
Obese (≥ 30.0 kg/m^2)	5-9	11-20	0.22 (0.17-0.27)	0.5 (0.4-0.6)

[1]Calculations assume a 0.5-2 kg (1.1-4.4 lbs) weight gain in the first trimester (based on Siega-Riz et al., 1994; Abrams et al., 1995; Carmichael et al., 1997).

Except for the prepregnancy obese category, the IOM's recommended GWG ranges are the same as those issued in 1990. With regard to obese women, the new guidelines provide an upper limit to their recommended GWG range, based on evidence mostly derived from class I obese women (BMI: 30-34.9). Another difference between the 1990 and 2009 IOM guidelines is that the cut-off points for the prepregnancy BMI categories are now based on the World Health Organization (WHO) instead of the Metropolitan Life Insurance Tables cut-off points. The 1990 IOM prepregnancy BMI categories (based on Metropolitan Life Insurance tables) were: underweight (<19.8); normal (19.8-26.0); overweight (26.1-29.0); obese (>29). The 2009 IOM prepregnancy BMI categories (based on WHO tables) were: underweight (<18.5); normal (18.5-24.9); overweight (25.0-29.9); obese (≥30).

The IOM's Recommendations for Implementing the Guidelines

The IOM recommends a comprehensive approach for carrying out its GWG guidelines and the DGAC concurs with these recommendations:

- Given the major influence that prepregnancy BMI has on GWG and key maternal and child health indicators, develop improved approaches to prevent the onset of obesity among girls so that they have a healthy weight by the time they become pregnant for the first time.
- During prenatal care, provide women with sound dietary and physical activity counseling to help them attain GWG within their recommended ranges. Dietary guidance needs to emphasize that energy intake requirements during pregnancy increase to a lower extent than other nutrient requirements. Thus, the DGAC recommends that women be advised to consume nutrient-dense diets to ensure an optimal nutrient supply for themselves and their offspring without exceeding their energy intake needs.
- Provide proper guidance to women between pregnancies to help them avoid retaining excessive postpartum weight.
- Effectively disseminate the new GWG guidelines through relevant clinical and community contact points, including the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) program. Because women belonging to racial/ethnic minority groups are disproportionately affected by overweight or obesity, it is essential for dissemination efforts to be conducted with cultural competency. They also need to take into account the structural barriers that prevent low-income women from accessing healthy foods and being physically active in their living and working environments.

Question 3: What Is the Relationship Between Breastfeeding and Maternal Postpartum Weight Change?

Conclusion

A moderate body of consistent evidence shows that breastfeeding may be associated with maternal postpartum weight loss. However, this weight loss is small, transient, and depends on breastfeeding intensity and duration.

Implications

Transient weight loss has been associated with intensive breastfeeding. However, it is unlikely that breastfeeding currently plays a significant role in promoting more rapid postpartum maternal weight loss in the U.S. given the small size of the effect, large inter-individual variability in maternal postpartum weight changes, and the fact that in the U.S., only one-third of women breastfeed exclusively at 3 months postpartum. Thus, breastfeeding should not be promoted as an effective maternal postpartum weight loss method.

Review of the Evidence

Background

Lactation substantially increases maternal energy demands during the postpartum period (500 additional kcal per day; IOM, 2002/2005). From the energy expenditure side of the energy balance equation, lactation increases energy intake, in part as a result of endocrinological changes (e.g., higher prolactin levels; Dewey, 2004), and there is no evidence that lactation increases physical activity (Dewey, 2004). Thus, it is important to determine the net effect of lactation on maternal postpartum weight retention.

Breastfeeding and Maternal Postpartum Weight Change

The Committee identified four reviews that addressed the question of interest (Dewey, 2004; Fraser, 2003; Ip/AHRQ, 2007; Kramer, 2004). Its conclusion is drawn from two reviews (Ip/AHRQ, 2007; Dewey, 2004) as the Agency for Health Care Research and Quality (AHRQ) review builds upon Fraser's review, and this review also included all 11 studies with measured postpartum weight outcomes that were identified by Dewey. Kramer's review only included two randomized controlled trials (RCTs) conducted in Honduras, and these were examined in-depth in Dewey's review.

Dewey based her review on 15 studies. Two RCTs conducted in Honduras by her group showed that exclusive breastfeeding for 6 months (vis-a-vis 4 months) led to greater weight loss between 4 and 6 months postpartum. In one of the trials, the weight loss was -0.6 kilogram and in the second one it was -0.2 kilogram. The difference in weight loss across trials was explained by the between-group differences in breast milk energy output. Dewey classified the 13 prospective studies that met the initial inclusion criteria into those that actually measured versus those that estimated weight changes. Six out of the seven studies that had the best methodology found an inverse association between breastfeeding and postpartum weight change. By contrast, only one out of the six studies with poor methodology detected such association. Dewey concluded that there is a dose-response relationship between breastfeeding duration/intensity and postpartum weight loss, and that weight loss differences attributed to breastfeeding were transient, being more evident within 3 to 6 months postpartum.

The AHRQ identified eight prospective studies that met their inclusion criteria, most of which were published after the reviews by Dewey and Fraser. From three studies that examined return to prepregnancy weight, one found that exclusive breastfeeding was not associated with weight change from prepregnancy to 1 to 2 years postpartum. A second study found that breastfeeding at 1 year was associated with -1.2 kilograms of weight retention at 1 year postpartum, compared with a weight accretion of 2 kilograms among women formula feeding during the same period. A third study found that breastfeeding was associated with reaching prepregnancy weight 6 months earlier, vis-a-vis formula feeding. Two prospective studies found that postpartum weight change was inversely associated with breastfeeding intensity/duration. The remaining three studies that classified women according to different infant feeding categories (breastfeeding, partial breastfeeding, formula feeding) did not find significant between-group differences in total postpartum weight changes. However, consistent with the conclusions reached by Dewey, one study did find more rapid weight loss between 3 and 6 months postpartum among women exclusively breastfeeding. The AHRQ review concluded that the effect of breastfeeding on postpartum weight loss is unclear and that if an association is present, the effect size is likely to be small.

In sum, Dewey and AHRQ reported similar findings with mostly different studies. Dewey's review examined the transient effects in more detail and included RCTs, providing strong support to the conclusion reached by the Committee.

Question 4: How Is Dietary Intake Associated With Childhood Adiposity?

Conclusion

Evidence suggests that certain aspects of dietary intake are associated with greater or lesser adiposity in children. Moderately strong evidence from recent prospective cohort studies that identified plausible reports of energy intake support a positive association between total energy (caloric) intake and adiposity in children. Moderately strong evidence from methodologically rigorous longitudinal cohort studies of children and adolescents suggests that there is a positive association between dietary energy density and increased adiposity in children. Moderate evidence from prospective cohort studies suggests that increased intake of dietary fat is associated with greater adiposity in children; however, no studies were conducted under isocaloric conditions. Strong evidence supports the conclusion that greater intake of sugar-sweetened beverages is associated with increased adiposity in children. Moderate evidence suggests that there is not a relationship between intake of calcium and/or dairy (milk and milk products) and adiposity in children and adolescents. A limited body of evidence from longitudinal studies suggests that greater intake of fruits and/or vegetables may protect against increased adiposity in children and adolescents. Limited and inconsistent evidence suggests that for most children, intake of 100 percent fruit juice is not associated with increased adiposity when consumed in amounts that are appropriate for age and energy needs of the child. However, intake of 100 percent juice has been prospectively associated with increased adiposity in children who are overweight or obese. There is insufficient evidence that dietary fiber is associated with adiposity in children.

Implications

Strategies to prevent childhood obesity should include efforts to reduce surplus energy intake, especially energy from foods and beverages that provide empty calories from added sugars and solid fats. Total fat intake should not exceed the IOM acceptable ranges, and should consist primarily of mono-and polyunsaturated fats that promote heart health and provide essential fatty acids for growth and development. Increasing consumption of vegetables and fruits in childhood is an important public health goal, not only from the perspective of increasing intake of "shortfall" nutrients, but also because diets high in a variety of vegetables and fruits tend to be lower in energy density, and therefore likely to improve energy balance and prevent obesity. When consumed in moderation as part of a nutrient rich, energy-balanced diet, 100 percent juice can be a healthy part of a child's diet. Children should be encouraged to consume recommended servings of low-fat dairy products daily in order to meet recommended dietary intake levels for key nutrients, such as calcium. Children should also be encouraged to consume greater amounts and varieties of high-fiber foods in order to increase nutrient density, and promote healthy lipid profiles, glucose tolerance, and normal gastrointestinal function. Consumption of sugar-sweetened beverages in childhood should be discouraged (1) because of the positive association with increased adiposity; and (2) because of the need to replace empty calories with nutrient-rich energy for optimal growth and development.

Review of the Evidence

Background

The rapid increase in childhood obesity has created a public health crisis because obesity is associated with serious comorbidities in childhood, and also significantly increases risk of future chronic diseases in adult life. Overweight children and adolescents have an increased prevalence of CVD risk factors, such as hyperlipidemia, hypertension, and T2D. In addition, other adverse health conditions are more prevalent as well, including asthma, hepatic steatosis (fatty liver), sleep apnea, gallbladder disease, endocrine and musculoskeletal disorders, and psychosocial problems (Daniels, 2009). Annual hospital costs related to obesity in children and adolescents were $127 million between 1997 and 1999 (Wang, 2002).

There is general agreement that childhood obesity results from long-term, poorly regulated energy balance, with gradual increases in body fat, as stored energy, resulting from energy intake that exceeds energy expenditure. The epidemic characteristics of the recent increase in childhood obesity suggests that powerful obesogenic environmental factors have resulted in increased energy (caloric) intake, as well as decreased energy expenditure (less physical activity or increased inactivity). Both dietary intake and physical activity patterns in U.S. youth have changed significantly over the past several decades. National health and nutrition surveys of U.S. youth between 1977-78 and 2001-02, a 25-year period characterized by increasing prevalence of childhood obesity, have identified major changes in food and beverage choices during this period of time. Beverage choices shifted from milk to less nutritious choices, and foods with energy dense or high calorie content relative to their nutrient density increased in popularity. Children increasingly consumed more food away-from-home, as well as more take-out foods eaten at home. Children increased the number of daily snacks, the energy density of snacks, and the total energy derived from snacks as well. Meanwhile, dietary intake of fruits and vegetables, as well as dietary fiber and whole grains, has remained at undesirably low levels.

Recent data illustrate that the top sources of calories for children and adolescents tend to be high in energy density, solid fats, added sugars, and sodium, and in many cases, low in nutrient density (e.g., soda/energy/sports drinks). NHANES of U.S. youth in 2005-2006 found that the top source of calories for boys ages 2 to 3 years is whole milk, the top source for boys ages 4 to 8 years is grain-based desserts, the top source for boys ages 9 to 13 years is pizza, and the top source for boys ages 14 to 18 years is soda/energy/sports drinks (Table D1.6). The top source of calories for girls ages 2 to 3 years is 100 percent non-citrus fruit juice, the top source for girls ages 4 to 8 and 9 to 13 years is grain-based desserts, and the top sources for girls ages 14 to 18 years are pizza and soda/energy/sports drinks (Table D1.7). Additional information on the dietary intake, trends, and food sources for selected nutrients and food groups of U.S. children and adolescents can be found in *Part B. Section 2: The Total Diet: Combining Nutrients and Consuming Food* and *Part D. Section 2: Nutrient Adequacy*. These continuing and changing patterns of food and beverage intake are disturbing and underlie the choice of research questions driving this evidence review for the 2010 DGAC Report. These questions represent dietary factors frequently hypothesized to promote or protect against increased adiposity, or actual obesity in children and adolescents.

Table D1.6. Mean intake of energy and mean contribution (kcal) of various foods among U.S. male children and adolescents, by age, NHANES 2005-2006

Age/Sex		**All Males, 2-18 years**	**Males, 2-3 years**	**Males, 4-8 years**	**Males, 9-13 years**	**Males, 14-18 years**
Sample Size		n=1857	n=250	n=431	n=522	n=654
Mean Intake of Energy (kcal)		2249	1519	1923	2158	2865
Rank[1]	**Food Group**[2,3]					
1	Pizza	**173**	55	**119**	**158**	**274**
2	Grain-based desserts	**149**	**82**	**157**	**144**	**171**
3	Soda/energy/sports drinks	**146**	22	45	**119**	**299**
4	Chicken and chicken mixed dishes	**135**	63	**101**	**145**	**181**
5	Yeast breads	**126**	67	**114**	**105**	**178**
6	Reduced fat milk	94	**84**	**110**	96	81
7	Dairy desserts	87	38	98	100	83
8	Pasta and pasta dishes	84	**77**	91	91	74
9	Ready-to-eat cereals	76	58	92	69	77
10	Burgers	73	10	31	62	140
11	Potato/corn/other chips	72	36	74	68	87
12	Whole milk	69	**120**	83	46	61
13	Mexican mixed dishes	65	30	40	79	86
14	Fruit drinks	61	46	53	62	71
15	Candy	59	38	58	64	62
16	Fried white potatoes	56	41	42	48	81
17	Sausage, franks, bacon, and ribs	56	57	48	62	57
18	Beef and beef mixed dishes	48	25	15	42	91

Table D1.6 (continued). Mean intake of energy and mean contribution (kcal) of various foods among U.S. male children and adolescents, by age, NHANES 2005-2006

Age/Sex		**All Males, 2-18 years**	**Males, 2-3 years**	**Males, 4-8 years**	**Males, 9-13 years**	**Males, 14-18 years**
Sample Size		n=1857	n=250	n=431	n=522	n=654
Mean Intake of Energy (kcal)		2249	1519	1923	2158	2865
Rank[1]	**Food Group**[2,3]					
19	Regular cheese	47	37	27	46	67
20	*100% non-citrus fruit juice*	*33*	***81***	*47*	*16*	*20*
22	*Nuts/seeds and nut/seed mixed dishes*	*31*	*19*	*39*	*29*	*30*
23	*Crackers*	*29*	*36*	*41*	*27*	*18*
24	*Pancakes/waffles/French toast*	*28*	*21*	*20*	*45*	*23*

[1]Rank for males 2-18 years old only. Columns for other age groups are ordered by this ranking. The top five food groups for each age group are **bolded**.
[2]Specific foods contributing at least 2 percent of energy for males 2-18 years old in descending order are listed. Specific foods contributing at least 2 percent of energy for any given subgroup are then also listed in *italics*.
[3]Specific foods contributing at least 1 percent of energy for males 2-18 years old in descending order: 100 percent fruit juice, not orange/grapefruit; eggs and egg mixed dishes; nuts/seeds and nut/seed mixed dishes; crackers; pancakes/waffles/French toast; rice and rice mixed dishes; cold cuts; and quick breads.
Source: *Sources of Calories Among the U.S. Population, 2005-06*. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/foodsources/. Updated May 21, 2010. Accessed May 21, 2010.

Table D1.7. Mean intake of energy and mean contribution (kcal) of various foods among U.S. female children and adolescents, by age, NHANES 2005-2006

Age/Sex		**All Females, 2-18 years**	**Females, 2-3 years**	**Females, 4-8 years**	**Females, 9-13 years**	**Females, 14-18 years**
Sample Size		n=1921	n=247	n=468	n=525	n=681
Mean Intake of Energy (kcal)		1796	1419	1691	1903	1937
Rank[1]	**Food Group**[2,3]					
1	Grain-based desserts	**126**	53	**117**	**147**	**141**
2	Yeast breads	**101**	**64**	**83**	**114**	**120**
3	Pasta and pasta dishes	**98**	**97**	**103**	**111**	82
4	Pizza	**97**	38	73	**96**	**144**
5	Chicken and chicken mixed dishes	**89**	54	**84**	**96**	**101**
6	Soda/energy/sports drinks	88	23	54	90	**144**
7	Reduced fat milk	77	**100**	81	87	56
8	Potato/corn/other chips	67	38	46	77	88
9	Dairy desserts	65	42	**88**	71	43
10	Mexican mixed dishes	62	21	41	74	85
11	Candy	54	43	42	53	71
12	Ready-to-eat cereals	54	58	63	52	45
13	Whole milk	50	**87**	70	38	27
14	Fruit drinks	49	47	49	39	59
15	Fried white potatoes	47	29	44	50	53
16	Regular cheese	39	26	35	35	53

Table D1.7 (continued). Mean intake of energy and mean contribution (kcal) of various foods among U.S. female children and adolescents, by age, NHANES 2005-2006

Age/Sex		**All Females, 2-18 years**	**Females, 2-3 years**	**Females, 4-8 years**	**Females, 9-13 years**	**Females, 14-18 years**
Sample Size		n=1921	n=247	n=468	n=525	n=681
Mean Intake of Energy (kcal)		1796	1419	1691	1903	1937
Rank[1]	**Food Group**[2,3]					
17	Sausage, franks, bacon, and ribs	38	27	40	43	35
18	100% non-citrus fruit juice	37	**107**	38	26	21
19	Beef and beef mixed dishes	37	12	31	42	47
20	Burgers	36	19	24	36	*54*
21	*Pancakes/waffles/French toast*	*29*	*21*	*37*	*39*	*14*
23	*Crackers*	*26*	*41*	*27*	*22*	*24*

[1]Rank for females 2-18 years old only. Columns for other age groups are ordered by this ranking. The top five food groups for each age group are **bolded**.
[2]Specific foods contributing at least 2 percent of energy for females 2-18 years old in descending order are listed. Specific foods contributing at least 2 percent of energy for any given subgroup are then also listed in *italics*.
[3]Specific foods contributing at least 1 percent of energy for females 2-18 years old in descending order: pancakes/waffles/French toast; eggs and egg mixed dishes; crackers; cold cuts; rice and rice mixed dishes; nuts/seeds and nut/seed mixed dishes; soups; salad dressing; and 100 percent orange/grapefruit juice.
Source: *Sources of Calories Among the U.S. Population, 2005-06*. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/foodsources/. Updated May 21, 2010. Accessed May 21, 2010.

Methodological Challenges

The methodological challenges associated with accurately measuring energy intake and energy expenditure in children are significant. Young children, for example, are unable to report for themselves what they have consumed, thus parents or other caregivers must provide proxy diet intake for the child. Older children vary with respect to the age at which they can provide reasonable accurate dietary intake information, and this is difficult to assess (Newby, 2007). Even relatively small increases in daily energy intake can result in significant excess weight gain over time, however, dietary assessment methods generally lack the sensitivity to detect small differences in energy intake.

Accurate assessment of adiposity also poses a methodological challenge. The majority of studies assessing the relationship between dietary intake and adiposity in children have relied on BMI as a surrogate measure of adiposity, even though it provides a poor estimate of body fat. In a report by Freedman et al. (2009) only 77 percent of children with BMI $\geq 95^{th}$ percentile had elevated percent body fat as measured by dual energy x-ray absorptiometry, and an even smaller percent of children (20%) with BMI between the 85^{th} and 94^{th} percentile had elevated body fatness.

The greatest challenge, however, with respect to accurately assessing dietary intake in children, is due to the inevitable bias that results from implausible reports of energy intake, which in several studies has been shown to affect one-third to one-half of children's dietary reports (Gibson and Neate, 2007; Huang, 2004; Johnson, 2008a, 2009; Savage, 2008a; Timpson, 2008). In a review of 10 validation studies, underreporting of energy intake was much more common among overweight children, and also varied by age, such that older and heavier children were more likely to underreport energy intake compared with younger, normal weight children (Livingstone, 2000). In a study by Savage et al. (2008a), nearly two-thirds of implausible energy intake reporters were overweight (BMI>85^{th} percentile), compared with only 27 percent of the plausible energy intake reporters. Recent reports in the pediatric scientific literature have stressed the importance of assessing and adjusting for implausible energy intake in order to more precisely assess associations between dietary intake and adiposity in children. In these studies, rather than simply eliminating outliers, sex and age group-specific ±1 SD cutoffs for reported energy intake (rEI) as a percent of predicted energy requirements (pER; rEI/pER x 100), updated with the 2002 DRI values, were applied individually to identify plausible energy intake reports (McCrory, 2002; IOM, 2002/2005). Using this methodology, a growing number have reported a positive association between energy intake and adiposity in children, an association that is often masked when implausible energy intake reports are not excluded.

Although energy intake and energy expenditure are the two key components of the energy balance equation, literally hundreds of behavioral, environmental and genetic factors have been proposed to affect a child's risk of becoming overweight or obese; these are outside of the scope of this Report. This evidence review focused only on selected foods and beverages that provide energy and nutrients to children, and that may be related either in a positive or negative way to adiposity and risk of obesity. *Part D. Section 2: Nutrient Adequacy* addresses the important topic of nutrient adequacy in childhood and adolescence.

Total Energy (Caloric) Intake and Adiposity in Children

Background—Because obesity results from a positive energy balance, it has been of particular interest to review the evidence linking total energy intake and adiposity in research studies of children, especially observational longitudinal cohort studies, and those of an interventional nature. In addition, examination of secular trends in total energy intake among U.S. children and adolescents since the obesity epidemic emerged provides additional evidence that increased total energy intake is a risk factor for childhood overweight and obesity.

Evidence Summary—Convincing evidence from recent methodologically strong research supports a positive association between total energy (caloric) intake and adiposity in children. This conclusion relies heavily on new evidence that when plausible reports of energy intake are adequately identified by applying age- and sex-specific cutoffs for reported energy intake as a percent of predicted energy requirements, a positive association between energy intake and adiposity in childhood is generally apparent. In contrast, when implausible reports are included, which are predominately from overweight and obese individuals who underreport energy intake and also tend to overreport energy expenditure, the association between energy intake and adiposity is masked.

This conclusion is based on the review of four prospective cohort studies that examined the relationship between total energy intake and adiposity in children (Fulton, 2009; Ong, 2006; Savage, 2008a; Stunkard, 2004). All four studies were conducted in the U.S., and all were methodologically strong. Three of the four studies found a positive association between total energy intake and adiposity (Ong, 2006; Savage, 2008a; Stunkard, 2004). The three studies that found a positive association between total energy (caloric) intake and adiposity in children all distinguished between plausible and implausible reports of energy intake on an individual basis.

For example, in the 2-year cohort study by Savage et al. (2008a), investigators examined reported energy intake among girls at age 9 years as a predictor of BMI at age 11 years. In this study, plausible reports of energy intake were determined by comparing reported energy intake (rEI) with predicted energy requirements (pERs). Sex- and age-specific ±1 SD cutoffs for rEI as a percent of pERs (pER; rEI/pER x 100) were developed (McCrory, 2002) and updated with the 2002 DRI values (IOM, 2002). A report was considered plausible if rEI as a percent of pER was within ±1 SD cutoff (84.8% to 115.2% at 9 years of age). Those below the lower cutoff were classified as energy intake underreporters, and those above were classified as energy intake overreporters. Results showed that 58.4 percent (n=107) were plausible energy intake reporters; compared with 16.4 percent (n=30) who were underreporters; and 25.1 percent (n=46) who were overreporters. Notably, nearly two-thirds of implausible reporters were overweight (BMI>85^{th} percentile), compared with only 31 percent of the total sample and 27 percent of the plausible energy intake reporters. Underreporters of energy intake had significantly higher BMI, BMI z-score, and BMI percentile, and reported significantly lower energy intake versus both plausible and overreporters. Plausible reporters who were overweight had significantly higher reported energy intake (mean 1897, SD=242) versus normal weight girls (mean=1713, SD=170). Among plausible reporters, energy intake predicted 14 percent of variance in BMI at 11 years of age. The authors conclude that systematic bias related to underreporting in dietary data can obscure relationships with weight status, even among young girls, and that a relatively simple analytical procedure can be used to identify the magnitude and nature of reporting bias in dietary data. Importantly, this study found that the positive association between energy intake and adiposity was observed only after excluding implausible energy intake reports—but not in the total sample which included implausible reporters, the majority of which were overweight children who underreported energy intake.

Stunkard et al. (2004) followed a cohort of newborn infants, consisting of 40 who were considered high-risk for obesity based on high maternal prepregnancy BMI, and 38 others who were considered low risk. Their results showed that total energy intake, and not energy expenditure, was the determinant of body weight in these infants both at 1 and at 2 years of age, as it had been at 1 year of age. Ong et al. (2006) also found that energy intake during infancy influenced later infant weight gain, and increased obesity risk during early childhood. In this study higher energy intake at 4 months of age was associated with higher rates of rapid weight gain between birth and 2 years of age ($p< 0.0001$). In addition, higher energy intake at 4 months of age showed greater gains in weight standard deviation scores between birth and 1, 2, and 3 years of age ($p=0.007$ to $p=0.0004$). These associations were present for children who had been formula fed, or received mixed feedings of formula plus breast milk, but were not present for exclusively breastfed infants. Among formula or mixed-fed infants, higher energy intake at 4 months of age also predicted larger childhood body weight and BMI at ages 1, 2, 3, and 5 years. Each 420 KJ per day increase in energy intake was associated with increased risk of being overweight or obese (BMI>85th percentile) at age 3 years (odds ratio [OR]: 1.46; 95% CI: 1.2-1.78); and at age 5 years (OR: 1.25; 95% CI: 1.0-1.55).

A fourth longitudinal study (Fulton, 2009) did not find an association between total energy intake and adiposity. In this study, which enrolled 472 children between 1991-1993, three groups of children, enrolled at either ages 8, 11, or 14 years were followed for 4 years to examine the relationship between physical activity, energy intake, and sedentary behavior and concurrent values of BMI, fat-free mass index, and fat mass index, as measured by bioimpedance. Diet was assessed at baseline and annually with a food frequency questionnaire, which is less accurate than other methods with respect to assessing individual energy intake. In this study, neither energy intake nor sedentary behavior was associated with BMI, fat mass index, or fat-free mass index. However, moderate-to-vigorous physical activity was inversely related to BMI and to fat mass index. Dietary reports of energy intake in this study were not individually assessed for plausibility, based on predicted energy requirements.

Although cross-sectional studies were not included in the formal NEL evidence review, findings from several studies published in the past 5 years are notable (Aeberli, 2007; Gibson and Neate, 2007; Huang, 2004; Timpson, 2008) because the investigators carefully identified plausible energy reporters and excluded implausible reports in the analysis of outcomes. Of particular importance was a pivotal study by Huang et al. (2004), who reported findings from children examined in the 1994-1996 and 1998 CSFII Surveys, a cross-sectional study of a nationally-representative sample of 1,995 U.S. children between the ages of 3 and 19 years. This was one of the earliest studies to determine the plausibility of reported energy intake of individual children, using gender and age group-specific ±1 SD cutoffs for reported energy intake (rEI) as a percent of predicted energy requirements (pER; rEI/pER x 100). These criteria were developed and updated with the 2002 DRI values (McCrory, 2002; IOM, 2002/2005). A record was considered “plausible” if rEI as a percent of pER was within 1 SD cutoff, and participants with implausible energy intake reports were excluded (rEI outside ± 18 to 23% of predicted energy requirement). In this national survey of U.S. children, 45.3 percent of the sample provided plausible reports of energy intake, and 54.7 percent had implausible reports. Among plausible reporters, energy intake, meal portion size and meal energy were positively associated with BMI percentile among all adolescents ages 12 to 19 years, and among boys ages 6 to 11 years; but not for younger children ages 3 to 5 years, or for girls ages 6 to 11 years. Thus, implausible dietary reports are prevalent in childhood and adolescence (54.7% of total sample) and shift from overreporting at ages 3 to 11 years to underreporting at ages 12 to 19 years in overweight boys and girls, and to a lesser extent among normal-weight girls. In this study, daily energy intake, meal portion and meal energy were positively and significantly associated with BMI percentile in boys 6 years and older, and in girls 12 years and older. However, this observation would not have been apparent if implausible reports of energy intake had not been excluded in the analysis. We have treated studies that failed to assess and adjust for implausible energy intake reports as negative studies.

Similarly, several research reports from the United Kingdom have also emphasized the critical importance of identifying plausible reports of energy intake when investigating relationships between dietary intake and adiposity in children. Gibson and Neate (2007) conducted a national survey of 1,294 United Kingdom children, ages 7 to 18 years, and found that 64 percent were plausible reporters of energy intake, using a cutoff based on a ratio between energy intake and basal metabolic rate (EI:BMR). When analyses were limited to children with plausible reports of energy intake, there was a positive association between energy intake and overweight status, with total energy intake significantly higher for the heaviest children. Those in the highest quintile of BMI z-scores consumed about 400 kilocalories per day more than those in the lowest quintile.

Three reports from the Avon Longitudinal Study of Parents and Children, ALSPAC, in the United Kingdom also stressed the importance of identifying plausible reports of energy intake. Among children examined at age 5 years, and again at ages 7 and 9 years, Johnson et al. (2008a) found that 72 percent had plausible reports of energy intake at age 5 years versus 76 percent at age 7 years. In addition, the prevalence of overweight was up to four times greater among underreporters compared to plausible reporters of energy intake. In a subsequent report on the same cohort studied between ages of 10 and 13 years, Johnson et al. (2009) found that energy intake was underreported by 34 percent, compared with only 3 percent who overreported energy intake. Again, a significantly greater proportion of children who underreported energy intake were overweight at age 10 years (42% vs. 12%) as well as age 13 years (47% vs. 19%), compared with children who provided plausible energy intake reports. In a third report from the ALSPAC study, Timpson et al. (2008) conducted a cross-sectional analysis of 3,741 children in the cohort who were studied at age 10 years. Similar to the reports above (Johnson, 2008a, 2009), underreporters of energy intake were identified and excluded from the study (38%). Notably, underreporters had significantly higher BMI compared with plausible reporters [19.96 (19.81, 20.11) and 17.36 (17.29, 17.44) respectively; p<0.001]. When underreporting was taken into account there was a significant effect of energy intake on the BMI of children. Per tertile of energy intake, the effect on BMI was 0.34 SD (SE: 0.017) increase, which was 10 times greater than for the total sample, before underreporters were excluded.

Accuracy in Reporting and True Associations— These reports illustrate the importance of excluding underreporters of energy intake in order to more precisely estimate the association between energy intake and adiposity in youth. The failure to assess and adjust for underreporting of energy intake in many earlier epidemiologic studies of diet and adiposity in children has likely contributed to the inconsistent findings among published reports because it tends to bias the relationship between dietary intake and adiposity toward the null if not accounted for in the analysis, as reviewed by Mendez et al. (2004).

An earlier evidence review of the literature conducted by the ADA (1982-2004) did not find evidence for an association between energy intake and adiposity in children. However, this review differed from the present NEL review in that two-thirds of the studies included in the ADA review were cross-sectional in design, whereas such studies were excluded in the NEL review. In addition, none of the studies in the earlier ADA review excluded implausible reports of energy intake, based on individual gender and age group-specific ±1 SD cutoffs for rEI as a percent of predicted energy requirements, a methodology which was promulgated subsequent to 2004 (Aeberli, 2007; Gibson and Neate, 2007; Huang, 2004; Johnson, 2008a, 2009; Savage, 2008a; Timpson, 2008). These and other methodological issues related to accurately measuring energy intake and expenditure in children are reflected in the varied and inconsistent findings among earlier reviews and published reports.

In summary, the increase in childhood obesity in the U.S. over the past several decades suggests that there has been an increase in energy intake, a decrease in energy expenditure, or both. Epidemiologic studies designed to assess these changes have often reported mixed results. Many earlier studies, however, did not appreciate the degree of underreporting of energy intake, which occurs significantly more often among overweight and obese children compared with their normal weight peers. The majority of more recent, methodologically stronger studies that accurately assessed and adjusted for underreporting of energy intake support a positive association between total energy intake and adiposity in children.

Dietary Energy Density and Adiposity in Children

Background—Although obesity results from a combination of genetic, behavioral and environmental influences on diet, physical activity, and metabolism, consumption of energy-dense foods has been highlighted as an important contributing factor (WHO, 2006). An aspect of total energy, energy density, is defined as the amount of available dietary energy per unit weight of a food or beverage (kcal/g or kJ/g). Water accounts for much of the variability in dietary energy density, because it provides a significant amount of weight without adding energy. Dietary fiber also contributes weight with little energy, thus foods high in water and/or fiber are generally of low dietary energy density. On the other hand, because dietary fat provides the greatest number of calories per gram, foods high in fat are characterized by high dietary energy density.

As discussed in Question 6, among adults, dietary energy density is positively associated with increased body weight and BMI. Fewer studies have been conducted in children, raising questions about whether the same association applies in youth. Such studies are important because children differ from adults in short-term laboratory studies that measure energy compensation in response to high energy preloads. Evidence suggests, for example, that among children, especially young children, energy compensation is better than among adults (Birch, 1985, 1986). Because energy compensation after preloads of varying energy density is incomplete, however, continual exposure to an energy-dense diet may have a cumulative effect over time resulting in passive overconsumption of energy and eventual overweight or obesity. It has been estimated for example, that even a small difference of 5 kiloJoules (kJ) per gram in the energy density of snacks consumed by children could translate into an increase in energy intake of 200 kJ per day (47.8 kcal/d) (Maffeis, 2008).

Evidence Summary—Convincing evidence from a limited number of methodologically strong, longitudinal cohort studies of children and adolescents supports a positive association between dietary energy density and adiposity in children. This conclusion is based on a review of five prospective studies, conducted in the United Kingdom and Germany, which examined the association between dietary energy density (kJ/g or kcal/g) and adiposity among youth (Alexy, 2004; Johnson, 2008a, 2008b, 2009; McCaffrey, 2008). All of the studies included actual calculations of energy density as well as an objective measure of adiposity. Cross-sectional studies were not included in the review. Four of the longitudinal studies (two study cohorts), found a positive association between dietary energy density and adiposity (Johnson, 2008a, 2008b, 2009; McCaffrey, 2008), whereas one longitudinal study reported no association (Alexy, 2004).

In the first published prospective analysis of the effect of energy-dense diets on body fatness and weight status in children, Johnson et al. (2008a) assessed the association of dietary energy density with direct measures of adiposity at ages 5, 7, and 9 years. Implausible energy intake reports were identified and adjusted for in the analysis. Results showed that mean dietary energy density at age 7 years was higher among children with excess adiposity compared to the remaining sample (9.1 ± 0.12 vs. 8.8 ± 0.06 kJ/g) and was prospectively associated with excess adiposity at age 9 years. A rise in dietary energy density of 1 kJ per gram at 7 years of age increased the odds of increased adiposity at age 9 years by 36 percent (OR = 1.36, 95% Cl 1.09-1.69). Among younger children, age 5 years, however, higher dietary energy density was not associated with excess adiposity at age 9 years. This finding may reflect better compensation for high energy intake at younger ages, a control that appears to weaken with age as environmental, social, and cultural cues for eating increase (Johnson, 2008a). In the same cohort, a dietary pattern at ages 5 and 7 years characterized by high energy density, low dietary fiber density, and a high percent of energy from fat, was associated with a 0.15 kilogram and a 0.28 kilogram higher fat mass at 9 years of age after controlling for confounders. Children at 7 years of age who were in the highest quintile of pattern score (dietary energy density = 10.67 ± 1.20) were more than four times more likely to have excess adiposity at age 9 years, compared to children initially in the lowest quintile (dietary energy density = 7.24 ± 0.87) (Johnson, 2008b). Finally, in a third report from the ALSPAC cohort at ages 10 to 13 years, Johnson et al. (2009) evaluated the effect of dietary energy density in relation to the effect of variants in a genotype associated with fat mass and obesity (the FTO genotype [rs9939609, A allele]). In this study, each 1 kJ per gram higher dietary energy density at age 10 years was associated with 0.16 ± 0.06 kilogram more fat mass at age 13 years, and each additional high-risk A allele of FTO independently associated with 0.35 ± 0.13 kilogram more fat mass at age 13 years. Thus, although genetic factors may put some children at greater risk of obesity, the independent effect of low dietary energy density in reducing adiposity could prove to be an effective strategy for obesity prevention for all children.

A smaller cohort of children followed prospectively from ages 6 to 8 years at baseline to ages 13 to 17 years at follow-up by McCaffrey et al. (2008) also found a positive association between dietary energy density and adiposity. In this study, dietary energy density was calculated by five different methods, three of which excluded all or most beverages, and two that included beverages. Results showed that dietary energy density at baseline, calculated by the three methods that excluded all or most beverages, predicted those children who had the greatest increase in Fat Mass Index (body fat normalized for height) on follow-up. Thus, subtle differences in calculating energy density by various methods may result in a positive or null association between energy density and change in fat mass over time.

It is noteworthy that the four longitudinal studies described above that found positive associations of dietary energy density with adiposity, calculated energy density by methods that excluded all or most beverages (Johnson, 2008a, 2008b, 2009; McCaffrey, 2008). This method was chosen because the high water content of beverages can disproportionately contribute to the overall energy density values and have been shown to dilute associations with health outcomes (Kant, 2005; Cox, 2000; Ledikwe, 2005). In addition, they measured adiposity (fat mass) objectively by dual energy x-ray absorptiometry (Johnson, 2008a, 2008b, 2009), or by doubly-labeled water technique (McCaffrey, 2008).

One longitudinal study found no association between dietary energy density and adiposity among children who were followed annually from age 2 to 18 years (Alexy, 2005). Participants in this cohort were classified by dietary pattern into clusters based on percent energy from fat, with dietary energy density lowest at 3.7 (0.4) in the low fat cluster; 4.0 (0.4) in the medium fat intake; and highest at 4.1 (0.4) in the high fat cluster. Mean BMI during the study period differed significantly, with the highest BMI in the low-fat, low dietary energy density cluster, a result the investigators suggest may have reflected underreporting of energy intake among overweight participants, difficulty in detecting minor overconsumption of energy, and lack of power due to small sample size. In addition, dietary energy density in this study was calculated by including all beverages which may have diluted associations with health outcomes; and BMI was used as a surrogate measure of adiposity which may have limited precision and specificity. In a report by Freedman et al. (2009) only 77 percent of children with BMI at or greater than the 95th percentile had elevated percent body fat as measured by dual energy x-ray absorptiometry, and an even smaller percent of children (20%) with BMI between the 85th and 94th percentile had elevated body fatness.

In summary, evidence from a limited number of methodologically strong, longitudinal cohort studies of children and adolescents suggests that there is a positive association between dietary energy density and increased adiposity in children. This is based on reports that used objective measures of adiposity (dual energy x-ray absorptiometry or doubly labeled water technique), carefully assessed and adjusted for under and overreporting of energy intake, and calculated dietary energy density by methods which excluded all or most beverages.

Dietary Fat and Adiposity in Children

Background—The relationship of dietary fat to adiposity in children has been studied more extensively than for other macronutrients, primarily because of its high energy density and palatability, both qualities likely to promote passive overconsumption of energy if not regulated (Parsons, 1999). In addition, studies suggest that fat intake induces less potent satiety signals and less compensation with respect to subsequent energy intake, compared with dietary protein or carbohydrate (Doucet, 1997; Bray, 2004), and that fat oxidation is not as highly regulated as carbohydrate utilization (see *Part D.5 Section: Carbohydrates* for a discussion of the varying influences of fat, carbohydrate, and protein on satiety). In metabolic studies of children, meal induced thermogenesis increased more after a high-carbohydrate meal than after a high-fat meal; and although fat oxidation increased after the high fat meal, postprandial fat storage was greater after the high fat meal compared with the high carbohydrate meal (Maffeis, 2001).

Evidence Summary—Increased intake of dietary fat is associated with greater adiposity in children. The DGAC conducted a full NEL search to evaluate the association between dietary fat intake and adiposity in children. Results of this review were supplemented by the findings of prospective studies included in an earlier evidence review conducted by the ADA. This conclusion was based on 28 peer-reviewed articles which addressed the research question, 21 studies from the earlier ADA review; and seven studies from the subsequent NEL review. This included four RCTs (Caballero, 2003; Hakanen, 2006; Lauer, 1995; Niinikoski, 2007); and 24 longitudinal studies (21 from the ADA review and 3 from the NEL review) (Alexy, 2004, 1999; Johnson, 2008b; Karaolis-Danckert, 2007; Berkey, 2000; Bogaert, 2003; Boulton, 1995; Carruth, 2001; Davison, 2001; Eck, 1992; Francis, 2003; Gazzaniga, 1993; Klesges, 1995; Lee, 2001; Maffeis, 1998; Magarey, 2001; Newby, 2003; Robertson, 1999; Rolland-Cachera, 1995; Scaglioni, 2000; Shea, 1993; Skinner, 2003, 2004; Wang, 2003). Fourteen of the studies were conducted in the U.S.

Of the 24 longitudinal studies, 15 found a positive association between total fat intake or intake of high-fat foods and adiposity in all or a subsample of the population studied (Carruth, 2001; Davison, 2001; Eck, 1992; Francis, 2003; Gazzaniga, 1993; Johnson, 2008a; Karaolis-Dankert, 2007; Klesges, 1995; Lee, 2001; Magarey, 2001; Newby, 2003; Robertson, 1999; Skinner, 2003, 2004; Wang, 2003). The varied results between studies were a product of using multiple measures of adiposity within the same study, conducting analyses stratified by different variables (e.g., sex, weight status), and/or dietary fat measured in both absolute terms (total grams) as well as a percent of energy intake. Nine other longitudinal studies found no association between total fat intake and adiposity in children (Alexy, 1999, 2004; Berkey, 2000; Bogaert, 2003; Boulton, 1995; Maffeis, 1998; Rolland-Cachera, 1995; Scaglioni, 2000; Shea, 1993). A greater proportion of the studies that found a positive association between dietary fat and adiposity, however, used multiple measures of adiposity, such as skinfold measures, and body composition by dual energy x-ray absorptiometry, rather than only BMI, which provides a poor estimate of actual body fat (Freedman, 2009).

Three of the four RCTs found no association between percent energy from dietary fat and adiposity. The STRIP clinical trial, which tested the effects of a fat-modified diet from 7 months of age (Hakanen, 2006), reported less obesity among intervention girls compared with control girls at age 10 years, but no differences for boys; while at age 14 years, Niinikoski et al. (2007) found no difference in obesity between treatment groups, for either males or females. Caballero et al. (2003) reported no change in percent body fat in a 3-year school-based nutrition and physical activity intervention among 1,704 Native American children, who were age 7 years at baseline. Results showed that percent body fat and BMI did not differ by treatment group at study end. However, children in the intervention group reported lower total energy intake (1892 vs. 2157 kcal/d) and percent energy from total fat (31.1% vs. 33.6%) compared with the control group, and percent energy from fat was lower in the intervention school lunches compared to the control schools (28.2% vs. 32.0%). Finally for the Dietary Intervention in Children (DISC) trial (Lauer, 1995), which tested the safety and efficacy of lowering dietary intake of fat and cholesterol in children with elevated low-density lipoprotein (LDL)-cholesterol, analyses of growth patterns showed no difference in BMI, height, or weight between the lower fat, lower saturated fat intervention groups versus controls. It should be noted, however, that in this trial, great effort was taken to ensure that energy intake would not decrease and growth would be maintained, because the goal was to show that lipids could be improved without a deleterious effect on growth.

In summary, the combination of evidence from methodologically strong studies in the NEL and ADA reviews supports a conclusion that dietary fat and adiposity in children are positively associated. Methodological differences between studies, however, were significant, especially with respect to dietary assessment procedures, identification of implausible energy intake reports, choice of anthropometrics, and statistical approaches. Despite these methodological differences and limitations, collectively the studies tended to find either a positive association or no significant association between dietary fat and adiposity with the weight of evidence leaning towards a positive association. Additional prospective studies that assess both the amount and type of fat in relation to changes in childhood adiposity are warranted, however. *Part D. Section 3: Fatty Acids and Cholesterol* provides additional information about dietary fat.

Intake of Fruits and Vegetables and Adiposity in Children

Background—Fruits and vegetables are excellent sources of complex carbohydrates, dietary fiber, and several vitamins and minerals that are important for normal growth and development in childhood. In addition, fruits and vegetables are a good source of shortfall nutrients, such as dietary fiber and potassium, which are currently consumed by children in amounts that are less than adequate for optimal health benefits. Among adults, diets that are high in fruits and vegetables are associated with decreased risk of hypertension, T2D, CVD, and certain cancers. Evidence from epidemiologic studies also suggests that childhood eating patterns are associated with risk of some diet-related cancers (Steinmetz, 1991; Krebs-Smith, 1996; Maynard, 2003). Although fewer studies have been conducted in children, associations have been found between increased intake of fruits and vegetables and lower blood pressure (Couch, 2008; Lazarou, 2009; McNaughton, 2008; Moore, 2005) and reduced prevalence of metabolic syndrome (Pan, 2008). Because evidence that dietary intake of foods and nutrients tends to track over time through childhood and adolescence, as well as to adulthood (Bertheke, 2001; Kelder, 1994; Lake, 2006; Mikkila, 2005; Nicklas, 1991; Resnicow, 1998; Singer, 1995; Stein, 1991), the public health benefits of achieving optimal intake of fruits and vegetables in childhood are significant.

Evidence Summary—Evidence from a limited number of studies suggests that greater intake of fruits and/or vegetables may protect against increased adiposity in children and adolescents (see *Part D. Section 5: Carbohydrates* for a review of vegetables and fruits and body weight among adults). The conclusion that increased fruit and/or vegetable intake may protect against increased adiposity in children when consumed as part of a nutrient-rich, energy balanced diet is based on a full NEL literature search, supplemented by the findings of prospective studies included in an earlier evidence review conducted by the ADA (1982-2004). Collectively, the evidence review led to the conclusion that increased intake of fruits and/or vegetables may be associated with reduced adiposity in children. In combination, the two systematic literature searches identified seven RCT or longitudinal studies that addressed the research question and met other inclusion criteria. This included one randomized controlled trial (Epstein, 2008), and six longitudinal studies of five cohorts (Faith, 2006; Field, 2003; Newby, 2003, 2004; Sugimori, 2004; Wang, 2003). Five studies were conducted in the U.S., one in Japan, and one in China. Overall, of the seven included studies, three studies found evidence for an inverse, protective association between dietary intake of fruits and/or vegetables and adiposity in children, either for the total sample (Epstein, 2008; Wang, 2003), or for a subsample of children, based on gender (Field, 2003). Results from three other cohorts (four reports) found no association between intake of fruits and/or vegetables and adiposity (Faith, 2006; Newby, 2003, 2004; Sugimori, 2004).

In summary, results from longitudinal studies and one RCT in general found either a negative, protective association, or no association between increased consumption of vegetables and/or fruits and adiposity in children. However, interpretation of results and comparison of results across studies is hampered by lack of uniformity as to which vegetables and fruits were included in each respective food group; or whether fruit juice was included in the fruit food group. In addition, none of the studies rigorously assessed or adjusted for implausible energy intake; and all used BMI as an estimate of fatness, which has been shown to be a poor measure of adiposity in children. Despite these methodological difficulties, review of the evidence to date provided some support for an inverse (protective) association between increased vegetable and/or fruit intake and adiposity in children.

Intake of 100 Percent Fruit Juice and Adiposity in Children

Background—In general, consumption of whole fruits rather than 100 percent juice is likely to confer greater health benefits in childhood. Many whole fruits are rich in dietary fiber, but most 100 percent juices contain little or none. In addition, some studies have linked consumption of fruit juice with obesity, diarrhea, tooth decay, and failure to thrive, especially if consumed in large quantities, and for infants, if juice replaces milk in the diet (AAP, 2001). On the other hand, 100 percent fruit juice can be a healthy part of a child's diet when consumed in moderation as part of a well-balanced diet. Some, such as 100 percent orange juice, are good sources of vitamins C and B (thiamin, B_6, and folate), as well as potassium. In a recent study, children ages 2 to 11 years who consumed more than 6 fluid ounces of 100 percent fruit juice had significantly higher intakes of total carbohydrates, vitamins C and B_6, folate, potassium, magnesium, and iron ($p<0.001$), and lower intakes of total fat and saturated fat ($p<0.001$) compared with non-consumers. However, children who consumed more than 12 fluid ounces of 100 percent fruit juice had significantly higher energy intake (2138 kcal) compared with children who did not consume 100 percent juice (1828 kcal) ($p< 0.001$) (Nicklas, 2008).

Evidence Summary—Evidence suggests that for most children, intake of 100 percent fruit juice is not associated with increased adiposity, when consumed in amounts that are appropriate for age and energy needs of the child. This conclusion is based on a full NEL literature search (2004-2009), supplemented by the findings of prospective studies included in an earlier evidence review conducted by the ADA (1982-2004). In combination, the two systematic literature searches identified 12 peer-reviewed prospective studies that addressed the research question and met the inclusion criteria (Alexy, 1999; Berkey, 2004; Blum, 2005; Faith, 2006; Field, 2003; Kral, 2008; Libuda, 2007; Newby, 2004; Skinner, 1999, 2001; Sugimori, 2004; Welsh, 2005). Nine studies were conducted in the U.S., two in Germany, and one in Japan. Overall, of the 12 cohort studies, eight studies found no association between intake of fruit juice and adiposity in children (Alexy, 1999; Berkey, 2004; Blum, 2005; Field, 2003; Kral, 2008; Newby, 2004; Skinner, 1999, 2001); two found no association between intake of fruit juice and adiposity in normal weight children, but found a positive association for children who were at-risk of overweight, or overweight at baseline (Faith, 2006; Welsh, 2005); and two studies found mixed results by sex. Libuda et al. (2007) found no association for boys, but a positive association for girls, while Sugimori et al. (2004) found no association for girls, but a positive association for boys.

Overall, the preponderance of evidence led to the conclusion that for most children 100 percent fruit juice intake and adiposity are not associated. Two of the studies, however, found a positive association between 100 percent fruit juice intake and adiposity among overweight and obese children (Welsh, 2005; Faith, 2006). These findings are of concern because about one-third of U.S. children and adolescents are currently overweight or obese. Therefore, it is recommended that 100 percent juice be consumed in moderation, as part of a nutrient-rich, energy-balanced diet, in amounts are appropriate for the overall energy needs and nutrient requirements of the child.

Intake of Sugar-sweetened Beverages and Adiposity in Children

Background—The relationship of sugar-sweetened beverages to obesity in children has been studied more extensively than for many other foods and beverages because many such beverages provide energy only, without added nutrients, and because some evidence suggests that individuals are less able to reduce subsequent intake of energy after consuming liquid versus solid calorie preloads. Thus, diets including significant amounts of sugar-sweetened beverages could more easily result in passive overconsumption of energy if not regulated.

Examination of temporal trends reveals that consumption of sugar-sweetened beverages, particularly soft drinks, has increased dramatically among U.S. children and adolescents. In the 2005-2006 NHANES, soda was the top beverage choice for children and adolescents, ages 2 to 18 years, supplying more of both fluid weight (grams) and energy (calories) than any other single beverage. Regular soda accounted for 33 percent of the gram weight of beverages consumed and 29 percent of total beverage calories. Among top sources of total energy intake, soda ranked third (118 kcal/d) behind grain-based desserts (138 kcal/d) and pizza (136 kcal/d). Across beverage categories, children ages 2 to 18 years consumed 173 kilocalories per day from sugar-sweetened beverages (soda and fruit drinks combined) (NHANES 2005-06). In addition, sugar-sweetened beverages provide about 22 percent of empty calories (sum of calories from solid fats and added sugars) for children and adolescents (NHANES 2005-06) (NCI, 2010). Thus, reducing the consumption of sugar-sweetened beverages is desirable, if replaced with nutrient-dense foods and beverages, within calorie needs for a healthy weight. Literature examining the relationship between sugar-sweetened beverages and body weight in adults is discussed in *Part D. Section 5: Carbohydrates*. Additional information about added sugars is also provided in *Part D. Section 2: Nutrient Adequacy*.

Evidence Summary—Increased intake of sugar-sweetened beverages is associated with greater adiposity in children. The DGAC conducted a full NEL search to evaluate the association between sugar-sweetened beverages and adiposity in children. Results of this review, covering 2004-2009 were supplemented by the findings of prospective studies included in an earlier evidence review conducted by the ADA (1982-2004). In combination, the two systematic literature searches identified 18 peer-reviewed articles which addressed the research question, seven studies from the earlier ADA review; and 11 studies from the subsequent NEL review. This included two RCTs (Ebbeling, 2006; James, 2004); 16 longitudinal studies (6 from the ADA review [Ludwig, 2001; Philipis, 2004; Sugimori, 2004; Mrdjenovic, 2003; Newby, 2004; Berkey, 2004] and 10 from the NEL review [DuBois, 2008; Fiorito, 2009; Johnson, 2007; Kral, 2008; Kvaavik, 2005; Libuda, 2008; Mundt, 2006; Striegel-Moore, 2006; Tam, 2006;Welsh, 2005]). Ten of the studies were conducted in the U.S., and the others were conducted outside of the U.S.

Overall, the majority of included studies (12 of 19) found a positive association between sugar-sweetened beverage intake and adiposity in all or a subsample of the population studied. Of these studies, two were RCTs (Ebbeling, 2006; James, 2004) and 10 were longitudinal cohort studies (DuBois, 2008; Fiorito, 2009; Kral, 2008; Libuda, 2008; Striegel-Moore, 2006; Tam, 2006; Welsh, 2005; Ludwig, 2001; Philips, 2004; Berkey, 2004). Seven other studies, all of a longitudinal design, found no association between sugar-sweetened beverage intake and adiposity in children (Blum, 2005; Johnson, 2007; Kvaavik, 2005; Mrdjenovic, 2003; Mundt, 2006; Newby, 2004; Sugimori, 2004).

Both RCTs included in the review reported some results consistent with a positive association between intake of sugar-sweetened beverages and adiposity in children. In the study by Ebbeling et al. (2006), children in the upper third of the BMI distribution at baseline reduced adiposity subsequent to reducing intake of sugar-sweetened beverages, and the RCT conducted by James et al. (2004) found that a targeted, school-based education program which produced a modest reduction in the number of carbonated drinks consumed, was associated with a reduction in the number of overweight and obese children.

Intake of Calcium and/or Dairy (Milk and Milk Products) and Adiposity in Children

Background—The relationship of dairy products (milk and milk products) to obesity in U.S. children has been of interest because of the trend toward decreased consumption of fluid milk and increased consumption of sugar-sweetened beverages and juice. Milk and milk products have traditionally been a source of nutrient-rich foods and beverages for children and adolescents. Besides providing energy, they are a concentrated source of highly bioavailable calcium, providing about three-fourths of the calcium in the U.S. diet. In addition, they are a rich source of essential amino acids, have a good balance of macronutrients, are a rich source of riboflavin, and contain high-quality proteins. Although some studies suggested a protective effect of dairy intake against obesity in adults and children, others have found no association, or in some cases, even a positive association with adiposity.

Inconsistencies across studies have reflected lack of consensus on which foods to include, varying methods used to quantify dairy consumption (amount vs. frequency of dairy intake), varying definitions of health outcomes, and lack of compliance monitoring during intervention. In addition, inclusion of physiologically implausible reports of energy intake has been shown to mask observed diet-obesity relationships in children (Huang, 2005; Johnson, 2009; Savage, 2008a). Among children, the extent of underreporting of energy intake increases with age, and is significantly greater for obese relative to lean youth (Bandini, 2003; McCrory, 2002; Huang, 2005). Additional information on milk products can be found in *Part D. Section 2: Nutrient Adequacy* and *Part D. Section 4: Protein*.

Evidence Summary—Insufficient evidence is available to document that low intake of calcium or dairy (milk and milk products) is associated with greater adiposity in children. The DGAC conducted a full NEL search to evaluate the association between intake of calcium and/or dairy (milk and milk products) and adiposity in children. Results of this review, covering 2004-2009 were supplemented by the findings of prospective studies included in an earlier evidence review conducted by the ADA (1982-2004).

In combination, the two systematic literature searches included five randomized clinical trials, 12 longitudinal studies, and three review articles. Of the five RCTs, two found no association between intake of calcium/dairy and adiposity (Lappe, 2004; St Onge, 2009), two reported mixed results (DeJongh, 2006; Lorenzen, 2006), and one found evidence for a negative (protective) association between intake of calcium/dairy and adiposity (Abrams, 2007). Of the 12 longitudinal studies, six found no association between calcium and/or dairy and adiposity in children (Berkey, 2004; Fisher, 2004; Fiorito, 2006; Newby, 2004; Philips, 2003; Sugimori, 2004) and four found a negative (protective) association between calcium and/or dairy intake (Carruth, 2001; Boon, 2005; Moore, 2006; Skinner, 2001). One study reported mixed results, in that calcium or dairy intake was not associated with adiposity in hypercholesterolemic children or in non-hypercholesterolemic children ages 4 to 6 years. However, calcium intake was inversely associated with BMI and skinfolds among the older non-hypercholesterolemic children ages 7 to 10 years (Dixon, 2005). Finally, a prospective study by Berkey et al. (2005) found a positive association between calcium intake and adiposity in children, as well as a positive association for 1 percent milk intake in boys and skim milk in girls.

Thus for the 17 RCT and longitudinal studies included in the combined NEL and ADA evidence reviews, eight found no association between calcium and/or dairy and adiposity in children, five found an inverse (protective) effect, three found mixed results, and one found a positive association. Thus, the preponderance of evidence from these studies was greatest for no association, although there was some evidence for a weak inverse (protective) association.

The NEL review also included three systematic reviews published between 2004 and 2009 that were limited to longitudinal studies and/or RCTs. The overall consensus of the review articles was that the preponderance of evidence did not support a protective association between intake of dairy/calcium and adiposity. Thus, although results of included studies are mixed, overall, there is insufficient evidence to suggest that intake of calcium or dairy (milk and milk products) plays a significant role in regulating adiposity in children and adolescents. Regardless of these findings, it is important to emphasize that dairy products remain rich sources of essential nutrients for children, including calcium, vitamin D, and other micronutrients for bone health, and potassium for healthy blood pressure.

Intake of Dietary Fiber and Adiposity in Children

Background—Dietary fiber is often a marker for a healthy, nutrient-rich diet in childhood. Nicklas et al. (1995 and 2000) found that children with higher dietary fiber intakes consumed less total and saturated fat, and greater intakes of vitamins A, B_6, B_{12}, and C, and niacin, thiamin, riboflavin, folate, magnesium, iron, zinc, and calcium. In a study by Hampl et al. (1998), the recommended dietary fiber intake was associated with lower intake of fat and cholesterol, and higher intakes of vitamin A, folate, magnesium, and iron. Kranz et al. (2005) found that preschool children in the highest quartile for dietary fiber intake consumed diets with higher nutrient and fiber density, and increased number of servings of Food Guide Pyramid food groups. Mean intake of dietary fat decreased with increasing fiber intake, and mean intake of calcium increased. Iron, folate, vitamins A and C intake increased significantly across quartiles of fiber consumption. Similarly, in a prospective study of healthy Finnish children followed annually from late infancy to age 15 years in the STRIP study (Special Turku Risk Intervention Project), Ruottinen et al. (2009) found that children in the highest decile (10%) of dietary fiber intake had higher vitamin and mineral intakes compared to children with lower fiber intakes. In addition, the group of children with high-fiber intakes had lower total fat, saturated fat, monounsaturated fat, and sucrose intakes, and higher protein intakes, compared with children with lower fiber intake.

Evidence also is strong for an inverse, protective association between dietary fiber and serum cholesterol in children. In the STRIP RCT, Ruottinen et al. (2009) found that serum cholesterol concentrations decreased with increasing fiber intakes among children between ages 8 months and 9 years, and the authors conclude that part of the cholesterol-lowering effect observed in this study might be explained by the effect of dietary fiber, in addition to the lower saturated fat intake in the intervention group. The authors also emphasize that dietary fiber did not reduce energy intake, as reflected in annual dietary intake reports, as well as assessment of longitudinal growth patterns, which revealed similar heights and weights in all fiber intake groups from highest to lowest.

Dietary fiber in childhood also plays an important role in supporting healthy gastrointestinal function and normal laxation. Constipation among children has been estimated to affect 1 in 10 or more of U.S. children, and ranks among the most common complaints for children seen by pediatric gastroenterologists. Thus, reductions in the incidence and prevalence of this common but vexing disorder would translate into significant health care cost savings, in addition to the overall health of the children.

It has been hypothesized that dietary fiber could play a role in weight management and prevention of obesity in children and adolescents. From a physiological point of view, high-fiber diets could promote a healthy weight because (1) high-fiber foods require more time to chew, slowing down the rate at which food is eaten and allowing more time for satiety signals; (2) fiber absorbs fluid, increasing the bulk of ingested food and promoting a feeling of fullness; (3) high-fiber foods are generally lower in energy density, having fewer calories than the same weight of low-fiber foods. Higher dietary fiber intake, as one component of a healthy dietary pattern that also includes lower intake of dietary fat and reduced energy density, has been shown to be associated with decreased adiposity in young children (Johnson, 2008b). In addition, recent studies among adults provide support for the importance of dietary fiber in protection against obesity (Du, 2010; Tucker and Thomas, 2009; Byrd-Williams, 2009; McKeown, 2009). Additional information about dietary fiber can be found in *Part D. Section 2: Nutrient Adequacy* and *Part D. Section 5: Carbohydrates*.

Evidence Summary—Insufficient evidence is available at present to support the hypothesis that dietary fiber is protective against obesity in children. Unfortunately, very few prospective studies or clinical trials have examined the association between dietary fiber intake and adiposity in children and adolescents. A literature search conducted during the NEL review of this research question yielded six studies for the final review: two randomized clinical trials (Ventura, 2009; Vido, 1993) and four longitudinal studies (Berkey, 2000; Cheng, 2009; Davis, 2009; Newby, 2003). Studies with a cross-sectional design were excluded.

Of the two RCTs included in the review, one by Ventura et al. (2009) found an inverse protective effect of dietary fiber on adiposity. In this 16-week trial, overweight Latino adolescents (mean age 15 years) who increased dietary fiber intake, had an improvement in BMI (-2% vs. +2%; p=0.01) and visceral adipose tissue (-10% vs. no change; p=0.03) compared with controls. A second study by Vido et al. (1993) compared the effects of a dietary fiber supplement (glucomannan, 1 gram twice a day) versus placebo, on weight change in 60 overweight Italian children (mean age 11.2 years).

At the end of the intervention, weight decreased significantly in both treatment groups ($p<0.01$). However, the difference between the groups was not significant.

One of the four longitudinal studies found an inverse, protective association between dietary fiber intake and adiposity in children. Davis et al. (2009) conducted a longitudinal study of dietary intake on metabolic risk factors in 85 overweight Latino Youth, 11 to 17 years of age. They assessed the relation between changes in dietary intake, specifically dietary fiber and sugar intakes, with changes in adiposity and risk factors for T2D. Overweight Latino youth (n=85, ages 11-17 years) were followed for 2 years and data collected included dietary intake by 2-day diet recalls, body composition by dual-energy x-ray absorptiometry and magnetic resonance imaging, and glucose and insulin indexes by oral- and intravenous-glucose-tolerance tests. Results showed that increases in total dietary fiber (g/1000 kcal) and insoluble fiber (g/1000 kcal) were associated with decreases in visceral adipose tissue (VAT) ($r=-0.29$; $p=0.02$, and $r=-0.27$; $p=0.03$, for total dietary fiber and insoluble fiber, respectively. In addition, participants who decreased their total fiber intake during the study (mean decrease ~3 g/d) had significant increases in VAT compared to participants who had increased dietary fiber (21% compared with -4%; $p=0.02$). No relationship was found between other dietary variables, including sugar and visceral adiposity.

Three other longitudinal studies found no association between dietary fiber intake and adiposity in children. Berkey et al. (2000) studied dietary intake, physical activity and inactivity among 10,769 U.S. children, ages 9 to 14 years, and concluded that there were no significant associations between energy-adjusted dietary fiber or dietary fat and BMI. Cheng et al. (2009) assessed dietary intake and adiposity in a cohort of 215 German adolescents from puberty onset until 4 years later. They found that neither dietary fiber intake, whole grain intake, dietary glycemic index, nor glycemic load were associated with changes in percent body fat or BMI Z-score throughout puberty. Newby et al. (2003) measured dietary intake and adiposity at baseline and again 6 to 12 months later in a cohort of 1,379 low-income U.S. preschool children enrolled in the WIC program. In this population, intake of total dietary fiber was not associated with weight change. However, intake of breads and grains was associated with a lower weight change per year ($p<0.01$).

In summary, the NEL review identified few prospective studies and clinical trials that examined the relationship between dietary fiber and adiposity in children, and evidence from these studies was mixed. Thus, the review led to the conclusion that there is insufficient evidence at present to support the hypothesis that dietary fiber is protective against obesity in children. Regardless of evidence for or against a role for dietary fiber in regulating adiposity in children, however, the health benefits of adequate dietary fiber in childhood are significant, and children should be encouraged to consume greater amounts and varieties of high fiber foods in order to increase nutrient density, and promote healthy lipid profiles, glucose tolerance, and normal gastrointestinal function. Currently, dietary fiber is underconsumed by U.S. children, whose intake is far less than the recommended adequate intake (AI) of 14 grams of per 1000 kilocalories. Thus, public health strategies to increase consumption of dietary fiber are vitally important to promote the health of U.S. children (see Figure D2.20 *Part D. Section 2: Nutrient Adequacy* for more information on fiber intake versus the Adequate Intake level).

Summary of Dietary Intake and Childhood Adiposity

In summary, for the overarching question related to dietary intake and childhood adiposity, the DGAC review documents evidence for a positive association between dietary energy density, total energy, dietary fat, sugar-sweetened beverages, and adiposity in children; while some evidence supported an opposite, protective effect for increased consumption of fruits and vegetables. For 100 percent juice, evidence was lacking for an association with adiposity for most children. However, juice intake may increase adiposity for those who are overweight or obese. Finally, at the present time, evidence is insufficient that intake of calcium and/or dairy (milk and milk products), or dietary fiber, play a significant role in regulating adiposity in youth. Translating this evidence into public health strategies to prevent childhood obesity requires careful consideration of the nutrient requirements of children at each age, integration with physical activity guidelines to promote energy balance, and changes that begin to transform our social and cultural environment from obesogenic to healthful.

Question 5: What Is the Relationship Between Macronutrient Proportion and Body Weight in Adults?

Conclusion

There is strong and consistent evidence that when calorie intake is controlled, macronutrient proportion of the diet is not related to losing weight. A moderate body of evidence provides no data to suggest that any one macronutrient is more effective than any other for avoiding weight regain in weight reduced persons. A moderate body of evidence demonstrates that diets with less than 45 percent of calories as carbohydrates are not more successful for long-term weight loss (12 months). There is also some evidence that they may be less safe. In shorter-term studies, low calorie, high protein diets may result in greater weight loss, but these differences are not sustained over time. A moderate amount of evidence demonstrates that intake of dietary patterns with less than 45 percent calories from carbohydrate or more than 35 percent calories from protein are not more effective than other diets for weight loss or weight maintenance, are difficult to maintain over the long term, and may be less safe.

Implications

No optimal macronutrient proportion was identified for enhancing weight loss or weight maintenance. However, decreasing caloric intake led to increased weight loss and improved weight maintenance. Therefore, diets that are reduced in calories and have macronutrient proportions that are within the ranges recommended in the Dietary References Intakes (IOM, 2002/2005) (protein: 10%-35%; carbohydrate: 45%-65%; fat: 20%-35%) are appropriate for individuals who desire to lose weight or maintain weight loss. Diets that are less than 45 percent carbohydrate or more than 35 percent protein are difficult to adhere to, are not more effective than other calorie-controlled diets for weight loss and weight maintenance, and may pose health risk, and are therefore not recommended for weight loss or maintenance.

Review of the Evidence

Macronutrient Proportion and Weight Loss

When overweight/obese persons attempt to lose weight with reduced calorie intake, there are no differences in weight loss with differing macronutrient proportions, if diets are followed for longer than 6 months. In shorter-term studies, low calorie, high protein diets may result in greater weight loss, but these differences are not sustained over time.

This conclusion is based on 36 articles published since 2004: five review articles, 31 RCTs, and one non-randomized controlled trial (Arvidsson, 2004; Avenell, 2004; Benassi-Evans, 2009; Bopp, 2008; Buscemi, 2009; Capel, 2008; de Luis, 2009; Frisch, 2009; Gordon, 2008; Halton, 2004; Halyburton, 2007; Hession, 2009; Jenkins, 2009; Johnston, 2006; Johnstone, 2008; Keogh, 2008; Krieger, 2006; Leidy, 2007; Lim, 2009; Lopez-Fontana, 2009; Mahon, 2007; McAuley, 2005; McLaughlin, 2006; McMillan-Price, 2006; Miller, 2009; Nickols-Richardson, 2005; Noakes, 2006; Nordmann, 2006; Rankin, 2007; Sacks, 2009; Shai, 2008; Tay, 2008; Viguerie, 2005; Volek, 2009; Wal, 2007; White, 2007). Studies were conducted in Australia, Canada, Germany, Israel, New Zealand, Spain, Sweden, the UK, and the U.S. The active weight loss phase in these studies ranged from 2 weeks to 6 months, with weight maintenance assessed through 24 months. Studies also ranged in sample size from 17 to 645 participants, and had drop-out rates from 0 percent to 34 percent. Diets tested ranged from 26 to 66 percent energy from fat, 15 to 50 percent energy from protein, and 4 to 54 percent energy from carbohydrate.

Twenty studies found no difference in weight loss between diets differing in macronutrient proportion (Arvidsson, 2004; Avenell, 2004; Benassi-Evans, 2009; Capel, 2008; de Luis, 2009; Frisch, 2009; Gordon, 2008; Jenkins, 2009; Johnston, 2006; Leidy, 2007; Lim, 2009; Lopez-Fontana, 2009; McLaughlin, 2006; Miller, 2009; Noakes, 2006; Sacks, 2009; Tay, 2008; Viguerie, 2005; Wal, 2007; White, 2007).

Thirteen studies found that lower carbohydrate diets reduced weight significantly more than low-fat or higher-carbohydrate diets (Buscemi, 2009; Halyburton, 2007; Hession, 2009; Johnstone, 2008; Keogh, 2008; Krieger, 2006; Mahon, 2007; McAuley, 2005; Nickols-Richardson, 2005; Nordmann, 2006; Rankin, 2007; Shai, 2008; Volek, 2009).

Four studies found that higher-protein diets reduced weight significantly more than lower-protein or higher-carbohydrate diets (Bopp, 2008; Halton, 2004; Mahon, 2007; McMillan-Price, 2006). One study found a diet higher in protein from chicken, but not beef, to be more effective than a lower-protein diet for weight loss (Mahon, 2007). One study found higher-protein diets to be more effective than lower-protein diets for short-term weight loss, but the evidence for effectiveness of higher-protein diets for long-term weight loss was inconclusive (Halton, 2004).

Macronutrient Proportion and Avoidance of Weight Regain

There are no data to suggest that any one macronutrient is more effective than any other for avoiding weight regain in weight-reduced persons. This conclusion is based on 12 articles published since 2004: two review articles, nine RCTs, and one prospective cohort study (Benassi-Evans, 2009; Dale, 2009; Due, 2008; Frisch, 2009; Hession, 2009; Lim, 2009; McAuley, 2005; Noakes, 2006; Nordmann, 2006; Phelan, 2007; Sacks, 2009; Westerterp-Plantenga, 2004). Studies were conducted in Australia, Denmark, Germany, Israel, New Zealand, the Netherlands, and the U.S. Studies ranged in length from 1 month to 24 months. Studies also ranged in sample size from 33 to 891 participants, and had drop-out rates from 12 percent to 34 percent. Diets tested ranged from 10 to 61 percent energy from fat, 15 to 36 percent energy from protein, and 4 to 70 percent energy from carbohydrate.

Ten studies found no difference in weight maintenance between diets differing in macronutrient proportion (Benassi-Evans, 2009; Dale, 2009; Due, 2008; Frisch, 2009; Lim, 2009; McAuley, 2005; Noakes, 2006; Nordmann, 2006; Phelan, 2007; Sacks, 2009). One study found that lower carbohydrate diets diet resulted in better weight maintenance than low-fat, low-calorie diets (Hession, 2009). One study found that a higher-protein diet resulted in better weight maintenance than a lower-protein diet (Westerterp-Plantenga, 2004).

Safety and Effectiveness of Low-carbohydrate (less than 45%) Hypocaloric Diets for Long-term (more than 6 month) Weight Loss or Weight Maintenance

Carbohydrate diets below 45 percent of calories are not more successful for long-term weight loss (12 months). Some evidence also suggests that they may be less safe. This conclusion is based on 15 articles published since 2004: three review articles, eight RCTs, and four prospective cohort studies (Avenell, 2004; Dale, 2009; Due, 2008; Frisch, 2009; Halton, 2006, 2008; Hession, 2009; Lagiou, 2007; Lim, 2009; McAuley, 2005; Nordmann, 2006; Sacks, 2009; Shai, 2008; Tay, 2008; Trichopoulou, 2007). Studies were conducted in Australia, Denmark, Germany, Greece, Israel, New Zealand, Sweden, and the U.S. Studies ranged in length from 6 months to 24 months. Studies also ranged in sample size from 55 to 98,462 participants, and had drop-out rates from 12 percent to 34 percent. Diets tested ranged from 10 to 61 percent energy from fat, 15 to 36 percent energy from protein, and 4 to 70 percent energy from carbohydrate.

Nine studies found no difference in long-term (>6 months) weight loss between low-carbohydrate (<45%) diets compared to others differing in macronutrient proportion (Avenell, 2004; Dale, 2009; Due, 2008; Frisch, 2009; Lim, 2009; McAuley, 2005; Nordmann, 2006; Sacks, 2009; Tay, 2008). Two studies found that lower-carbohydrate diets resulted in better long-term (>6 months) weight loss than low-fat, low-calorie diets (Hession, 2009; Tay, 2008).

One study found that high-carbohydrate diets increased total and LDL-cholesterol compared to low-fat diets (Hession, 2009). One study found that a high-fat (monounsaturated fat) diet increased total and LDL-cholesterol compared to a high-carbohydrate diet (Dale, 2009). One study found that a high-fat diet increased LDL cholesterol compared to a high-protein diet (McAuley, 2005). Two studies found that diets lower in carbohydrate and higher in protein were associated with increased total and cardiovascular mortality (Lagiou, 2007; Trichopoulou, 2007). One study found no association between low-carbohydrate, high-protein diets and risk of CVD (Halton, 2006). One study found no associated between low-carbohydrate, high-protein diets and risk of T2D (Halton, 2008).

Safety and Effectiveness of High-protein (more than 35%) Hypocaloric Diets for Long-term (more than 6 months) Weight Loss or Maintenance

Intake of diets higher in protein than accepted standards (>35% of total calories) provides no advantages for weight loss or maintenance or for improved health biomarkers compared to other diets with differing macronutrient composition. Also, such diets may be less safe than diets within the Dietary Reference Intakes (DRI) ranges for macronutrients.

This conclusion is based on four articles published since 2004: three RCTs and one prospective cohort study (Benassi-Evans, 2009; Lim, 2009; Tay, 2008; Trichopoulou, 2007). Studies were conducted in Australia, Greece, and Israel. Studies ranged in length from 6 months to 15 months. Studies also ranged in sample size from 33 to 22,944 participants, and had drop-out rates from 0 percent to 34 percent. Diets tested ranged from 10 to 61 percent energy from fat, 17 to 50 percent energy from protein, and 4 to 70 percent energy from carbohydrate. Three studies found no difference in long-term (>6 months) weight loss between high-protein (>35 percent) diets and diets differing in macronutrient proportion (Benassi-Evans, 2009; Lim, 2009; Tay, 2008).

Biomarkers improved in all macronutrient groups, including blood pressure, fasting glucose, C-reactive protein, and triglycerides. Biomarkers were associated with weight loss and did not vary by diet treatment. In addition, one study found that diets lower in carbohydrate and higher in protein were associated with increased total and cardiovascular mortality (Trichopoulou, 2007).

Question 6: Is Dietary Energy Density Associated With Weight Loss, Weight Maintenance, and Type 2 Diabetes Among Adults?

Conclusion

Strong and consistent evidence indicates that dietary patterns that are relatively low in energy density improve weight loss and weight maintenance among adults. Consistent but limited evidence suggests that lower energy density diets may be associated with lower risk of T2D among adults.

Implications

Dietary patterns relatively low in energy density that have been associated with beneficial body weight outcomes also may be associated with lower risk of T2D. They are characterized by a relatively high intake of vegetables, fruit, and total fiber and a relatively low intake of total fat, saturated fat, and added sugars (Kant and Graubard, 2005; Ledikwe, 2006a, 2006b; Lindstrom, 2006; Murakami, 2007; Savage, 2008b; Wang, 2008). Additionally, lower dietary energy density may be associated with a dietary intake pattern characterized by lower consumption of meat and processed meats and energy-containing beverages (Wang, 2008). The Committee’s conclusion applies to the whole dietary pattern, not to individual foods, and recognizes that a beneficial low-energy density dietary pattern can include consumption of some energy-dense foods (e.g., olive oil and nuts) that have been associated with improved health outcomes (see *Part D. Section 3: Fatty Acids and Cholesterol*).

Review of the Evidence

Background

The energy density of a food is defined as the amount of energy per unit of weight, usually expressed as kilocalories per 100 gram. The energy density of an entire dietary pattern is estimated by dividing the total amount of calories by the total weight of food consumed. The overall fat and water content of the diet is the key determinant of energy density (Drewnowski, 2004). Short-term feeding studies have consistently shown that lower-energy dense food choices lead to a higher amount of food consumption but lower energy intakes compared to higher-energy density diets. This suggests that lower-energy density diets may lead to better appetite regulation and improved body weight control (Rolls, 2009). This hypothesis is supported by studies conducted among free-living individuals (Ledikwe, 2007; Savage, 2008b).

The 2005 DGAC Report concluded that at the time of their deliberations, evidence was insufficient to come to a firm conclusion on the impact of dietary energy density on body weight. Since then, four RCTs and five prospective studies have been published. The resulting clear and consistent evidence led the 2010 Committee to conclude that dietary energy density does affect both weight loss and weight maintenance. Additional evidence has also indicated a potential association between dietary energy density and T2D.

Energy Density and Weight Loss

Four randomized controlled weight loss trials found that lowering food-based energy density is linked with significantly higher weight loss (De Oliveira, 2008; Ello Martin, 2007; Rolls, 2005; Saquib, 2008). In these RCTs, the average weight loss resulting from lower dietary energy density ranged from 0.8 kilogram to 1.5 kilograms across studies. Dietary energy density was reduced by either increasing fruit and/or vegetable intake (De Oliveira, 2008; Ello Martin, 2007; Saquib, 2008) or soup consumption (Rolls, 2005).

Energy Density and Weight Maintenance

Four observational prospective studies with follow-ups ranging from 6 months to 8 years have consistently documented a positive association between energy density and weight maintenance (Bes-Rastrollo, 2008; Greene, 2006; Ledikwe, 2007; Savage, 2008b). Bes-Rastrollo et al. (2008) found that women who moved their energy density from the highest to the lowest quintile gained significantly less weight than those who moved from the lowest to the highest energy density quintile (4.7 ± 0.09 kg vs. 6.4 ± 0.09 kg, respectively). Ledikwe et al. (2007) found that pre-hypertensive and hypertensive adults who reduced their energy density the most during 6 months lost 5.9 kilograms, compared to 4.0 kilograms among those in the middle tertile, and 2.4 kilograms among those in the lowest tertile. Savage et al. (2008b) found over a 6-year period that women in the highest energy density tertile gained 6.4 ± 6.5 kilograms compared to 2.5 ± 6.8 kilograms among those in the lowest energy density tertile. Greene et al. (2006) found that 2 years after the completion of an effective 12-week weight loss program, individuals who were able to maintain the weight loss benefit consumed fewer calories and ate a lower-energy density diet.

Energy Density Definition and Weight Outcomes

The Committee's conclusion is based on studies that estimated dietary energy density based on foods only. However, two additional studies calculated energy density using a different definition had inconsistent weight outcome results. Inclusion of beverages in energy density estimation yields inconsistent results. Kant and Graubard (2005) found that energy density among adults was associated with BMI when energy density was defined based on "foods and energy-containing beverages" or "foods only" but not when energy density was estimated including "all foods and beverages." Consistent with this, Iqbal et al. (2006) did not find a relationship between energy density, estimated including all liquids, and 5-year weight change in two adult Danish cohorts. These findings illustrate the importance of standardizing energy density measures across studies.

Energy Density and Type 2 Diabetes

Two longitudinal cohort studies have examined the association between energy density and the risk of T2D. One cross-sectional study examined the association between energy density and risk factors for T2D, including hyperinsulinemia and metabolic syndrome. All three studies found a relationship between energy density and increased risk for T2D and/or having risk factors for T2D.

Two European cohort studies, one conducted in the United Kingdom (Wang, 2008) and one in Finland (Lindstrom, 2006), with follow-up periods lasting for 10 years and 3 years, respectively, found a relationship between energy density and T2D. Whereas the United Kingdom study was observational, the Finnish study was designed as an RCT although reported findings were based on pooled analyses. When expressed as energy density quartiles, the Finnish study results did not reach statistical significance even though effect size was strong (70% increased risk), a finding likely explained by the lack of statistical power. Findings from this study were, however, statistically significant when dietary intake patterns were modeled based on their energy and fiber content. T2D was either diagnosed through plasma biomarkers (Lindstrom, 2006) or a participant self-report confirmed with medical records (Wang, 2008). Both studies controlled statistical analyses for relevant anthropometric measures (weight, BMI, weight change, and/or waist circumference) and the United Kingdom study adjusted for energy intake as well. Thus, findings suggest that diet composition, independent of energy balance, may play a role in potential association between energy density and T2D. This conclusion is consistent with 1999-2002 NHANES cross-sectional findings (Mendoza, 2007) documenting an association of energy density with elevated fasting insulin, after controlling for waist circumference and physical activity.

Question 7: For Older Adults, What Is the Effect of Weight Loss Versus Weight Maintenance on Selected Health Outcomes?

Conclusion

Weight loss in older adults has been associated with an increased risk of mortality, but because most studies have not differentiated between intentional versus unintentional weight loss, recommending intentional weight loss has not been possible. Recently, however, moderate evidence of a reduced risk of mortality with intentional weight loss in older persons has been published. Intentional weight loss among overweight and obese older adults, therefore, is recommended. In addition, with regard to morbidity, moderate evidence suggests that intentional weight loss in older adults has been associated with reduced development of T2D and improved cardiovascular risk factors. There are insufficient data on cancer to come to a conclusion. Weight gain produces increased risk for several health outcomes.

Implications

Observational studies of weight loss, especially when intentionality cannot be rigorously established, may be misleading with respect to the effect of weight on mortality. Loss of weight is appropriate advice for elderly overweight/obese persons. Weight gain should be avoided.

Review of the Evidence

The risks and benefits of weight loss in older adults have been widely debated. While it has been clearly reported that weight loss improves risk factors for diabetes and cardiovascular disease (Pi-Sunyer, 2007; Villareal, 2006; Whelton, 1998), some studies have showed that weight loss increases mortality (Knudtson, 2005; Sorenson, 2003; Yaari, 1998). However, it is not clear in these studies whether the weight loss was intentional or unintentional.

Thirty-five cohort studies, two longitudinal observational studies, one structural equation model and one RCT were reviewed, dating from 1995 to the present. There was strong unanimity that, in elderly persons followed for 2 to 23 years, a baseline BMI below normal (18.5-25 kg/m^2) was associated with a higher risk of mortality whereas a BMI above normal (>25 kg/m^2) was associated with a lower risk. The mortality curve in relation to baseline BMI was U-shaped, with minimal mortality risk occurring over a wide range (BMI of 25 to 34 kg/m^2). In a modeling report by Yang et al. (2008), the highest life expectancy was in participants with a BMI range of 18.5 to 25 kilograms/m^2.

Weight loss in elderly persons was associated with a higher mortality, but no data were available about the intentionality of the weight loss except for one study by Locher et al. (2007) in a 3-year follow-up of individuals with a mean age of 73 years, who found that non-intentional weight loss was associated with higher mortality whereas intentional weight loss was not. A recent RCT (Shea, 2010) assessed the influence of weight loss and/or exercise in overweight/obese older adults with knee osteoarthritis. After an average of 8 years of follow-up, the mortality rate was significantly lower for those randomized to the weight loss intervention, who initially lost 4.8 kilograms. Intentional weight loss therefore did not lead to increased total mortality but actually reduced it. In addition, interventional studies have shown that this intentional weight loss in older persons is not associated with greater adverse events (Diabetes Prevention Program Research Group, 2002; Pi-Sunyer, 2007; Whelton, 1998).

With regard to the risk of developing diabetes, cardiovascular disease, or cancer with weight loss, one study has reported that both T2D and CVD risk factors can be improved with weight loss in older Americans. Another study has shown that in people with T2D, intentional weight loss improves glycemia and CVD risk factors (Pi-Sunyer, 2007), and Whelton et al. (1998) have reported that intentional weight loss lowers blood pressure. The SOS study (Sjostrom, 2007), while a bariatric surgery study, has shown that intentional weight loss with bariatric surgery greatly lowers the risk of morbidity for T2D, CVD, as well as mortality for CVD and cancer, in more elderly as well as younger individuals.

Weight gain was associated with either the same or higher mortality than in weight maintenance.

PHYSICAL ACTIVITY

Question 8: What Is the Relationship Between Physical Activity, Body Weight, and Other Health Outcomes?

Conclusion

Strong, consistent evidence indicates that physically active people are at reduced risk of becoming overweight or obese. Furthermore, there is strong evidence that physically active adults who are overweight or obese experience a variety of health benefits that are generally similar to those observed in people of ideal body weight. Because of the health benefits of physical activity that are independent of body weight classification, people of all body weight classifications gain health and fitness benefits by being habitually physically active.

In addition, strong and consistent evidence based on a wide range of well-conducted studies indicates that physically active people have higher levels of health-related fitness, lower risk of developing most chronic disabling medical conditions, and lower rates of various chronic diseases than do people who are inactive. The health benefits of being habitually active appear to apply to all people regardless of age, sex, race/ethnicity, socioeconomic status, and to people with physical or cognitive disabilities.

Implications

Americans are encouraged to meet the 2008 *Physical Activity Guidelines for Americans*. Children and adults should avoid inactivity. Some physical activity is better than none, and more is better. Achieving energy balance and a healthy weight depends on both energy intake and expenditure.

Review of the Evidence

Background

In October 2008, the inaugural *Physical Activity Guidelines for Americans* were released by the U.S. Department of Health and Human Services (HHS). Similar to the process used by HHS and USDA in developing the *Dietary Guidelines for Americans*, HHS relied on the Physical Activity Guidelines Advisory Committee (PAGAC) Report released in May of 2008 to develop the *Physical Activity Guidelines for Americans* (Table D1.8) (PAGAC, 2008). The 683-page PAGAC report outlined the evidence for developing *Physical Activity Guidelines for Americans*, and Part G, Section 4 focused on physical activity and energy balance. Other sections of the report focused on all-cause mortality, cardiorespiratory health, metabolic health, musculoskeletal and functional health, cancer, mental health, and adverse events. In addition, the report provided evidence regarding physical activity for youth and for understudied groups, including pregnant and postpartum women, people with disabilities, and racial and ethnically diverse populations. Because the PAGAC report was guided by 13 physical activity experts and is recent, systematic, and thorough, the 2010 DGAC felt it was prudent to use the PAGAC report's evidence to answer several questions related to physical activity, energy balance, and health.

The PAGAC report noted four important points, which apply to understanding physical activity and energy balance. First, achieving energy balance and a healthy weight depends on both energy intake and expenditure. Any statements about the amount of physical activity required for healthy weight, weight loss, and weight maintenance after loss must take into account energy intake. Second, the effect of a caloric deficit on weight does not depend upon whether the deficit is produced by reducing intake, increasing expenditure, or both. However, in research studies, the proportion of the caloric deficit due to physical activity often is only a small fraction of the overall deficit. Third, bouts of moderate- or vigorous-intensity physical activity, which count toward meeting physical activity guidelines, are not the only source of energy expenditure due to activity. Light-intensity activity and very short bouts of moderate- or vigorous physical activity also expend calories. Changes in this source of energy expenditure influence the amount of moderate- or vigorous-intensity physical activity necessary for energy balance. Fourth, even among people at a healthy body weight, regular physical activity is required to maintain health and prevent disease. Indeed, sedentary behavior is a risk factor for all individuals.

While the PAGAC separately addressed the three topics of weight maintenance, weight loss, and avoidance of weight regain, its report and the subsequent *Physical Activity Guidelines for Americans* took an integrated approach to weight management. Obesity is one of many chronic conditions that illustrate a dose-response effect between volume of physical activity and health benefit, and therefore the PAGAC did not make separate recommendations for the three topics. The first step in achieving or maintaining a healthy body weight is to meet the baseline level of physical activity per week (150 minutes of moderate-intensity, 75 minutes of vigorous-intensity, or an equivalent combination of moderate- and vigorous-intensity). Then, if a person is not at a healthy weight, he or she would either increase activity, decrease dietary intake, or both, until a healthy weight is achieved. This approach is appropriate whether a person is maintaining weight, losing weight, or avoiding weight regain. The magnitude of change in weight due to physical activity is additive to that associated with caloric restriction.

Amount of Physical Activity Needed to Maintain a Healthy Body Weight

Clear, consistent evidence shows that physical activity provides benefit for weight stability. For children and adolescents, 60 minutes or more of physical activity per day is recommended. For adults and older adults, 150 to 300 minutes per week of moderate-intensity physical activity or 75 to 150 minutes per week of vigorous-intensity physical activity, or an equivalent combination of the two is recommended to maintain body weight over time.

The PAGAC report noted that a great deal of inter-individual variability exists with physical activity and weight stability. For this reason, some adults may need more physical activity per week than others to maintain body weight. The PAGAC report also noted that high amounts of physical activity are not feasible for all adults because chronic conditions, such as osteoarthritis, create activity limitations. In such cases, adults should be as active as possible, and if a healthy weight is not attained, they then need to reduce caloric intake.

Amount of Physical Activity Needed to Lose Weight if Overweight or Obese

Clear, consistent research shows that a large dose of physical activity is needed for substantial weight loss (greater than 5% of body weight). Adults who are most successful at achieving weight loss combine calorie restriction with increased physical activity participation. The PAGAC Report noted that adults who participate in physical activity during weight loss have improved body composition (reduced abdominal obesity and preserved muscle mass) compared to adults who lose weight by calorie restriction alone.

For overweight and obese adults who need to lose substantial weight, a combination of calorie restriction with participation in 150 to 300 minutes per week of moderate-intensity physical activity or 75 to 150 minutes per week of vigorous-intensity physical activity, or an equivalent combination of the two is recommended. Many adults may need to exceed this amount of physical activity to achieve substantial weight loss.

Amount of Physical Activity Needed to Avoid Regain After Weight Loss

The scientific evidence for the effectiveness of physical activity *alone* in preventing weight regain following significant weight loss is limited. The strongest evidence indicates that adults who are successful at long-term weight maintenance following weight loss appear to limit caloric intake in addition to maintaining a high level of physical activity. Available research indicates that to prevent substantial weight regain over 6 months or longer, many adults may need more than 300 minutes a week of moderate-intensity, or 150 minutes a week of vigorous-intensity aerobic activity, or an equivalent combination of the two.

Chapter Summary

The prevalence of overweight and obesity in the U.S. has increased dramatically in the past three decades. This is true of children, adolescents, and adults and it is more severe in minority groups. There is an increased morbidity in the obese, with diabetes, heart disease, and cancer being particular risks, leading to a greater mortality. The American environment is conducive to this epidemic, presenting an abundance of foods to the populace in the form of tasty, energy-dense, micronutrient poor foods and beverages. The macronutrient distribution of a person’s diet is not the driving force behind the obesity, rather it is the overly large amount of total calories eaten coupled with very low physical activity. There is no optimal proportion of dietary fat, carbohydrate, and protein to maintain a healthy body weight, to lose weight, or to avoid weight regain after weight loss. It is the total amount of calories eaten that is essential. While weight can be reduced with diets where the macronutrient proportions vary widely, the crucial issue is not the macronutrient proportion but rather the compliance with a reduced-calorie intake. The energy density of the foods eaten is important in causing the overeating. This is true not only for adults but also for children, who take in energy-dense fats and added sugars at levels higher than required to maintain themselves at normal weight.

With regard to special subgroups, pregnancy is a time when many women gain too much weight. Excessive maternal weight gain during pregnancy is deleterious for the mother and also the fetus. Mothers very often put on much more weight than is healthy during pregnancy and then have trouble losing it after delivery. Fetuses of these mothers tend to be fatter at and after birth and are more at risk of obesity and T2D later in life. Breastfeeding is good for a number of reasons and should be encouraged, but has no real impact on weight gain or loss.

Older overweight or obese persons can derive as much benefit from losing weight and keeping it off as do younger persons, with resulting improvements in quality of life, disabilities, and risk factors for chronic diseases. Selected behaviors lead to a greater propensity to gain weight. These include too much TV watching, too little physical activity, eating out frequently (especially at fast food restaurants), snacking on energy-dense food and drink, skipping breakfast, and taking large portions. Self-monitoring is a very important lifestyle habit that will tend to control weight gain and enhance weight loss and maintenance by making individuals conscious of what, when, and how much they are eating.

Needs for Future Research

1. Conduct well-controlled and powered prospective studies to characterize the associations between specific dietary factors and childhood adiposity.

Rationale: While many of the studies included in the DGAC 2010 evidence reviews were methodologically strong, many were limited by small sample size, lack of adequate control for confounding factors, especially implausible energy intake reports, and use of surrogate, rather than direct measures of body fatness.

2. Conduct well-controlled and powered research studies testing interventions that are likely to improve energy balance in children at increased risk of childhood obesity, including dietary approaches that reduce energy density, total energy, dietary fat, and sugar-sweetened beverages, and promote greater consumption of fruits and vegetables.

   Rationale: Very few solid data are available on interventions in children.

3. Conduct research to clarify both the positive and negative environmental influences that affect body weight.

   Rationale: How changing the environment affects dietary intake and energy balance needs documentation.

4. Conduct research on the effect of local and national food systems on dietary intake.

   Rationale: It is necessary to clarify the relative contributions of the different sectors on dietary intake.

5. Conduct considerable new research on other behaviors that might influence eating practices.

   Rationale: We need to know more about child feeding practices, family influences, peer influences, etc., and what can improve them.

6. Conduct research on the influence of snacking behavior and meal frequency on body weight and obesity. Develop better definitions for snacking as the research moves forward.

   Rationale: These are two issues that may alter food intake and body weight but of which we know little.

7. Invest in well-designed randomized controlled trials with long-term follow-up periods to assess the influence of different dietary intake and physical activity patterns, and their combinations, on gestational weight gain patterns.

   Rationale: The new gestational weight gain guidelines are based on observational studies. Randomized controlled trials are urgently needed to answer these questions.

8. Conduct studies to refine gestational weight gain recommendations among obese women according to their level of prepregnancy obesity.

   Rationale: The recommended gestational weight gain range for obese women was based mostly on evidence from class I obese women (BMI: 30-34.9). This represents an important gap in knowledge at a time when the prevalence of class II (BMI: 35-39.9) and class III obese (BMI $\geq$ 40) women continues to rise in the U.S., with 14.2 percent of women (25.5% of non-Hispanic Black women) falling in these two categories (IOM, 2009).

9. Substantially improve prepregnancy BMI and gestational weight gain monitoring and surveillance in the U.S.

   Rationale: No nationally representative data are available to describe pre-gravid BMI and gestational weight gain patterns in the U.S. population.

10. Conduct longitudinal studies with adequate designs to further examine the association between breastfeeding and maternal postpartum weight changes, as well as impact on offspring.

    Rationale: Studies need to have a sample size large enough to take into account the small effect size thus far detected and the large inter-subject variability in maternal postpartum weight loss. (Ohlin and Rossner [1990] found that maternal weight loss ranged from -12.3 kg to +26.5 kg during the first year following the delivery of the child). Studies need to have adequate comparison groups that are clearly and consistently defined according to their breastfeeding intensity/duration patterns. Women who practice different infant feeding methods have different background characteristics. Thus, it is essential that future observational studies control statistically for key confounders including prepregnancy BMI, gestational weight gain, socio-economic and demographic characteristics, and intentional weight loss. Studies need to measure maternal weight at different time points to be able to validate the use of either self-reported weights or weights recorded in clinical charts.

11. Determine whether and how isocaloric solid foods and liquids differ in their influence on satiety (De Graaf, 2006; Rolls, 2009).

    Rationale: The great majority of studies reviewed estimated dietary energy density based on foods only, excluding all beverages (Bes-Rastrollo, 2008; Ello Martin, 2007; Greene, 2006; Ledikwe, 2007; Rolls, 2005; Savage, 2008b; Saquib, 2008). The decision to include only foods in dietary energy density estimations has been largely justified on statistical and not physiological grounds (Ledikwe, 2005). Studies that have incorporated all beverages in the dietary energy density estimations, including water (Iqbal, 2006) have yielded null results. Few studies have examined weight outcomes using different energy density definitions, these studies have identified inconsistent results as a function of the definition used (Kant and Graubard, 2005).

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Table D1.8. 2008 Physical Activity Guidelines for Americans

Age group	Guidelines
Children and Adolescents	• Children and adolescents should do 60 minutes (1 hour) or more of physical activity daily. — **Aerobic:** Most of the 60 or more minutes a day should be either moderate- or vigorous-intensity aerobic physical activity, and should include vigorous-intensity physical activity at least 3 days a week. — **Muscle-strengthening**: As part of their 60 or more minutes of daily physical activity, children and adolescents should include muscle-strengthening physical activity on at least 3 days of the week. — **Bone-strengthening**: As part of their 60 or more minutes of daily physical activity, children and adolescents should include bone-strengthening physical activity on at least 3 days of the week. • It is important to encourage young people to participate in physical activities that are appropriate for their age, that are enjoyable, and that offer variety.
Adults	• All adults should avoid inactivity. Some physical activity is better than none, and adults who participate in any amount of physical activity gain some health benefits. • For substantial health benefits, adults should do at least 150 minutes (2 hours and 30 minutes) a week of moderate-intensity, or 75 minutes (1 hour and 15 minutes) a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity. Aerobic activity should be performed in episodes of at least 10 minutes, and preferably, it should be spread throughout the week. • For additional and more extensive health benefits, adults should increase their aerobic physical activity to 300 minutes (5 hours) a week of moderate-intensity, or 150 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity activity. Additional health benefits are gained by engaging in physical activity beyond this amount. • Adults should also include muscle-strengthening activities that are moderate or high intensity and involve all major muscle groups on 2 or more days a week, as these activities provide bone-strengthening and other additional health benefits.
Older Adults	• Older adults should follow the adult guidelines. When older adults cannot meet the adult guidelines, they should be as physically active as their abilities and conditions will allow. • When older adults cannot do 150 minutes of moderate-intensity aerobic activity a week because of chronic conditions, they should be as physically active as their abilities and conditions allow. • Older adults should do exercises that maintain or improve balance if they are at risk of falling. • Older adults should determine their level of effort for physical activity relative to their level of fitness. • Older adults with chronic conditions should understand whether and how their conditions affect their ability to do regular physical activity safely.

Note: The PAGAC report applies to children age 6 years and older. There was not enough evidence to review to determine the relationship between dose of physical activity and health outcomes in children younger than age 6. There is every reason to believe that these guidelines promote healthy growth and development for children under age 6.
Source: HHS, 2008. http://www.health.gov/paguidelines/committeereport.aspx.

Table D1.9. Caloric value of select beverages

Beverage	Standard Serving Size	Calories per Standard Serving Size
Alcoholic Beverages		
Beer		
Regular beer	12 fl oz	153
Light beer	12 fl oz	103
Wine		
Table wines, all	5 fl oz	123
Sake	1 fl oz	39
Distilled spirits/mixed drinks		
Distilled spirits (gin, rum, vodka, whiskey), 80 Proof	1.5 fl oz	97
Crème de menthe, 72 Proof	1.5 fl oz	186
Cosmopolitan (vodka, orange liqueur, cranberry juice, lime juice)	2.75 fl oz	146
Gin & tonic (gin, tonic water)	6.5 fl oz	147
Margarita (tequila, orange liqueur, lime juice)	4 fl oz	168
Martini (gin, dry vermouth)	2.25 fl oz	124
Mojito (white rum, lime juice, club soda, mint, sugar)	6 fl oz	143
Pina colada (light rum, coconut cream, pineapple juice)	9 fl oz	495
Rum & cola (dark rum, cola)	6.5 fl oz	152
Screwdriver (vodka, orange juice)	6.5 fl oz	172
Whiskey sour (whiskey, sour mix)	3.5 fl oz	162
Milk		
Whole milk	8 fl oz	149
Reduced fat (2%) milk	8 fl oz	122
Low-fat (1%) milk	8 fl oz	102
Fat-free milk	8 fl oz	83
Coffee and Tea		
Black tea	8 fl oz	0
Green tea	8 fl oz	0
Tea sweetened with 2 sugar packets	8 fl oz	22
Regular coffee	8 fl oz	0
Decaffeinated coffee	8 fl oz	0
Coffee sweetened with 2 sugar packets	8 fl oz	22

Table D1.9 (continued). Caloric value of select beverages

Beverage	Standard Serving Size	Calories per Standard Serving Size
100% Juice		
Apple juice	8 fl oz	114
Carrot juice	8 fl oz	94
Cranberry juice	8 fl oz	137
Grape juice	8 fl oz	152
Orange juice	8 fl oz	117
Pineapple juice	8 fl oz	133
Pomegranate juice	8 fl oz	136
Tomato juice	6 fl oz	31
Sugar Sweetened Beverages		
Cola	12 fl oz	136
Energy drink	8 fl oz	115
Fruit punch drink	8 fl oz	117
Hot cocoa	8 fl oz	192
Lemonade drink	8 fl oz	99
Orange Juice drink	8 fl oz	134
Sports drink	8 fl oz	50
Diet beverages		
Diet Fruit and Vegetable Drinks	8 fl oz	10
Diet cola	12 fl oz	0
Low calorie cola	12 fl oz	7
Low calorie sports drink	8 fl oz	26
Nutrient enriched water beverage	8 fl oz	0
Sugar free energy drink	8 fl oz	10

Source: U.S. Department of Agriculture, Agricultural Research Service, USDA Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. http://www.ars.usda.gov/nutrientdata.

Part D. Section 2: Nutrient Adequacy

Introduction

Numerous nutrients and food components are needed for normal growth, development, and body functioning. Essential nutrients—those that the body cannot produce itself in adequate amounts—must be obtained from foods. Nutrients function in many ways to build, maintain, and protect body structures and systems and to promote health. For example, some nutrients provide substrates or structure for various body tissues. Others serve as antioxidants, counteracting oxidative damage to biomolecules. Many nutrients are necessary for the production and functioning of compounds necessary for health, such as hormones, enzymes, or coenzymes and for homeostasis of physiological systems. Some nutrients can be used as an energy source, and others are necessary in various stages of energy production. In addition to preventing classic nutrient deficiency diseases, prospective epidemiologic studies suggest that a healthy dietary pattern—one that provides recommended intakes of essential nutrients within recommended energy levels—reduces the risk of some common chronic diseases, including obesity, cardiovascular disease, and some cancers (see *Part D. Section 1: Energy Balance and Weight Management*; *Part D. Section 3: Fatty Acids and Cholesterol*; *Part D. Section 4: Protein*; *Part D. Section 5: Carbohydrates*; and *Part D. Section 6: Sodium, Potassium, and Water*).

A fundamental premise of the DGAC is that nutrient intake should come primarily from foods. Many people understand the importance of good nutrition but believe that a daily multivitamin/mineral pill will substitute for actually eating the foods that they know are good for them. However, the more scientists learn about nutrition and the human body, the more they realize the importance of eating foods in their most intact forms without added solid fats, sugars, starches, or sodium. For example, some studies have shown that people who eat a diet rich in beta-carotene have a lower rate of several kinds of cancer. In contrast, studies have shown that taking beta-carotene in pill form does not decrease the risk of cancer in healthy individuals, and that, indeed, supplemental nutrients may be harmful in some cases (Bjelakovic, 2007) (see Question 7 on Vitamin, Mineral, and Nutrient Supplements). It is possible that beta-carotene and other nutrients are most beneficial to health when they are consumed in their natural form and in combination with each other, such as in vegetables (including cooked dry beans and peas), fruits, and whole grains. These foods contain not only the essential vitamins and minerals that are often targeted in nutrient supplement pills, but also hundreds of naturally-occurring phytonutrients and other substances, including carotenoids, flavonoids, isoflavones, and protease inhibitors that may protect against cancer, heart disease, osteoporosis, and other chronic health conditions. The Institute of Medicine (IOM) report *Dietary Reference Intakes: Applications in Dietary Planning* (FNB, 2003) notes instances when fortification of certain foods may be advantageous, including provision of additional sources of key nutrients that might otherwise be present only in low amounts in some food sources, and providing nutrients in highly bioavailable forms. Fortification can provide a food-based means for increasing intakes of particular nutrients, for example, folic acid fortification of grains to reduce the incidence of neural tube defects (NTDs) (see Questions 4, 5, and 6 within Nutrient Issues for Selected Population Subgroups).

The DGAC advocates the consumption of nutrient-dense forms of foods by all Americans to provide the maximum nutrition intake within calorie needs. Nutrient-dense foods were defined in the 2005 *Dietary Guidelines for Americans* as those "that provide substantial amounts of vitamins and minerals (micronutrients) and relatively few calories" (HHS and USDA, 2005a, p. 7). The DGAC accepts this definition, with the following clarification. Nutrient-dense foods are forms of foods that are lean or low in solid fats and without added solid fats, sugars, starches, or sodium and that retain naturally-occurring components such as fiber. For example, all vegetables, fruits, whole grains, fish, eggs, and nuts prepared without added solid fats or sugars are considered nutrient-dense, as are lean or low-fat forms of fluid milk, meat, and poultry prepared without added solid fats or sugars. While a variety of equations are available with which to calculate the nutrient density of specific foods (Drewnowski, 2005, 2008; Kennedy, 2008), the DGAC does not advocate the use of any particular equation over the others because all foods in nutrient-dense forms within a total dietary pattern are more likely to confer health benefits compared to non-nutrient-dense forms of foods. Non-nutrient-dense foods supply relatively few micronutrients and/or more calories than their nutrient-dense counterparts because nutrient-bearing components have been removed or calories from solid fats or added sugars have been added. If non-nutrient-dense foods displace nutrient-dense foods, an individual's ability to achieve recommended nutrient intakes is lessened despite often excessive calorie intakes. This can leave a person overweight but undernourished and thus, at higher risk of disease. Nutrient-dense foods are found in a variety of forms (e.g., intact, minimally processed, sliced, diced, frozen, canned, cooked), and a range of nutrient-dense forms of food can be included in a healthful, energy balanced, total diet.

As defined in *Part D. Section 1: Energy Balance and Weight Management*, "energy density is the amount of energy per unit of weight, usually expressed as calories per 100 grams of food." To achieve food and nutrient recommendations without exceeding recommended energy intake levels, Americans are encouraged to consume a variety and balance of nutrient-dense forms of foods within and among the basic food groups, while keeping the energy density of the total diet relatively low. Some nutrient-dense foods also are naturally energy-dense (e.g., nuts, olive oil), and these foods can be incorporated into a total diet that is relatively low in energy density.

Another basic premise of the DGAC is that *Dietary Guidelines for Americans* should provide guidance in obtaining all the nutrients needed for growth and health. To this end, the DGAC recommends that food guidance aim to achieve the most recent Dietary Reference Intakes (DRIs), including Acceptable Macronutrient Distribution Ranges (AMDRs), Recommended Dietary Allowances (RDAs), and Adequate Intakes (AIs) that consider the individual's life stage, sex, and activity level (FNB, 2006), as well as Tolerable Upper Intake Levels (ULs) for nutrients (FNB, 2006). These DRIs are to be considered in diet planning for individuals. Table D2.1 lists nutritional goals for age-sex groups, based on DRI and *Dietary Guidelines for Americans* recommendations, and USDA Food Patterns using these goals as targets (see *Part B. Section 2: Total Diet* for a related discussion of dietary patterns).

The AMDRs for dietary carbohydrate, fat, and protein are relative to total energy intake. Each AMDR "is the range of intakes of an energy source that is associated with a reduced risk of chronic disease, yet can provide adequate amounts of essential nutrients" (FNB, 2006, p. 11). Macronutrients are discussed in *Part D. Section 3: Fatty Acids and Cholesterol*, *Part D. Section 4: Protein*, and *Part D. Section 5: Carbohydrates*.

The RDA is "the average daily dietary nutrient intake level that is sufficient to meet the nutrient requirements of nearly all (97 to 98%) healthy individuals in a particular life stage and gender group" (FNB, 2006, p. 8). RDAs are established from Estimated Average Requirements (EARs) which are the "average daily nutrient intake level that is estimated to meet the requirements of half of the healthy individuals in a particular life stage and gender group" (FNB, 2006, p. 8). AIs are used when scientific evidence is insufficient to determine EARs, and thus RDAs, for nutrients. AIs are "based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people that are assumed to be adequate" (FNB, 2006, p. 8). EARs should be used to plan intakes for groups, while the IOM recommends that RDAs or AIs be used to plan diets for individuals (FNB, 2006). The planning of food intake patterns, which was introduced in *Part C: Methodology*, is an example of this application. Both the RDAs and AIs are intended to serve as goals for individual intakes by apparently healthy people. In general, these values are intended to cover the needs of nearly all persons in a life-stage group. Meeting the DRIs provides assurance that the probability of inadequate dietary intake of a nutrient will not exceed 2 percent to 3 percent of the population (FNB, 2003). The UL is "the highest average daily nutrient intake level that is likely to pose no risk of adverse health effects to almost all individuals in the general population" (FNB, 2006, p. 8). Because consuming intakes below the UL minimizes risk to the individual, dietary guidance for individuals should avoid exceeding the UL (FNB, 2003).

List of Questions

This section addresses eight major questions related to achieving nutrient adequacy in an overall food intake pattern that is within defined energy levels. Special considerations for meeting recommended intakes of nutrients also are considered.

DIETARY COMPONENTS OVERCONSUMED

1. What nutrients and dietary components are overconsumed by the general public?

FOOD GROUPS AND SELECTED DIETARY COMPONENTS UNDERCONSUMED

2. What food groups and selected dietary components are underconsumed by the general public?

NUTRIENTS OF CONCERN

3. What nutrients are underconsumed by the general public and present a substantial public health concern?

4. What is the relationship between folate intake and health outcomes in the United States (U.S.) and Canada following mandatory folic acid fortification?

5. Is iron a nutrient of special concern for women of reproductive capacity?

6. Are older adults consuming sufficient vitamin B_{12}?

VITAMIN, MINERAL, AND NUTRIENT SUPPLEMENTS

7. Can a daily multivitamin/mineral supplement prevent chronic disease?

NUTRIENT INTAKE AND SELECTED BEHAVIORS

8. What is the relationship between nutrient intake and breakfast consumption, snacking, and eating frequency?

Methodology

The DGAC promotes achievement of recommended nutrient intake by consuming foods. In order to recognize nutrient shortfalls and nutrients that present a public health concern, the DGAC began its review with an examination of nutrients and dietary components consumed in amounts high enough or low enough to be of concern. Questions 1 and 2 are new to the 2010 DGAC Report and provide a foundation for understanding the food-based gaps in nutrient intakes of Americans. Nutrient and selected dietary component intakes by Americans are drawn from analyses conducted by the National Cancer Institute (NCI) (NCI, 2009), USDA's Food and Nutrition Service (FNS) (FNS, Report No. FSP-08-NH, 2008; FNS, Report No. CN-08-NH, 2008; FNS, Report No. WIC-08-NH, 2008), USDA's Agricultural Research Service (ARS) (ARS, 2008), and the IOM (FNB, 2009), using standard methodologies and data from the National Health and Nutrition Examination Survey (NHANES).

The 2005 *Dietary Guidelines for Americans* was the reference point for comparing recommended intake levels to usual intakes of food groups and dietary components. Food pattern modeling was used to determine recommended amounts from each food group—that is the amount that should be consumed in order to meet nutrient needs. The process and detailed results are described in the USDA Food Patterns modeling report (see online Appendix E3.1 at www.dietaryguidelines.gov) and are also summarized in *Part B. Section 2: Total Diet: Combining Nutrients, Consuming Food*. These food group recommendations were compared to typical intakes to identify food groups of concern. Recommendations for dietary components (e.g., oils and refined grains) also were included in USDA Food Patterns modeling, and usual intakes were compared to limits for these items to identify dietary components of concern. The modeling process also was used to determine the maximum amounts of additional calories from non-essential nutrient sources (primarily solid fats and added sugars) that individuals could consume, while at the same time staying within energy needs and consuming recommended amounts of food from all food groups in nutrient-dense forms. These maximum limits were compared to usual intake levels to identify components that are overconsumed. The maximum limit for calories from solid fats and added sugars replaces the "discretionary calorie allowance" used by the 2005 DGAC. The concept of discretionary calories is considered scientifically relevant and theoretically valid. However, it has been difficult to translate into meaningful consumer education. Also, the inclusion of a discretionary calorie allowance may place too much emphasis on a portion of the diet that for most Americans should be a very small contribution (an average of about 150 to 200 kcal/d) and is not needed for nutrient adequacy.

Food sources of energy, food groups, nutrients, and other dietary components were identified through analyses that grouped specific foods reported in dietary surveys into 96 mutually exclusive food categories. These categories were described and used by Bachman (2008), and also used by Bosire et al.

(2009), and additional analyses conducted for the DGAC by the Risk Factor Monitoring and Methods Branch of the NCI (available at http://riskfactor.cancer.gov/diet/foodsources/).

Nutrients of concern (Question 3) were identified using a two-step approach. First, dietary intake data were compared to DRIs to identify shortfall nutrients. Second, biochemical indices of nutrient or functional status, when available, and/or disease prevalence data were further considered to identify nutrients underconsumed and of substantial public health significance. This chapter also addresses special nutrient recommendations for certain population subgroups. A complete systematic review was conducted for folate (Question 4), due to the documented importance of folate in preventing neural tube defects (NTDs) and emerging evidence of health risks with increased folic acid intakes in the post-fortification era. Conclusions for iron in women of reproductive capacity (Question 5) and vitamin B_{12} in older adults (Question 6) are based on the 2005 DGAC Report and relevant new literature from updated searches. Vitamin, mineral, and nutrient supplements (Question 7) are new to the 2010 Report. More than half of all Americans report using nutrient supplements. Their use in primary prevention of chronic disease warrants evaluation. Conclusions are based on evidence compiled for use by the 2006 National Institutes of Health (NIH) “State-of-the-Science Conference on Multivitamin/Mineral Supplements for Chronic Disease Prevention” (NIH, 2006), NIH panel conclusions, and subsequent evidence reviewed by the 2010 DGAC. The DGAC also was interested in identifying behaviors that help individuals achieve nutrient intake recommendations. Hence, the chapter ends with a question new to this report, involving a discussion of nutrient intake based on selected behaviors (Question 8)—derived from a full systematic review.

USDA Food Pattern modeling analyses were conducted to provide additional contextual information for two questions (Questions 3 and 4) related to nutrient adequacy and food group intakes. These analyses include nutrient adequacy if fluid milk and milk products intake is eliminated, modified, or replaced with alternative sources of calcium (within Question 3) and the adequacy of folate and other nutrient intakes if all grains are consumed as whole grains (within Question 4). The process and detailed results for both modeling analyses are described in the full Milk Group and Alternates and Replacing all Non-Whole Grains with Whole Grains reports (see online appendices E3.6 and E3.7 at www.dietaryguidelines.gov).

The search strategies used to identify relevant literature and update scientific evidence appear in *Part C: Methodology*. Additional information about the search strategies and criteria used to review specific questions can be found online in the Nutrition Evidence Library (NEL) at www.NutritionEvidenceLibrary.gov.

DIETARY COMPONENTS OVERCONSUMED

Americans eat certain nutrients and dietary components in excess compared to dietary targets. Americans are strongly encouraged to modify their dietary patterns to lower intakes of non-nutrient-dense items that are overconsumed and may contribute to overweight and obesity.

Question 1: What Nutrients and Dietary Components Are Overconsumed by the General Public?

Conclusion

Estimated intakes of the following nutrients and dietary components are high enough to be of concern:

- For adults: total energy intake, particularly energy intake from solid fats and added sugars; sodium; percentage of total energy from saturated fats; total cholesterol (in men); and refined grains.
- For children: energy intake from solid fats and added sugars; sodium; percentage of total energy from saturated fats; total cholesterol (only in boys, aged 12 to 19 years); and refined grains.

Implications

To lower overall energy intakes (see *Part D. Section 1: Energy Balance and Weight Management*) without compromising nutrient intakes, Americans should reduce consumption of calories from solid fats and added sugars (SoFAS). SoFAS generally provide few, if any, micronutrients. Intakes of SoFAS should be kept as low as possible across all age-sex groups, to less than the maximum limits calculated for the USDA Food Patterns. Concentrated efforts are needed to lower total sodium intakes by all Americans (see *Part D. Section 6:*

Sodium, Potassium, and Water). Likewise deliberate public health efforts are warranted to reduce intakes of saturated fats to meet dietary guidelines for optimal health. Males older than age 12 years also are encouraged to consume less total dietary cholesterol (see *Part D. Section 3: Fatty Acids and Cholesterol*). Intakes of refined grains are too high and at least half of all refined grains should be replaced with high-fiber whole grains (see *Part D. Section 5: Carbohydrates*).

Review of the Evidence

To reach this conclusion, the DGAC examined usual intake distributions from 2001-2004 NHANES data (NCI, 2009) and usual mean intakes from 2005-2006 NHANES data (ARS, 2008). In all cases, the most current NHANES data available for a specific nutrient or food component was used. In addition, the Committee reviewed FNS reports on quality of American diets and the IOM report on school meals.

Methods to Identify Components Overconsumed

When a population group has dietary intakes that exceed recommended maximum levels for a food group, dietary component, or nutrient, that dietary constituent is considered a component consumed in an amount high enough to be of "concern" (i.e., the component is overconsumed). Such components are consumed in amounts higher than levels recommended in the USDA Food Patterns or by the IOM to promote optimal health. When basic food groups, energy intake, proportions of energy intake, or specific nutrients are consumed in amounts higher than recommended levels, such intakes are of concern because their contributions to overall nutrient intakes, overall dietary components, and the balance of macro- and micronutrients in the total dietary pattern may be unsuitable to confer potential health benefits.

Findings Regarding Components Overconsumed

Energy—Appropriate intake levels for total energy vary based on a person's age, sex, size, and level of physical activity. Overconsumption of total energy in comparison to individual need on an ongoing basis results in weight gain. Although mean intakes of energy may be within recommended ranges, the increase over time in the number of adults and children classified as overweight or obese indicates that for some, usual energy intakes exceed needs. The mean energy intakes of men and women older than age 19 years are 2638 calories and 1785 calories per day, respectively (ARS, 2008), while recommended total energy intakes range from 2000 to 3000 calories per day for men and 1600 to 2400 calories per day for women, depending on age and physical activity level. Many men and women appear to balance their energy intakes based on energy needs, but there are clearly many more whose usual energy intakes exceed their daily needs, thereby contributing to the massive obesity epidemic currently affecting Americans.

Data document that adult men and women who are classified as overweight (body mass index [BMI] of 25.0 to 29.9 kg/m^2) or obese (BMI of greater than or equal to 30.0 kg/m^2) often systematically underreport their dietary intakes (Karelis, 2010). For example, Moshfegh et al. (2008) compared self-reported energy intake, estimated using the automated multiple-pass dietary intake method used in NHANES, to total energy expenditure measured by doubly labeled water in 221 normal weight, 193 overweight, and 110 obese men and women. Overweight and obese men underestimated energy intake by 14 percent and 20 percent, respectively. Overweight and obese women underestimated energy intake by 15 percent and 21 percent, respectively, while normal weight men and women underestimated energy intake by 1 percent and 6 percent, respectively (Moshfegh, 2008). Hence, actual average energy intakes are likely greater than estimated by NHANES from self-reported intakes, particularly in individuals who are overweight or obese, suggesting that total energy is overconsumed.

Children, aged 2 to 18 years, on average, consume calories within the recommended ranges for their ages and physical activity levels (ARS, 2008). Yet, as with adults, subgroups of children may be consuming calories in amounts too high for their daily energy needs, and as with adults, there is significant underreporting of energy intake among overweight and obese children compared with normal weight children. Calories, energy needs, energy balance, and relationships to BMI and health outcomes are thoroughly discussed in *Part D. Section 1: Energy Balance and Weight Management*.

Five categories of foods contribute nearly 30 percent of the total calories consumed in the American diet (Bosire, 2009). These five categories—grain-based desserts (e.g., cakes, cookies, donuts, pies, crisps, cobblers, granola bars); yeast breads; chicken and chicken-mixed dishes; sodas, energy, and sports drinks; and pizza—are often consumed in forms high in SoFAS and should be replaced with other foods that are more nutrient-dense or prepared in a way that reduces the content of SoFAS. Replacing foods containing higher amounts of SoFAS with foods from each of the basic food groups in nutrient-dense forms, to achieve appropriate dietary patterns within individual calorie needs, can help promote health (see the online resource for *Part D. Section 1: Energy Balance and Weight Management* at www.dietaryguidelines.gov for information on the primary energy sources in the diets of children).

Energy from Solid Fats and Added Sugars—Solid fats are fats that are solid at room temperature. Solid fats come from many animal foods and can be made from vegetable oils through hydrogenation. Some common solid fats are butter, beef tallow (tallow, suet), chicken fat, pork fat (lard), stick margarine, and shortening. Foods high in solid fats include many cheeses, creams, ice cream, well-marbled cuts of meats, regular ground beef, bacon, sausages, poultry skin, and many baked goods (such as cookies, crackers, donuts, pastries, and croissants). Most solid fats are high in saturated fats and/or *trans* fats and have less monounsaturated or polyunsaturated fats. Animal products containing solid fats also contain cholesterol.

Added sugars are sugars and syrups that are added to foods or beverages during processing or preparation. They do not include naturally occurring sugars such as those in milk and fruits. Names for added sugars include brown sugar, corn sweeteners, corn syrup, dextrose, fructose, fruit juice concentrates, glucose, high-fructose corn syrup, honey, invert sugar, lactose, maltose, malt syrup, molasses, raw sugar, and sucrose.

Together, SoFAS contribute greatly to overall energy intake without contributing importantly to nutrient intakes (i.e., they are non-nutrient-dense). Intakes of SoFAS come from foods that are high in solid fats (naturally present or added) and added sugars and from the SoFAS that are added to foods during preparation, service, and intake. The major food sources of SoFAS in American diets for those ages 2 and older were identified by Bachman et al. (2008), using NHANES 2001-2002 intake data. Top sources of solid fats included grain-based desserts (10.9% of total energy from solid fats); regular-fat cheese (7.7%); sausage, franks, ribs, and bacon (7.1%); pizza (5.9%); fried white potatoes (mainly French fries [5.5%]); and dairy-based desserts (5.1%). The top sources of added sugars included sodas (36.6% of total energy from added sugars); grain-based desserts (11.7%); sugar-sweetened fruit drinks (11.5%); dairy-based desserts (6.4%); candy (6.2%); ready-to-eat cereals (4.0%); sugars/honey (3.9%); tea (3.2%); syrups and toppings (2.7%), and yeast breads (2.0%). For children, aged 2 to 18 years, the major sources of SoFAS were very similar to those for the overall population, with the exception that whole milk was the top source of solid fats for children aged 2 to 8 years. Very similar results for the top sources of added sugars were reported by Marriott et al. (2010) in an analysis of added sugars intake for individuals 4 years and older, using NHANES 2003-2006 intake data. These included sodas (30.7%); sugars/sweets (which included candy, sugars, syrups and toppings, and jams and jellies [13.7%]); sweetened grains (which included cakes, cookies, pies, pastries, crackers, and snacks, [12.6%]); and fruitades/fruit drinks (10.3%).

Neither a recommendation for intake of SoFAS, nor a reasonable proportion of total energy intake as SoFAS has been determined. Nutrient recommendations may be met on a daily basis without consuming SoFAS; thus, SoFAS are not an essential component of the diet. If consumed at all, intake of SoFAS should be infrequent and in quantities as small as possible. The USDA Food Patterns offer guidance on the maximum amount of SoFAS that can be accommodated within an individual's energy allotment *only after* nutrient requirements have been met (Table B2.3 in *Part B. Section 2: Total Diet*). SoFAS should not be misconstrued as a goal or daily allowance, but rather, are a maximum daily amount that most Americans routinely exceed and do not need to meet nutrient requirements. These SoFAS substitute for discretionary calories that were included in the 2005 *Dietary Guidelines for Americans* dietary patterns. In this report, SoFAS do not include calories from alcohol because alcohol makes a very minor contribution to overall energy intake in the diets of most Americans and does not apply to children.

Slightly more than one-third of all calories currently consumed in the average American diet come from SoFAS (Figure D2.1[1]). On a caloric basis, the individual components of SoFAS (i.e., solid fats and added sugars) are consumed in roughly equal amounts (Figure D2.2). SoFAS contribute little or nothing to overall nutrient adequacy of the diet but add from 500 calories to 1050 calories to total energy intake each day for many Americans. This is excessive. Most Americans overconsume SoFAS. More than 95 percent of children, aged 2 to 13 years, adolescent girls and women, aged 14 to 50 years, and men, aged 19 to 30 years; more than 90

[1] Note: All Figures and Tables for this chapter are found at the end of the chapter.

percent of adolescent boys, aged 14 to 18 years, and men, aged 31 to 50 years; more than 75 percent of men and women older than 50 years of age consume more than the maximum caloric limit for SoFAS intake identified in the USDA Food Patterns (Figure D2.3). Median intakes of energy as SoFAS in the typical American diet are 536 calories and 701 calories per day for children, aged 2 to 3 years and 4 to 8 years, respectively; 730 calories to 1028 calories per day for children, aged 9 to 18 years; and 603 calories and 852 calories per day for women and men older than 19 years of age, respectively (NCI, 2009). This means the majority of Americans eat too many calories from non-nutritious sources. The DGAC is concerned that Americans are overweight and undernourished. In support of this conclusion, Marriott et al. (2010) reported lower intakes of micronutrients in Americans with higher intakes of added sugars beyond 5 percent to 10 percent of total calories.

Other Evidence Considered for Energy from SoFAS—The Committee on Nutrition Standards for National School Lunch and Breakfast Programs examined 1999-2002 NHANES data and found that average caloric intakes from SoFAS for school-aged children, aged 5 to 8 years, 9 to 13 years, and 14 to 18 years, were 719, 810, and 946 calories per day (FNB, 2009). The contrast with discretionary calorie allowances, which accommodate intakes of SoFAS, for these same ages was striking. The allowances in typical energy intake patterns for children were 132 (for 1600 calorie pattern), 267 (for 2000 calorie pattern) and 362 (for 2400 calorie pattern) calories per day.

The Food and Nutrition Service (FNS) evaluated diet quality of several groups of Americans using the Healthy Eating Index [HEI] 2005, which examined components of the overall diet compared to compliance with 2005 *Dietary Guidelines for Americans*. Using 1999-2004 NHANES data, the FNS reported that 41 percent of total energy consumed came from SoFAS and alcohol (SoFAAS) in the typical diet of all Americans (FNS, Report No. FSP-08-NH, 2008), 39 percent among all school-aged children (SoFAS only, assuming no alcohol intake) (FNS, Report No. CN-08-NH, 2008), and 37 percent among all preschool-aged children (SoFAS only, assuming no alcohol intake) (FNS, Report No. WIC-08-NH, 2008). In contrast, calories from SoFAS should theoretically comprise only up to 20 percent of total energy intake in boys, aged 14 to 18 years, who exercise at recommended levels (the age-sex group that also has a high energy need for growth and development). Even in the average school-aged child, SoFAS should contribute only up to 13 percent of calories or with added physical activity up to 17 percent of calories.

In summary, SoFAS contribute to excessive intakes of non-nutrient-dense foods and extra calories in a substantial proportion of boys and girls, aged 2 to 18 years, as well as in women and men older than age 19 years. Food sources of SoFAS include sodas, grain-based desserts, fruit drinks, fried white potatoes, dairy desserts, and whole milk (Bachman, 2008).

Sodium—Based on evidence of the relationship of sodium intake to health outcomes, which places the majority of Americans at risk of developing hypertension, intake of less than the UL of 2300 milligrams per day of sodium by all individuals is recommended with an eventual goal of the AI for sodium of 1500 milligrams per day (see *Part D. Section 6: Sodium, Potassium, and Water* for a detailed discussion of sodium intakes and implication of excessive sodium intake). Usual intakes of sodium exceed the AI for more than 97 percent of all age-sex groups. Usual intakes also exceed the UL for more than 90 percent of boys older than 9 years and adult men up to age 70 years, as well as for 50 percent to 75 percent of girls older than 9 years and women of all ages (Figure D2.4) (ARS, 2010a).

Saturated Fats—Based on evidence of the relationship of saturated fat intake to health outcomes and the absence of any biologic requirement for saturated fat, an immediate reduction to less than 10 percent of energy from saturated fats is recommended as a step toward an eventual goal of less than 7 percent of energy from saturated fats (see *Part D. Section 3: Fatty Acids and Cholesterol* for an extensive discussion of this relationship). Current usual intakes of saturated fats are in excess of this recommendation for more than half of the total American population. More than 75 percent of children, aged 1 to 13 years, and 50 percent of older children and adults consume more than 10 percent of calories as saturated fats (Figure D2.5) (NCI, 2010). Median usual intakes of saturated fats (ARS, 2008) in the typical American diet are:

- 12.6 percent and 11.4 percent of calories for children, aged 1 to 3 years and 4 to 8 years, respectively
- 11.1 percent to 11.7 percent of calories for children, aged 9 to 18 years
- 10.6 percent to 11.1 percent of calories for women and men older than 19 years, respectively.

Cholesterol—Based on evidence of the relationship of cholesterol intake to health outcomes, intake of less than 300 milligrams of cholesterol per day by all individuals is recommended (see *Part D. Section 3: Fatty Acids and Cholesterol* for additional information on the health implications of overconsuming dietary cholesterol). Current usual intakes of cholesterol exceed this amount for more than 50 percent of boys, aged 14 to 18 years, and adult men, aged 19 to 70 years, while only 25 percent of men older than 70 years and 5 percent to 10 percent of children, aged 2 to 13 years, girls, aged 14 to 18 years, and adult women consume more than the recommended limit for cholesterol (Figure D2.6) (ARS, 2010b). Median usual intakes of cholesterol (ARS, 2010b) in the typical American diet are:

- 164 milligrams and 190 milligrams per day for children, aged 1 to 3 years and 4 to 8 years, respectively
- 200 milligrams to 230 milligrams for children, aged 9 to 13 years
- 190 milligrams to 226 milligrams for girls and women older than 14 years
- 206 milligrams to 363 milligrams for boys and men, aged 14 to 70 years
- 269 milligrams for men older than 70 years

Refined Grains—Although intakes of whole grains are far below recommended levels for all age-sex groups (see Question 2 on Food Groups and Selected Dietary Components Underconsumed), intakes of refined grains are higher than recommended. Refined grains are "a grain product that is missing the bran, germ, and/or endosperm (a grain product that is not a whole grain)." Many refined grains are enriched with thiamin, riboflavin, niacin, and iron, and fortified with folic acid (USDHHS and USDA, 2005b) but also are high in SoFAS and calories.

Usual intakes of refined grains exceed recommendations for 90 to 95 percent of all age-sex groups, (Figure D2.7) (NCI, 2009). Recommended intakes of refined grains are defined as up to one-half or less of the total grain intake recommendation, which translates to 3 ounce equivalents in the reference 2000 calorie food pattern, and no more than 5 ounce equivalents in the highest calorie patterns. Median usual intakes of refined grains (NCI, 2009) in the typical American diet are:

- 3.8 ounce equivalents for children, aged 1 to 3 years
- 6.0 ounce equivalents for children, aged 4 to 8 years
- 7.5 ounce equivalents for boys, aged 9 to 13 years
- 6.3 ounce equivalents for girls, aged 9 to 13 years
- 8.3 ounce equivalents for boys, aged 14 to 18 years
- 5.9 ounce equivalents for girls, aged 14 to 18 years
- 7.0 ounce equivalents for men older than 19 years
- 5.2 ounce equivalents for women older than 19 years

Usual intakes of refined grains alone are very close to or are above total grain recommendations for all age-sex groups, reflecting the extremely low intakes of whole grains. Overconsumption of refined grains is a major source of extra calories in the diet. When refined grains are consumed, these grains should be enriched and fortified.

Lowering intakes of total energy, calories from SoFAS, sodium, saturated fats, total cholesterol (in adolescent boys and men), and refined grains is important for meeting essential nutrient requirements and promoting health. Nutrient-dense forms of foods should be consumed within a total diet that has relatively low energy-density.

FOOD GROUPS AND SELECTED DIETARY COMPONENTS UNDERCONSUMED

Nutrient recommendations should be met by consuming nutrient-dense forms of foods and from the basic food groups. Paralleling the overconsumption of some dietary components that are not essential for health, many Americans are not consuming enough of certain foods and dietary components that are essential for health. Estimated usual intakes of food groups and dietary components by Americans are evaluated against recommendations for intakes.

Question 2: What Food Groups and Selected Dietary Components Are Underconsumed by the General Public?

Conclusion

Currently reported dietary intakes of the following food groups and selected dietary components are low enough to be of concern:

- For both adults and children: vegetables, fruits, whole grains, fluid milk and milk products, and oils.

Implications

Despite the evidence that health-promoting dietary patterns are those that include a variety of foods and combinations of foods from each of the basic food groups, many Americans make food choices that do not meet the characteristics of healthy dietary patterns (Bachman, 2008). A fundamental premise of the DGAC is that nutrients should come from foods. Often, nutrient intake shortfalls are an indicator of low intakes of certain food groups that provide specific nutrients. Hence, efforts are warranted to promote increased intakes of vegetables (especially dark-green vegetables, red-orange vegetables, and cooked dry beans and peas), fruits, whole grains, and fat-free or low-fat fluid milk and milk products (including calcium and vitamin D fortified soymilk) among all ages; substitution of oils for solid fats, regardless of age; and increased intakes of lean, heme-iron-rich meat, poultry, and fish by adult women and adolescent girls. Intake of nutrient-dense foods—that is, foods in their leanest or lowest fat forms and without added fats, sugars, starches, or sodium—should replace foods in the current American diet that contribute to high intakes of SoFAS and refined grains (see Question 1 on Nutrients and Dietary Components Overconsumed). Oils should only be substituted for solid fats rather than added to the diet. Substitutions and selection of nutrient-dense forms of vegetables, fruits, whole grains, and fluid milk and milk products to replace non-nutrient-dense forms of foods should be done in a manner such that total caloric intake falls within or below daily energy needs.

Review of the Evidence

To reach this conclusion, the DGAC examined data published by the NCI (NCI, 2009). The NCI reported findings from 2001-2004 NHANES data of usual (i.e., long-term daily average) food intakes. In addition, the Committee considered the FNS reports on diet quality as well as findings from the IOM report on the state of school meals.

Methods to Identify Components Underconsumed

If a population group has a high prevalence of intakes of a basic food group that are below recommended levels, that food group is called a shortfall food group. Such food groups are consumed in amounts lower than the minimum levels recommended in the USDA Food Patterns to meet IOM nutrient intake recommendations for each age-sex group. (Some food group recommendations in the USDA Food Patterns are higher for those within an age-sex group who have higher energy needs.) When basic food groups are consumed in low amounts, such intakes are of concern because their contributions to overall nutrient intakes and other beneficial dietary components would be inadequate to confer potential health benefits.

Findings Regarding Components Underconsumed

Vegetables—Most Americans of all ages have usual intakes of vegetables that fall below minimum recommended intakes (Figure D2.8). For 75 percent to 95 percent of almost all age-sex groups, usual intakes of all vegetable subgroups, including dark-green vegetables, red-orange vegetables, cooked dry beans and peas, starchy vegetables, and other vegetables fall below amounts recommended. For example, more than 95 percent of all age-sex groups, except for men and women older than age 50 years, consume less than the recommended amounts of dark-green vegetables. Men and women older than age 50 years do only slightly better, with 75 percent to 90 percent not meeting the recommended intake. Similarly, 95 percent of all females, adolescent boys and older men consume less cooked dry beans than are recommended, while 75 percent to 90 percent of men aged 19 to 50 years fail to meet intake recommendations. Recommended intake of total vegetables for individuals with the lowest energy needs in their age-sex group is 2.5 to 3 cup equivalents per day (in adult men and adolescent boys, aged 14 to 18 years), and 2 to 2.5 cup equivalents per day (in adult women, adolescent girls, aged 9 to 18 years, and boys, aged 9 to 13 years).

Median intakes, which fall below these minimum recommendations, are:

- 1.8 cup equivalents per day for adult men
- 1.5 cup equivalents for adult women
- 1.4 cup equivalents for adolescent boys, aged 14 to 18 years
- 1.1 cup equivalents for girls, aged 9 to 13 and 14 to 18 years
- 1.2 cup equivalents per day for boys, aged 9 to 13 years

Children, aged 1 to 8 years, also have low intakes of total vegetables, with 75 percent consuming less than recommended levels and median intakes less than 1 cup equivalent per day.

Fruits—Most children and adolescents aged 4 to 18 years, and most adult men and women have usual intakes of total fruits—including whole, sliced, diced, and processed fruits and 100 percent fruit juices—that fall below minimum recommended levels (Figure D2.9). More than 75 percent of adult men and women as well as boys and girls, aged 9 to 18 years, consume less than their minimum recommended level of fruit per day. The recommended intake for individuals with the lowest energy needs by age-sex group is 2 cup equivalents per day (in adult men and adolescent boys, aged 14 to 18 years), and 1.5 cup equivalents per day (in women, adolescent girls, aged 9 to 18 years, and boys, aged 9 to 13 years).

Median intakes fall far below these minimum recommendations. They are:

- 0.9 cup equivalents per day for adult men
- 0.8 cup equivalents for adult women
- 0.8 cup equivalents for adolescent boys, aged 14 to 18 years
- 0.6 cup equivalents for adolescent girls, aged 14 to 18 years
- 0.8 cup equivalents for boys, aged 9 to 13 years
- 0.8 cup equivalents for girls, aged 9 to 13 years

Children, aged 1 to 3 and 4 to 8 years, are more likely to consume recommended amounts of fruits, with about 25 percent and 50 percent, respectively, not consuming the minimum of approximately 1 cup equivalent per day. However, children, aged 2 to 18 years, consume more than half of their fruit intake as juice. While 100 percent fruit juice can be part of a healthful diet in childhood, consumption of excessive amounts has been associated with adverse health effects (AAP, 2001). Health-related organizations recommend limits on juice intake to 4 or 4 to 6 ounces per day for young children (AAP, 2001; AHA, 2010).

Collectively, vegetables and fruits are major contributors of vitamins A, C, and K, and magnesium, potassium, and dietary fiber—all shortfall nutrients (see Question 3 on Nutrients of Concern). Vegetables and fruits also contain dietary folate, a nutrient of special concern for women of reproductive capacity or those who do not eat fortified refined grains. In addition, many vegetables contain calcium, another nutrient of concern; although the bioavailability of calcium in these foods is limited (see Question 3 on Nutrients of Concern). Fruits contribute to vitamin C intake which may help to enhance iron absorption, a nutrient of particular concern for women of reproductive capacity.

Whole Grains—Americans of all ages consume fewer whole grains than recommended (Figure D2.10). Whole grains are those "foods made from the entire grain seed, usually called the kernel, which consists of the bran, germ, and endosperm. If the kernel has been cracked, crushed, or flaked, it must retain nearly the same relative proportions of bran, germ, and endosperm as the original grain in order to be called whole grain" (USDHHS and USDA, 2005b).

More than 95 percent of all age-sex groups fail to consume the minimum recommended amounts of whole grains. Median intakes for adult men and women are 0.50 and 0.47 ounce equivalents per day, respectively, compared to the recommended minimum of 3 ounce equivalents per day (one-half of total grains).

Median intakes are:

- 0.26 and 0.33 ounce equivalents per day, respectively, for adolescent boys and girls, aged 14 to 18 years, compared to the recommended level of 3.5 and 3 ounce equivalents per day, respectively; and
- 0.48 and 0.34 ounce equivalents per day for boys and girls, aged 9 to 13 years, respectively, compared to recommended levels of 3 and 2.5 ounce equivalents per day, respectively.

Children, aged 1 to 3 years and 4 to 8 years, also have low intakes of whole grains, with median intakes of 0.37 and 0.41 ounce equivalents per day, respectively, less than the recommended 1.5 or 2 ounce equivalents per day, respectively. Inadequate intakes of whole grains contribute to the lack of adequate intakes of magnesium and fiber across all age groups (see Question 3 on Nutrients of Concern). Most Americans consume more than the recommended amount of total grains per day (6 ounce equivalents for 2000 calories) but deliberate efforts are required to replace refined grains with whole grains, especially fiber-rich whole grains, such that at least one-half of all grains consumed are whole grains. Individuals with perceived allergies to grains should be evaluated before unnecessarily avoiding whole grains.

Fluid Milk and Milk Products—Intakes of fluid milk and milk products, including fortified soymilk, are less than the recommended 3 cup equivalents per day for most adult men and women and children and adolescents, aged 9 to 18 years, and less than the recommended 2 cup equivalents per day for many children, aged 4 to 8 years (Figure D2.11). In general, intakes are lower for females than males and decline with age. More than 50 percent of boys, aged 9 to 18 years, consume less than the recommended amount of fluid milk and milk products, while more than 75 percent to 90 percent of adult men consume less that the recommended amount. For all but 9-to 13-year-old girls, more than 90 percent to 95 percent of all women and girls consume less than the recommended amount of fluid milk and milk products.

Median intakes are:

- 1.6 cup equivalents per day for adult men
- 1.2 cup equivalents for adult women
- 2.3 cup equivalents for adolescent boys, aged 14 to 18 years
- 1.5 cup equivalents for adolescent girls, aged 14 to 18 years
- 2.4 cup equivalents for boys, aged 9 to 13 years
- 1.9 cup equivalents for girls, aged 9 to 13 years

For boys and girls, aged 1 to 3 and 4 to 8 years, median intakes are 2.35 and 2.18 cup equivalents, respectively, in comparison to the recommendation of 2 cup equivalents per day. However, at least 25 percent of children, aged 1 to 8 years, do not consume this recommended amount of fluid milk and milk products. Fluid milk and milk products contribute vitamin D, calcium, and potassium—targeted nutrients of concern—to the diet (see Question 3 on Nutrients of Concern). The majority of current fluid milk intake comes from 2 percent milk or whole milk, with smaller amounts of low-fat (i.e., 1 percent milk fat) or fat-free milk consumed. Choosing these fat-free, nutrient-dense forms of fluid milk and milk products provides essentially the same micronutrients with less solid fat (a source of saturated fat) and fewer calories.

Meat, Poultry, Fish, Eggs, Soy Products, Nuts, and Seeds—Usual intakes of meat, poultry, fish, eggs, soy products, nuts, and seeds are below recommended amounts for most adolescent girls and many adult women (Figure D2.12). For men, boys, aged 9 to 18 years, and children, aged 1 to 8 years, low intakes of foods from this food group are less prevalent. About 75 percent of girls, aged 9 to 18 years, and about 50 percent of adult women consume less than the amounts recommended for those with lower energy needs.

Median intakes are:

- 4.5 ounce equivalents per day for adult women, in comparison to a recommendation of 5 to 5.5 ounce equivalents per day
- 3.7 and 3.6 ounce equivalents per day for adolescent girls, aged 14 to 18 years, and girls, aged 9 to 13 years, respectively, in comparison to a recommendation of 5 ounce equivalents per day

Foods from this group contribute to heme-iron intake—a nutrient of concern for the special population of women of reproductive capacity (see Question 5 within Nutrient Issues for Selected Population Subgroups).

Oils—Oils are fats that are liquid at room temperature. Oils come from many different plants and from fish. Some common oils include canola, corn, olive, peanut, safflower, soybean, and sunflower oils. A number of foods are naturally high in oils, such as nuts, olives, some fish, and avocados. Foods that are mainly oil include mayonnaise, certain salad dressings, and soft (tub or squeeze) margarine with no *trans* fats. Most oils are high in monounsaturated or polyunsaturated fats, and low in saturated fats. A few plant oils, including coconut oil and palm kernel oil, are high in saturated fats and for nutritional purposes should be considered solid fats. Hydrogenated oils that contain *trans* fats should also be considered solid fats for nutritional purposes.

Americans of all ages do not achieve recommended intakes of oils (Figure D2.13). While solid fats and saturated fatty acids are consumed in excess (see Question 1 on Nutrients and Dietary Components Overconsumed), oils fall short of dietary targets. These oils provide essential fatty acids and vitamin E, a shortfall nutrient (see Question 3 on Nutrients of Concern). Intakes of oils would be sufficient if these oils were to be substituted for a portion of the excessive current intake of solid fats, which contributes to the intake of saturated and *trans* fats (see *Part D. Section 3: Fatty Acids and Cholesterol* for discussions of health-related issues regarding dietary fats).

Other Evidence Considered for Components Underconsumed—The IOM Committee on Nutrition Standards for National School Lunch and Breakfast Programs examined estimates from 1999-2002 NHANES data and also found that school-aged children consumed inadequate amounts of vegetables, specifically dark-green and orange vegetables, and legumes, fruits, whole grains, fluid milk and milk products, meats and beans, and oils (FNB, 2009). Efforts should be made to ensure that school meals promote intake of these underconsumed food groups and selected dietary components.

Using 1999-2004 NHANES data, the FNS reported that many areas of concern for food group intakes, based on HEI-2005 analysis, existed for adults, aged 19 years and older, and for school-age children, aged 5 to 8 years and 9 to 18 years (FNS, Report No. FSP-08-NH, 2008; FNS, Report No. CN-08-NH, 2008). For adults, shortfalls in intakes of vegetables, notably dark-green and orange vegetables, and cooked dry beans, fruits, particularly whole fruits (among adults, aged 19 to 59 years only), whole grains, fluid milk and milk products, and oils were reported, regardless of participation status in the Supplemental Nutrition Assistance Programs, formerly known as the Food Stamp Program.

For children, shortfalls in intakes of vegetables, notably dark-green and orange vegetables, and legumes, fruits, particularly whole fruits, whole grains, fluid milk and milk products, meat and beans, and oils were identified, regardless of participation status in the School Lunch Program. Preschool children, aged 2 to 4 years, had shortfalls in intakes of vegetables, notably dark-green and orange vegetables, and legumes, whole fruits (but not total fruits due to consumption of 100% fruit juice), whole grains, meat and beans, and oils, regardless of participation in the Special Supplemental Nutrition Program for Women, Infants and Children (FNS, Report No. WIC-08-NH, 2008).

Relevant Contextual Issues

Barriers to Achieving Dietary Guidelines for Americans—As evidenced by analyses of NHANES data, a substantial portion of the population fails to meet intakes of food groups recommended in the 2005 *Dietary Guidelines for Americans*. Among selected subgroups of Americans, primarily those with low incomes, five key barriers to adopting dietary guidance have been identified—accessibility, expense, knowledge/understanding, cultural issues, and other factors (physical limitations, psychosocial issues, and stage of change) (Marriott, 2008). At present, the food environment—from individual or personal factors to social networks to the physical settings of communities to macro-level sectors of human ecosystems—does not fully support the ability of Americans to achieve dietary targets for food group intakes and may be compromising the health of Americans (see *Part D. Section 1: Energy Balance and Weight Management* and *Part B. Section 3: Translating and Integrating the Evidence: A Call to Action*).

Using the HEI-2005 as a benchmark, current data demonstrate that dietary quality is inadequate. This is true at the individual level (HEI-2005 score = 57.5 out of 100), community level (represented by the dollar menu at a typical fast-food restaurant [HEI-2005 score = 43.4]), and macro-level (represented by the U.S. food supply in 2005 [HEI-2005 score = 54.9]) (Reedy, 2010). Americans' choices and consumption patterns of the basic food groups and dietary components as shown in their total diets are limited by the degree to which the food environment offers higher nutrient-dense forms of foods. Specifically, while the quality of the food supply in the U.S. has improved somewhat from 1970 (HEI-2005 score = 47.5) to 2007 (HEI-2005 score = 57.5) (Krebs-Smith, 2010), the macro-level food environment fails to achieve an acceptable level of dietary quality, notably because vegetables, fruits, whole grains, fat-free and low-fat fluid milk and milk products, and fish are in short supply.

Food Production—To meet intake targets by Americans for the basic food groups, an additional 7.4 million acres of cropland per year must be harvested (Economic Research Service [ERS], ERR-31, 2006). Specifically, 8.9 and 4.1 million more acres of cropland would be needed to support vegetable and fruit production, respectively. At the same time, sufficient cropland is currently devoted to wheat production and could, in fact, be reduced by 5.6 million acres. Emphasis could be placed on increased production of vegetables and fruit and a shift in manufacturing toward more whole grains (specifically high-fiber, whole wheat products) and fewer refined grain products. Farm milk production must increase by 107.7 billion pounds for Americans to have full availability to fluid milk and milk products to meet recommendations for this food group, according to ERS estimates (ERS, ERR-31, 2006).

NUTRIENTS OF CONCERN

In this segment, shortfall nutrients and nutrients of concern are addressed. Public health implications are identified.

Question 3: What Nutrients Are Underconsumed by the General Public and Present a Substantial Public Health Concern?

Conclusion

Reported dietary intakes and associated indices of nutrient status for the following nutrients are of public health concern:

- For both adults and children: vitamin D, calcium, potassium, and dietary fiber.

Implications

Efforts are warranted to promote increased dietary intakes of foods higher in vitamin D, calcium, potassium, and dietary fiber for all Americans regardless of age. Recommended intakes of these nutrients of concern, in particular, and of all essential nutrients, in general, should be achieved within the context of flexible dietary intake patterns that balance energy intake with energy expenditure.

Review of the Evidence

To reach this conclusion, the DGAC examined dietary intake data from reports that used methods recommended by the IOM for assessing the prevalence of inadequate nutrient intakes in a population (FNB, 2001), supplemented by data from the ARS and FNS. In addition, the Committee considered data on biochemical indices of nutrient status from the Centers for Disease Control and Prevention (CDC) and current peer-reviewed published research, as well as disease prevalence data.

Methods to Identify Shortfall Nutrients

A high prevalence of inadequate dietary intake of a nutrient among any segment of the population constitutes a *shortfall* nutrient. Although RDAs are intended to be used in planning diets, they are not to be used for identifying the proportion of a group whose usual intake of a nutrient is less than the requirement for that nutrient (FNB, 2003). When available, the EAR is the appropriate value to be used for assessing adequacy of intake—that is, for determining the proportion of individuals whose *usual* intake is less than the EAR (FNB, 2006). The usual intake is the long-run average intake. If intake data are available for at least two days, statistical methods can be used to estimate usual intake (Guenther, 1997; Nusser, 1996). Because the requirement distribution for iron is skewed, the probability approach (FNB, 2006) is the recommended method for determining the adequacy of iron intake. For nutrients for which there are AIs rather than EARs, usual intake distributions are examined, if available, and mean intakes are compared with the corresponding AI (FNB, 2001). If mean intake is above the AI, a low prevalence of inadequate intake for that nutrient is likely.

Analyses that use the nutrient assessment methods recommended by the IOM (FNB, 2003) were available from several published sources to examine nutrient intakes in comparison to nutrient recommendations. Data on the distribution of usual nutrient intakes from food sources for the U.S. population ages 1 year and older, 2001-2002, were available for vitamins A, C, E, K, B_6 and B_{12}, thiamin, riboflavin, niacin, folate, phosphorus, magnesium, iron, zinc, copper, selenium, carbohydrate, protein, calcium, potassium, sodium, dietary fiber, linoleic acid, and linolenic acid (Moshfegh, 2005) and from 2005-2006 for vitamin D, calcium, phosphorus, and magnesium (Moshfegh, 2009). In addition, data on usual intakes from both food sources and supplements were available for vitamin D and calcium (Bailey, 2010a). Data for specific population subgroups also were available for vitamins A, C, and E, thiamin, riboflavin, niacin, folate, vitamins B_6 and B_{12}, phosphorus, magnesium, iron, zinc, calcium, potassium, sodium, and dietary fiber (FNS, Report No. FSP-08-NH, 2008; FNS, Report No. CN-08-NH, 2008; FNS, Report No. WIC-08-NH, 2008). The DGAC also examined mean one-day intakes from 2005-2006 NHANES data for 25 nutrients, including energy, total fat, carbohydrate, protein, vitamins A, C, E, and K, thiamin, riboflavin, niacin, folate, vitamins B_6 and B_{12}, choline, phosphorus, magnesium, iron, zinc, copper, selenium, calcium, potassium, sodium, and dietary fiber (ARS, 2008). Overlap among nutrients across these reports existed. The DGAC considered all of these reports because findings were presented as means, medians, and percentiles, depending on the availability and analyses of dietary intake data.

Overall Findings Regarding Shortfall Nutrients

As shown in Figures D2.14 and D2.15, the probability of adequate dietary intake of 10 nutrients is tenuous for adult men and women. These nutrients include vitamins A, C, D, E, and K, and choline, calcium, magnesium, potassium, and dietary fiber. Results of an analysis of food intake from 1999-2004 NHANES data for school-aged children (FNS, Report No. CN-08-NH, 2008) showed that shortfall nutrients for children (most notably adolescents) include vitamins A, C, D, and E, and phosphorus and magnesium. Calcium is a shortfall nutrient for boys and girls, aged 9 to 18 years, and more recent intake data suggest that calcium is a shortfall nutrient for boys and girls, aged 4 to 8 years (Bailey, 2010a). Intakes of potassium and dietary fiber are inadequate among nearly all school-aged children.

Biochemical Indices and Disease Prevalence Data— Biochemical indices, when available, were considered for shortfall nutrients.

Vitamins A, C, K, and E: NHANES data from 1999-2002 (USDHHS, 2008) show that less than 5 percent of the population in the U.S. has an inadequate serum retinol concentration, defined as less than or equal to 20 μg/dL. Based on 2003-2004 NHANES data, age-adjusted serum vitamin C deficiency, defined as less than 11.4 μmol/L, is found in 7.1 percent of the population in the U.S. (Schleicher, 2009). Current data are not available for vitamin K status in a large representative sample of individuals in the U.S. In addition, less than 5 percent of the population in the U.S has an inadequate serum alpha-tocopherol concentration, defined as less than or equal to 500 μg/dL (USDHHS, 2008). Thus, it is unlikely that vitamins A, C, K, and E, respectively, are of major public health significance for the vast majority of healthy individuals in the U.S.

Intakes of vitamins A, C, and K tend to reflect low intakes of vegetables and fruits (see Question 2 on Food Groups and Selected Dietary Components Underconsumed), and food pattern modeling shows that these nutrient requirements can easily be met by increasing dietary intakes of these foods. Tables D2.2, D2.3, and D2.4 list the best food sources of vitamins A, C, and K per standard amount, respectively, from the ARS nutrient database, along with the number of calories for each standard amount. Most Americans do not typically consume foods that are especially rich in vitamin E on a daily basis. Table D2.5 lists the best food sources of vitamin E per standard amount from the ARS nutrient database, along with the number of calories for each standard amount. Although salad dressings, mayonnaise, and oils provide the greatest amount of vitamin E in American diets overall, the oil most commonly used in these products—soybean oil—is not an especially rich source of vitamin E. Oils containing higher amounts of vitamin E—sunflower, cottonseed, and safflower oils—are less commonly consumed. The same is true for nuts—almonds and hazelnuts are relatively rich in vitamin E, but peanuts and peanut butter, with lower levels of vitamin E, represent the majority of all nut consumption in the U.S. Food composites used in modeling food patterns are relatively low in vitamin E content, reflecting Americans' limited use of foods rich in vitamin E. As the energy level of the food pattern increases, the pattern comes closer to providing the recommended intake of vitamin E. To come closer to achieving the recommended intake, vitamin E-rich oils can be substituted for some other oils in the diet, and vitamin E-rich nuts can replace some other nuts. Americans should not increase total energy intake to achieve a higher intake of vitamin E, in light of adequate serum alpha-tocopherol concentrations.

Choline: Choline is required for cell structure and function, neurotransmission, lipid transport from the liver, and as a dietary methyl group source (Zeisel, 2006). Deficiency states that can arise from inadequate choline intake include fatty liver and muscle dysfunction in postmenopausal women and men across all ages, as well as elevated plasma homocysteine level after methionine loading. Risk of NTDs in infants of choline-deficient mothers have been reported in some epidemiologic studies, but very little evidence of overt choline deficiency symptoms exists in the American population (Sanders, 2007). Americans could meet recommendations for choline by consuming modest amounts of eggs and by replacing other meat, poultry, and starchy vegetables with cooked dry beans and peas, within fixed energy intakes. Table D2.6 lists the best food sources of choline per standard amount, from the ARS nutrient database, along with the number of calories for each standard amount.

Magnesium and Phosphorus: Intakes of magnesium tend to reflect low intakes of vegetables, nuts, seeds, and cooked dry beans and peas. Phosphorus intake among adolescent girls reflects a low intake of fluid milk and milk products (see Question 2 on Food Groups and Selected Dietary Components Underconsumed). Magnesium and phosphorus requirements may be met by increasing dietary intakes of vegetables, nuts, seeds, cooked dry beans and peas, and fluid milk and milk products. Tables D2.7 and D2.8 list the best food sources of magnesium and phosphorus per standard amount, respectively, from the ARS nutrient database, along with the number of calories for each standard amount.

Vitamin D: A substantial number of Americans have lower serum 25-hydroxyvitamin D [25(OH)D] concentrations during the wintertime (USDHHS, 2008; Looker, 2002). Combined with evidence of widespread inadequacy of vitamin D intake, this nutrient presents a public health concern (discussed below).

Calcium: NHANES data from 2005-2006 indicate that 10 percent of women and 2 percent of men older than 50 years have osteoporosis of the femoral neck; moreover, 49 percent of women and 30 percent of men older than 50 years have osteopenia at this same skeletal site (Looker, 2010). Nearly 40 million men and women in the U.S. have low bone mass (Looker, 2010), with bone mineral density or content change serving as a criterion for adequacy of calcium status (FNB, 1997). Calcium is discussed below as a nutrient of public health significance.

Potassium: Increased potassium consumption modifies systolic and diastolic blood pressure (see *Part D. Section 6: Sodium, Potassium, and Water*). Approximately 57 percent of adults living in the U.S. have prehypertension or hypertension (Ostchega, 2008) and many more have inadequate dietary intake of potassium. Thus, potassium is a nutrient of public health significance.

Dietary Fiber: Adequacy of dietary fiber intake cannot be determined by biochemical or clinical indices (FNB, 2006). Rather, dietary fiber is considered in light of risk reduction of coronary heart disease (CHD) (FNB, 2006), which is the leading cause of death in the U.S. The widespread inadequate intake of dietary fiber among adults and children coupled with the prevalence of CHD and fiber's possible role in contributing to satiety (important for weight control) constitute a major public health concern for this nutrient (see *Part D. Section 5: Carbohydrates*).

Specific Underconsumed Nutrients of Public Health Concern

The DGAC gives special attention to four underconsumed nutrients of public health concern: vitamin D, calcium, potassium, and dietary fiber. These four shortfall nutrients are clearly linked to indicators of nutrient inadequacy or disease prevalence and require special consideration in developing dietary guidance to meet recommended food intakes, as explained later in this section.

Table D2.9 identifies the functions of the nutrients of concern—vitamin D, calcium, potassium, and dietary fiber. Americans should increase intakes of these nutrients to achieve recommended levels, within limited energy intakes, for health promotion.

Vitamin D—Strong evidence indicates that many children and a majority of adults do not meet the AI for vitamin D. Furthermore, a significant portion of the population has deficient or inadequate blood levels of vitamin D to promote health and prevent chronic diseases, such as poor bone health and possibly certain types of cancers, cardiovascular disease, and immune-related disorders. This is especially apparent in people living in northern latitudes, in persons with dark skin, and in overweight and obese adults.

All children, adults, and the elderly are encouraged to meet the AI for vitamin D by consuming vitamin D-rich foods in both naturally occurring and fortified forms. Children, adults, and the elderly with deficient or inadequate blood levels of vitamin D should consume more vitamin D-rich foods. If necessary, individuals may consider vitamin D supplementation if they are having difficulty meeting the AI through vitamin D-rich foods.

The DGAC chose not to conduct an independent systematic review of vitamin D due to the fact that the IOM concurrently empanelled an expert committee to review the DRI for vitamin D. The previous DRI for vitamin D was established in 1997. The IOM empanelled the committee because significant new and relevant research had become available to review the existing DRI for vitamin D (Yetley, 2009). Recommendations from the IOM committee are expected to be available in Fall 2010.

For this review of vitamin D and health, the DGAC primarily relied upon three different sources of information: (1) vitamin D intake data from the NHANES (Bailey, 2010a); (2) an *American Journal of Clinical Nutrition* (AJCN) supplement (Brannon et al, 2008a) that presented findings from two sources, including proceedings from the NIH conference "Vitamin D and Health in the 21st Century: An Update" held in September 2007 and an NIH roundtable discussion with expert scientists held after the conference (Brannon et al, 2008b); and (3) an Agency for Healthcare Research and Quality (AHRQ) evidence report, *Vitamin D and Calcium: A Systematic Review of Health Outcomes* (Chung, 2009) prepared for use by the 2009-2010 IOM committee. The results of the DGAC's review are presented below.

Vitamin D and Health: Adequate vitamin D status, which depends upon dietary intake and cutaneous synthesis, is important for health (Brannon et al, 2008a). Well-established research demonstrates the importance of vitamin D for bone health. Vitamin D deficiency results in rickets in children and osteomalacia in adults (Brannon et al, 2008a). In adults and older adults, adequate vitamin D reduces risk of fractures (Looker, 2010). Recent evidence suggests that vitamin D is important for other body systems (Brannon et al, 2008a; *Nutrition Reviews,* 2007). Emerging research has shown a reduced risk for type 1 diabetes, some cancers, autoimmune diseases, and infectious diseases (Brannon, 2008b; Chung, 2009). Further well-designed, dose-response research is needed to fully establish the relationship between vitamin D and many of these outcomes (Chung, 2009).

Vitamin D Intake: Results from 2003-2006 NHANES data indicate that the majority of the population does not meet the AI for vitamin D (Bailey, 2010a). With diet alone, less than 10 percent of men and women older than 50 years meet the AI, and less than 2 percent of adults older than 70 years meet the AI (10 μg/d for 51 to 70 years of age; 15 μg/d for 71 years of age and older) (Figure D2.16). Approximately 47 percent and 53 percent, respectively, of adolescent girls and boys older than 9 years meet the AI. About 53 percent and 67 percent of girls and boys, respectively, aged 4 to 8 years, meet the AI (5 μg/d). The only population subgroup that comes close to meeting the AI with diet alone, due to fluid milk consumption, is children, with 70 percent and 72 percent of girls and boys, respectively, aged 1 to 3 years, meeting the AI of 5 μg per day.

When supplements are added to dietary intake, the percentage of children and adults who meet the AI improves. Thirty-seven percent of the population consumes supplements that contain vitamin D. However, even with combined dietary intakes and supplementation, a majority of adults still do not meet the AI:

- less than 50 percent of men and women, aged 19 to 30 years
- less than 60 percent of men and women, aged 31 to 50 years
- less than 45 percent of adults older than 50 years
- less than 25 percent of adults older than 70 years

Less than 1 percent of the population exceeds the UL for vitamin D intake (Bailey, 2010a). These vitamin D intakes are compared against the 1997 AI for vitamin D. Should the IOM determine new AIs for vitamin D, comparisons of intakes to AI standards should be adjusted accordingly.

Vitamin D Status: The criterion used by the IOM for setting the AI in 1997 was the normal level of serum 25(OH)D concentration, an indicator of vitamin D status. The 1997 25(OH)D criterion of greater than or equal to 27.5 nmol/L for children up to age 18 years and greater than or equal to 30 nmol/L for adults aged 19 years and older set by the IOM was based upon associations with bone growth in children and normal parathyroid concentrations in adults. This criterion has been brought into question based on new information on the relationship of serum 25(OH)D to health, the relationship of vitamin D intake to serum 25(OH)D concentration, vitamin D status of the U.S. population, and safety of vitamin D status, as summarized in the September 2008 supplement of the *American Journal of Clinical Nutrition* and elsewhere (Dawson-Hughes, 2005; Norman, 2007). The DGAC expects that the IOM empanelled committee will carefully evaluate the criteria for determining deficient, marginal or insufficient, and adequate serum vitamin D concentrations. Until a determination is made by the IOM panel, the DGAC must independently consider published evidence of potential thresholds for adequacy regarding health outcomes and implications related to food guidance.

Contributing scientists to the 2007 NIH roundtable discussion used the following cutoff points to evaluate vitamin D adequacy: less than 27.5 nmol/L, less than 50 nmol/L, and less than 75 nmol/L when analyzing blood samples from the 2002-2004 NHANES (Yetley, 2008). Approximately 30 percent of people aged 12 years and older had serum 25(OH)D levels lower than 50 nmol/L. For children, aged 1 to 11 years, approximately 15 percent had serum 25(OH)D levels lower than 50 nmol/L. Slightly more women than men had serum 25(OH)D concentrations lower than 50 nmol/L. Yetley (2008) further reported an inverse association of body fatness and BMI on serum 25(OH)D concentrations. Leaner women, regardless of the method used to assess body fatness, had higher concentrations of serum 25(OH)D. A more recent evaluation in children, aged 1 to 11 years, using 2001-2006 NHANES findings reported that 18 percent of children in this age range had serum 25(OH)D concentrations below 50 nmol/L (Mansbach, 2009). An even higher percentage of non-

Hispanic Black and Hispanic children had serum 25(OH)D concentrations below 50 nmol/L.

These data should be interpreted with caution because of lingering questions related to measurement drift from assay method changes and completeness of data (Looker, 2008; Yetley, 2008). However, using the NHANES values, after adjusting for an apparent measurement drift, serum 25(OH)D concentrations for the U.S. population were lower in the years 2000 to 2004 than in 1988 to 1994 (Looker, 2008). In adults, increases in BMI, reductions in fluid milk intakes, and increases in sun protection appeared to contribute to this decline (Looker, 2008).

Sources of Vitamin D: Vitamin D can be obtained through dietary sources, cutaneous synthesis, and supplementation. Fatty fish, such as salmon and herring, is the primary natural food source of vitamin D. Based on 2005-2006 NHANES data, fish and shellfish provide 8.6 percent of the vitamin D intake in the U.S. All fluid milk must be fortified with vitamin D, and other foods (e.g., cereals, margarine, and yogurt) and beverages (e.g., orange juice) are also commonly fortified. The best sources of vitamin D include fortified fluid milk, fatty fish such as salmon and trout, portabella mushrooms, and fortified orange juice (Table D2.10). Slightly more than 52 percent of the total intake comes from vitamin D-fortified fluid milk, milk drinks and desserts, and yogurt (Table D2.11). Fortified cereals account for an additional 6.5 percent of intake, and meat, poultry, and eggs together account for 11.2 percent. Various vitamin D-fortified foods differ in the amounts of vitamin D that they contain.

The USDA Food Patterns include vitamin D from fortified fluid milk, fortified ready-to-eat cereals, fortified butter and margarine, and the naturally occurring vitamin D in meat, poultry, fish, and eggs. The food patterns that contain 3 cup equivalents from the fluid milk and milk products food group provide sufficient vitamin D to meet the current AI for all children and adults, aged 19 to 50 years (i.e., 5 μg/d). However, the patterns do not provide sufficient vitamin D for adults over 50 years (i.e., 10 μg/d). The Food Patterns at 1000 to 1400 calories that contain only 2 cup equivalents from the fluid milk and milk products group do not provide adequate vitamin D to meet the AI of 5 μg per day for children, aged 2 to 8 years. Additional vitamin D could be obtained by selecting more natural food sources of vitamin D, such as certain fish, and fortified sources of vitamin D, such as fortified orange juice. In addition, choosing fortified fluid milk or yogurt rather than including cheese or non-fortified yogurt when making selections from the fluid milk and milk products food group would increase vitamin D intakes to adequate amounts for all age-sex groups, except those over 70 years of age. When necessary, individuals may consider vitamin D supplementation along with dietary intake, especially in older individuals because endogenous production of vitamin D from sun exposure is reduced by more than 50 percent in elderly populations.

Calcium—Strong evidence shows that many children and a majority of adults do not meet the AI for calcium. Furthermore, a significant number of Americans have low bone mass, placing them at risk of bone fractures and falls. Fluid milk and milk products contribute substantially to calcium intakes by Americans. Removing fluid milk and milk products from the diet requires careful replacement with other calcium-rich or calcium-fortified foods.

All children, adults, and the elderly are encouraged to meet the AI for calcium. Nutrient recommendations for calcium may be achieved by meeting recommended levels of fluid milk and milk products or consuming alternative calcium sources (see Table D2.12).

The DGAC chose to not conduct an independent systematic review of calcium due to the fact that the IOM concurrently empanelled an expert committee to review the DRI for calcium. As with vitamin D, the previous DRI for calcium was established in 1997. Recommendations from the IOM committee are expected to be available in Fall 2010.

For this review of calcium and health, the DGAC primarily relied upon three sources of information: (1) calcium intake data from the NHANES (Bailey, 2010a); (2) an AHRQ evidence report, *Vitamin D and Calcium: A Systematic Review of Health Outcomes* (Chung, 2009); and (3) the 1997 IOM report on *Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D and Fluoride* (FNB, 1997). The results of the Committee's review are presented below.

Calcium and Health: Adequate calcium status is important for optimal health of the skeleton, in addition to having vital roles in nerve transmission, vasoconstriction, vasodilation, and muscle contraction (FNB, 1997). Emerging evidence suggests a role for calcium intake in cardiovascular health and lowering risk for breast cancer (Chung, 2009). Evidence on other health-related outcomes, such as growth in infants and children, body weight (see *Part D. Section 1: Energy Balance and Weight Management* and *Part D. Section 4: Protein*), colorectal (CRC), prostate and pancreatic cancer, preeclampsia, pregnancy-induced hypertension, and preterm birth, is too insufficient or inconsistent to permit strong conclusions (Chung, 2009).

Calcium Intake: NHANES data from 2003-2006 indicate that the majority of the population does not meet the AI for calcium, except for boys and girls, aged 1 to 3 years, due to fluid milk consumption (Bailey, 2010a). With diet alone, 96 percent and 94 percent of girls and boys, aged 1 to 3 years, respectively, and 67 percent and 80 percent of girls and boys, aged 4 to 8 years, respectively, meet the AI (500 mg/d and 800 mg/d for 1- to 3-year-olds and 4- to 8-year-olds, respectively). However, only 15 percent and 22 percent of girls and boys, aged 9 to 13 years, respectively, are above the AI of 1300 milligrams per day for calcium, and only 10 percent and 42 percent of adolescent girls and boys, respectively, aged 14 to 18 years, are above the AI of 1300 milligrams per day for calcium. Between 70 percent to 75 percent of women and 37 percent to 44 percent of men, aged 19 to 50 years, fail to meet the AI for calcium (1000 mg/d) (Figure D2.17). Less than 10 percent of women and less than 22 percent of men older than 51 years meet the AI for calcium (1200 mg/d). Forty-three percent of the population consumes supplements that contain calcium. When supplements are added to dietary intake, the percentage of children and adults up to age 30 years who meet their AIs improve very little. However, total calcium intakes increase substantially in women and men, aged 31 to 50 years, 51 to 70 years, and those older than 71 years when calcium supplements are used (Bailey, 2010a). Less than 2 percent of the population exceeds the UL for calcium (Bailey, 2010a). These calcium intakes are compared against the 1997 AI for calcium. Should the IOM determine new AIs for calcium, comparisons of intakes to AI standards should be adjusted accordingly.

Sources of Calcium: Fluid milk and milk products are the most bioavailable sources of calcium (Table D2.12) and are also the major sources of calcium in typical American diets (Table D2.13). The USDA Food Patterns specify 2 (for those 8 years and under) or 3 (for those 9 years and older) cup equivalents per day from the fluid milk and milk products food group and meets the goals for calcium intake.

The DGAC conducted a food pattern modeling analysis to assess nutrient adequacy with various changes in intake from the fluid milk and milk products group because: (1) many Americans fall short of the recommended intake levels for fluid milk and milk products (see Question 2 on Food Groups and Selected Dietary Components Underconsumed); (2) relative proportions of fluid milk and cheese consumption have changed over time and they differ in some important ways in nutrient content (Figure D2.18); and (3) some individuals desire non-dairy calcium sources for a variety of physiological, psychosocial, and personal reasons (see Appendix E3.6 at www.dietaryguidelines.gov for the full report). When fluid milk and milk products are removed from the USDA Food Patterns, calcium drops substantially below the AI across all energy levels. In addition, vitamins D and A, and choline, magnesium, phosphorus, and potassium also fall below 100 percent of DRI levels in some or all patterns. When fat-free fluid milk is substituted for some or all of the low-fat cheese in the USDA Food Patterns: (1) energy, protein, and calcium levels remain similar; (2) vitamin A, and choline, magnesium, and potassium increase slightly; (3) sodium, cholesterol, and saturated fatty acids decrease slightly; and (4) vitamin D content is substantially improved across energy levels. Of the non-dairy alternatives evaluated as a substitute for fluid milk, yogurt, and cheese in the USDA Food Patterns, soymilk fortified with calcium and vitamins A and D is the alternative with the most similar nutrient profile to fluid milk (compared to calcium-fortified rice drink or orange juice; tofu prepared with calcium sulfate; green vegetables; green soybeans; white beans; almonds; and canned sardines and salmon with bone).

Both calcium content and bioavailability should be considered when selecting dietary sources of calcium. The fluid milk and milk products food group provides more than 70 percent of the calcium consumed by Americans. Some plant foods contribute calcium that is well absorbed, but the large quantity of these plant foods that would be needed to provide the equivalent amount of calcium found in 8 ounces of fluid milk may be unachievable for many. Individuals who perceive that they are lactose intolerant or allergic to dairy products should be evaluated for such before unnecessarily limiting or eliminating dairy-based foods from their dietary patterns (NIH, 2010). Lactose-reduced or low-lactose dairy-based products may assist in obtaining nutrients provided by the fluid milk and milk products food group for those who are lactose intolerant.

Potassium—Conclusions and implications of inadequate dietary intakes of potassium related to health outcomes are presented in *Part D. Section 6: Sodium, Potassium, and Water*. Based on 2001-2002 NHANES data, usual intakes for less than 3 percent of Americans, older than 1 year, meet the AI for potassium (Moshfegh, 2005). Approximately 6 percent and less than 3 percent of adult men and women, respectively, consume potassium at intake levels that reach the AI. For boys and girls, aged 9 to 13 years and 14 to 18 years, and for children, aged 4 to 8 years, less than 3 percent of these age-sex groups meet AIs for potassium intakes. Approximately 6 percent of children, aged 1 to 3 years, reach the AI for potassium intake. Analysis of 2005-2006 NHANES data also indicates that potassium intakes fall short of the AIs for all age-sex groups, with approximately 97 percent of Americans not meeting recommended intake levels (Figure D2.19) (ARS, 2008).

Dietary sources of potassium are found in all food groups, notably in vegetables and fruits (see Question 2 on Food Groups and Selected Dietary Components Underconsumed). Table D2.14 lists the best food sources of potassium per standard amount, from the ARS nutrient database, along with the number of calories for each standard amount. Table D2.15 lists the major sources of potassium from American food consumption data. Americans typically consume potassium-rich foods in relatively low amounts. Americans should select foods from all food groups that are higher in potassium content to better meet recommendations for intake.

Dietary Fiber—Conclusions and implications regarding inadequate intakes of dietary fiber related to health outcomes are presented in *Part D. Section 5: Carbohydrates*. Based on 2003-2006 NHANES data, less than 3 percent of Americans, older than 1 year, have a usual intake of dietary fiber that exceeds the AI (ARS, 2010c). Less than 3 percent of adult men and approximately 6 percent and of adult women consume dietary fiber at intake levels that reach the AI. For boys and girls, aged 9 to 13 years and 14 to 18 years, and children, aged 1 to 3 years and 4 to 8 years, less than 3 percent of these age-sex groups meet their AIs for dietary fiber intakes (Figure D2.20).

Mean intakes of dietary fiber in 2005-2006, based on one-day data, were well below AI levels. For men, mean intake was 17.8 grams, in comparison to AIs of 38 gram (ages 19 to 50 years) or 30 grams (older than age 50 years). Mean intakes were similarly low in women, with a mean of 14.1 grams, in comparison to AIs of 25 grams (ages 19 to 50 years) or 21 grams (older than age 50 years) (ARS, 2008). For all Americans, older than 1 year, mean intakes of dietary fiber fall short of the AIs, with less than 3 percent meeting recommended intake levels (ARS, 2010c). Inadequate intake of dietary fiber is widespread.

Dietary sources of fiber are found in vegetables and fruits, whole grains, cooked dry beans and peas, and nuts—all foods that are lacking in the typical American diet (see Question 2 on Food Groups and Selected Dietary Components Underconsumed). Table D2.16 lists the best food sources of dietary fiber per standard amount, from the ARS nutrient database, along with the number of calories for each standard amount. Table D2.17 lists the major sources of dietary fiber from American food consumption data. Refined breads, rolls, buns, and pizza crust are not among the best sources of dietary fiber, but contribute substantially to what little dietary fiber is consumed because they are so ubiquitous in current dietary patterns of Americans. Refined grains are overconsumed in the American diet (see Question 1 on Nutrients and Dietary Components Overconsumed) and provide less dietary fiber per portion than vegetables, fruits, whole grains, cooked dry beans and peas, and nuts. Americans should replace such foods with foods that are higher in dietary fiber while not increasing total energy intakes.

NUTRIENT ISSUES FOR SELECTED POPULATION SUBGROUPS

The 2010 DGAC agrees with the 2005 DGAC Report, noting that special nutrient recommendations are warranted for the following subgroups and nutrients:

- Adolescent females and women of reproductive capacity—folic acid
- Adolescent females and women of reproductive capacity—iron
- Persons over age 50 years—vitamin B_{12}

Question 4: What Is the Relationship Between Folate Intake and Health Outcomes in the U.S. and Canada Following Mandatory Folic Acid Fortification?

Conclusion

Strong and consistent evidence demonstrates a large reduction in the incidence of NTDs in the U.S. and Canada following mandatory folic acid fortification. A limited body of evidence suggests stroke mortality has declined in the U.S. and Canadian populations following mandatory folic acid fortification. A limited body of evidence suggests that mandatory folic acid fortification has increased the incidence of colorectal cancer (CRC) in the U.S. and Canada.

Implications

Folic acid fortification in the U.S. and Canada appears to be successful in the primary health objective of reducing the incidence of NTDs. Although some negative consequences appear to have occurred (i.e., possible increase in CRC), the evidence supports the continuation of folic acid fortification of flour and uncooked cereals at current levels (140 μg/100 g). Despite the increases in folic acid through fortification, about 22 percent of women of reproductive capacity still do not meet the EAR. Women of reproductive capacity should continue to be counseled to select foods high in folate, and when necessary, take a folic acid supplement to meet their folate requirements. As a result of the increase in folic acid in food from fortification and because many adults take a supplement containing folic acid, approximately 5 percent of adults older than age 50 years now exceed the UL (1000 μg/d) for folic acid intake. To avoid exceeding the UL, adults over age 50 years should not supplement with folic acid in excess of 400 μg per day. Because whole grain foods are not always fortified with folic acid, individuals who consume mainly whole grains in their dietary patterns should ensure that some of these whole grains are fortified to achieve dietary folate recommendations.

Review of the Evidence

Background

In 1992, the U.S. Public Health Service recommended that all women of reproductive capacity consume 400 μg of folic acid daily to reduce the risk of NTDs. To help the public better meet this nutritional need, the Food and Drug Administration (FDA) authorized the addition of synthetic folic acid to all flour and uncooked cereal grains in March 1996, with mandatory compliance by January 1998. Similar mandates were authorized in Canada, with full compliance by November 1998.

As a result of mandated folic acid fortification, blood concentrations of folate increased in the U.S. and Canada. Five nationally representative studies (all using NHANES data) demonstrated that serum folate more than doubled between the pre- and post-fortification periods and that red blood cell (RBC) folate, a marker of long-term folate status, increased approximately 57 percent (Dietrich, 2005; Dowd, 2008; Ganji, 2006; Pfeiffer, 2007; Quinlivan, 2007). Prevalence of low serum folate (less than 3 ng/mL) and low RBC folate (less than 140 ng/mL) was significantly lower in the post-fortification periods. However, some women of reproductive capacity are still at risk for low folate concentrations (1% and 5%, respectively, for serum and RBC folate concentrations) (Pfeiffer, 2007). The prevalence of high serum folate (greater than 20 ng/mL) concentrations in children and adults older than age 60 years increased (from 5% to 42% and from 7% to 38%, respectively), but have decreased somewhat, especially in children, since fortification was first mandated and food companies have adjusted fortification levels to accurately meet the mandate (Pfeiffer, 2007).

Current dietary folate and supplemental folic acid intakes in the U.S. indicate that the majority of the population is achieving adequate folate intakes. A recent study by Bailey et al. (2010b) used NHANES data to estimate total folate and folic acid intakes in the U.S. between the years 2003 and 2006. Because the bioavailability of dietary folate is much lower than that of folic acid added to fortified foods and dietary supplements, researchers used a dietary folate equivalent (DFE) conversion (1 DFE = 1 μg food folate = 0.6 μg folic acid from supplements and fortified food) to reflect the differential bioavailability. Results of this study demonstrated that approximately 22 percent of all women were below the EAR for folate from diet only, though 28 percent of non-Hispanic Black women were below the EAR. For all men, only 5 percent to 10 percent across the different age categories were below the EAR, though 13 percent of non-Hispanic Black men were below the EAR. In all age-sex categories, slightly fewer people were below the EAR when folic acid from supplements was included. In the Bailey et al. (2010b) study, 53 percent of the population took dietary supplements, 34 percent of which contained folic acid.

Total folate and folic acid intakes were the highest in people older than age 50 years, with 5 percent of this population exceeding the UL. Another study, using the same NHANES data, reported that 34 percent of adults who consumed folic acid supplements in excess of 400 μg per day exceeded the UL (Yang, 2010). Exceeding the UL for folate intake is a concern as it may intensify or worsen neurological damage caused by vitamin B_{12} deficiency, as outlined by the IOM (FNB, 1998). In addition, some recent evidence indicates that folic acid at high exposure may have harmful effects even without vitamin B_{12} deficiency (Morris, 2005). Table D2.18 lists the best food sources of folate per standard amount, from the ARS nutrient database, along with the number of calories for each standard amount.

Folic Acid Fortification and Neural Tube Defects

Strong and consistent evidence demonstrates that the incidence of children being born with NTDs has been reduced following mandatory folic acid grain fortification in the U.S. and Canada. This conclusion is based on the review of 13 studies (Besser, 2007; Canfield, 2005; CDC, 2004; Chen, 2008; de Wals, 2007, 2008; Forrester, 2005; Godwin, 2008; Honein, 2001; Mosley, 2007; Persad, 2002; Williams, 2002, 2005). Of these 13 studies, nine were conducted in the U.S. and four were conducted in Canada. Given the ecologic nature of mandatory fortification, it was impossible to conduct a controlled trial during this time. The range of NTD reduction varied depending upon the study size and study design. The large, nationally representative trials conducted in the U.S. reported reductions of 23 percent to 54 percent in spina bifida and 11 percent to 16 percent in anencephaly. In Canada, one national trial demonstrated a 53 percent reduction in spina bifida and a 31 percent reduction in anencephaly.

Folic Acid Fortification and Stroke

A limited body of evidence suggests that stroke mortality has declined in the U.S. and Canada following mandatory folic acid fortification. This evidence is based upon one population cohort study conducted in the U.S., Canada, England, and Wales (Yang, 2006). This study evaluated trends in stroke-related mortality before and after folic acid fortification in the U.S. and Canada and, as a comparison, during the same period in England and Wales, where fortification is not mandated. The ongoing decline in stroke mortality observed in the U.S. and Canada between 1990 and 1997, accelerated in the years 1998 to 2002, in nearly all population strata. In contrast, the decline in stroke mortality in England and Wales did not change significantly between 1990 and 2002.

Folic Acid Fortification and Colorectal Cancer

A limited body of evidence suggests that mandatory folic acid fortification has increased the incidence of CRC in the U.S. and Canada. This evidence is based on two trend studies in the U.S. and Canada (Mason, 2007) and one in Chile, which instituted mandatory folic acid fortification in 2000 (Hirsch, 2009). In these studies, the increase in incidence of CRC coincided with mandatory folic acid fortification in each country. Mason et al. (2007) used U.S. and Canadian data collected between 1986 and 2002, by the Surveillance, Epidemiology and End Results Program to address the question. In the U.S., the absolute rates of CRC began to increase in 1996 and peaked in 1998. In Canada, the absolute rates of CRC began to increase in 1997 and peaked in 2000. The sudden increase in CRC incidence represents a significant deviation from the time period just before folic acid fortification in the U.S. by four to six additional cases per 100,000 individuals. It does not appear that changes in colorectal endoscopic procedures accounted for the increase in CRC incidence. Hirsch et al. (2009) compared rates of hospital discharges due to CRC in Chile before (1992-1996) and after (2001-2004) mandatory folic acid fortification (220 μg/100 g wheat flour). Results were described in two groups: (1) adults, aged 45 to 64 years, and (2) adults aged 65 to 70 years. In age group 1, the rate ratio of hospital discharges due to CRC was 2.6 for an overall increase of 162 percent. In age group 2, the rate ratio was 2.9. Hirsh et al. (2009) concluded that mandatory folic acid fortification may be associated with an increased risk of CRC.

Folic Acid Supplements and Other Health Outcomes

The DGAC also evaluated the health impact of folic acid supplementation in people with pre-existing cardiovascular disease (CVD). A systematic review was conducted to evaluate the effect of folic acid supplementation with or without additional B-vitamin supplementation on CVD. Strong evidence demonstrates that folic acid supplementation with or without additional B-vitamins in adult men and women with pre-existing vascular disease does not appear to reduce risk of CVD, and may even increase risk slightly. This conclusion is based on results from four well-designed randomized double-blind placebo controlled trials (Albert, 2008; Bonaa, 2006; Ebbing, 2008; Ray, 2007) and one meta-analysis (Bazzano, 2007) that analyzed 12 relevant randomized controlled trials. All of the reviewed studies were in consistent agreement that folic acid supplementation conferred no benefit, and two studies reported an increased CVD risk Evidence that folic acid supplementation might prevent stroke is inconsistent (Bazzano, 2007; Wang 2007; Sapsonik, 2009), with the most recent meta-analysis documenting no benefit (Miller, 2010).

Relevant Contextual Issues

Impact on Intake of Folate and Other Nutrients of Selecting All Grains as Whole Grains Rather Than Half Whole and Half Enriched Refined Grains

The USDA Food Patterns are designed to meet *Dietary Guidelines for Americans* and IOM recommendations. To achieve this, the 2005 *Dietary Guidelines for Americans* recommended that at least half of all grain intake come from whole grain sources. For the standard 2000 calorie dietary pattern, 6 ounce equivalents of grains are recommended, with 3 or more of these consumed as whole grains and preferably fiber-rich whole grains. This is interpreted in the USDA Food Patterns to be half of the recommended ounce equivalents of grains as whole grains, and half as enriched refined grains. For example, in the 2000 calorie pattern, 3 ounce equivalents of whole grains and 3 of enriched refined grains are included. The most commonly consumed refined grains are enriched with iron and other B-vitamins and fortified with folic acid. Whole grain products are typically not fortified with folic acid or enriched because many enrichment nutrients are naturally present in the whole grain. Ready-to-eat (RTE) whole grain cereals are the exception—many are fortified with a range of nutrients, including folic acid and enrichment nutrients. The DGAC chose to use modeling (see *Part C: Methodology*) to determine the impact on intake of folate and other nutrients if all recommended grains were selected as whole grains rather than half whole and half enriched refined grains (see online Appendix E3.7 at www.dietaryguidelines.gov for the full report). The whole grains selected to replace enriched refined grains for the purpose of this analysis were not enriched or fortified with folic acid, except for RTE cereals. To replace enriched-grain RTE cereals, two replacement foods were identified: (1) a non-fortified whole grain RTE cereal (scenario 1); and (2) a fortified whole grain RTE cereal (scenario 2).

The base USDA Food Patterns that include foods from all of the basic food groups provide adequate amounts of folate and other enrichment nutrients for all age-sex groups, with 625 μg of folate (155% of the RDA for women, aged 19 to 30 years) in the reference 2000 calorie pattern. The modified food patterns without any fortified whole grains (scenario 1) did not provide sufficient folate for girls, aged 14 to 18 years, women of all ages with low to moderate energy needs, and men older than age 50 years with relatively low energy needs. For example, in the 2000 calorie pattern, dietary folate levels fell to 332 μg (83% of the RDA for adults). In addition, the all-whole grains dietary patterns were low in iron for boys and girls, aged 2 to 8 years, and adolescent girls and women, aged 14 to 50 years. Inclusion of some fortified whole grain RTE cereals (scenario 2) in the all-whole grains dietary patterns improved nutrient levels to adequate amounts for dietary folate (392 μg or 98% of RDA) and also increased amounts of iron in the patterns somewhat.

As shown by food pattern modeling, consumption of all grains as whole grains, without including any fortified whole grain products, would lower dietary folate and iron intake levels to less than adequate amounts for individuals in population groups who may be at high risk for inadequate intakes of these nutrients. Individuals are encouraged to consume most of their grains as fiber-rich whole grains, and when doing so, should select some of these fiber-rich whole grains as products that have been fortified with folic acid and possibly other nutrients.

Question 5: Is Iron a Nutrient of Special Concern for Women of Reproductive Capacity?

Conclusion

Substantial numbers of adolescent girls and women of reproductive capacity have laboratory evidence of iron deficiency.

Implications

Efforts are warranted to increase dietary intake of heme-iron-rich foods and of enhancers of iron absorption by these special populations.

Review of the Evidence

A full systematic review was not conducted, because although the DGAC believes that the issue is still pertinent, little new data have been published since

2005. Laboratory values from 1999-2002 NHANES blood samples indicate that more than 5 percent of individuals, aged 1 to 59 years, have inadequate serum ferritin concentrations of less than 12 ng/mL or less than 15 ng/mL for children less than 5 years or greater than or equal to 5 years of age, respectively, and that more than 10 percent of individuals of all ages have low levels of transferrin saturation (less than 16%), suggestive of iron deficiency (USDHHS, 2008). More recent data indicate that from 3.7 percent to 14.4 percent of children, aged 1 to 5 years, and about 9 percent of women, aged 12 to 49 years, have inadequate stores of body iron (Cogswell, 2009).

From 15 percent to 17 percent of adolescent girls and women younger than 51 years, have usual iron intakes below their EARs (Moshfegh, 2005). In contrast, less than 3 percent of any other age-sex group has a usual intake below their EAR (Moshfegh, 2005). Adolescent girls consume a usual average daily intake of 13.3 milligrams per day, while adult women, aged 20 to 49 years, consume between 13.9 to 14.9 milligrams of iron per day (ARS, 2008). Moreover, women older than age 19 years fall short of meeting the recommended number of servings from the meat, poultry, fish, eggs, soy, nuts, and seeds food group, and a substantial number of adolescent girls also do not meet the recommended servings for this food group (see Question 2 on Food Groups and Selected Dietary Components Underconsumed) (NCI, 2009). Approximately 6.5 million adolescent girls and women of childbearing age are iron deficient. These findings support the need to encourage these special populations to increase dietary intake of foods that are sources of heme-iron, such as meat, poultry, and fish, and sources of nonheme-iron, such as fortified cereals and whole grains, while also achieving energy balance. Foods containing nonheme-iron should be consumed along with enhancers of iron absorption, such as vitamin C-rich foods and foods containing heme-iron. Table D2.19 lists the best food sources of iron per standard amount, from the ARS nutrient database, along with the number of calories for each standard amount.

Question 6: Are Older Adults Consuming Sufficient Vitamin B_{12}?

Conclusion

Recent evaluation of NHANES data shows that individuals older than age 50 years are consuming adequate intakes of vitamin B_{12}, including B_{12} found naturally in foods and crystalline B_{12} consumed in fortified foods. Nonetheless, a substantial proportion of individuals older than age 50 years may have reduced ability to absorb naturally occurring vitamin B_{12} but not the crystalline form.

Implications

Although individuals older than age 50 years appear to be meeting their need for vitamin B_{12}, they should be encouraged to consume foods fortified with B_{12}, such as fortified cereals, or the crystalline form of B_{12} supplements, when necessary. Practitioners should assess vitamin B_{12} status in those older than age 65 years, using a low serum vitamin B_{12} value of less than 300 pg/mL, high serum methylmalonic acid value of greater than 0.4 μmol/L, and serum total homocysteine level of greater than 15.0 μmol/L as evidence of vitamin B_{12} deficiency.

Review of the Evidence

A full systematic review was not conducted, because although the DGAC believes that the issue is still pertinent, little new data have been published since 2005. However, the conclusion was supported by evidence from a published systematic review conducted for the IOM (FNB, 1998) and updated to 2009, by laboratory studies designed to screen for functional vitamin B_{12} status, as summarized below, and by dietary intake findings from the NHANES.

Based on a systematic, extensive review of published literature, the IOM (FNB, 1998) set the RDA for vitamin B_{12} at 2.4 μg per day for individuals aged 14 years and above and for both sexes. Because 10 percent to 30 percent of the older population may be unable to absorb naturally-occurring vitamin B_{12}, the IOM advised that people age 50 years and older should meet their RDA mainly by consuming foods fortified with vitamin B_{12} or by taking vitamin B_{12}-containing supplements. This RDA was based on the amount needed to maintain the hematological status, as well as the normal serum vitamin B_{12} level. Vitamin B_{12} deficiency, as determined by serum B_{12} of less than 148 pmol/L in combination with serum homocysteine of greater than 10 μmol/L, was found in approximately 2.5 percent of adults older than age 50 years. Supplement use reduced the prevalence of B_{12} deficiency to less than 0.5 percent of adults older than age 50 years (Evatt, 2010). The incidence of vitamin B_{12} deficiency increases with age, and marginal B_{12} status occurs in as many as 20 percent of individuals older than 60 years (Allen, 2009). Neurological manifestation of vitamin B_{12} deficiency was not used to establish vitamin B_{12} status because it occurs at a later depletion stage than does the hematological status. Furthermore, the progression of neurological manifestation is variable, generally gradual, and currently not amenable for easy quantification. A Cochrane review (Malouf, 2008) with a 2009 update concluded that the major effect of folate with or without vitamin B_{12} on cognitive function occurred in those individuals with high homocysteine concentrations. Three additional randomized controlled trials (RCTs) (Aisen, 2008; Ford, 2008; Gariballa, 2007), examining the effects of vitamin B_{12} supplementation in combination with folate and or vitamin B_6 on dementia, cognition, and depression, did not find beneficial effects in the groups studied despite an increase in B_{12} status (Aisen, 2008). Therefore, individuals older than age 50 years should achieve a total intake of vitamin B_{12} consistent with IOM recommendations by eating fortified foods or by taking the crystalline form of vitamin B_{12} supplements and in balance with folate and vitamin B_6.

Studies using serum radioimmunoassay of vitamin B_{12}—combined with serum homocysteine and methylmalonic acid values—to screen for functional vitamin B_{12} status further support this conclusion. A low serum vitamin B_{12} value (less than 300 pg/mL), high serum methylmalonic acid value (greater than 0.4 μmol/L) and homocysteine (greater than 15.0 μmol/L) would suggest vitamin B_{12} deficiency. Using results from these three laboratory tests, Clarke et al. (2004) reported the prevalence rate of vitamin B_{12} deficiency to be 1 in 20 among people aged 65 to 74 years, and 1 in 10 among people aged 75 years and older. In addition, various clinical trials (McKay, 2000), either among free-living or institutionalized elderly, demonstrated that either oral vitamin B_{12} supplements alone or as multivitamin/mineral supplements could improve vitamin B_{12} status. A systematic review of oral versus intramuscular vitamin B_{12} in the treatment of vitamin B_{12} deficiency found that oral doses may be as effective as intramuscular administration in inducing short-term hematological and neurological responses (Butler, 2006). All individuals older than age 65 years should be screened for deficiency with simple tests of serum vitamin B_{12} status (Goringe, 2006).

According to 2005-2006 NHANES data, the estimated mean daily vitamin B_{12} intakes from foods ranged from 3.96 (girls, aged 12 to 19 years) to 7.91 μg (men, aged 40 to 49 years) (ARS, 2008). For men and women, means and standard errors of vitamin B_{12} intakes were 6.62±0.763 μg per day (men aged 60 to 69 years), 6.092±0.477 μg per day (men aged 70+ years), 4.69±0.403 μg per day (women aged 60 to 69 years), and 4.38±0.171 μg per day (women aged 70+ years). These mean intakes were similar to or somewhat greater than mean intakes reported for 2001-2002, as estimates of usual intake distributions showed that more than 95 percent of men and 90 percent of women, aged 50 years and older, had usual total vitamin B_{12} intakes above the EAR (Moshfegh, 2005). These NHANES estimates included the B_{12} naturally occurring in foods and added to foods as fortificants. However, the IOM recommends that adults older than age 50 years meet much of their vitamin B_{12} requirement by consuming foods fortified with vitamin B_{12} or a supplement containing it (FNB, 1998). In 2005-2006, mean daily amounts of crystalline vitamin B_{12}, found in fortified foods, for older adults were 1.22 μg per day (men aged 60 to 69 years), 1.28 μg per day (men aged 70+ years), 0.84 μg per day (women aged 60 to 69 years), and 1.14 μg per day (women aged 70+ years) (ARS, 2008). Thus, 18 percent to 26 percent of the vitamin B_{12} in foods consumed by older adults is in crystalline form. Table D2.20 lists the best food sources of vitamin B_{12} per standard amount, from the ARS nutrient database, along with the number of calories for each standard amount.

VITAMIN, MINERAL, AND NUTRIENT SUPPLEMENTS

The DGAC encourages Americans to achieve nutrient adequacy through a total diet in which they select and consume nutrient-dense forms of foods from the basic food groups. However, 53 percent of the American population uses vitamin, mineral, and nutrient supplements (Bailey, 2010a). Therefore, the DGAC examined the literature regarding potential health effects of such supplementation in healthy Americans.

Question 7: Can a Daily Multivitamin/Mineral Supplement Prevent Chronic Disease?

Conclusion

For the general, healthy population, there is no evidence to support a recommendation for the use of multivitamin/mineral supplements in the primary prevention of chronic disease. Limited evidence suggests that supplements containing combinations of certain nutrients are beneficial in reversing chronic disease when used by special populations; in contrast, certain nutrient supplements appear to be harmful in other subgroups.

Implications

Although intake of a variety of multivitamin/mineral supplements increase blood levels of many nutrients, notably in individuals with suboptimal nutrient status before supplementation (Maraini, 2009), long-term effects on primary prevention of several chronic diseases has not been demonstrated. In this context, obtaining essential micronutrients from foods when possible is the optimal approach and reliance on multivitamin/mineral supplements is discouraged. At present, Americans are encouraged to meet overall nutrient requirements within energy levels that balance daily energy intake with expenditure. This can be accomplished through a variety of food intake patterns that include nutrient-dense forms of foods.

Review of the Evidence

The DGAC evaluated three primary sources of evidence to reach this conclusion: (1) an AHRQ-commissioned systematic review on nutrient supplements and chronic disease prevention (Huang, 2006); (2) the 2006 NIH "State-of-the-Science Conference on Multivitamin/Mineral Supplements for Chronic Disease Prevention" (Coates, 2007a); and (3) the *American Journal of Clinical Nutrition* supplement, "*n*-3 Fatty Acids: Recommendations for Therapeutics and Prevention" (Akabas, 2006a). This review was limited to vitamins, minerals, and EPA and DHA. Other dietary supplements—such as botanicals, hormones, peptides, and amino acids—were not evaluated.

Huang et al. (2006) established four key questions to guide the examination of published literature regarding health outcomes of multivitamin/mineral supplements in the primary prevention of 10 chronic disease categories, including cancer, vascular, endocrine, neurological, sensory, liver, renal, musculoskeletal, infectious, and pulmonary diseases. These investigators also evaluated published data on the effects of 14 single-nutrient supplements and four functionally related paired-nutrient supplements on these chronic diseases as well as the safety of eight single-nutrient supplements on health-related outcomes. Their conclusions were based on findings reported in 63 published papers. NIH conference panelists used this AHRQ report (Huang, 2006) as a foundational piece of evidence for their independent review, along with further scientific evidence provided by scientific experts who addressed six key questions posed by the NIH panel. The DGAC used the three key sources of evidence, as previously indicated, along with three meta-analyses, three systematic reviews, and 11 randomized controlled nutrient supplementation trials that were published after the 2006 AHRQ report and 2006 NIH conference to group and summarize overall evidence by outcome or body system.

Cancer

In healthy adults, no effects of beta-carotene supplementation or a combined vitamin A plus zinc supplement or vitamin A plus beta-carotene supplement on cancer prevention were reported. There was an observed beneficial effect of a combined beta-carotene, vitamin E, and selenium supplement on lowering gastric cancer incidence and gastric and overall cancer mortality in inadequately nourished men and women in China. A reduced overall cancer risk in men, but not women, in France, was noted with a beta-carotene, vitamins E and C, selenium, and zinc combination. Lowering of prostate cancer incidence and mortality in men and CRC in adult smokers with vitamin E supplementation was reported. An observed adverse effect of beta-carotene supplementation or a combined beta-carotene plus vitamin A supplement on lung cancer and mortality in adult smokers and in individuals exposed to asbestos was noted. Data presented by program participants of the NIH conference (NIH, 2006) were congruent with the AHRQ report (Huang, 2006) regarding beneficial effects of a combined beta-carotene, vitamin E, and selenium supplement on lowering gastric cancer in nutritionally deficient adults in China (Greenwald, 2007) and harmful effects of beta-carotene supplementation or a combined beta-carotene plus vitamin A supplement on increasing lung cancer in adult smokers and individuals exposed to asbestos (Greenwald, 2007).

A meta-analysis (Tanvetyanon 2008) confirmed that lung cancer incidence increased with beta-carotene supplementation in former smokers and individuals exposed to asbestos. Conversely, lung cancer incidence was not significantly increased in the overall population of male physicians (Hennekens, 1996) or women in health professions who were not former smokers (Lee, 1999) and who consumed beta-carotene supplements on alternate days. Among all current smokers, the risk of lung cancer incidence significantly increased by 24 percent in individuals receiving any beta-carotene supplement. A more recent study by Liu et al. (2009) examined a panel of cancer markers in stored lung tissue from participants of the Physician's Health Study who developed lung cancer. Neither smoking status nor beta-carotene supplementation status was significantly different for the 39 men from whom samples of lung tissue were provided. Significant differences in selected markers of lung cancer were not found between adult men supplemented with beta-carotene versus placebo, suggesting that factors other than the beta-carotene supplement lead to lung cancer development.

Among healthy postmenopausal women living in rural Nebraska, combined calcium plus vitamin D supplementation lowered all-cancer risk over a 4-year intervention compared to placebo or calcium alone (Lappe, 2007). Recent findings from the Selenium and Vitamin E Cancer Prevention Trial (SELECT) demonstrated that supplementation of selenium alone, vitamin E alone, or combined selenium plus vitamin E had no effect on prostate cancer compared to placebo in adult men in the U.S., Puerto Rico, and Canada (Lippman, 2009).

Cardiovascular Disease

In adults, no effect of beta-carotene supplementation on CVD was noted, and no effect of a combined beta-carotene, vitamins E and C, selenium, and zinc supplement on ischemic CVD incidence was reported. Among adults, a combined vitamin A plus zinc supplement or vitamin A plus beta-carotene supplement had no impact on cerebrovascular disease or CVD (Huang, 2006; NIH, 2006). The effect of vitamin E supplementation on CVD prevention, particularly among older women, had incomplete evidence on which to base a positive recommendation for supplementation (Traber, 2007). Additional vitamin K, beyond that consumed in a multivitamin supplement, reduced the progression of coronary artery calcification in individuals with greater than or equal to 85 percent supplementation compliance and in individuals with preexisting coronary artery calcification (Shea, 2009).

EPA and DHA supplementation as a treatment strategy lowered blood concentration of triacylglycerol as a marker of CVD, lowered overall mortality in persons with CVD, and lowered arrhythmias and sudden death (Akabas, 2006b). The American Heart Association recommends a total of 1 gram per day of EPA plus DHA from a combination of higher omega-3 fatty acid-containing fish and supplements, if needed, in individuals with coronary heart disease (Kris-Etherton, 2002) (see *Part D. Section 3: Fatty Acids and Cholesterol* for a discussion on fish intake).

Sensory Disease

In adults, no effects of beta-carotene supplementation on sensory diseases were reported. Lessening of age-related macular degeneration and total mortality, only in adults with intermediate or advanced disease, with supplementation of zinc or zinc plus antioxidant nutrients was noted. However, no effect of multivitamin/mineral supplements on preventing cataracts in healthy Americans was found (Huang, 2006; NIH, 2006).

A combined zinc plus antioxidant nutrients supplement that also included copper reversed age-related macular degeneration in individuals with diagnosed disease (Seddon, 2007). A common over-the-counter multivitamin/mineral supplement reduced total (by 18%) and nuclear (by 34%) lens events but doubled the number of posterior subcapsular cataracts in men and women, aged 55 to 75 years (Clinical Trial of Nutritional Supplements and Age-Related Cataract, CTNS, 2008). Findings from the Women's Health Study demonstrated that vitamin E supplementation on alternate days, versus placebo, had no effect on overall cataract incidence or nuclear, cortical or posterior subcapsular cataract incidence, even when controlling for cataract progression risk factors (Christen, 2008). Fish intake, but not EPA or DHA supplements, was related to lower risk of macular degeneration (Johnson, 2006).

Some evidence supports DHA supplementation by pregnant women and lactating mothers at 200 to 300 milligrams per day to promote cognitive development and possibly visual acuity in their offspring (Eilander, 2007; Koletzko, 2008). Consumption of 6 to 10 ounce equivalents of seafood per week would achieve the DHA intake goal (Brenna, 2009) for this population (see *Part D. Section 3: Fatty Acids and Cholesterol*).

Musculoskeletal Disease

Retention of bone mineral density in postmenopausal women is well-documented with calcium supplementation and a reduction in hip and non-vertebral fractures and falls with combined calcium and vitamin D supplements in older women, particularly those with low levels of these nutrients before supplementation (Huang, 2006; NIH, 2006). Modest positive effects of a combined calcium plus vitamin D supplement on bone health and fall prevention in older individuals has been confirmed in recent studies

(Heaney, 2007). Vitamin K supplementation does not appear to provide significant benefit to bone mineral density in older adults (Booth, 2008), although vitamin K is an important nutrient for bone health.

Neurological and Central Nervous System Disease

A study in community-living older adults in Scotland found that daily supplementation with combined vitamins A, C, D, E, B_6 and B_{12}, thiamin, riboflavin, niacin, folic acid, pantothenic acid, iron, zinc, copper, manganese, and iodine did not prevent cognitive decline, although supplementation was associated with positive changes in verbal fluency among participants older than age 75 years and in those at risk of nutritional deficiency (McNeill, 2007). Pitkin (2007) noted that supplementation of women of reproductive capacity with folic acid, along with adequate intake of folic acid-fortified foods and usual intakes of dietary folate, was beneficial in preventing NTDs in offspring (see Question 4 within Nutrient Issues for Selected Population Subgroups). An additional topic addressed by the NIH panel included the effect of vitamin B_6 and of folic acid, with or without vitamin B_{12}, supplementation on cognitive decline; no effects were reported in older adults (NIH, 2006) (see Question 6 within Nutrient Issues for Selected Population Subgroups).

DHA may lower risk of cognitive decline and Alzheimer's disease (Akabas, 2006b), although a more recent 2-year randomized controlled trial of EPA plus DHA supplementation in older individuals showed no change in cognitive function compared to an olive oil control (Dangour, 2010). DHA supplementation modulated functional brain activity in healthy boys, aged 8 to 10 years (McNamara, 2010), although this evidence was exploratory and requires further investigation. EPA plus DHA supplementation did not impact self-rated depression in a group of non-depressed older individuals compared to a placebo group (van de Rest, 2008). One meta-analysis concluded that EPA plus DHA supplementation improved mood only in individuals already diagnosed with mood disorders (Appleton, 2010).

Other Systems

In adults, no effects of beta-carotene supplementation on endocrine diseases were reported (Huang, 2006). EPA and DHA may improve insulin sensitivity (Akabas, 2006b). Effects of a daily multivitamin/mineral supplement on liver, renal, infectious, and pulmonary diseases have not been documented (NIH, 2006).

Other Factors

An increased risk of kidney stone formation with calcium supplementation and discoloration of the skin with beta-carotene supplement use was noted (Huang, 2006). However, few, if any, randomized placebo-controlled clinical trials have tested the safety of nutrient supplements used as single or combinations of nutrients by the healthy population of Americans. A meta-analysis that examined effects of beta-carotene, vitamins A, C, and E, and selenium as single nutrients or as combinations of antioxidants on various outcome measures reported increased risk of death across a variety of low-bias clinical trials with beta-carotene and vitamins A and E supplementation (Bjelakovic, 2007).

Relevant Contextual Issues

One distinct limitation to studies on the effects of multivitamin/mineral supplement use on chronic disease endpoints is insufficient standardization of preparation compositions and characteristics (Yetley, 2007). Some discrepancies exist between the actual content of nutrients in supplements and the amounts reported on product labels, along with differences in chemical formulations and dosing regimens that affect bioavailability, bioequivalency, and, ultimately, biological effects. Although randomized placebo-controlled trials reduce confounding effects on primary outcomes of interest in rigorous studies, the fact that 53 percent of adults in the U.S. use multivitamin/mineral supplements on a somewhat regular basis (Bailey, 2010a), with supplements contributing substantially to overall adequacy of nutrient intakes among adults (Murphy, 2007), limits the generalizability of nutrient supplement effects within a healthy and adequately nourished population. Nutritional status at baseline may modify long-term health effects of nutritional supplements as may the age at which nutritional supplements are initiated and the duration of their use (Fairfield, 2007). Moreover, typical users of multivitamin/mineral supplements are older, non-Hispanic white women and individuals with higher education and physical activity levels, lower BMI, and greater nutrient adequacy from dietary intake (Rock, 2007). These demographic and physical characteristics are also positively correlated to an overall healthy lifestyle, including health care screening and self-efficacy in primary prevention of chronic disease. Distinguishing the contribution of a single-nutrient or combined-nutrient supplement to long-term health outcomes is difficult in a healthy population (Coates, 2007b).

NUTRIENT INTAKE AND SELECTED BEHAVIORS

Meeting food and nutrient intake recommendations is challenging for many Americans. The DGAC evaluated selected individual behaviors to explore factors that may be associated with nutrient intakes.

Question 8: What Is the Relationship Between Nutrient Intake and Breakfast Consumption, Snacking, and Eating Frequency?

Conclusion

Moderate evidence supports a positive relationship between breakfast consumption and intakes of certain nutrients in children, adolescents, and adults. A limited body of evidence supports a positive relationship between snacking and increased nutrient intake in children, adolescents, adults, and older adults, and inadequate evidence is available to evaluate the relationship between eating frequency and nutrient intakes.

Implications

Americans are encouraged to eat nutrient-dense forms of foods for breakfast while staying within energy needs to facilitate achieving nutrient recommendations. Likewise nutrient-dense forms of foods are suggested for any snacks, if energy allowance permits this behavior without incurring weight gain.

Review of the Evidence

Individual behaviors influence the intake of foods and nutrients. The DGAC conducted systematic reviews to address selected behaviors and their association with nutrient intakes.

Breakfast Consumption

Without consideration of nutrient composition, some evidence supports a positive relationship between the behavior of breakfast eating and higher intakes of certain nutrients across different stages of the lifespan. The DGAC reviewed 15 studies published since 2004. Of these 15 studies, one systematic review included studies with children and adolescents (Rampersaud, 2005), while four primary studies included only adults (Kerver, 2006; Song, 2005; van der Heijden, 2007; Williams, 2005), nine evaluated children and/or adolescents (Affenito, 2005; Dubois, 2009; Matthys, 2007; Nelson, 2007; Stockman, 2005; Timlin, 2008; Williams, 2007, 2009; Woodruff, 2008), and one included adolescents and adults (Song, 2006). The exact same nutrients were not evaluated in all studies, but individuals who consumed breakfast on a daily basis consistently reported higher intakes of thiamin, niacin, riboflavin, vitamins B_6 and B_{12}, dietary folate, vitamins A and C, calcium, iron, magnesium, phosphorus, potassium, and zinc. In studies that included dietary fiber, breakfast intake was associated with higher intakes. An equal number of studies showed that breakfast consumers had higher, lower, or no difference in total fat, saturated fat, cholesterol, and sodium intakes compared to non-consumers of breakfast.

Snacking

Limited evidence published since 2004 supports a positive relationship between snacking and higher nutrient intakes at various stages of the lifespan. Seven studies were reviewed; three included children or adolescents (Macdiarmid, 2009; Maffeis, 2008; Sebastian, 2008), and four examined adults or older adults (Kerver, 2006; Ovaskainen, 2006; Stockman, 2005; Zizza, 2007). The same nutrients were not evaluated in all studies, but in general, snacking was associated with higher intakes of macronutrients and dietary folate, vitamin C, calcium, magnesium, iron, potassium, and dietary fiber but also higher intakes of total sugars and saturated fatty acids. Snacking by some adolescents and adults was associated with lower intakes of protein, fat, cholesterol, and iron, but data were inconsistent.

Eating Frequency

Only three cross-sectional studies were published since 2004 (Kerver, 2006; Macdiarmid, 2009; Storey, 2009) that met the criteria for review to evaluate the relationship between eating frequency and nutrient intakes. Given this lack of robust evidence, the DGAC was unable to draw a conclusion regarding nutrient intakes and eating frequency.

Relevant Contextual Issues

A clear and consistent operational definition of breakfast did not exist and varied across studies reviewed. In fact, breakfast consumption and breakfast skipping were defined uniquely in most studies. Likewise, consistent definitions for snacking and eating frequency were not used. A variety of nutrients were included in dietary intake analyses, and the possibility of publication bias for positive results exists. Energy density of breakfast foods has an inverse relationship with daily intakes of selected micronutrients, including vitamins A, C, and E, and potassium, magnesium, and phosphorus, as well as dietary fiber (Kant, 2008). Consuming nutrient-dense breakfast foods within a total daily diet that is low in energy-density may facilitate meeting nutrient recommendations.

Chapter Summary

Americans are encouraged to lower overall energy intakes to match their energy needs. Energy-dense forms of foods, especially foods high in SoFAS, should be replaced with nutrient-dense forms of vegetables, fruits, whole grains, and fluid milk and milk products to increase intakes of shortfall nutrients and nutrients of concern—vitamin D, calcium, potassium, and dietary fiber. Women of reproductive capacity should consume foods rich in folate and iron, and older individuals should consume foods rich in vitamin B_{12} or the crystalline form of B_{12} supplements. A daily multivitamin/mineral supplement is unlikely to offer health benefits to healthy Americans. Breakfast consumption and some snacking may assist in meeting nutrient recommendations, notably if included foods are in nutrient-dense forms.

Needs for Future Research

Recommendations for further studies include:

Nutrients and Dietary Components Overconsumed

1. Develop and test behavior-based interventions designed to lower dietary intakes of nutrients and dietary components overconsumed, focusing on SoFAS.

   Rationale: SoFAS contribute a substantial number of calories to the typical American diet without adding important micronutrients. Interventions that are proven successful in lowering dietary components overconsumed are needed to assist consumers and health care providers.

Food Groups and Selected Dietary Components Underconsumed

2. Conduct clinical trials in children and adults to critically examine the impact of adherence to the 2010 *Dietary Guidelines for Americans* as a total dietary approach to a healthy lifestyle on body weight change, CVD, T2D, cancer, and osteoporosis and related clinical endpoints.

   Rationale: Theoretically, food-based dietary guidance supports achievement of nutrient adequacy across age-sex groups. Total diets, including variation in eating and dietary patterns, compared to individual nutrients, have been insufficiently tested for their health outcomes.

3. Quantitatively and/or qualitatively investigate how the food environment facilitates or hinders achievement of food groups and dietary components recommendations, notably in individuals enrolled in food assistance programs, particularly children participating in school breakfast and lunch programs, and/or across various ethnic and cultural groups.

   Rationale: Compliance with dietary guidance is poor. Understanding the food environment at all levels will assist individuals and shape public policy toward intakes that meet recommendations for food groups and dietary components.

Vitamin D

4. Conduct high-quality, long-term dose-response studies with relevant health outcomes including bone as well as functional outcomes related to the immune system, autoimmune disorders, and chronic diseases such as coronary heart disease, hypertension, cancer, and diabetes.

   Rationale: There is a need for additional research on the relation between threshold values of 25(OH)D and relevant functional outcomes at each life stage and in understudied populations.

5. Investigate the metabolic partitioning, fate, and mobilization of key vitamin D metabolites at recommended and greater than recommended levels.

Rationale: Studies that assess the availability of stored vitamin D, relative contributions of endogenously produced and dietary vitamin D, and impact of important confounders such as body weight and body fat on vitamin status are warranted (Brannon, 2008b).

Folate

6. Conduct studies on the long-term health impact of fortification on NTDs, CRC, stroke, cognitive function, and other health outcomes, such as emerging evidence suggesting that high folic acid intakes in some pregnant women may lead to asthma in their offspring (Whitrow, 2009), to fully understand the impact of this ecological experiment.

   Rationale: A substantial amount of time has elapsed since the U.S. and Canada mandated folic acid fortification. Since 1998, many research studies have evaluated the benefits and risks of fortification. Much of the research demonstrated benefit, while some of the research has shown increased health risk. Further research is warranted.

Vitamin, Mineral, and Nutrient Supplements

7. Conduct studies on the precision in self-reported intakes of multivitamin/mineral supplements.

   Rationale: More than one-half of the population reports the use of nutrient supplements; however, the frequency and consistency of this use is sporadic for many. Greater accuracy in self-reported use of nutrient supplements is important to understanding short- and long-term health effects.

8. Develop accurate composition and bioavailability data across the multitude of vitamin, mineral, and nutrient supplements. Evaluate outcomes based on nutrient composition and bioavailability within the multivitamin/mineral matrix.

   Rationale: Precise composition of supplements is critical to determining interactions of nutrients within each supplement preparation and potential benefits and risks of the matrix of nutrients from supplements consumed with foods.

9. Conduct randomized controlled trials that rigorously test health outcomes, including safety and risk assessments, of nutrient supplements in a diverse range of healthy population groups.

   Rationale: Research on the efficacy and safety of nutrient supplements is vital to the guidance of public policy recommendations, given that the majority of Americans use nutrient supplements at any point in time.

Nutrient Adequacy and Eating Behaviors

10. Convene a consensus panel to define breakfast, breakfast consumers, and breakfast skipping; snacking; and eating frequency that can be consistently applied to studies.

    Rationale: Identifying healthful eating behaviors is important to primary prevention of chronic disease in Americans. Common definitions of specific eating behaviors are vital to testing and understanding the role of these behaviors in health and wellness.

11. Conduct longitudinal studies on the cumulative nutritional risks of breakfast skipping and/or health benefits of breakfast consumption. Identify critical components of breakfast and snacks, such as vegetables, fruits, whole grains, and/or fluid milk and milk products, and their related health benefits.

    Rationale: Breakfast intake is associated with positive outcomes such as improved school performance among children. Further understanding of other nutrition-related health benefits is needed.

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Part D. Section 2: Nutrient Adequacy—Tables

Table D2.1. Nutritional goals for age/sex groups, based on Dietary Reference Intakes and Dietary Guidelines recommendations, and USDA food patterns using these goals as targets[1]

Nutrient (units)	Source of Goal	Child 1-3	Female 4-8	Male 4-8	Female 9-13	Male 9-13	Female 14-18	Male 14-18	Female 19-30	Male 19-30	Female 31-50	Male 31-50	Female 51+	Male 51+
Macronutrients														
Protein (g)	RDA[2]	13	19	19	34	34	46	52	46	56	46	56	46	56
(% of calories)	AMDR[3]	5-20	10-30	10-30	10-30	10-30	10-30	10-30	10-35	10-35	10-35	10-35	10-35	10-35
Carbohydrate (g)	RDA	130	130	130	130	130	130	130	130	130	130	130	130	130
(% of calories)	AMDR	45-65	45-65	45-65	45-65	45-65	45-65	45-65	45-65	45-65	45-65	45-65	45-65	45-65
Total fiber (g)	14g/1000 kcal[4]	14	17	20	22	25	25	31	28	34	25	31	22	28
Total fat (% kcal)	AMDR	30-40	25-35	25-35	25-35	25-35	25-35	25-35	20-35	20-35	20-35	20-35	20-35	20-35
Saturated fat (% kcal)	DG[5]	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%
Linoleic acid (g)	AI	7	10	10	10	12	11	16	12	17	12	17	11	14
(% kcal)	AMDR	5-10	5-10	5-10	5-10	5-10	5-10	5-10	5-10	5-10	5-10	5-10	5-10	5-10
α-Linolenic acid (g)	AI	0.7	0.9	0.9	1.0	1.2	1.1	1.6	1.1	1.6	1.1	1.6	1.1	1.6
(% kcal)	AMDR	0.6-1.2	0.6-1.2	0.6-1.2	0.6-1.2	0.6-1.2	0.6-1.2	0.6-1.2	0.6-1.2	0.6-1.2	0.6-1.2	0.6-1.2	0.6-1.2	0.6-1.2
Cholesterol (mg)	DG	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Minerals														
Calcium (mg)	AI[6]	500	800	800	1300	1300	1300	1300	1000	1000	1000	1000	1200	1200
Iron (mg)	RDA	7	10	10	8	8	15	11	18	8	18	8	8	8
Magnesium (mg)	RDA	80	130	130	240	240	360	410	310	400	320	420	320	420
Phosphorus (mg)	RDA	460	500	500	1250	1250	1250	1250	700	700	700	700	700	700
Potassium (mg)	AI	3000	3800	3800	4500	4500	4700	4700	4700	4700	4700	4700	4700	4700
Sodium (mg)	UL[7]	<1500	<1900	<1900	<2200	<2200	<2300	<2300	<2300	<2300	<2300	<2300	<2300	<2300
Zinc (mg)	RDA	3	5	5	8	8	9	11	8	11	8	11	8	11
Copper (μg)	RDA	340	440	440	700	700	890	890	900	900	900	900	900	900
Selenium (μg)	RDA	20	30	30	40	40	55	55	55	55	55	55	55	55

Table D2.1 (continued). Nutritional goals for age/sex groups, based on Dietary Reference Intakes and Dietary Guidelines recommendations, and USDA food patterns using these goals as targets[1]

Nutrient (units)	**Source of Goal**	**Child 1-3**	**Female 4-8**	**Male 4-8**	**Female 9-13**	**Male 9-13**	**Female 14-18**	**Male 14-18**	**Female 19-30**	**Male 19-30**	**Female 31-50**	**Male 31-50**	**Female 51+**	**Male 51+**
Vitamins														
Vitamin A (μg RAE)	RDA	300	400	400	600	600	700	900	700	900	700	900	700	900
Vitamin D (μg)	AI	5	5	5	5	5	5	5	5	5	5	5	10	10
Vitamin E (mg AT)	RDA	6	7	7	11	11	15	15	15	15	15	15	15	15
Vitamin C (mg)	RDA	15	25	25	45	45	65	75	75	90	75	90	75	90
Thiamin (mg)	RDA	0.5	0.6	0.6	0.9	0.9	1	1.2	1.1	1.2	1.1	1.2	1.1	1.2
Riboflavin (mg)	RDA	0.5	0.6	0.6	0.9	0.9	1	1.3	1.1	1.3	1.1	1.3	1.1	1.3
Niacin (mg)	RDA	6	8	8	12	12	14	16	14	16	14	16	14	16
Vitamin B_6 (mg)	RDA	0.5	0.6	0.6	1	1	1.2	1.3	1.3	1.3	1.3	1.3	1.5	1.7
Vitamin B_{12} (μg)	RDA	0.9	1.2	1.2	1.8	1.8	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Choline (mg)	AI	200	250	250	375	375	400	550	425	550	425	550	425	550
Vitamin K (μg)	AI	30	55	55	60	60	75	75	90	120	90	120	90	120
Folate (μg DFE)	RDA	150	200	200	300	300	400	400	400	400	400	400	400	400
USDA Food Pattern **using goals as targets**		1000	1200	1400	1600	1800	1800	2200	2000	2400	1800	2200	1600	2000

[1]USDA Food intake patterns at 2600, 2800, 3000, and 3200 calories were designed to meet the needs of males 14 to 18 and 19 to 30. Their nutritional goals are the same as for the patterns at 2200 and 2400 calories.
[2] Recommended Dietary Allowance, IOM.
[3] Acceptable Macronutrient Distribution Range, IOM.
[4] 14 grams per 1000 calories, IOM.
[5] Dietary Guidelines recommendation.
[6] Adequate Intake, IOM.
[7] Upper Limit, IOM.
Sources: IOM 2006, Britten et al., 2006.

Table D2.2. Vitamin A: Food sources ranked by amounts of vitamin A and energy per standard food portions and per 100 grams of foods (Amounts of vitamin A present in standard food portions are ≥ 20% of RDA for adult men, which is 900 μg RAE [1])

Food	Standard Portion Size	Calories in Standard Portion[2]	Vitamin A in Standard Portion (μg RAE)[2]	Calories per 100 grams[2]	Vitamin A per 100 grams (μg RAE)[2]
Organ meats (liver, giblets), various, cooked	3 ounces	133-169	1490-9126	157-199	1753-10737
Carrot juice	1 cup	94	2256	40	956
Braunschweiger (pork liver sausage)	2 slices (~1 ½ ounces)	118	1519	327	4220
Sweet potato, baked	1 medium	103	1096	90	961
Pumpkin, cooked from fresh or canned	½ cup	24-42	306-953	20-34	250-778
Carrots, cooked from fresh, frozen, or canned	½ cup	18-27	407-665	25-37	558-852
Spinach, cooked from fresh, frozen, or canned	½ cup	21-32	472-573	23-34	490-603
Carrot, raw	½ cup	25	509	41	835
Collards, cooked from fresh or frozen	½ cup	25-31	386-489	26-36	406-575
Kale, cooked from fresh or frozen	½ cup	18-20	443-478	28-30	681-735
Mixed vegetables, cooked from frozen or canned	½ cup	40-59	195-475	49-65	214-583
Turnip greens, cooked from fresh or frozen	½ cup	14-24	274-441	20-29	381-538
Fortified instant cereals (various)	1 packet	102-157	318-376	68-101	186-265
Fortified ready-to-eat cereals (various)	¾ - 1 ¼ cup (~1 ounce)	110-190	177-307	322-433	442-991
Beet greens, cooked from fresh	½ cup	19	276	27	383
Winter squash, cooked	½ cup	38	268	37	261
Mustard greens, cooked from fresh	½ cup	10	221	15	316
Pickled herring	3 ounces	223	219	262	258
Romaine lettuce	1 cup	8	205	17	436
Dandelion greens, cooked	½ cup	17	180	33	342
Chinese cabbage, cooked	½ cup	10	180	12	212

[1]Retinol activity equivalents.
[2]Source: U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Table D2.3. Vitamin C: Food sources ranked by amounts of vitamin C and energy per standard food portions and per 100 grams of foods (amounts of vitamin C present in standard food portions are ≥ 20% of RDA for adult men, which is 90 mg)

Food	**Standard Portion Size**	**Calories in Standard Portion**[1]	**Vitamin C in Standard Portion (mg)**[1]	**Calories per 100 grams**[1]	**Vitamin C per 100 grams (mg)** [1]
Guava	½ cup	37	126	68	228
Orange juice	1 cup	112	124	45	50
Peaches, frozen, sweetened	½ cup	118	118	94	94
Sweet red pepper, cooked from fresh	½ cup	19	115	28	171
Grapefruit juice	1 cup	96	94	39	38
Orange	1 medium	62	70	47	53
Vegetable juice cocktail	1 cup	46	67	19	28
Kiwi	1 medium	42	64	61	93
Fortified ready-to-eat cereals (various)	¾ - 1 1/3 cup (~1 ounce)	92-112	60-61	318-373	200-207
Grape juice cocktail	1 cup	128	60	51	24
Sweet red pepper, raw	½ cup	14	59	31	128
Strawberries, frozen, sweetened	½ cup	122	53	96	41
Broccoli, cooked from fresh and frozen	½ cup	26-27	37-51	28-35	40-65
Sweet green pepper, cooked from fresh	½ cup	19	50	28	74
Strawberries	½ cup	27	49	32	59
Brussels sprouts, cooked from fresh and frozen	½ cup	28	48	36	62
Kohlrabi, cooked	½ cup	24	45	29	54
Papaya	½ cup	27	43	39	62
Broccoli, raw	½ cup	15	39	34	89
Pineapple	½ cup	41	39	50	48
Edible pea pods, cooked	½ cup	34	38	42	48
Grapefruit	½ cup	38	38	33	33
Sweet green pepper, raw	½ cup	9	37	20	80
Cantaloupe	½ cup	27	29	34	37
Cauliflower, cooked from fresh and frozen	½ cup	14-17	28	19-23	31-44
Cabbage, cooked from fresh	½ cup	17	28	23	38
Grapefruit, canned	½ cup	76	27	60	21
Kale, cooked from fresh	½ cup	18	27	28	41
Sweet potato, canned	½ cup	91	26	91	26
Cauliflower, raw	½ cup	13	26	25	48

Table D2.3 (continued). Vitamin C: Food sources ranked by amounts of vitamin C and energy per standard food portions and per 100 grams of foods (amounts of vitamin C present in standard food portions are ≥ 20% of RDA for adult men, which is 90 mg)

Food	**Standard Portion Size**	**Calories in Standard Portion[1]**	**Vitamin C in Standard Portion (mg)[1]**	**Calories per 100 grams[1]**	**Vitamin C per 100 grams (mg)[1]**
Tangerines (mandarin oranges), canned	½ cup	77	25	61	20
Tangerine	1 medium	47	24	53	27
Mango	½ cup	54	23	65	28
Tomato juice	½ cup	21	22	17	18
Collards, cooked from frozen	½ cup	31	22	36	26
Chinese cabbage, cooked from fresh	½ cup	10	22	12	26
Asparagus, cooked from frozen	½ cup	16	22	18	24
Sweet potato, baked	1 medium	103	22	90	20
Raspberries, frozen, sweetened	½ cup	129	21	103	17
Red cabbage, raw	½ cup	11	20	31	57
Turnip greens, cooked from fresh	½ cup	14	20	20	27
Potato, baked	1 medium	145	20	93	13
Carambola (starfruit)	½ cup	17	19	31	34

[1]Source: U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Table D2.4. Vitamin K: Food sources ranked by amounts of vitamin K and energy per standard food portions and per 100 grams of foods (amounts of vitamin K present in standard food portions are ≥ 20% of RDA for adult men, which is 120 μg)

Food	**Standard Portion Size**	**Calories in Standard Portion**[1]	**Vitamin K in Standard Portion (μg)**[1]	**Calories per 100 grams**[1]	**Vitamin K per 100 grams (μg g)**[1]
Kale, cooked from fresh or frozen	½ cup	18-20	531-573	28-30	817-882
Collards, cooked from fresh or frozen	½ cup	25-31	418-530	26-36	440-623
Spinach, cooked from fresh, frozen, or canned	½ cup	21-32	444-514	23-34	462-541
Turnip greens, cooked from fresh or frozen	½ cup	14-24	265-426	20-29	368-519
Beet greens, cooked from fresh	½ cup	19	349	27	484
Dandelion greens, cooked from fresh	½ cup	17	290	33	551
Mustard greens, cooked from fresh	½ cup	10	210	15	300
Spinach egg noodles, cooked	1 cup	211	162	132	101
Brussels sprouts, cooked from fresh or frozen	½ cup	28-33	109-150	36-42	140-194
Spinach, raw	1 cup	7	145	23	483
Broccoli, cooked from fresh or frozen	½ cup	26-27	81-110	28-35	88-141
Cabbage, cooked from fresh	½ cup	17	82	23	109
Asparagus, cooked from frozen	½ cup	16	72	18	80
Green leaf lettuce	1 cup	5	63	15	174
Cabbage, raw	1 cup	18	53	25	76
Romaine lettuce	1 cup	8	48	17	103
Savoy cabbage	1 cup	19	48	27	69
Broccoli, raw	½ cup	15	46	34	102
Okra, cooked from fresh or frozen	½ cup	18-26	32-44	22-28	40-48
Tuna, canned in oil, drained	3 ounces	168	37	198	44
Dried plums (prunes), stewed	½ cup	133	32	107	26
Green peas, canned	½ cup	60	32	69	37
Cowpeas, cooked from frozen	½ cup	112	31	132	37
Green snap beans, canned	½ cup	18	30	23	39
Chinese cabbage, cooked from fresh	½ cup	10	29	12	34
Celery, cooked	½ cup	14	28	18	38
Kiwifruit	1 medium	42	28	61	40
Dried plums (prunes)	¼ cup	104	26	240	60
Rhubarb, cooked from frozen, sweetened	½ cup	139	25	116	21
Peas, edible-podded, cooked from frozen	½ cup	42	24	52	30

[1]Source: U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Table D2.5. Vitamin E: Food sources ranked by amounts of vitamin E and energy per standard food portions and per 100 grams of foods (amounts of vitamin E present in standard food portions are ≥ 10% of RDA for adults, which is 15 mg)

Food	Standard Portion Size	Calories in Standard Portion[1]	Vitamin E in Standard Portion (mg)[1]	Calories per 100 grams[1]	Vitamin E per 100 grams (mg) [1]
Fortified ready-to-eat cereals (various)	¾ - 1 1/3 cup (~1 ounce)	92-188	3.2-13.5	309-384	6.6-46.4
Almonds	1 ounce	163	7.4	575	26.2
Sunflower seeds, dry roasted	1 ounce	165	7.4	582	26.1
Sunflower oil, high linoleic	1 Tbsp	120	5.6	884	41.1
Cottonseed oil	1 Tbsp	120	4.8	884	35.3
Safflower oil, high oleic	1 Tbsp	120	4.6	884	34.1
Hazelnuts (filberts)	1 ounce	178	4.3	628	15.0
Spinach, cooked from fresh, frozen, or canned	½ cup	21-32	1.9-3.4	23-34	1.9-3.5
Mixed nuts, dry roasted	1 ounce	168	3.1	594	10.9
Peanut butter	2 Tbsp	188	2.9	588	9.0
Tomato paste	¼ cup	54	2.8	82	4.3
Pine nuts	1 ounce	191	2.7	673	9.3
Tomato puree	½ cup	48	2.5	38	2.0
Canola oil	1 Tbsp	124	2.4	884	17.5
Peanuts, dry roasted	1 ounce	166	2.2	585	7.8
Turnip greens, cooked from frozen	½ cup	24	2.2	29	2.7
Peanut oil	1 Tbsp	119	2.1	884	15.7
Corn oil	1 Tbsp	120	1.9	884	14.3
Olive oil	1 Tbsp	119	1.9	884	14.4
Sardines, canned in oil, drained	3 ounces	177	1.7	208	2.0
Soybean oil	1 Tbsp	120	1.7	884	12.1
Blue crab, cooked or canned	3 ounces	84-87	1.6	99-102	1.8
Brazil nuts	1 ounce	186	1.6	656	5.7
Orange roughy, cooked	3 ounces	89	1.6	105	1.9
Avocado	½ cup	117	1.5	160	2.1

[1]Source: U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Table D2.6. Choline: Food sources ranked by amounts of choline and energy per standard food portions and per 100 grams of foods (amounts of choline present in standard food portions are ≥ 10% of AI for adult men, which is 550 mg)

Food	**Standard Portion Size**	**Calories in Standard Portion**[1]	**Choline in Standard Portion (mg)**[1]	**Calories per 100 grams**[1]	**Choline per 100 grams (mg)**[1]
Organ meats (liver, giblets), various, cooked	3 ounces	133-169	133-356	157-199	157-418
Egg, hard-boiled	1 large	78	113	155	225
Beef, various cuts, lean, cooked	3 ounces	144-215	95-111	169-253	112-131
Pork, various cuts, lean, cooked	3 ounces	153-211	65-94	180-248	76-111
Braunschweiger (pork liver sausage)	2 slices (~1 ½ ounces)	118	92	327	256
Lamb, various cuts, lean, cooked	3 ounces	162-184	89-92	191-216	104-108
Herring, pickled	3 ounces	223	89	262	104
Ham, cured, lean	3 ounces	133	87	157	102
Corned beef	3 ounces	213	76	250	89
Salmon, smoked	3 ounces	99	76	117	89
Salmon, canned	3 ounces	118	75	139	88
Chicken breast, cooked	3 ounces	140	73	165	85
Cod, canned	3 ounces	89	72	105	85
Flatfish (flounder and sole), cooked	3 ounces	99	71	117	83
Turkey, cooked	3 ounces	144	70	170	83
Rockfish, cooked	3 ounces	103	69	121	81
Pollock (walleye), cooked	3 ounces	96	69	113	81
Clams, canned, drained	3 ounces	126	69	148	81
Shrimp, canned	3 ounces	85	69	100	81
Blue crab, cooked	3 ounces	87	69	102	81
Lobster, cooked	3 ounces	83	69	98	81
Sardines, canned in oil, drained	3 ounces	177	64	208	75
Soymilk, original and vanilla	1 cup	131	57	54	23
Salmon, cooked	3 ounces	184	56	216	66

[1]Source: U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Table D2.7. Magnesium: Selected food sources ranked by amounts of magnesium and energy per standard food portion and per 100 grams of foods (amounts of magnesium present in standard food portions are ≥ 10% of RDA for adult men, which is 420 mg)

Food	**Standard Portion Size**	**Calories in Standard Portion**[1]	**Magnesium in Standard Portion (mg)**[1]	**Calories per 100 grams**[1]	**Magnesium per 100 grams (mg)**[1]
Pumpkin/squash seed kernels, roasted	1 ounce	163	156	574	550
Brazil nuts, dried	1 ounce	186	107	656	376
Oat bran muffin	1 small	178	104	270	157
Halibut, cooked	3 ounces	119	91	140	107
Bran ready-to-eat cereal (100%)	1/3 cup (~1 ounce)	81	112	260	362
Spinach, cooked from fresh, frozen, or canned	½ cup	21-32	78-81	23-34	76-87
Almonds	1 ounce	163	76	575	268
Cashews, dry roasted	1 ounce	163	74	574	260
Soybeans, mature, cooked	½ cup	149	74	173	86
Pine nuts, dried	1 ounce	191	71	673	251
White beans, canned	½ cup	149	67	114	51
Mixed nuts with peanuts, dry roasted	1 ounce	168	64	594	225
Pollock, walleye, cooked	3 ounces	96	62	113	73
Soymilk	1 cup	131	61	54	25
Black beans, cooked	½ cup	114	60	132	70
Soybeans, green, cooked	½ cup	127	54	141	60
Tuna, yellowfin, cooked	3 ounces	118	54	139	64
Peanuts, dry roasted	1 ounce	166	50	585	176
Lima beans, cooked	½ cup	94	50	105	56
Flatfish (flounder and sole), cooked	3 ounces	99	49	117	58
Beet greens, cooked from fresh	½ cup	19	49	27	68
Navy beans, cooked	½ cup	127	48	140	53
Tofu, firm, nigari	½ cup	88	47	70	37
Okra, cooked from frozen	½ cup	26	47	28	51
Cowpeas, cooked	½ cup	100	46	116	53
Hazelnuts	1 ounce	178	46	628	163
English walnuts	1 ounce	185	45	654	158
Great northern beans, cooked	½ cup	104	44	118	50
Oat bran, cooked	½ cup	44	44	40	40
Plain yogurt, nonfat	8 ounce container	127	43	56	19
Buckwheat groats, roasted, cooked	½ cup	77	43	92	51
Brown rice, cooked	½ cup	109	43	112	44
Pinto beans, cooked	½ cup	122	43	143	50
Haddock, cooked	3 ounces	95	42	112	50

[1]Source: U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Table D2.8. Phosphorus: Food sources ranked by amounts of phosphorus and energy per standard food portions and per 100 grams of foods (amounts of phosphorus present in standard food portions are ≥ 25% of AI for adults, which is 700 mg)

Food	**Standard Portion Size**	**Calories in Standard Portion**[1]	**Phosphorus in Standard Portion (mg)** [1]	**Calories per 100 grams**[1]	**Phosphorus per 100 grams (mg)** [1]
Pasteurized process Swiss cheese	2 ounces	189	432	334	762
Sardines, canned in oil, drained	3 ounces	177	417	208	490
Beef liver, pan-fried	3 ounces	149	412	175	485
Pollock, cooked	3 ounces	96	410	113	482
Bran ready-to-eat cereal (100%)	½ cup (~1 ounce)	81	356	260	1150
Plain yogurt, whole, low-fat, and nonfat	8 ounce container	127-143	216-356	56-63	95-157
Pumpkin and squash seed kernels, roasted	1 ounce	163	333	574	1174
Sunflower seed kernels, roasted	1 ounce	165	327	582	1155
Clams, canned, drained	3 ounces	126	287	148	338
Swordfish, cooked	3 ounces	132	286	155	337
Salmon, canned	3 ounces	118	280	139	329
Tuna, light, canned in oil, drained	3 ounces	168	264	198	311
Chocolate milk, whole, reduced fat, and low-fat	1 cup	158-208	252-258	63-83	101-103
Evaporated milk, whole and nonfat	½ cup	100-169	250-256	78-134	195-203
Oat bran muffin	1 small	178	248	270	376
Milk, whole, reduced fat, low-fat, and skim	1 cup	83-149	205-247	34-61	84-101
Chicken giblets, cooked	3 ounces	133	246	157	289
Flatfish (flounder and sole), cooked	3 ounces	99	246	117	289
Halibut, cooked	3 ounces	119	242	140	285
Swiss cheese	1 ½ ounces	162	241	380	567
Pork, cooked, various cuts	3 ounces	153-337	180-239	180-397	212-281
Alaska king crab, cooked	3 ounces	82	238	97	280
Sockeye salmon, cooked	3 ounces	184	235	216	276
Perch, cooked	3 ounces	103	235	121	277
Rainbow trout, cooked	3 ounces	144	226	169	266
Ricotta cheese, whole and part skim	½ cup	170-216	196-225	138-174	158-183
Part skim mozzarella cheese	1 ½ ounces	128	223	302	524
Cod, canned	3 ounces	89	221	105	260
Blue crab, canned	3 ounces	84	221	99	260

Table D2.8 (continued). Phosphorus: Food sources ranked by amounts of phosphorus and energy per standard food portions and per 100 grams of foods (amounts of phosphorus present in standard food portions are ≥ 25% of AI for adults, which is 700 mg)

Food	**Standard Portion Size**	**Calories in Standard Portion**[1]	**Phosphorus in Standard Portion (mg)** [1]	**Calories per 100 grams**[1]	**Phosphorus per 100 grams (mg)** [1]
Low-fat buttermilk (1%)	1 cup	98	218	40	89
Cheddar cheese	1 ½ ounces	171	218	403	512
Soybeans, mature, cooked	½ cup	149	211	173	245
Provolone cheese	1 ½ ounces	149	211	351	496
Yellowfin tuna, cooked	3 ounces	118	208	139	245
Brazil nuts, dried	1 ounce	186	206	656	725
Haddock, cooked	3 ounces	95	205	112	241
Beef, cooked, various cuts	3 ounces	151-215	178-200	178-253	209-235
Muenster cheese	1 ½ ounces	156	199	368	468
Lamb, cooked, various cuts	3 ounces	184-294	175-197	216-346	206-232
Turkey giblets, cooked	3 ounces	169	196	199	231
Rockfish, cooked	3 ounces	103	194	121	228
Cured ham	3 ounces	133-207	182-193	157-243	214-227
Cod, cooked	3 ounces	89	190	105	223
Cottage cheese, nonfat, 1% and 2%	½ cup	52-97	138-184	72-86	134-190
Turkey, cooked	3 ounces	144	181	170	213
Lentils, cooked	½ cup	115	178	116	180
Blue crab, cooked	3 ounces	87	175	102	206
Chicken, cooked	3 ounces	201	173	237	204

[1]Source: U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Table D2.9. Functions of nutrients of concern

Nutrient	**Function**
Calcium	Calcium is the key nutrient in the development and maintenance of bones; additionally calcium aids in blood clotting and muscle and nerve functioning.
Vitamin D	Vitamin D aids in the intestinal absorption of calcium and phosphorus, so it helps to maintain serum levels of these minerals in the body at normal levels. Vitamin D also plays roles in cellular metabolism, which involve antiproliferation and prodifferentiation actions.
Potassium	Potassium assists in muscle contraction, maintaining fluid and electrolyte balance in cells, transmitting nerve impulses, and releasing energy during metabolism. Diets rich in potassium lower blood pressure, blunt the adverse effects of salt on blood pressure, may reduce the risk of developing kidney stones, and may decrease bone loss.
Dietary Fiber	Fiber helps maintain the health of the digestive tract and promotes proper bowel functioning.

Source: Adapted from *Dietary Reference Intakes: The Essential Guide to Nutrient Requirements*, (IOM, 2006).

Table D2.10. Vitamin D: Food sources ranked by amounts of vitamin D and energy per standard food portions and per 100 grams of foods (amounts of vitamin D present in standard food portions are ≥ 10% of AI for adults 19-50, which is 5 μg)

Food	Standard Portion Size	Calories in Standard Portion[1]	Vitamin D in Standard Portion (μg)[1]	Calories per 100 grams[1]	Vitamin D per 100 grams (μg)[1]
Salmon, sockeye, cooked	3 ounces	184	19.8	216	23.3
Salmon, smoked	3 ounces	99	14.5	117	17.1
Salmon, canned	3 ounces	118	11.6	139	13.7
Rockfish, cooked	3 ounces	103	6.5	121	7.7
Tuna, light, canned in oil, drained	3 ounces	168	5.7	198	6.7
Sardine, canned in oil, drained	3 ounces	177	4.1	208	4.8
Tuna, light, canned in water, drained	3 ounces	99	3.8	116	4.5
Orange juice[2]	1 cup	118	3.4	94	2.8
Whole milk[2]	1 cup	149	3.2	61	1.3
Whole chocolate milk[2]	1 cup	208	3.2	83	1.3
Reduced fat chocolate milk (2%)[2]	1 cup	190	3.0	76	1.2
Milk (nonfat, 1% and 2%)[2]	1 cup	83-122	2.9	34-50	1.2
Low-fat chocolate milk (1%)[2]	1 cup	158	2.8	63	1.1
Soymilk[2]	1 cup	104	2.7	43	1.1
Evaporated milk, nonfat[2]	½ cup	100	2.6	78	2
Flatfish (flounder and sole), cooked	3 ounces	99	2.5	117	3.0
Fortified ready-to-eat cereals (various)[2]	¾ - 1 ¼ cup (~1 ounce)	92-190	0.9-2.5	309-387	2.9-8.3
Rice drink[2]	1 cup	113	2.4	47	1.0
Herring, pickled	3 ounces	223	2.4	262	2.8
Pork, cooked (various cuts)	3 ounces	153-337	0.6-2.2	180-397	0.7-2.6
Cod, cooked	3 ounces	89	1.0	105	1.2
Beef liver, cooked	3 ounces	149	1.0	175	1.2
Cured ham	3 ounces	133-207	0.6-0.8	157-243	0.7-0.9
Egg, hard-boiled	1 large	78	0.7	155	1.3
Shiitake mushrooms	½ cup	41	0.6	56	0.8
Canadian bacon	2 slices (~1 ½ ounces)	87	0.5	185	1.1

[1]Source: U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.
[2]Vitamin D fortified.

Table D2.11. Food sources of vitamin D listed in descending order by percentages of their contribution to intake among the U.S. population ages 2+, WWEIA, NHANES 2005-2006

Food Category	**Contribution to Intake, %**	**Cumulative Contribution, %**
Milk, milk drinks and desserts, yogurt	52.1	52.1
Finfish and shellfish	8.6	60.7
Ready-to-eat and cooked cereal	6.5	67.2
Meat, poultry, franks, sausages, lunch meats	6.2	73.4
Eggs and egg products	5.0	78.4
Meat, poultry, fish items with sauces, gravies, bread, other starch, and/or vegetables	5.0	83.4
Grain mixtures	3.3	86.7
Orange juice	3.1	89.8
Infant formulas	1.7	91.5
Cheese and cheese mixtures	1.6	93.1
Cappuccino, frappuccino, latte	1.2	94.3
Butter and margarine	0.9	95.2

Source: What We Eat in America, NHANES, 2005-2006, all individuals (excluding breast-fed children), Day 1, weighted. Vitamin D Addendum to USDA Food and Nutrient Database for Dietary Studies 3.0 (2009) www.ars.usda.gov/ba/bhnrc/fsrg. Unpublished Data: USDA, Agricultural Research Service, Food Surveys Research Group. Table available at www.dietaryguidelines.gov

Table D2.12. Calcium: Food sources ranked by amounts of calcium and energy per standard food portion and per 100 grams of foods (amounts of calcium present in standard food portions are ≥ 20% of AI for adults 19-50, which is 1000 mg)

Food	**Standard Portion Size**	**Calories in Standard Portion**[1]	**Calcium in Standard Portion (mg)**[1]	**Calories per 100 grams**[1]	**Calcium per 100 grams (mg)**[1]
Fortified ready-to-eat cereals (various)	¾ - 1 cup (~1 ounce)	100-210	250-1000	309-373	1818-3333
Orange juice, calcium fortified	1 cup	117	500	47	201
Plain yogurt, nonfat	8 ounces	127	452	56	199
Romano cheese	1.5 ounces	165	452	387	1064
Pasteurized process Swiss cheese	2 ounces	189	438	334	772
Evaporated milk, nonfat	½ cup	100	371	78	290
Tofu, raw, regular, prepared with calcium sulfate	½ cup	94	434	76	350
Plain yogurt, low-fat	8 ounces	143	415	63	183
Fruit yogurt, low-fat	8 ounces	232	345	102	152
Ricotta cheese, part skim	½ cup	171	337	138	272
Swiss cheese	1.5 ounces	162	336	380	791
Sardines, canned in oil, drained	3 ounces	177	325	208	382
Pasteurized process American cheese food	2 ounces	187	323	330	570
Provolone cheese	1.5 ounces	149	321	351	756
Mozzarella cheese, part-skim	1.5 ounces	128	311	302	731
Cheddar cheese	1.5 ounces	171	307	403	721
Muenster cheese	1.5 ounces	156	305	368	717
Low-fat milk (1%)	1 cup	102	305	42	125
Soymilk, original and vanilla, with added calcium	1 cup	104	299	43	123
Skim milk (nonfat)	1 cup	83	299	34	122
Reduced fat milk (2%)	1 cup	122	293	50	120
Low-fat chocolate milk (1%)	1 cup	158	290	63	116
Low-fat buttermilk (1%)	1 cup	98	284	40	116
Rice milk, with added calcium	1 cup	113	283	47	118
Whole chocolate milk	1 cup	208	280	83	112
Whole milk	1 cup	149	276	61	113
Plain yogurt, whole milk	8 ounces	138	275	61	121
Reduced fat chocolate milk (2%)	1 cup	190	272	76	109
Ricotta cheese, whole milk	½ cup	216	257	174	207
Tofu, firm, prepared with calcium sulfate and magnesium chloride	½ cup	88	253	70	201

[1]Data source: U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Table D2.13. Food sources of calcium listed in descending order by percentages of their contribution to intake among the U.S. population ages 2+, WWEIA, NHANES 2005-2006

Food Category	**Contribution to Intake, %**	**Cumulative Contribution, %**
Reduced fat milk (2% and 1%)	12.2	12.2
Regular cheese	9.2	21.4
Whole milk	6.1	27.5
Pizza	6.1	33.6
Miscellaneous	5.7	39.3
Yeast breads	5.4	44.7
Skim milk	4.5	49.2
Dairy desserts	4.0	53.2
Mexican mixed dishes	3.8	57.0
Pasta and pasta dishes	3.0	60.0
100% orange/grapefruit juice	2.6	62.5
Ready-to-eat cereals	2.2	64.8
Grain-based desserts	2.1	66.9
Reduced fat cheese	2.0	68.9

Data source: Sources of Calcium Among the U.S. Population, 2005-06. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/foodsources/calcium/.

Table D2.14. Potassium: Food sources ranked by amounts of potassium and energy per standard food portion and per 100 grams of foods (the AI for potassium for adults is 4700 mg)

Food	**Standard Portion Size**	**Calories in Standard Portion**[1]	**Potassium in Standard Portion (mg)**[1]	**Calories per 100 grams**[1]	**Potassium per 100 grams (mg)**[1]
Potato, baked, flesh and skin	1 sm. potato	128	738	93	535
Prune juice, canned	1 cup	182	707	71	276
Carrot juice, canned	1 cup	94	689	40	292
Tomato paste	¼ cup	54	664	82	1014
Beet greens, cooked from fresh	½ cup	19	654	27	909
White beans, canned	½ cup	149	595	114	454
Tomato juice, canned	1 cup	41	556	17	229
Plain yogurt, nonfat	8 ounces	127	579	56	255
Tomato puree	½ cup	48	549	38	439
Sweet potato, baked in skin	1 medium	103	542	90	475
Clams, canned	3 ounces	126	534	148	628
Plain yogurt, low-fat	8 ounces	143	531	63	234
Orange juice, fresh	1 cup	112	496	45	200
Halibut, cooked	3 ounces	119	490	140	576
Soybeans, green, cooked	½ cup	127	485	141	539
Tuna, yellowfin, cooked	3 ounces	118	484	139	569
Lima beans, cooked	½ cup	108	478	115	508
Soybeans, mature, cooked	½ cup	149	443	173	515
Rockfish, Pacific, cooked	3 ounces	103	442	121	520
Cod, Pacific, cooked	3 ounces	89	439	105	517
Evaporated milk, nonfat	½ cup	100	425	78	332
Low-fat chocolate milk (1%)	1 cup	158	425	63	170
Reduced fat chocolate milk (2%)	1 cup	190	422	76	169
Bananas	1 medium	105	422	89	358
Spinach, cooked from fresh or canned	½ cup	21-25	370-419	23	346-466
Tomato sauce	½ cup	29	405	24	331
Peaches, dried, uncooked	¼ cup	96	398	239	996
Prunes, stewed	½ cup	133	398	107	321
Skim milk (nonfat)	1 cup	83	382	34	156
Rainbow trout, cooked	3 ounces	128	381	150	448
Apricots, dried, uncooked	¼ cup	78	378	241	1162
Pinto beans, cooked	½ cup	122	373	143	436
Pork loin, center rib, lean, roasted	3 ounces	190	371	223	437
Low-fat buttermilk (1%)	1 cup	98	370	40	151
Low-fat milk (1%)	1 cup	102	366	42	150
Lentils, cooked	½ cup	115	365	116	369
Plantains, cooked	½ cup	89	358	116	465
Kidney beans, cooked	½ cup	112	358	127	405

[1]Source: U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Table D2.15. Food sources of potassium listed in descending order by percentages of their contribution to intake among the U.S. population ages 2+, WWEIA, NHANES 2005-2006

Food Category	**Contribution to Intake, %**	**Cumulative Contribution, %**
Reduced fat milk (2% and 1%)	5.9	5.9
Coffee	5.2	11.1
Chicken and chicken mixed dishes	4.5	15.6
Beef and beef mixed dishes	3.6	19.2
100% orange/grapefruit juice	3.4	22.6
Fried white potatoes	3.3	25.9
Potato/corn/other chips	3.2	29.1
Whole milk	2.9	32.0
Other white potatoes	2.9	34.9
Pasta and pasta dishes	2.7	37.6
Mexican mixed dishes	2.6	40.2
Pizza	2.6	42.8
Dairy desserts	2.5	45.3
Yeast breads	2.4	47.7
Skim milk	2.2	49.9
Soups	2.2	52.1
Bananas	2.1	54.2
Tea	2.1	56.3
Burgers	1.9	58.2
Alcoholic beverages	1.9	60.1
100% fruit juice, not orange/grapefruit	1.9	62.0
Nuts/seeds and nut/seed mixed dishes	1.8	63.8
Grain-based desserts	1.8	65.6
Cold cuts	1.8	67.4
Other fish and fish mixed dishes	1.6	69.0
Ready-to-eat cereals	1.5	70.5
Beans	1.5	72.0
Condiments	1.5	73.5
Yogurt	0.9	74.4

Source: Sources of Potassium Among the U.S. Population, 2005-06. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/foodsources/potassium/.

Table D2.16. Dietary fiber: Food sources ranked by amounts of dietary fiber and energy per standard food portion and per 100 grams of foods (amounts of dietary fiber present in standard food portions are ≥ 10% of AI for adult women, which is 25 g)

Food	Standard Portion Size	Calories in Standard Portion[1]	Dietary Fiber in Standard Portion (g) [1]	Calories per 100 grams[1]	Dietary fiber per 100 grams (g) [1]
Navy beans, cooked	½ cup	127	9.6	140	10.5
Bran ready-to-eat cereal (100%)	1/3 cup (~1 ounce)	81	9.1	260	29.3
Split peas, cooked	½ cup	116	8.1	118	8.3
Lentils, cooked	½ cup	115	7.8	116	7.9
Pinto beans, cooked	½ cup	122	7.7	143	9.0
Black beans, cooked	½ cup	114	7.5	132	8.7
Artichoke, globe or French, cooked from fresh	½ cup hearts	45	7.2	53	8.6
Kidney beans, canned	½ cup	108	6.8	84	5.3
Lima beans, cooked	½ cup	108	6.6	115	7.0
White beans, canned	½ cup	149	6.3	114	4.8
Chickpeas, cooked	½ cup	134	6.2	164	7.6
Great northern beans, cooked	½ cup	104	6.2	118	7.0
Cowpeas, cooked	½ cup	100	5.6	116	6.5
Pear	1 medium	103	5.5	58	3.1
Soybeans, mature, cooked	½ cup	149	5.2	173	6.0
Plain rye wafer crackers	2 wafers	73	5.0	334	22.9
Bran ready-to-eat cereals (various)	1/3-3/4 cup (~1 ounce)	88-114	2.6-5.0	309-402	9.1-17.6
Asian pear	1 small	51	4.4	42	3.6
Green peas, cooked from fresh, frozen, or canned	½ cup	59-67	3.5-4.4	69-84	4.1-5.5
Whole wheat English muffin	1 muffin	134	4.4	203	6.7
Bulgur, cooked	½ cup	76	4.1	83	4.5
Mixed vegetables, cooked from frozen	½ cup	59	4.0	65	4.4
Raspberries	½ cup	32	4.0	52	6.5
Sweet potato, baked in skin	1 medium	103	3.8	90	3.3
Blackberries	½ cup	31	3.8	43	5.3
Potato, baked, with skin	1 medium	161	3.8	93	2.2
Soybeans, green, cooked	½ cup	127	3.8	141	4.2
Stewed prunes	½ cup	133	3.8	107	3.1
Shredded wheat ready-to-eat cereal (various)	½ cup (~1 ounce)	95-100	2.7-3.8	334-352	9.6-13.4
Figs, dried	¼ cup	93	3.7	249	9.8
Apple, with skin	1 small	77	3.6	52	2.4
Pumpkin, canned	½ cup	42	3.6	34	2.9

Table D2.16 (continued). Dietary fiber: Food sources ranked by amounts of dietary fiber and energy per standard food portion and per 100 grams of foods (amounts of dietary fiber present in standard food portions are ≥ 10% of AI for adult women, which is 25 g)

Food	**Standard Portion Size**	**Calories in Standard Portion**[1]	**Dietary fiber in Standard Portion (g)**[1]	**Calories per 100 grams**[1]	**Dietary fiber per 100 grams (g)**[1]
Spinach, cooked from frozen or canned	½ cup	25-32	2.6-3.5	23-34	2.4-3.7
Almonds	1 ounce	163	3.5	575	12.2
Sauerkraut, canned, solids and liquids	½ cup	22	3.4	19	2.9
Whole wheat spaghetti, cooked	½ cup	87	3.1	124	4.5
Banana	1 medium	105	3.1	89	2.6
Orange	1 medium	62	3.1	47	2.4
Guava	1 fruit	37	3.0	68	5.4
Oat bran muffin	1 small	178	3.0	270	4.6
Pearled barley, cooked	½ cup	97	3.0	123	3.8
Dates	¼ cup	104	2.9	282	8.0
Winter squash, cooked	½ cup	38	2.9	37	2.8
Parsnips, cooked	½ cup	55	2.8	71	3.6
Tomato paste	¼ cup	54	2.7	82	4.1
Collards, cooked from fresh	½ cup	25	2.7	26	2.8
Broccoli, cooked from fresh or frozen	½ cup	26-27	2.6-2.8	28-35	3.0-3.3
Okra, cooked from frozen	½ cup	26	2.6	28	2.8
Turnip greens, cooked from fresh or frozen	½ cup	14-24	2.5-2.8	20-29	3.4-3.5

[1]Source: U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Table D2.17. Food sources of dietary fiber listed in descending order by percentages of their contribution to intake among the U.S. population ages 2+, WWEIA< NHANES 2005-2006

Food Category	**Contribution to Intake, %**	**Cumulative Contribution, %**
Yeast breads	8.9	8.9
Mexican mixed dishes	7.0	15.9
Ready-to-eat cereals	5.6	21.5
Pasta and pasta dishes	5.3	26.8
Beans	4.2	31.0
Grain-based desserts	4.1	35.1
Pizza	3.9	39.0
Fried white potatoes	3.5	42.5
Nuts/seeds and nut/seed mixed dishes	3.4	46.0
Potato/corn/other chips	3.2	49.2
Apples and pears	3.0	52.2
Bananas	2.6	54.9
Chicken and chicken mixed dishes	2.5	57.3
Other white potatoes	2.4	59.7
Soups	2.1	61.8

Source: Sources of Fiber Among the U.S. Population, 2005-06. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/foodsources/fiber/.

Table D2.18. Folate: Food sources ranked by amounts of folate and energy per standard food portion and per 100 grams of foods (amounts of folate present in standard food portions are ≥ 10% of RDA for adults, which is 400 µg DFE)

Food	**Standard Portion Size**	**Calories in Standard Portion**[1]	**Folate in Standard Portion (µg DFE)**[1]	**Calories per 100 grams**[1]	**Folate per 100 grams (µg DFE)**[1]
Fortified ready-to-eat cereals (various)	1 cup (~1 ounce)	109-218	169-701	309-416	296-2630
Fortified instant cereals (various)	1 packet or ½ cup	56-157	138-378	42-101	89-282
Organ meats (liver, giblets), various, cooked	3 ounces	133-169	218-491	157-199	257-578
Lentils, cooked	½ cup	115	179	116	181
Cowpeas, cooked	½ cup	100	179	116	208
Pinto beans, cooked	½ cup	122	147	143	172
Chickpeas, cooked	½ cup	134	141	164	172
Okra, cooked from frozen	½ cup	26	134	28	146
Asparagus, cooked from fresh, frozen, or canned	½ cup	16-23	116-134	18-22	96-149
Spinach, cooked from fresh, frozen, or canned	½ cup	21-32	105-131	23-34	98-146
Black beans, cooked	½ cup	114	128	132	149
Navy beans, cooked	½ cup	127	127	140	140
Kidney beans, cooked	½ cup	112	115	127	130
Egg noodles, enriched, cooked	½ cup	110	110	138	138
Orange juice, from concentrate	1 cup	112	110	45	44
Rice, white, enriched, cooked	½ cup	97	107	123	136
Soybeans, green, cooked	½ cup	127	100	141	111
English muffin, enriched	1 muffin	140	94	270	180
Bagel, enriched	1 small (3” dia)	190	92	275	134
Oat bran muffin	1 small	178	92	270	139
Great northern beans, cooked	½ cup	104	90	118	102
Collards, cooked from fresh or frozen	½ cup	25-31	65-88	26-36	76-93
Hard roll	1 roll	167	86	293	151
Pretzels, hard, salted	5 twists	114	86	380	286
White beans, canned	½ cup	149	85	114	65
Turnip greens, cooked from fresh or canned	½ cup	14	66-85	19-20	92-118
Broccoli, cooked from fresh or frozen	½ cup	26-27	52-84	28-35	56-108

Table D2.18 (continued). Folate: Food sources ranked by amounts of folate and energy per standard food portion and per 100 grams of foods (amounts of folate present in standard food portions are ≥ 10% of RDA for adults, which is 400 μg DFE)

Food	**Standard Portion Size**	**Calories in Standard Portion[1]**	**Folate in Standard Portion (μg DFE)[1]**	**Calories per 100 grams[1]**	**Folate per 100 grams (μg DFE)[1]**
Spaghetti, cooked	½ cup	111	83	158	119
Chickpeas, canned	½ cup	143	80	119	67
Brussels sprouts, cooked from fresh or frozen	½ cup	28-33	47-78	36-42	60-101
Lima beans, cooked	½ cup	108	78	115	83
Artichoke, globe or French, cooked from fresh	½ cup hearts	45	75	53	89
Corn muffin	1 small	201	74	305	112
Beets, cooked from fresh	½ cup	37	68	44	80
Sunflower seed kernels, dry roasted	1 ounce	165	67	582	237
Cornmeal, degermed, enriched	2 Tbsp	61	65	355	374
Split peas, cooked	½ cup	116	64	118	65
Cowpeas, canned	½ cup	92	61	77	51
Sweet corn, canned	½ cup	83	51	79	49
Mustard greens, cooked from fresh or frozen	½ cup	10-14	51-52	15-19	70-73
Flour tortilla	1 tortilla (6" dia)	94	50	312	168
Green peas, cooked from fresh or frozen	½ cup	62-67	47-50	78-84	59-63
Wheat flour, white, enriched	2 Tbsp	62	49	361	288
Baked potato, flesh and skin	1 medium	161	48	93	28
Soybeans, mature, cooked	½ cup	149	46	173	54
Parsnips, cooked	½ cup	55	45	71	58
White bread	1 slice	66	43	266	171

[1]Source: U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Table D2.19. Iron: Food sources ranked by amounts of iron and energy per standard food portion and per 100 grams of food (amounts of iron present in standard food portions listed are ≥ 10% of RDA for teen and adult females, which is 18 mg)

Food	**Standard Portion Size**	**Calories in Standard Portion**[1]	**Iron in Standard Portion (mg)** [1]	**Calories per 100 grams**[1]	**Iron per 100 grams (mg)** [1]
Clams, canned, drained	3 ounces	126	23.8	148	28.0
Fortified ready-to-eat cereals (various)	¾ -1 1/3 cup (~1 ounce)	56-175	4.2-18.1	309-402	8.2-62.0
Fortified instant cereals (various)	1 packet	102-166	3.8-17.2	42-101	2.5-6.7
Organ meats (liver, giblets), various, cooked	3 ounces	133-187	4.3-15.2	157-220	5.1-18.0
Oysters, eastern, wild, cooked	3 ounces	116	10.2	137	12.0
Soybeans, mature, cooked	½ cup	149	4.4	173	5.1
Bagel, enriched	1 small (3" dia)	177	4.2	257	6.1
Braunschweiger (pork liver sausage)	2 slices (~1 ½ ounce)	118	4.0	327	11.2
White beans, canned	½ cup	149	3.9	114	3.0
Lentils, cooked	½ cup	115	3.3	116	3.3
Spinach, cooked from fresh, frozen or canned	½ cup	21-32	1.9-3.2	23-34	2.0-3.6
Beef, chuck, blade roast, lean, 0" fat, all grades, cooked	3 ounces	215	3.1	253	3.7
Sardines, canned in oil, drained	3 ounces	177	2.5	208	2.9
Chickpeas, cooked	½ cup	134	2.4	164	2.9
English muffin, enriched	1 muffin	140	2.4	270	4.7
Pumpkin and squash seed kernels, roasted	1 ounce	163	2.3	574	8.1
Duck, meat only, roasted	3 ounces	171	2.3	201	2.7
Soybeans, green, cooked	½ cup	127	2.3	141	2.5
Lima beans, cooked	½ cup	108	2.3	115	2.4
Ground beef (85% lean/15% fat), cooked	3 ounces	212	2.2	250	2.6
Navy beans, cooked	½ cup	127	2.2	140	2.4
Cowpeas, cooked	½ cup	100	2.2	116	2.5
Kidney beans, cooked	½ cup	112	2.0	127	2.2
Beef, rib, 1/8" fat, all grades	3 ounces	298	2.0	351	2.4
Beef, bottom round, 0" fat, all grades, cooked	3 ounces	159	1.9	187	2.2
Lamb, shoulder, arm, lean, ¼" fat, choice, cooked	3 ounces	163	1.9	192	2.2
Great northern beans, cooked	½ cup	104	1.9	118	2.1
Baked potato, flesh and skin	1 medium	161	1.9	93	1.1
Black beans, cooked	½ cup	114	1.8	132	2.1

[1]Source: U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Table D2.20. Vitamin B_{12}: Food sources ranked by amounts of vitamin B_{12} and energy per standard food portions and per 100 grams of foods (amounts of Vitamin B_{12} present in standard food portions are ≥ 50% of RDA for adult men, which is 2.4 μg)

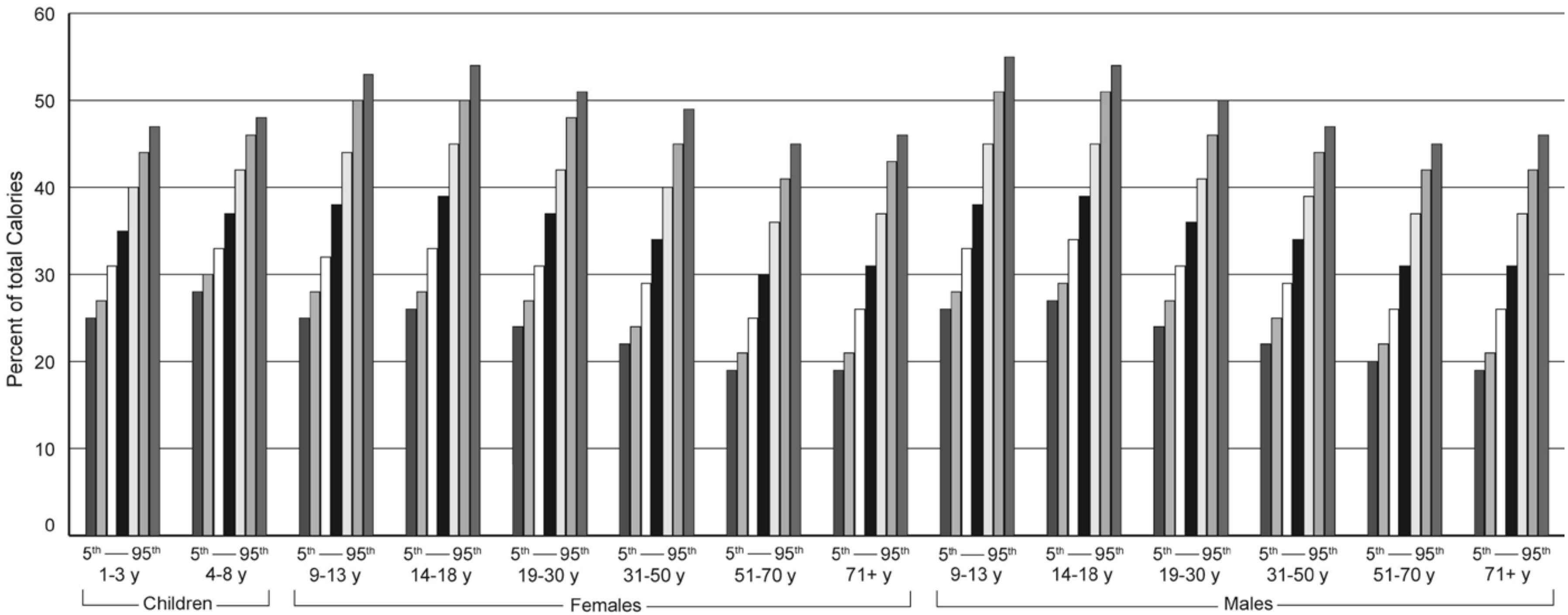
Food	**Standard Portion Size**	**Calories in Standard Portion**[1]	**Vitamin B_{12} in Standard Portion (μg)**[1]	**Calories per 100 grams**[1]	**Vitamin B_{12} per 100 grams (μg)**[1]
Clams, canned, drained	3 ounces	126	84.1	148	98.9
Organ meats (liver, giblets), various, cooked	3 ounces	133-169	8.0-70.7	157-199	9.4-83.1
Oysters, eastern, raw	3 ounces	58	16.5	68	19.5
Alaska king crab, cooked	3 ounces	82	9.8	97	11.5
Sardines, canned in oil, drained	3 ounces	177	7.6	208	8.9
Braunschweiger (pork liver sausage)	2 slices (~1 ½ ounces)	118	7.2	327	20.1
Blue crab, cooked	3 ounces	87	6.2	102	7.3
Ready-to-eat cereals (various)	¾ - 1 1/3 cup (~1 ounce)	81-190	1.5-6.0	260-400	2.7-20.7
Salmon, cooked from fresh, smoked, or canned	3 ounces	99-184	2.8-4.9	117-216	3.3-5.8
Rainbow trout, cooked	3 ounces	144	4.2	169	5.0
Pickled herring	3 ounces	223	3.6	262	4.3
Pollock, walleye, cooked	3 ounces	96	3.6	113	4.2
Lobster, cooked	3 ounces	83	2.6	98	3.1
Tuna, light, canned in water	3 ounces	99	2.5	116	3.0
Ground beef (75% lean/25% fat), cooked	3 ounces	236	2.4	278	2.8
Lamb, cooked, various cuts	3 ounces	197-237	1.8-2.3	232-279	2.2-2.7
Beef, cooked, various cuts	3 ounces	194-298	1.2-2.2	228-351	1.5-2.6
Flatfish (flounder and sole), cooked	3 ounces	99	2.13	117	2.51
Swordfish, cooked	3 ounces	132	1.72	155	2.02
Rice milk, unsweetened	1 cup	113	1.51	47	0.63
Plain yogurt, nonfat	8 ounces	127	1.38	56	0.61
Reduced fat milk (2%)	1 cup	122	1.29	50	0.53
Plain yogurt, low-fat	8 ounces	143	1.27	63	0.56
Skim milk (nonfat)	1 cup	83	1.23	34	0.5

[1]Source: U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Part D. Section 2: Nutrient Adequacy—Figures

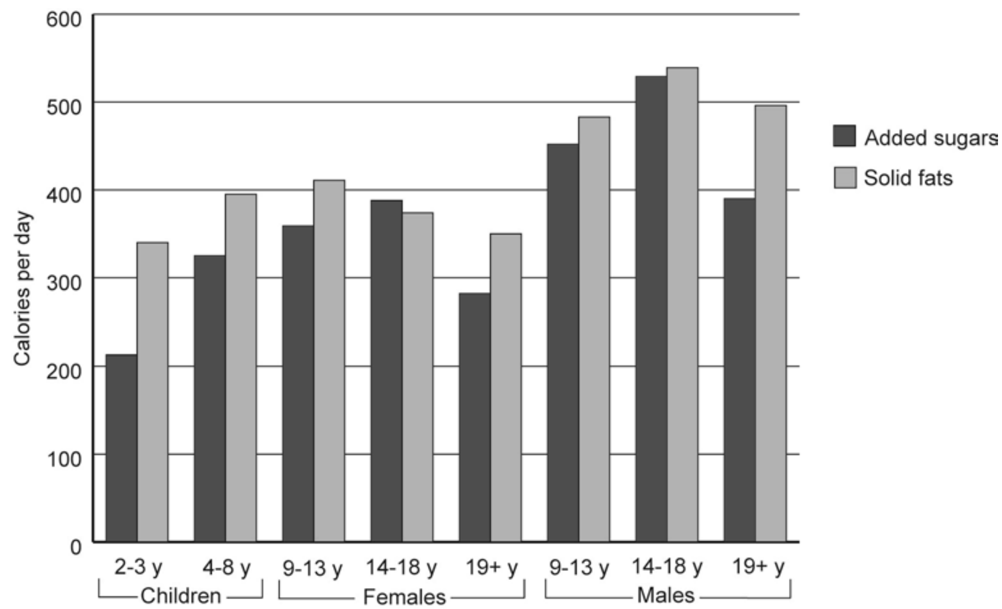
Figure D2.1. Distribution of usual intakes of SoFAS (solid fats and added sugars) as percent of total Calories, by age/sex group

Bars show, from left to right, percent of Calories from SoFAS at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles.



Source: Selected Intakes as Ratios of Energy Intake, U.S. Population, 2001-04. Risk Factor Monitoring and Methods Branch Web site. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/usualintakes/energy/. Updated April 13, 2010. Accessed April 22, 2010.

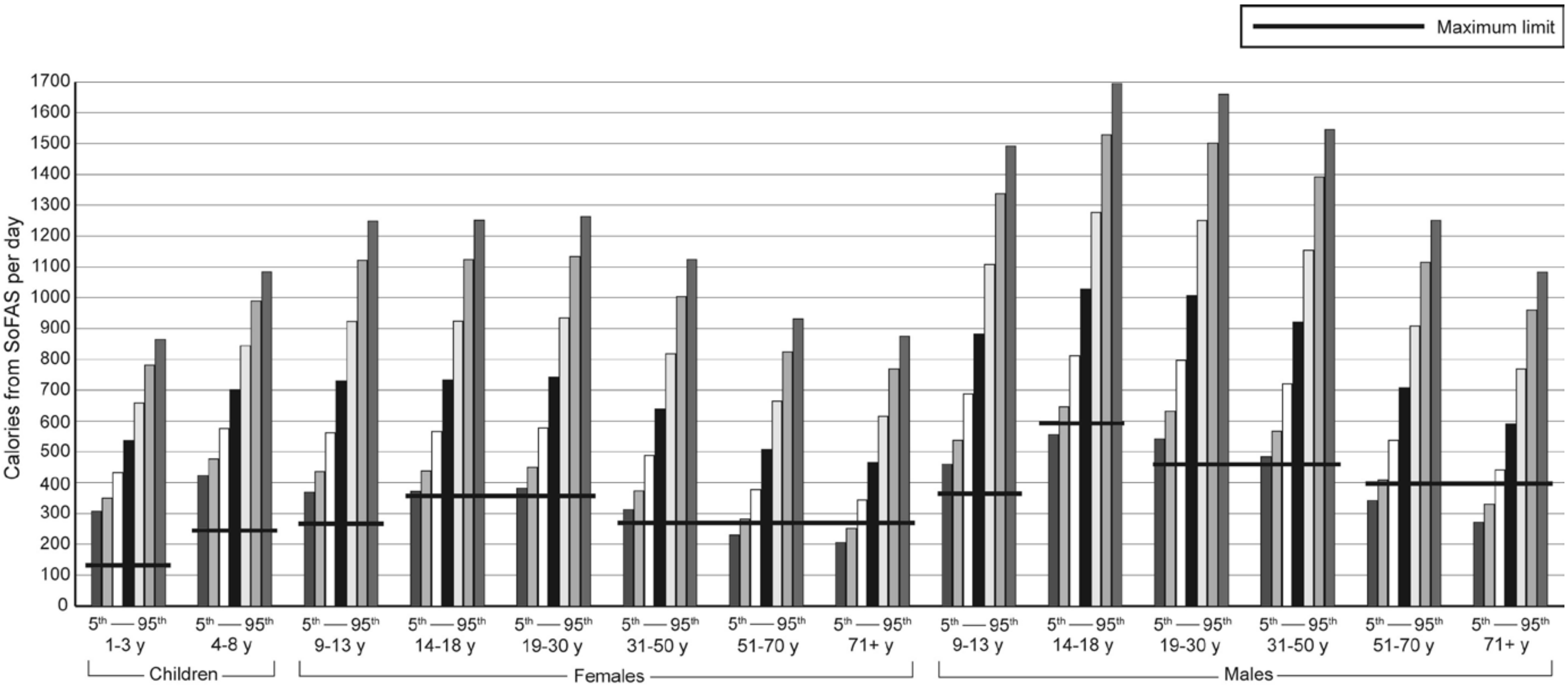
Figure D2.2. Comparison of mean usual daily intake of calories from solid fats and from added sugars, by age/sex group



Source: Usual Dietary Intakes: Food Intakes, U.S. Population, 2001-04. Risk Factor Monitoring and Methods Branch Web site. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/usualintakes/pop/. Updated April 13, 2010. Accessed April 22, 2010.

Figure D2.3. Distribution of usual daily intakes of SoFAS (solid fats and added sugars) in Calories, in comparison to maximum limits, by age/sex group

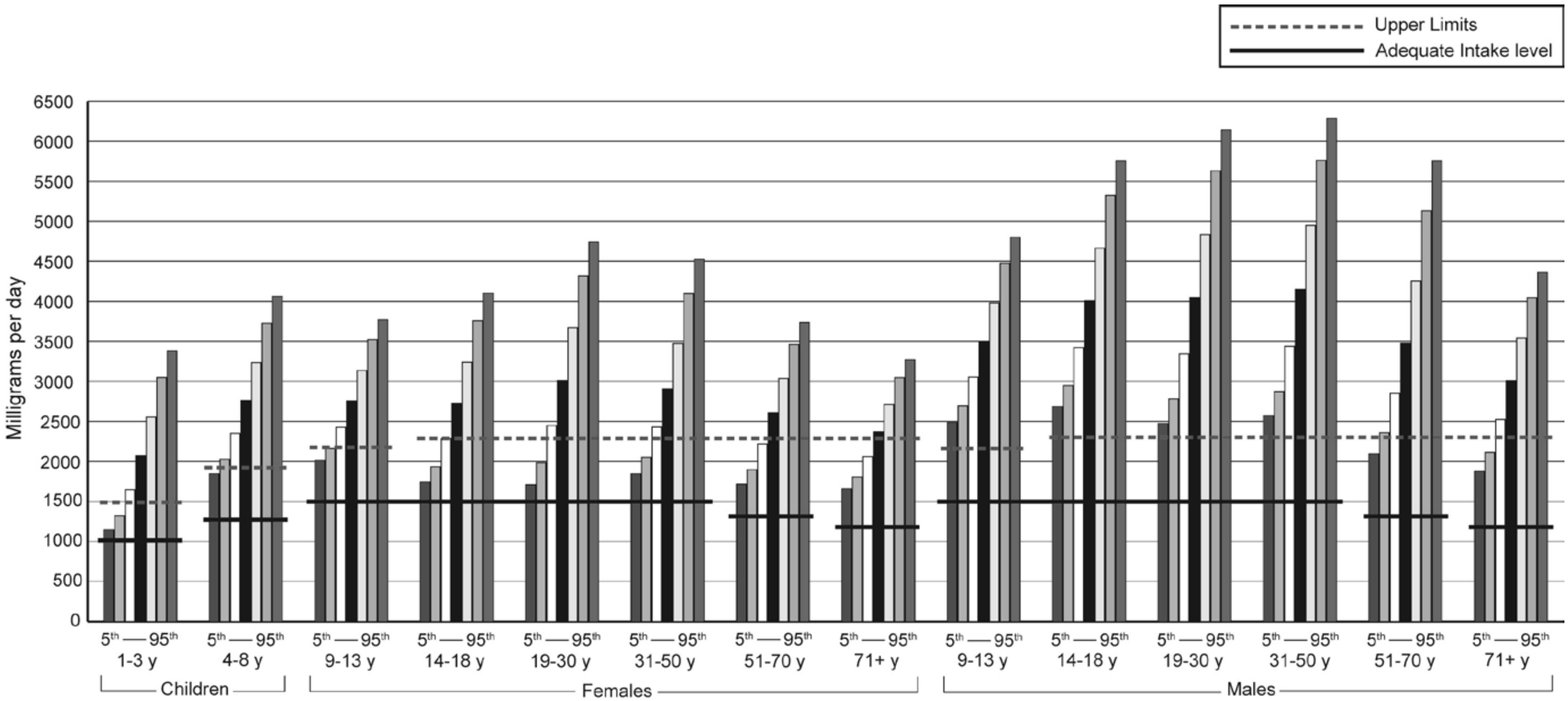
Bars show, from left to right, Calories from SoFAS at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Horizontal line shows maximum recommended limit for each age/sex group.



Source: Usual Dietary Intakes: Food Intakes, U.S. Population, 2001-04. Risk Factor Monitoring and Methods Branch Web site. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/usualintakes/pop/. Updated April 13, 2010. Accessed April 22, 2010.

Figure D2.4. Distribution of usual daily intakes of sodium, in milligrams, in comparison to Adequate Intake (AI) levels and Tolerable Upper Intake Limits (UL), by age/sex group

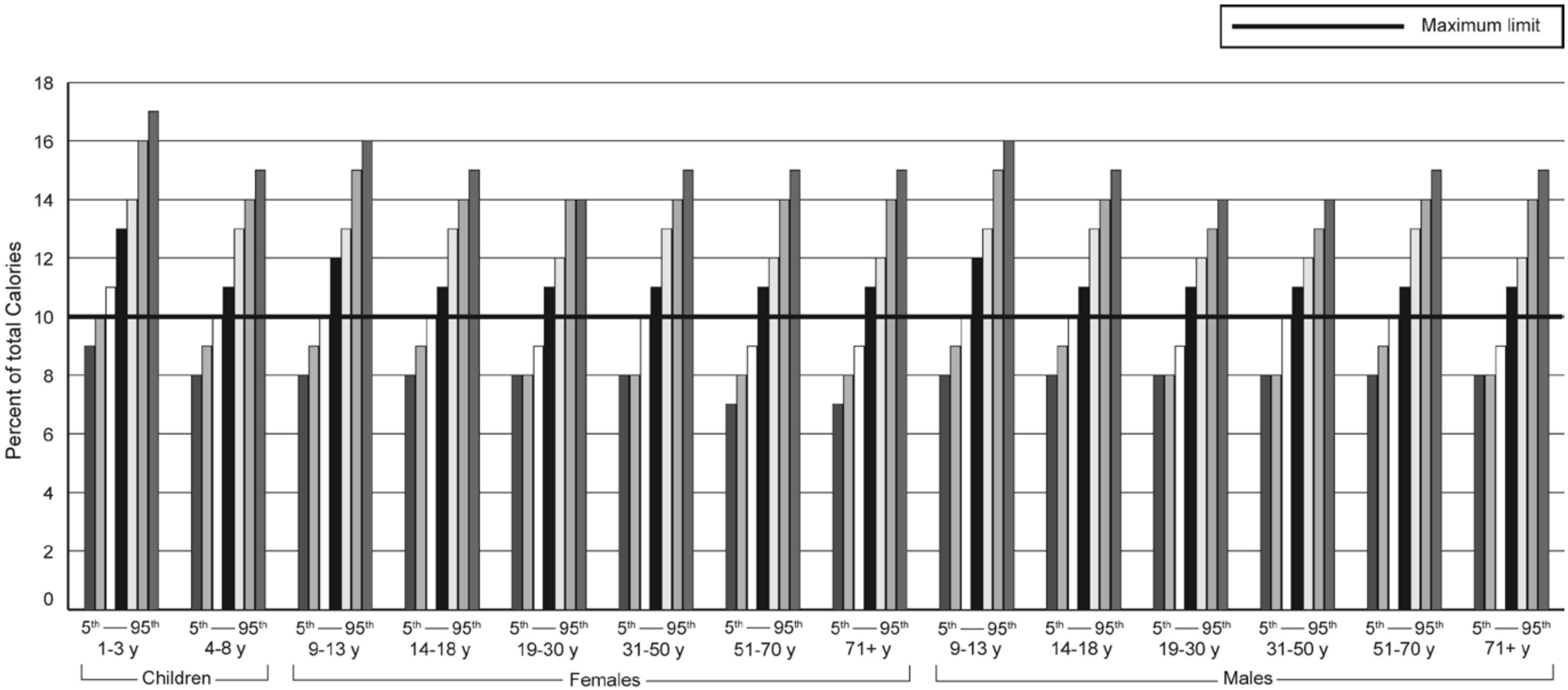
Bars show, from left to right, usual sodium intakes at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Solid horizontal line shows AI and dotted horizontal line shows UL for each age/sex group.



Source: Sodium (mg): Usual Intakes from Food and Water, 2003-2006, Compared to Adequate Intakes and Tolerable Upper Intake Levels. Food Surveys Research Group, Agricultural Research Service, USDA. What We Eat in America, NHANES 2003-2006. Web site: http://www.ars.usda.gov/Services/docs.htm?docid=18349 Updated April 1, 2010, Accessed April 22, 2010.

Figure D2.5. Distribution of usual daily intakes of saturated fatty acids as a percent of total Calories in comparison to maximum limit, by age/sex group

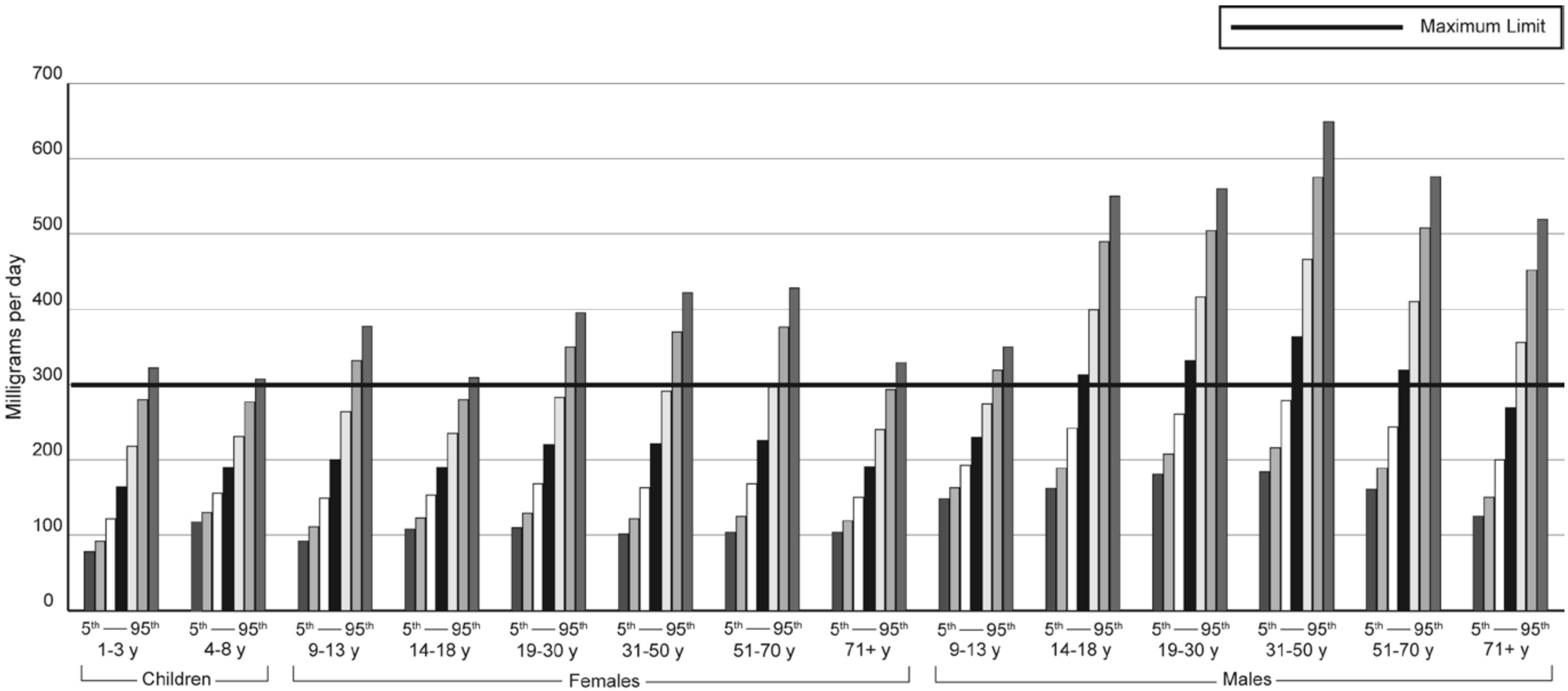
Bars show, from left to right, percent of Calories from saturated fatty acids at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Horizontal line shows maximum recommended limit.



Source: Usual Energy Intake from Saturated Fat. Risk Factor Monitoring and Methods Branch Web site. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/usualintakes/energy/t4.html. Updated April 13, 2010. Accessed April 22, 2010.

Figure D2.6. Distribution of usual daily intakes of cholesterol, in milligrams, in comparison to maximum limit, by age/sex group

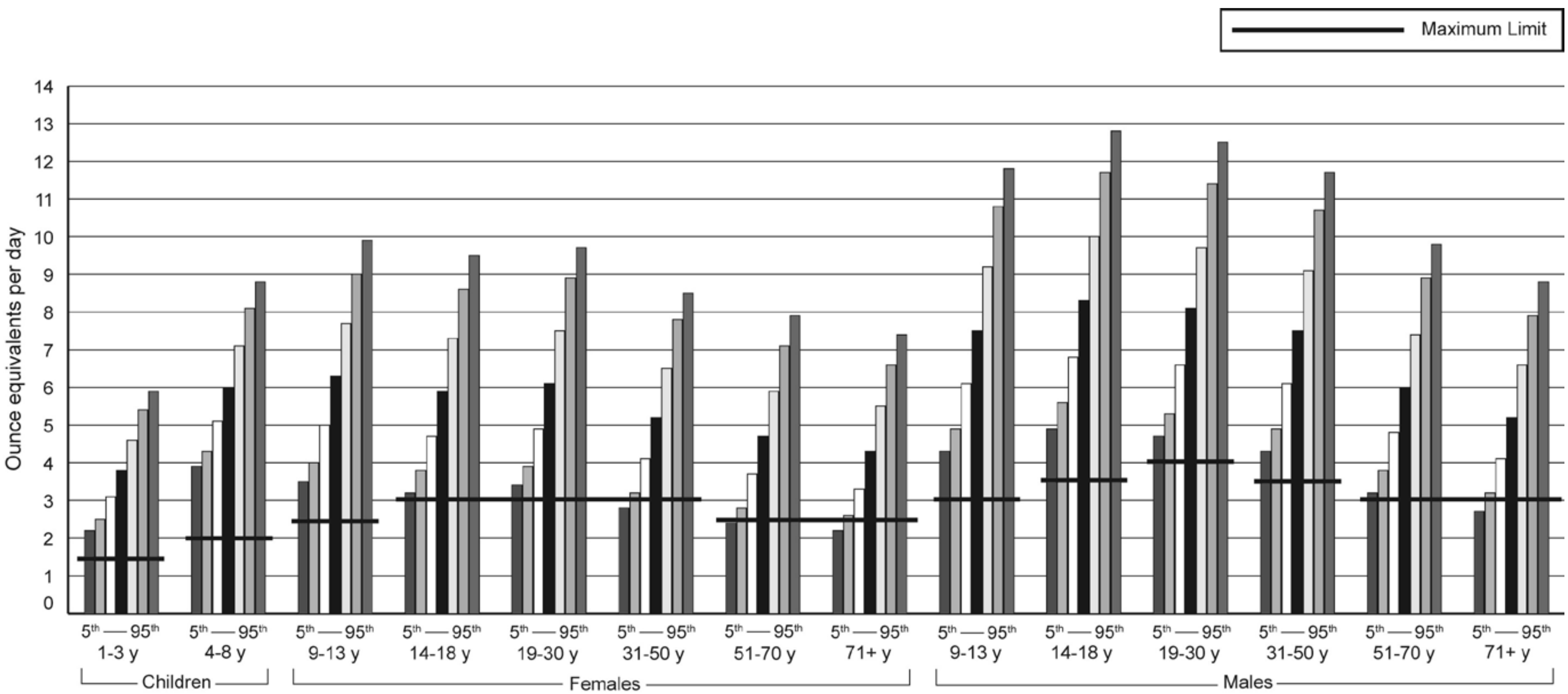
Bars show, from left to right, usual cholesterol intakes at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Horizontal line shows maximum recommended limit.



Source: Cholesterol (mg): Usual Intakes from Food and Water, 2003-2006, Compared to the Recommendation of Below 300 mg. Food Surveys Research Group, Agricultural Research Service, USDA. What We Eat in America, NHANES 2003-2006. Website: http://www.ars.usda.gov/Services/docs.htm?docid=18349 Updated April 1, 2010, Accessed April 22, 2010.

Figure D2.7. Distribution of usual daily intakes of refined grains, in ounce equivalents, in comparison to maximum limits, by age/sex group

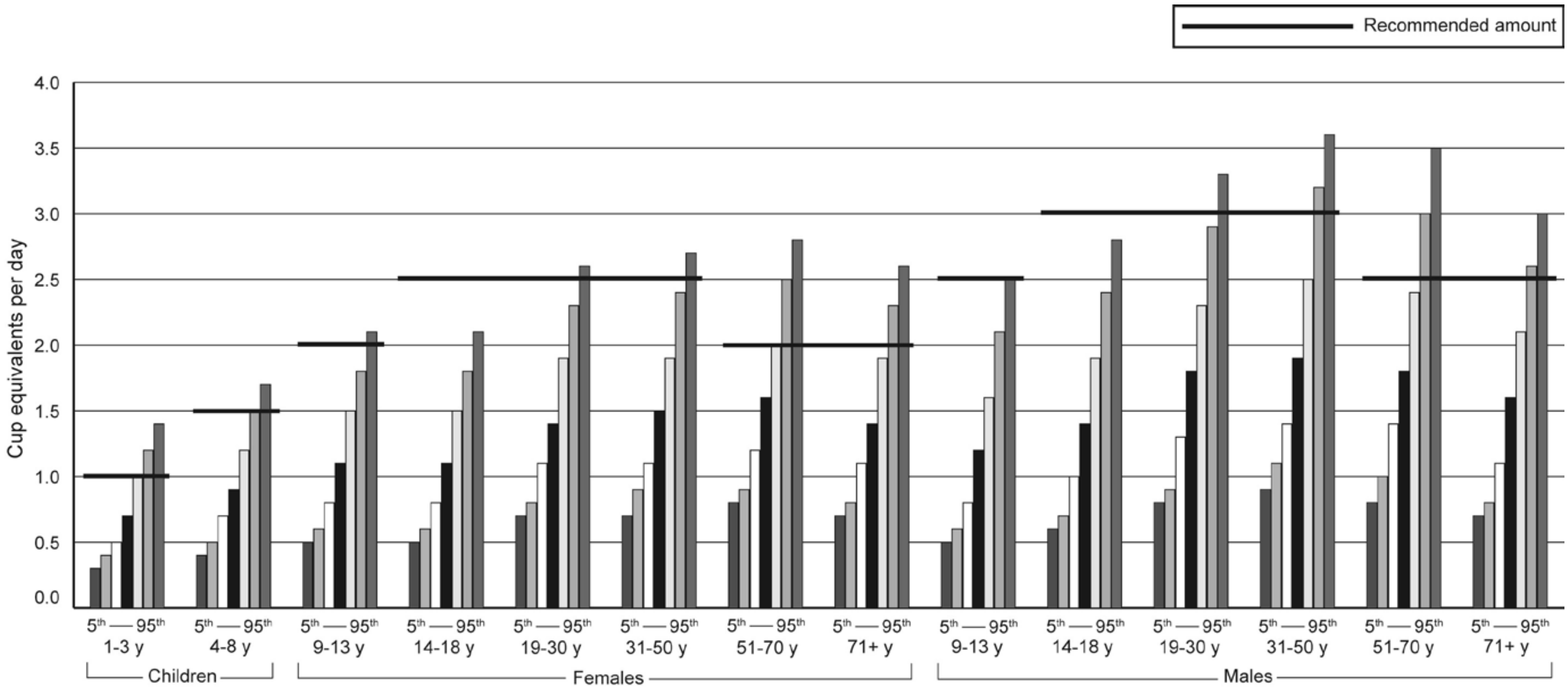
Bars show, from left to right, usual refined grains intakes at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Horizontal line shows maximum recommended limit for each age/sex group.



Source: Usual Intake of Non-whole Grains. Risk Factor Monitoring and Methods Branch Web site. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/usualintakes/pop/t16.html. Updated April 13, 2010. Accessed April 22, 2010.

Figure D2.8. Distribution of usual daily intakes of vegetables, in cup equivalents, in comparison to recommended intake levels, by age/sex group

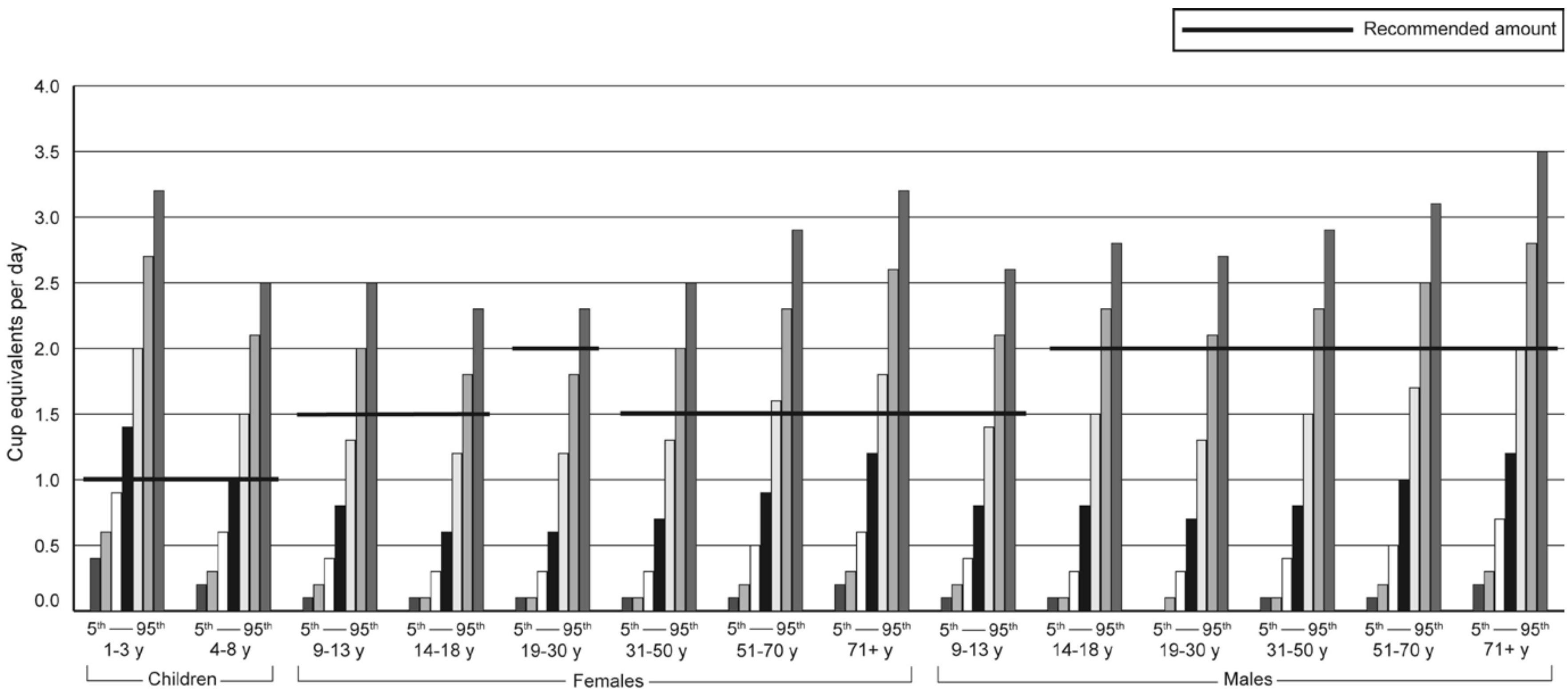
Bars show, from left to right, usual vegetable intakes at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Horizontal line shows recommended intake level for each age/sex group.



Source: Usual Intake of Total Vegetables, Including Cooked Dry Beans & Peas. Risk Factor Monitoring and Methods Branch Web site. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/usualintakes/pop/t14.html. Updated April 13, 2010. Accessed April 22, 2010.

Figure D2.9. Distribution of usual daily intakes of fruits, in cup equivalents, in comparison to recommended intake levels, by age/sex group

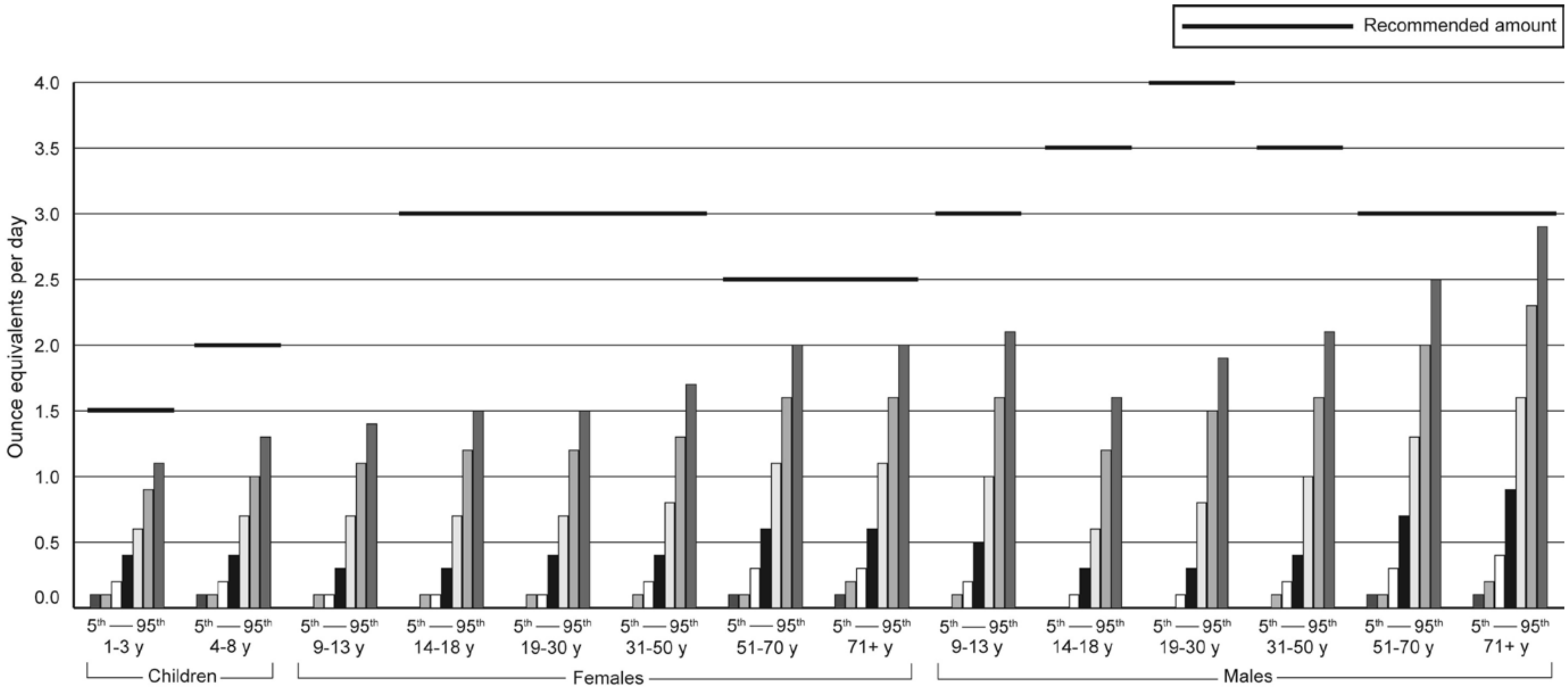
Bars show, from left to right, usual fruit intakes at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Horizontal line shows recommended intake level for each age/sex group.



Source: Usual Intake of Total Fruit. Risk Factor Monitoring and Methods Branch Web site. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/usualintakes/pop/t3.html. Updated April 13, 2010. Accessed April 22, 2010.

Figure D2.10. Distribution of usual daily intakes of whole grains, in ounce equivalents, in comparison to recommended intake levels, by age/sex group

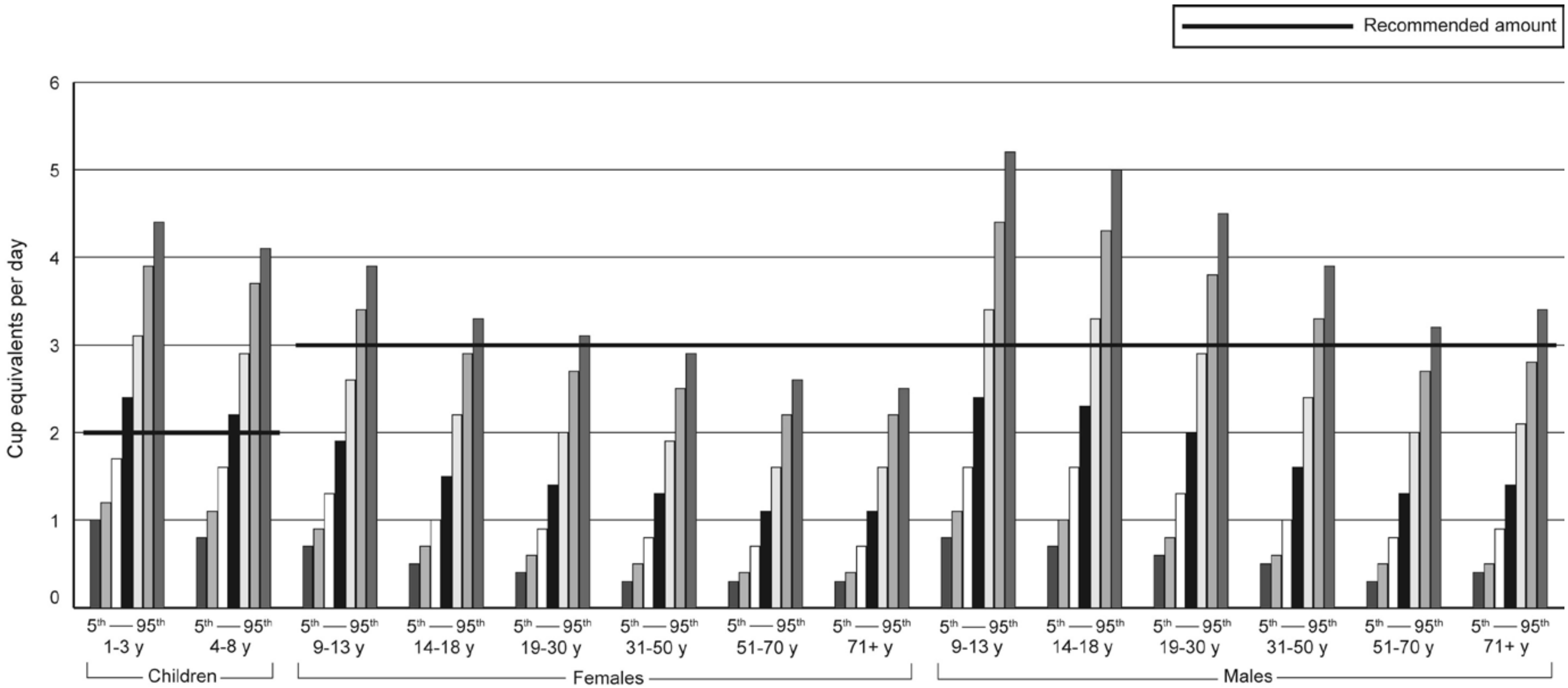
Bars show, from left to right, usual whole grains intakes at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Horizontal line shows recommended intake level for each age/sex group.



Source: Usual Intake of Whole Grains. Risk Factor Monitoring and Methods Branch Web site. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/usualintakes/pop/t15.html. Updated April 13, 2010. Accessed April 22, 2010.

Figure D2.11. Distribution of usual daily intakes of milk and milk products, in cup equivalents, in comparison to recommended intake levels, by age/sex group

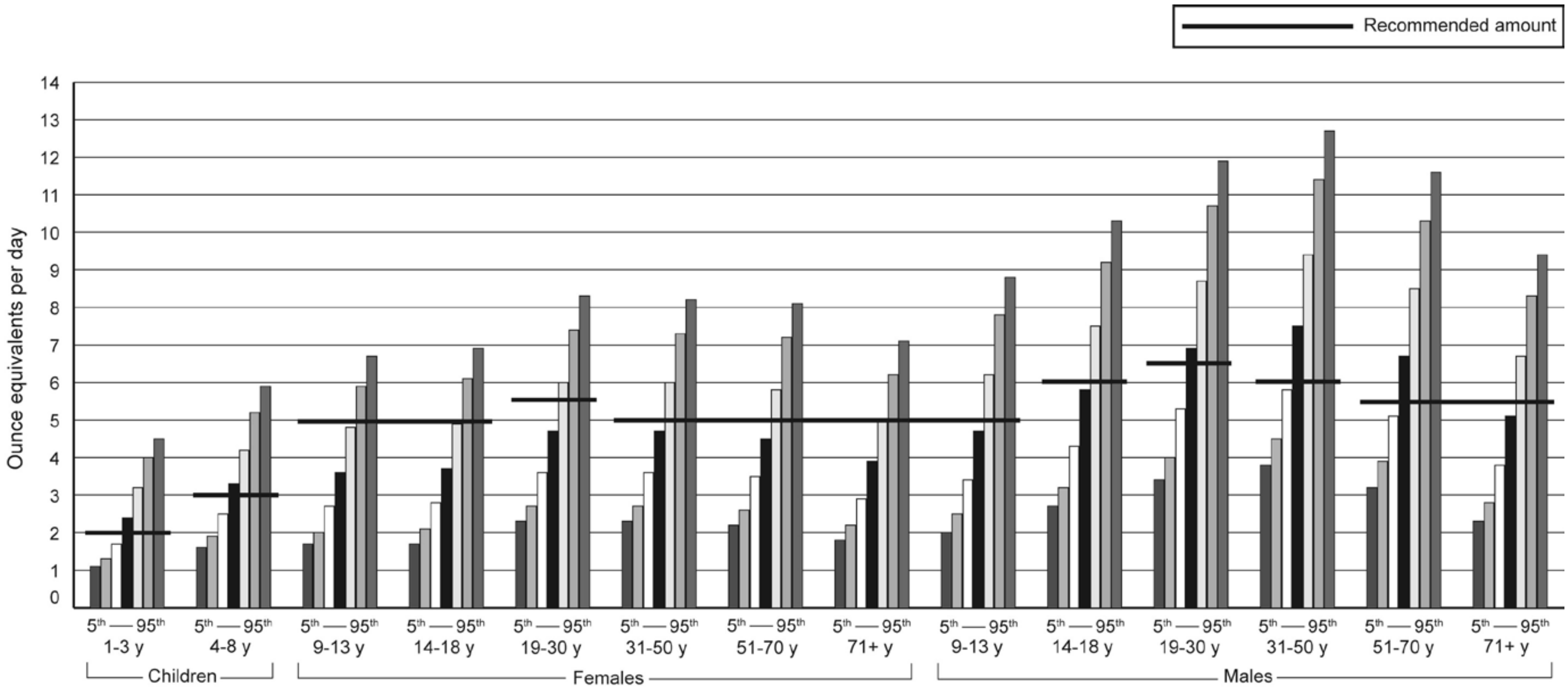
Bars show, from left to right, usual milk and milk product intakes at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Horizontal line shows recommended intake level for each age/sex group.



Source: Usual Intake of Total Milk, Yogurt, & Cheese. Risk Factor Monitoring and Methods Branch Web site. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/usualintakes/pop/t32.html. Updated April 13, 2010. Accessed April 22, 2010.

Figure D2.12. Distribution of usual daily intakes of meat, poultry, fish, eggs, soy products, nuts, and seeds, in ounce equivalents, in comparison to recommended intake levels, by age/sex group

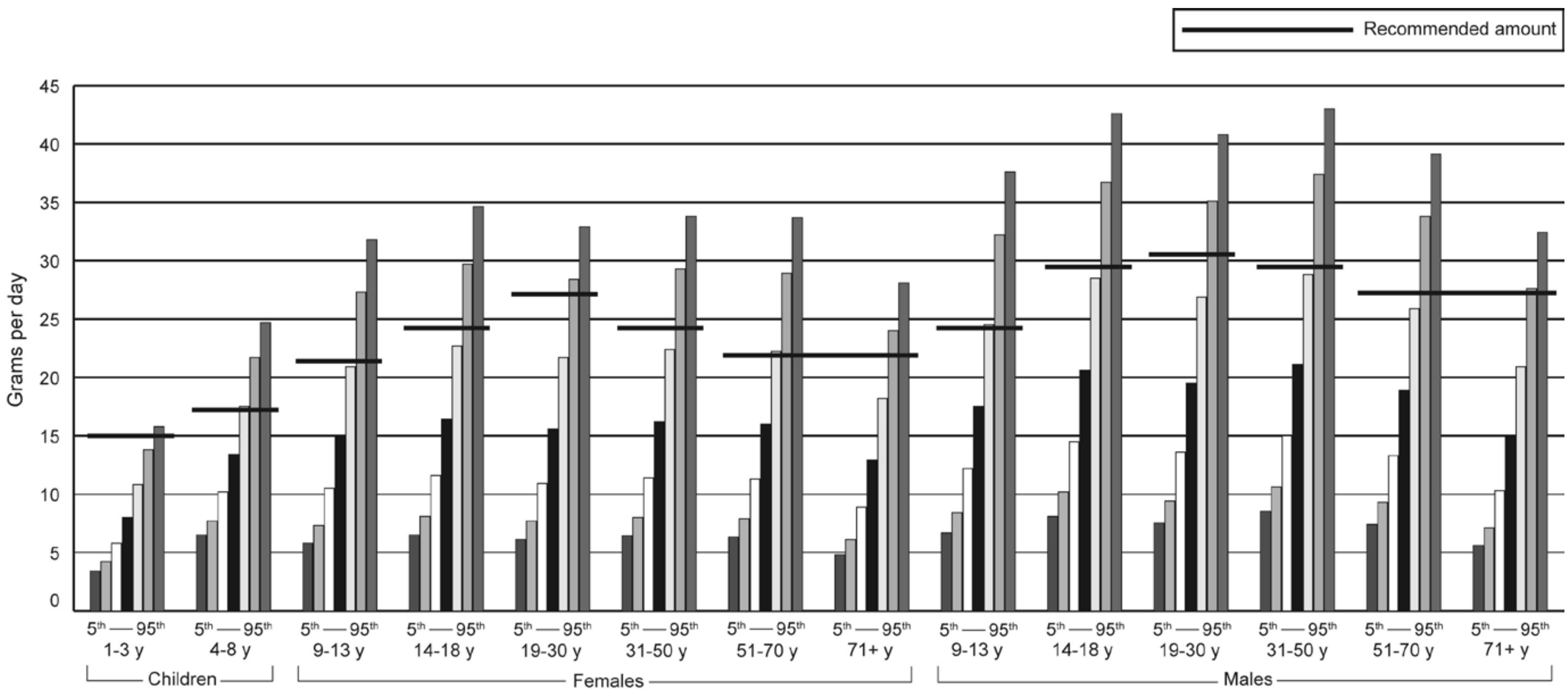
Bars show, from left to right, usual meat, poultry, fish, eggs, soy products, nuts, and seeds intakes at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Horizontal line shows recommended intake level for each age/sex group.



Source: Usual Intake of Total Meat, Fish, Poultry, Eggs, Soy Products, Nuts, & Seeds. Risk Factor Monitoring and Methods Branch Web site. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/usualintakes/pop/t28.html. Updated April 13, 2010. Accessed April 22, 2010.

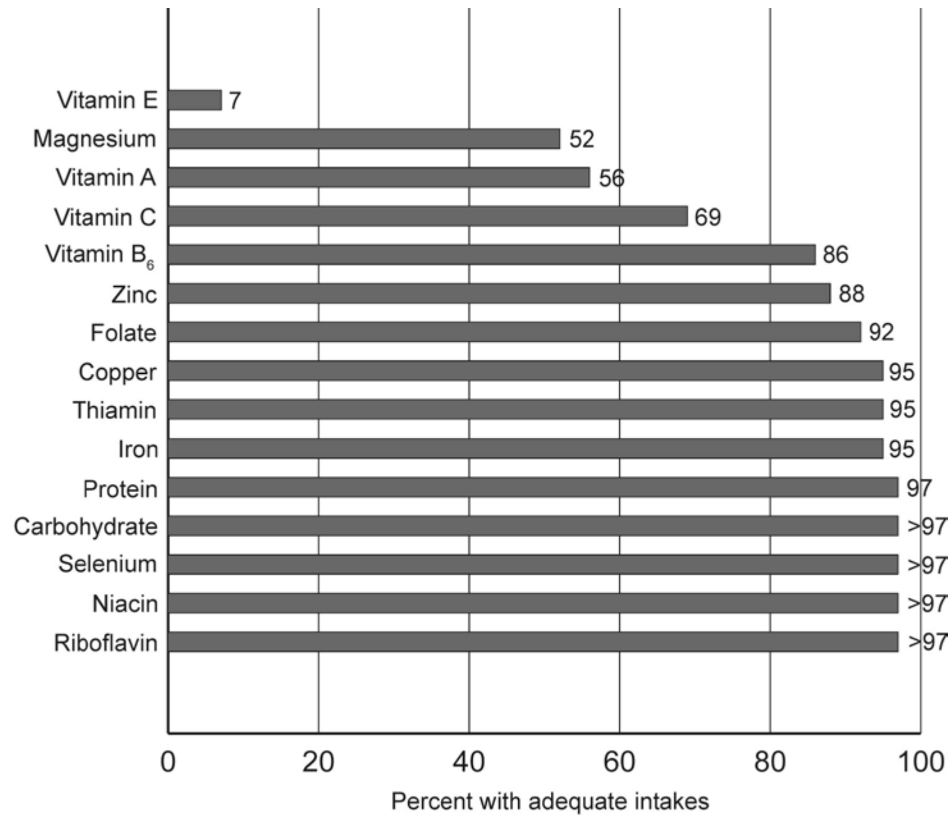
Figure D2.13. Distribution of usual daily intakes of oils, in grams, in comparison to recommended intake levels, by age/sex group

Bars show, from left to right, usual oils intakes at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Horizontal line shows recommended intake level for each age/sex group.



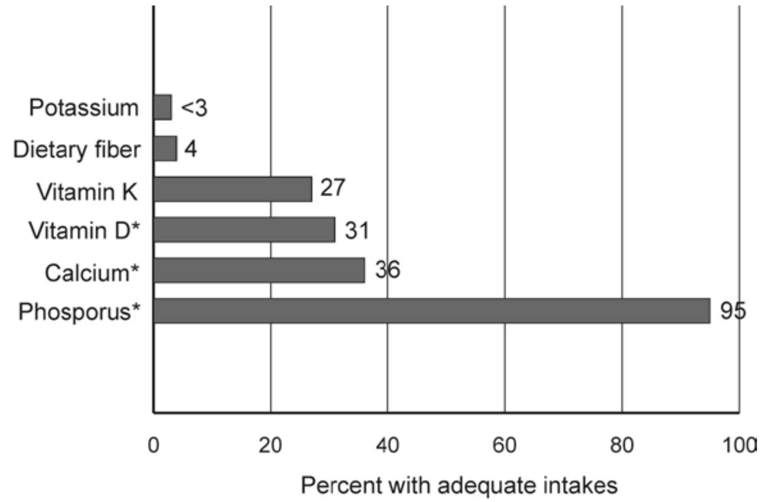
Source: Usual Intake of Oils. Risk Factor Monitoring and Methods Branch Web site. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/usualintakes/pop/t33.html. Updated April 13, 2010. Accessed April 22, 2010.

Figure D2.14. Level of adequacy expressed as estimated percentages of Americans with nutrient intakes from food above their requirements (EARs)



Source: Moshfegh, Alanna; Goldman, Joseph; and Cleveland, Linda. 2005. *What We Eat in America*, NHANES 2001-2002: Usual Nutrient Intakes from Food Compared to Dietary Reference Intakes. U.S. Department of Agriculture, Agricultural Research Service.

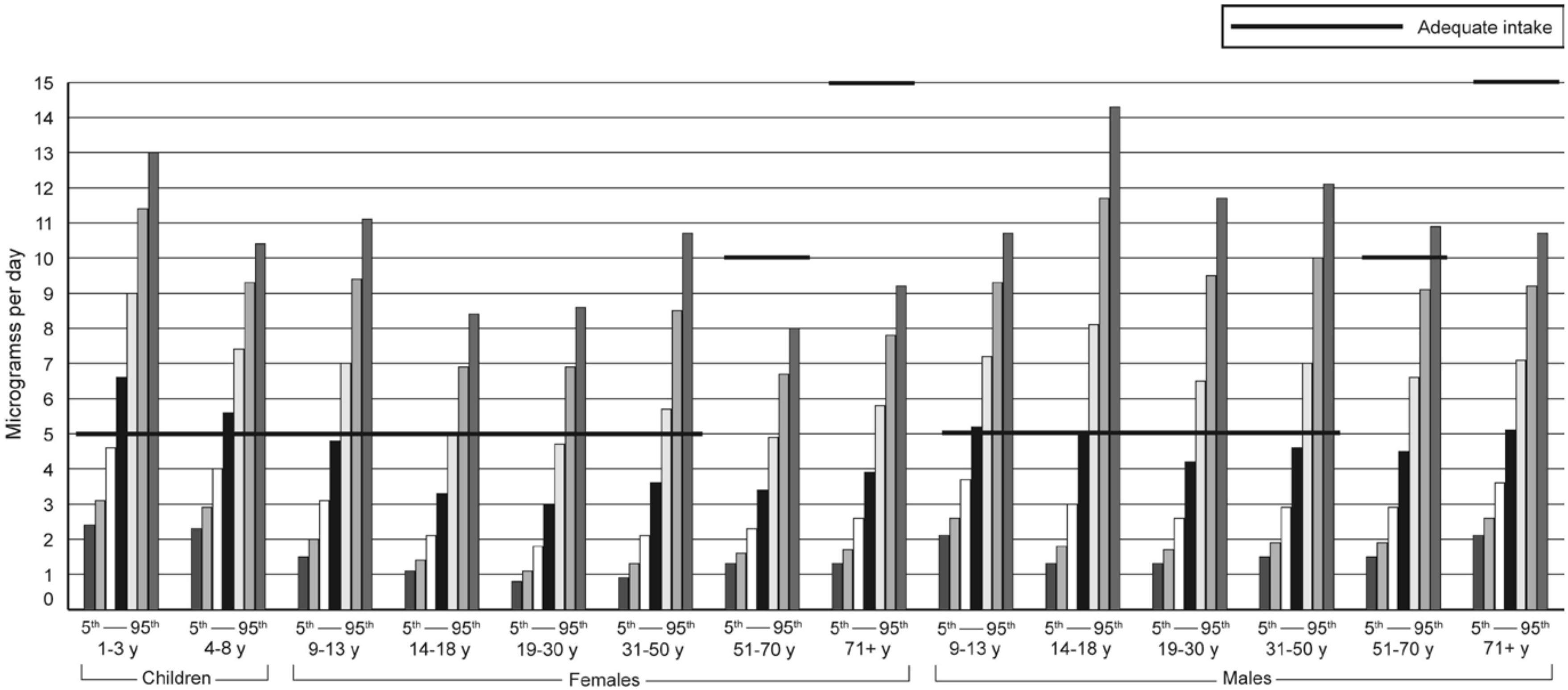
Figure D2.15. Level of adequacy expressed as estimated percentages of Americans with nutrient intakes from food above the Adequate Intake (AI) level.



Sources: Moshfegh, Alanna; Goldman, Joseph; and Cleveland, Linda. 2005. *What We Eat in America*, NHANES 2001-2002: Usual Nutrient Intakes from Food Compared to Dietary Reference Intakes. U.S. Department of Agriculture, Agricultural Research Service.
Moshfegh, Alanna; Goldman, Joseph; Ahuja, Jaspreet; Rhodes, Donna; and LaComb, Randy. 2009. *What We Eat in America*, NHANES 2005-2006: Usual Nutrient Intakes from Food and Water Compared to 1997 Dietary Reference Intakes for Vitamin D, Calcium, Phosphorus, and Magnesium. U.S. Department of Agriculture, Agricultural Research Service.

Figure D2.16. Distribution of usual daily intakes of vitamin D, in micrograms, in comparison to Adequate Intake (AI) levels, by age/sex group

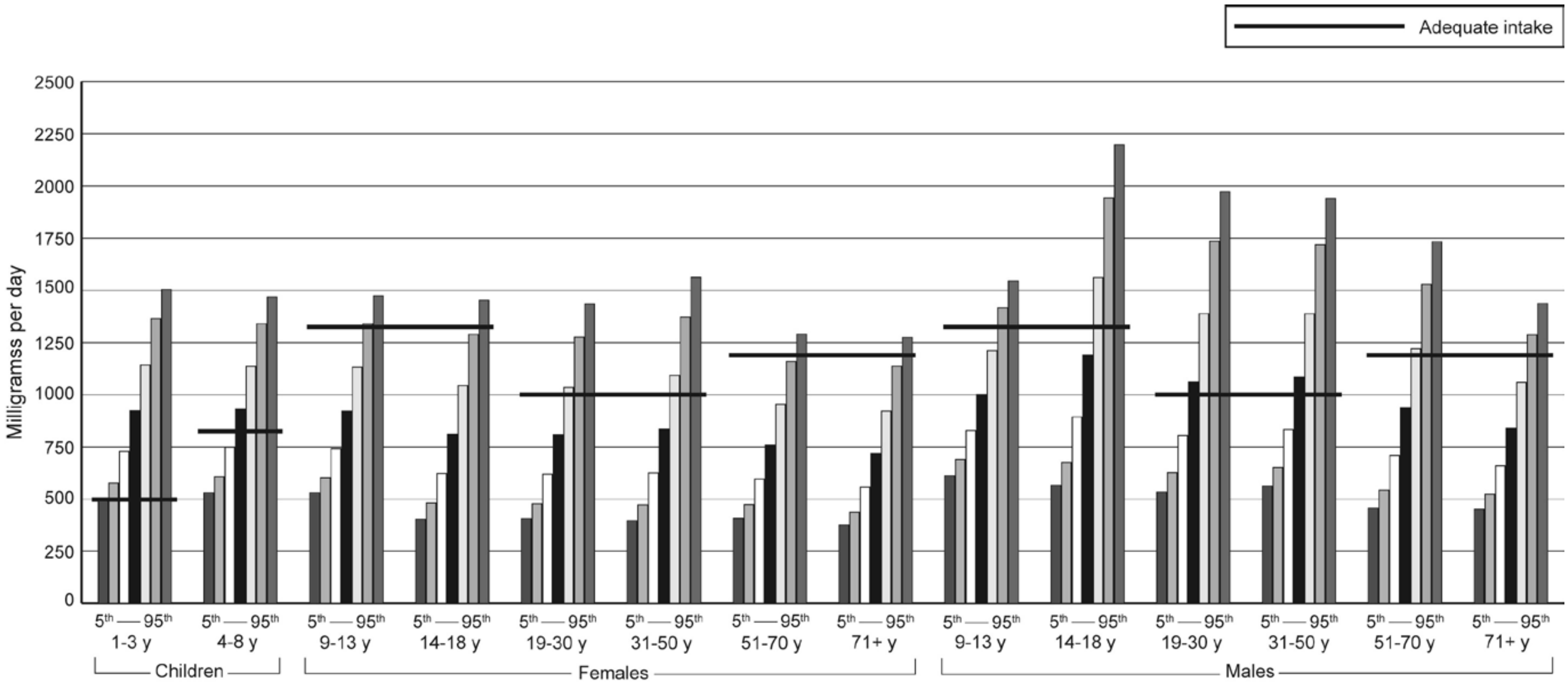
Bars show, from left to right, usual vitamin D intakes at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Horizontal line shows the AI level for each age/sex group.



Source: Moshfegh, Alanna; Goldman, Joseph; Ahuja, Jaspreet; Rhodes, Donna; and LaComb, Randy. 2009. *What We Eat in America*, NHANES 2005-2006: Usual Nutrient Intakes from Food and Water Compared to 1997 Dietary Reference Intakes for Vitamin D,Calcium, Phosphorus, and Magnesium. U.S. Department of Agriculture, Agricultural Research Service.

Figure D2.17. Distribution of usual daily intakes of calcium, in milligrams, in comparison to Adequate Intake (AI) levels, by age/sex group

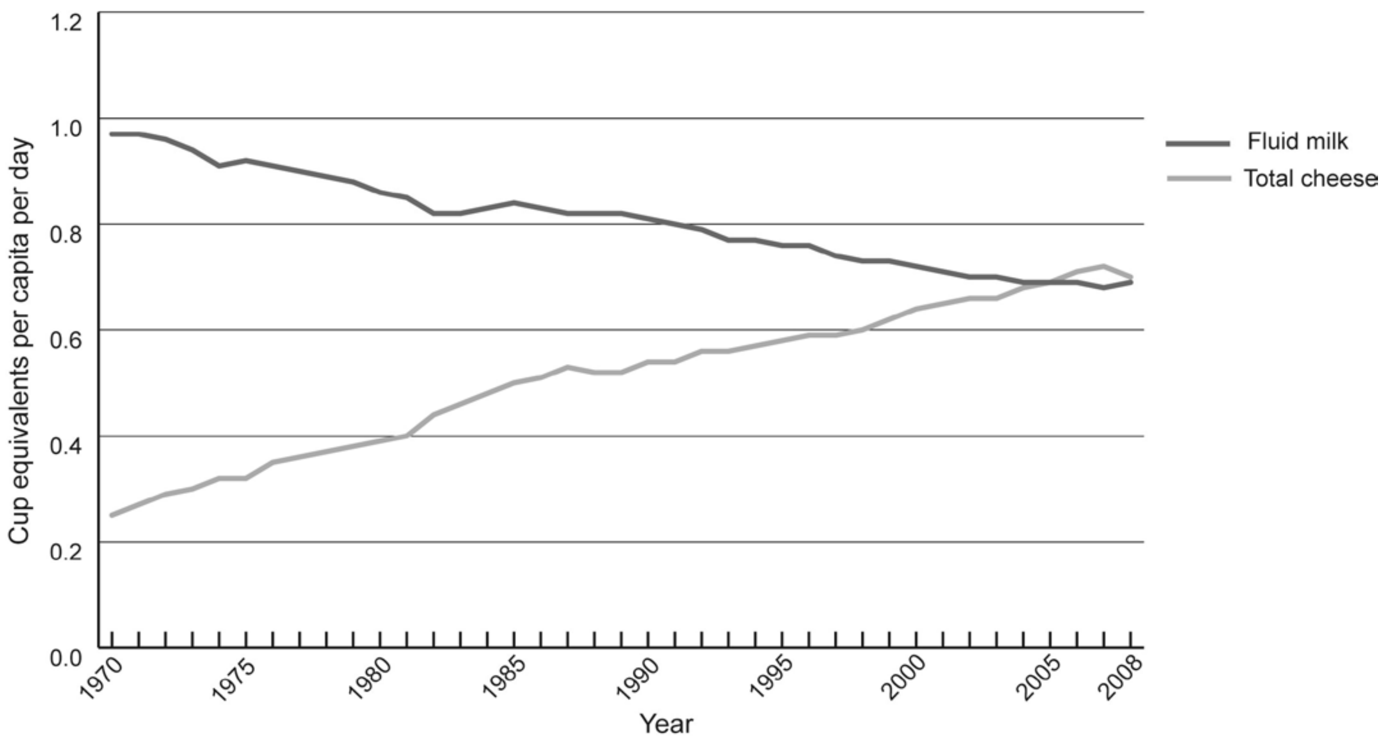
Bars show, from left to right, usual calcium intakes at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Horizontal line shows AI level for each age/sex group.



Source: Moshfegh, Alanna; Goldman, Joseph; Ahuja, Jaspreet; Rhodes, Donna; and LaComb, Randy. 2009. *What We Eat in America*, NHANES 2005-2006: Usual Nutrient Intakes from Food and Water Compared to 1997 Dietary Reference Intakes for Vitamin D, Calcium, Phosphorus, and Magnesium. U.S. Department of Agriculture, Agricultural Research Service.

Figure D2.18. Relative proportions of fluid milk and cheese available for consumption over time

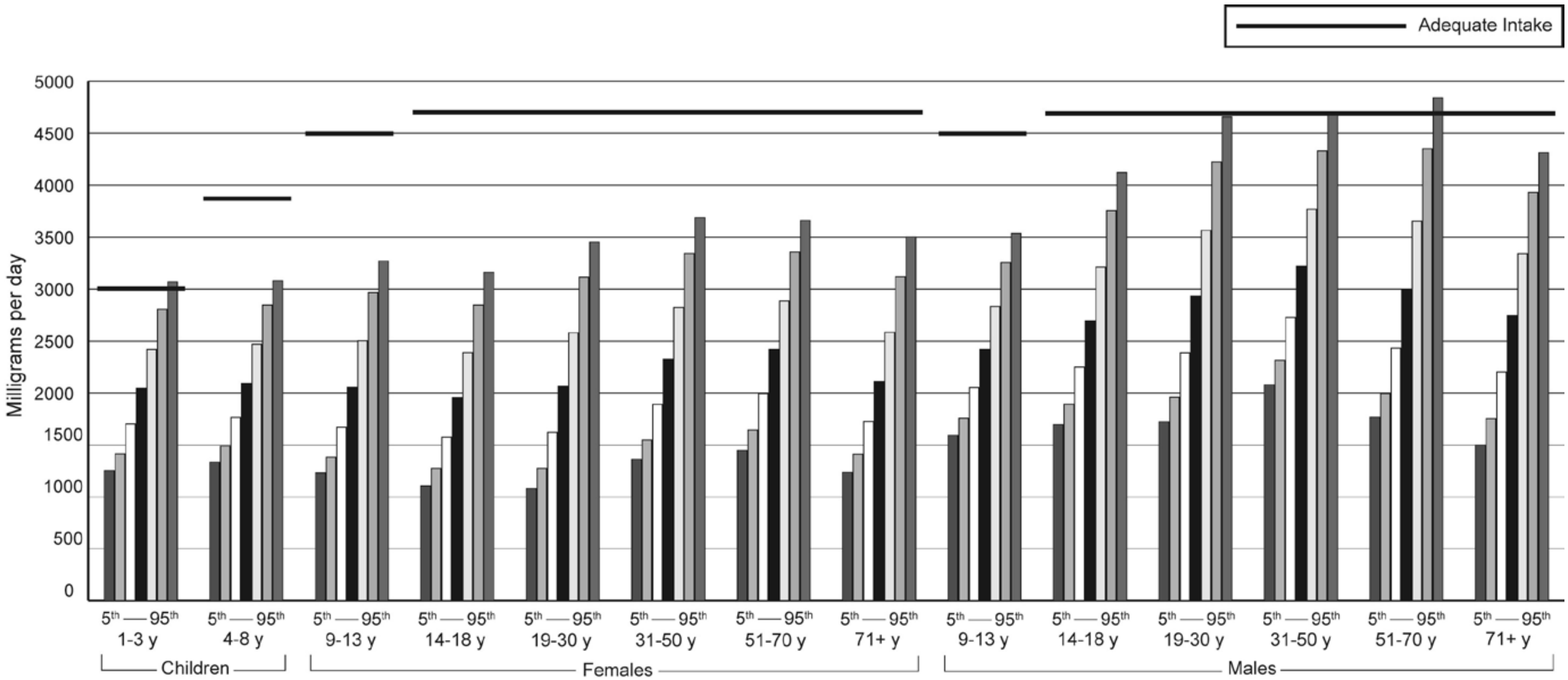
Graph shows loss adjusted availability of fluid milk and cheese in cup equivalents per capita per day.



Source: Economic Research Service (ERS), U.S. Department of Agriculture (USDA). Food Availability (Per Capita) Data System. http://www.ers.usda.gov/Data/FoodConsumption.

Figure D2.19. Distribution of usual daily intakes of potassium, in milligrams, in comparison to Adequate Intake (AI) levels, by age/sex group

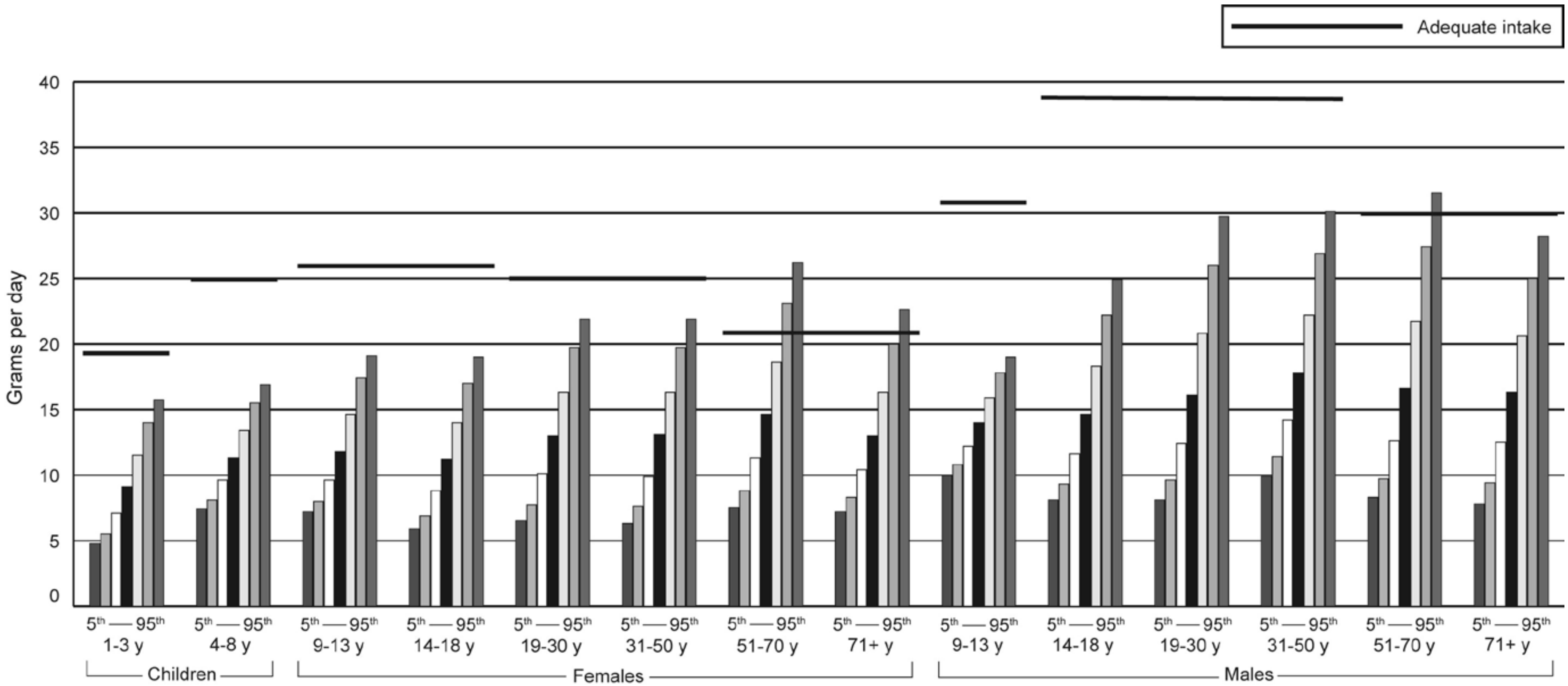
Bars show, from left to right, usual potassium intakes at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Horizontal line shows AI level for each age/sex group.



Source: Moshfegh, Alanna; Goldman, Joseph; and Cleveland, Linda. 2005. *What We Eat in America*, NHANES 2001-2002: Usual Nutrient Intakes from Food Compared to Dietary Reference Intakes. U.S. Department of Agriculture, Agricultural Research Service.

Figure D2.20. Distribution of usual daily intakes of dietary fiber, in grams, in comparison to Adequate Intake (AI) levels, by age/sex group

Bars show, from left to right, usual dietary fiber intakes at the 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th}, and 95^{th} percentiles. Horizontal line shows AI level for each age/sex group.



Source: Dietary Fiber (g): Usual Intakes from Food and Water, 2003-2006, Compared to Adequate Intakes. Food Surveys Research Group, Agricultural Research Service, USDA. What We Eat in America, NHANES 2003-2006. Website: http://www.ars.usda.gov/Services/docs.htm?docid=18349 Updated April 1, 2010, Accessed April 22, 2010.

Part D. Section 3: Fatty Acids and Cholesterol

Introduction

Dietary fats, or lipids, are a macronutrient class that includes fatty acids, triglycerides, and cholesterol. Fats supply fuel energy (9 kcal/g) and the essential fatty acids, linoleic and alpha-linolenic acids. Fats, therefore, are a key factor in the maintenance of caloric balance and body weight. Specific fatty acids also serve as precursors for numerous biological pathways that influence inflammation, coagulation, and gene expression among other functions. Fat soluble vitamins (vitamins A, D, E, K) and carotenoids are absorbed and transported with fats.

Fatty acids are bound to glycerol as triglycerides for transport and storage in the human body. Fatty acids are heterogeneous and classified based on their chain length, the number of double bonds, the position of the first double bond from the methyl end, and a *cis* versus *trans* configuration across a double bond. These heterogeneities are important determinants of the significant variation in biological effects of the different fatty acids. Fatty acid quantity and quality also vary by their source, with important differences between meat, fish, and plant sources, as well as natural versus synthetic sources. This heterogeneity allows for food consumption choices to modulate the quantity and quality of fats that, in turn, influence metabolic and health outcomes.

Cholesterol, a sterol, is an important structural component of cell walls of tissues of the human body. Cholesterol is also a precursor for a number of steroid hormones synthesized by the adrenal glands, ovaries, and testes. Bile acids, required for solubilization and absorption of dietary fats, are synthesized from cholesterol in the liver, stored in the gallbladder and secreted into the small intestine after a fat-containing meal. Endogenous hepatic synthesis of cholesterol is adequate to produce all the cholesterol needed for these vital functions. Exogenous, or dietary, cholesterol down-regulates cholesterol synthesis in the liver to maintain cholesterol balance. Pharmacologic agents inhibit the rate-limiting step of cholesterol synthesis, catalyzed by the enzyme HMG-CoA reductase, as a means of reducing endogenous cholesterol synthesis; this also increases receptor-mediated uptake of low-density lipoprotein (LDL) cholesterol by the liver.

A critical health issue related to dietary fat is the quality of fat in the American diet. The consumption of certain fats, such as saturated fatty acids (SFA) and *trans*[1] fatty acids, is associated with a poor lipid/lipoprotein profile and increased risk of cardiovascular disease (CVD). On the other hand, the unsaturated fats, monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) have significant metabolic benefits and are health-promoting. Currently, several lines of evidence indicate that the type of fat is more important in decreasing metabolic and CVD risk than the total amount of fat in the diet. Metabolic studies have established that it is the type of fat, rather than total fat intake that affects common intermediate risk factors, such as serum lipid and lipoprotein levels (Hu, 2001). Results from controlled clinical trials and epidemiological studies have shown that replacing SFA with unsaturated fats is more effective in decreasing CVD risk than is reducing total fat intake overall (Smit, 2009). Additionally, prospective cohort studies and secondary prevention trials provide methodologically strong evidence that consumption of *n*-3 fatty acids from seafood and plant sources has a significant cardio-protective effect and decreases cardiovascular mortality (Mozaffarian, 2008; Mozaffarian and Rimm, 2006). Furthermore, dietary fat and intermediate risk factors do not affect CVD risk in a uniform way. Numerous factors influence CVD risk, including fatty acids (*n*-3 fatty acids, specific SFA, MUFA and PUFA, and *trans* fatty acids); carbohydrate quantity, type, and quality; intakes of legumes, nuts, fruits, and vegetables; as well

[1] *Trans* fatty acids used in this Report is a term consistent with that defined by the US Food and Drug Administration for use in food labeling as unsaturated fatty acids that contain one or more isolated (i.e., nonconjugated) double bonds in a *trans* configuration (*Federal Register* notice. Food Labeling; *Trans* Fatty Acids in Nutrition Labeling; Final Rule and Proposed Rule. Vol. 68, No. 133, p. 41433-41506, July 11, 2003). *Trans* fatty acids (TFA) are from natural (or ruminant) or industrial (synthetic) sources and will be designated as rTFA and iTFA, respectively.

as micronutrients. For example, isocaloric substitution of dietary fat with carbohydrate can lead to increased serum triglycerides and decreased serum HDL cholesterol (Smit, 2009; Nordmann, 2006). Additionally, the effects of dietary fat, as well as the other macronutrients, and intermediate risk factors, are diverse and highly dependent on other factors such as physical activity and lifestyle habits, and, importantly, individual genetic predisposition that is based on underlying genetic polymorphisms.

The issue of excess dietary cholesterol is also of public health concern. Traditionally, because dietary cholesterol has been shown to raise LDL cholesterol and high intakes induce atherosclerosis in observational studies, the prevailing recommendation has been to restrict dietary cholesterol intake, including otherwise healthy foods such as eggs. The potential negative effects of dietary cholesterol are relatively small compared to those of SFA and *trans* fatty acids (Clarke, 1997; Howell, 1997). A further important consideration is significant variation in the population in individual responses to cholesterol intake; differences in susceptibility are likely based on well-characterized genetic polymorphisms in several genes encoding enzymes, apolipoproteins, receptors, and transporters involved in lipid metabolism and storage. The underlying genetic polymorphisms are manifested as individuals who are "hyper-responders" and "hypo-responders" referring to those who respond to cholesterol intake with elevated serum LDL cholesterol and those who, at the same level of cholesterol intake, do not exhibit increased serum LDL cholesterol, respectively.

This section of the 2010 DGAC Report continues with brief explanations on the types of fats and cholesterol and food sources of these nutrients, a discussion of trends in fat and cholesterol intakes in the American diet, and contextual information on recommended intakes and health outcomes. The chapter then provides Nutrition Evidence Library (NEL) systematic evidence-based reviews of 11 questions on a variety of issues related to fats, cholesterol, and health.

Background on Fats and Cholesterol

Types and Food Sources of Fatty Acids and Cholesterol

Fatty acids and cholesterol are a diverse group of compounds that are found across a wide variety of foods consumed by Americans. The following sections provide additional information on the specific fatty acids and common food sources in the diet.

Saturated Fatty Acids (SFA)—Saturated fatty acids are linear carbon chain molecules with each carbon fully saturated with hydrogen atoms and, therefore, containing no double bonds. Like all fatty acids, SFA have a methyl end and a carboxyl end with varying even number of carbons in between. Due to this configuration, their melting point is high and they are solid at room temperature. The major types of SFA in the American diet are lauric (C12), myristic (C14), palmitic (C16), and stearic (C18) acids. Palmitic and stearic acids are major constituents of animal fats, but plant sources, such as coconut, palm, cocoa, and shea nut oils, are also sources of SFA. Cholesterol-raising SFA, considered SFA minus stearic acid (discussed below), down-regulate the low density lipoprotein (LDL) receptor by increasing intracellular cholesterol pools and decreasing LDL-cholesterol uptake by the liver. The foods that contribute the most saturated fat to the diets of Americans are listed in Table D3.1.

Monounsaturated Fatty Acids—MUFA have one site of unsaturation between neighboring carbon atoms, constituting a single double bond; this chemical property lowers their melting point so that MUFA are liquid at room temperature. MUFA are beneficial in that they increase esterification of cholesterol in the liver, thereby reducing the free cholesterol pool and increasing receptor-mediated uptake of LDL cholesterol, resulting in a decrease in blood cholesterol levels. Oleic acid (18:1), a MUFA common in the diet, is a major constituent of certain vegetable oils (e.g., olive, canola) but is present in many other foods such as nuts, meat, and poultry. The foods that contribute the most oleic acid to the diets of Americans are listed in Table D3.2.

Table D3.1. Food sources of saturated fat by percent contribution to intake, based on National Health and Nutrition Examination Survey, 2005-2006

Food Item	**Contribution to Intake %**	**Cumulative Contribution %**
Regular cheese	8.5	8.5
Pizza	5.9	14.4
Grain-based desserts	5.8	20.2
Dairy desserts	5.6	25.8
Chicken and chicken mixed dishes	5.5	31.2
Sausage, franks, bacon, and ribs	4.9	36.2
Burgers	4.4	40.5
Mexican mixed dishes	4.1	44.6
Beef and beef mixed dishes	4.1	48.7
Reduced fat milk	3.9	52.6
Pasta and pasta dishes	3.7	56.3
Whole milk	3.4	59.7
Eggs and egg mixed dishes	3.2	62.9
Candy	3.1	66.0
Butter	2.9	68.9
Potato/corn/other chips	2.4	71.3
Nuts/seeds and nut/seed mixed dishes	2.1	73.4
Fried white potatoes	2.0	75.4

Source: Sources of Saturated Fat Among the U.S. Population, 2005-2006. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/foodsources Updated November 9, 2009. Accessed April 16, 2010.

Table D3.2. Food sources of oleic acid by percent contribution to intake based on National Health and Nutrition Examination Survey, 2005-2006

Food Item	**Contribution to Intake %**	**Cumulative Contribution %**
Grain-based desserts	8.9	8.9
Chicken and chicken mixed dishes	7.6	16.6
Sausage, franks, bacon, and ribs	5.9	22.5
Nuts/seeds and nut/seed mixed dishes	5.5	27.9
Pizza	5.4	33.3
Fried white potatoes	4.9	38.2
Mexican mixed dishes	4.6	42.8
Burgers	4.1	46.9
Beef and beef mixed dishes	3.9	50.8
Eggs and egg mixed dishes	3.5	54.3
Regular cheese	3.3	57.5
Potato/corn/other chips	3.2	60.7
Pasta and pasta dishes	3.1	63.8
Salad dressing	2.6	66.4
Dairy desserts	2.3	68.7
Yeast breads	2.2	70.9

Source: Sources of Oleic Acid Among the U.S. Population, 2005-2006. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/foodsources Updated November 9, 2009. Accessed April 16, 2010.

Polyunsaturated Fatty Acids—PUFA, which have two or more sites of unsaturation (double bonds), are a heterogeneous class of fatty acids with chain length and position of the first double bond affecting important metabolic outcomes. The double bonds contribute to the lower melting point, making PUFA liquid at room temperature. Certain PUFA cannot be synthesized by the human body, but are required in small amounts as substrates for biological pathways that generate metabolic products required for structural and functional purposes. These PUFA are referred to as essential fatty acids and must be attained from the diet. Both linoleic acid (LA) (C18:2), an *n*-6 PUFA, and alpha-linolenic acid (ALA) (C18:3), an *n*-3 PUFA, are essential fatty acids in the diet.

The first double bond in *n*-6 (omega-6) PUFA is at the sixth carbon from the methyl end. These PUFA are largely derived from vegetable oils such as corn, sunflower, safflower, and soybean oils, but are present in other foods as well. The foods that contribute the most *n*-6 PUFA to the diets of Americans are listed in Table D3.3.

Table D3.3. Food sources of total *n*-6 fatty acids (18:2 + 20:4) by percent contribution to intake based on National Health and Nutrition Examination Survey, 2005-2006

Food Item	**Contribution to Intake %**	**Cumulative Contribution %**
Chicken and chicken mixed dishes	9.5	9.5
Grain-based desserts	7.4	16.9
Salad dressing	7.3	24.3
Potato/corn/other chips	6.9	31.2
Nuts/seeds and nut/seed mixed dishes	6.4	37.6
Pizza	5.3	42.9
Yeast breads	4.5	47.4
Pasta and pasta dishes	3.5	54.4
Fried white potatoes	3.5	50.9
Mexican mixed dishes	3.3	57.7
Mayonnaise	3.1	60.8
Quickbreads	3.0	63.8
Eggs and egg mixed dishes	2.9	66.7
Popcorn	2.6	69.2
Sausage, franks, bacon, and ribs	2.1	71.4

Source: Sources of *n*-6 PUFA Among the U.S. Population, 2005-2006. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/foodsources Updated November 9, 2009. Accessed April 16, 2010.

The first double bond in *n*-3 (omega-3) PUFA is at the third carbon from the methyl end. *n*-3 PUFA are often subcategorized based on their plant or marine source. ALA is an essential fatty acid from plant sources, such as soybean oil, canola oil, flaxseed, and walnuts. The foods that contribute the most ALA to the diets of Americans are listed in Table D3.4. ALA is poorly converted to long-chain *n*-3 PUFA, primarily docosahexaenoic acid (DHA), so increased intake of ALA does not substantially improve levels of DHA. The long-chain *n*-3 PUFA, eicosapentaenoic acid (EPA) and DHA, which are frequently called "marine oils," originate from marine phytoplankton and are found in seafood. Fish species vary considerably in their EPA and DHA content (Institute of Medicine [IOM] Seafood Choices, 2006). The cold water, oily fish (e.g., salmon, trout) have the highest levels of EPA and DHA. As described below, these long-chain *n*-3 PUFA have distinct properties, with evidence that EPA and DHA decrease adult CVD risk, and DHA provides benefits for infant neurodevelopment (see Questions 7 and 9). The foods that contribute the most EPA and DHA to the diets of Americans are listed in Table D3.5.

Table D3.4. Food sources of alpha-linolenic acid (ALA) by percent contribution to intake based on National Health and Nutrition Examination Survey, 2005-2006

Food Item	**Contribution to Intake %**	**Cumulative Contribution %**
Salad dressing	10.5	10.5
Grain-based desserts	6.1	16.6
Pizza	5.8	22.4
Chicken and chicken mixed dishes	5.4	27,8
Yeast breads	5.0	33.9
Mayonnaise	4.0	37.9
Pasta and pasta dishes	3.5	41.4
Quickbreads	3.4	44.9
Fried white potatoes	2.8	47.7
Nuts/seeds and nut/seed mixed dishes	2.7	50.4
Mexican mixed dishes	2.7	53.1
Regular cheese	2.6	55.7
Margarine	2.6	58.3
Burgers	2.6	60.8
Eggs and egg mixed dishes	2.2	63.0
Whole milk	2.2	65.2
Dairy desserts	2.2	67.4
Other fish and fish mixed dishes	2.0	69.4

Source: Sources of ALA Among the U.S. Population, 2005-2006. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/foodsources Updated November 9, 2009. Accessed April 16, 2010.

Table D3.5. Food sources of EPA and DHA by percent contribution to intake based on National Health and Nutrition Examination Survey, 2005-2006

Food Item	**Contribution to Intake %**	**Cumulative Contribution %**
Other fish and fish mixed dishes	53.1	53.1
Chicken and chicken mixed dishes	13.8	66.9
Shrimp and shrimp mixed dishes	12.9	79.8
Eggs and egg mixed dishes	5.8	85.6
Tuna and tuna mixed dishes	5.3	91.0

Source: Sources of EPA and DHA Among the U.S. Population, 2005-2006. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/foodsources Updated November 9, 2009. Accessed April 16, 2010.

Trans* Fatty Acids—Trans* fatty acids are unsaturated fatty acids that contain a double bond that is in the *trans* configuration, produced by a process referred to as hydrogenation. Hydrogenation has been used by food manufacturers to raise the melting point of PUFA to make products that are solid at room temperature and more resistant to spoilage or becoming rancid. Partial hydrogenation adds hydrogen to PUFA double bonds, thereby increasing the degree of saturation. However, this does not result in 100 percent saturation, and one or more of the remaining double bonds are isomerized from a *cis* to *trans* configuration. *Trans* fats produced this way are referred to as synthetic or industrial *trans* fatty acids (iTFA) and are used in margarines, snack foods, and prepared desserts. Elaidic acid (t9-C18:1) is the predominant *trans* fatty acid found in processed fats. *Trans* fatty acids also are produced in smaller amounts in the rumen of grazing animals and are termed natural or ruminant *trans* fatty acids (rTFA). Industrial and ruminant *trans* fatty acids vary in the location of the *trans* double bonds, and whether they differ in metabolic effects and health outcomes is a matter of debate (see Question 6). The presence of rTFA makes it difficult to totally eliminate *trans* fatty acids from the diet without eliminating dairy products and red meats.

Dietary Cholesterol and Plant Sterols/Stanols— Cholesterol is a sterol, i.e., a steroid-based alcohol with a hydrocarbon side-chain. Cholesterol has both hydrophilic properties, due to its hydroxyl end, and hydrophobic properties, due to its hydrocarbon side-chain. Therefore, it is commonly found in the lipid bilayer of cell membranes. The major sources of cholesterol in the American diet are egg yolks, dairy products, and meats. The foods that contribute the most cholesterol to the diets of Americans are listed in Table D3.6. Dietary cholesterol, found in cell walls of animal tissues, should be differentiated from plant sterols and stanols that are naturally occurring substances found in plants. These compounds compete with dietary and biliary cholesterol for sites on micelles and transport proteins, resulting in reduced cholesterol absorption. Plant sterols and stanols are absorbed across the epithelial barrier of the intestine but are pumped back into the lumen by ATP-binding cassette transporters. Although plant sterols/stanols are available as dietary supplements (not discussed here), they likely play a role in the cholesterol-lowering effect of plant-based diets.

Table D3.6. Food sources of cholesterol by percent contribution to intake based on National Health and Nutrition Examination Survey, 2005-2006

Food Item	**Contribution to Intake %**	**Cumulative Contribution %**
Eggs and egg mixed dishes	24.6	24.6
Chicken and chicken mixed dishes	12.5	37.1
Beef and beef mixed dishes	6.4	43.6
Burgers	4.6	48.2
Regular cheese	4.2	52.4
Sausage, franks, bacon, and ribs	3.9	56.3
Other fish and fish mixed dishes	3.4	59.7
Grain-based desserts	3.3	63.0
Dairy desserts	3.2	66.3
Pasta and pasta dishes	3.1	69.3
Mexican mixed dishes	2.9	75.1
Pizza	2.9	72.2
Cold cuts	2.7	77.8
Reduced fat milk	2.5	80.3
Pork and pork mixed dishes	2.3	82.6
Shrimp and shrimp mixed dishes	2.0	84.6

Source: Sources of Cholesterol Among the U.S. Population, 2005-2006. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/foodsources Updated November 9, 2009. Accessed April 16, 2010.

Trends in Fat and Cholesterol Intakes in the American Diet in Relation to Previous U.S. Dietary Guidelines Recommendations

The relationship between dietary saturated fat, *trans* fat, and cholesterol and deleterious health outcomes at the population level has long been recognized, with recommendations for modification of total fat, SFA, and cholesterol dating back to the 1980 Guidelines (Table D3.7). The recommendation for keeping *trans* fats as low as possible appeared in the 2005 DGA. As evidence accumulated, the restriction of SFA to less than 10 percent of energy first appeared in the 1990 Guidelines, and the restriction of dietary cholesterol to less than 300 milligrams per day appeared in the 1995 Guidelines. Recommendations related to total fat generally restricted consumption to less than 30 percent of energy. However, in the 2002 IOM report on macronutrient requirements there was the adoption of an Acceptable Macronutrient Distribution Range (AMDR) of fat intake of 20 to 35 percent of calories because there were no clear differences in health outcomes in populations consuming dietary fat within this range. Thus, the 2005 U.S. *Dietary Guidelines* adopted this range of percent energy from total fat.

Table D3.7. Quantitative advice related to dietary fat, Dietary Guidelines for Americans, 1980-2005

	1980	**1985**	**1990**	**1995**	**2000**	**2005**
Total Fat	Avoid too much	Avoid too much	<30%	<30%	<30%	20-35%[1]
Saturated Fat	Avoid too much	Avoid too much	<10%	<10%	<10%	<10%
Cholesterol	Avoid too much	Avoid too much	Low	<300mg	<300 mg	<300 mg

Note: [1]30-35% for ages 2-3 years; 25-35% for ages 4-18 years.
Source: Dietary Guidelines for Americans, 1980-2005.

Despite the consistency of advice, a comparison of the recommendations to trends in the American diet over the same period of time shows no reduction in the intake of total fat, SFA, or cholesterol. Tables D3.8 and D3.9 show USDA estimates from large samples of the U.S. population on consumption of fats and cholesterol, beginning with the Nationwide Food Consumption Survey in 1977-78 through the most recent National Health and Nutrition Examination Surveys (NHANES) in 2005-2006.

Sampling methods, data collection methods, dietary survey instruments, and food composition databases can vary from one survey to the next (Guenther, 1994). Especially problematic is detecting changes in macronutrient distributions, that is, the percentages of calories that come from carbohydrate, fat, protein, and alcohol. Nonetheless, trends in the estimates can be informative about U.S. dietary intakes over time. Table D3.8 shows a modest increase in total fat intake reported from the early 1990s, yet there was a decrease in the percent of energy from fat over the three decades covered in the table. Over this same time period there was an increase in total energy intake, driven mostly by an increase in total carbohydrate intake. Given the onset of a national epidemic of obesity over this time period, it is unlikely that total fat alone was an important contributory factor.

Dietary cholesterol intake has been stable over time, reaching and exceeding the Guideline target of less than 300 milligrams per day for men. It should be noted that cholesterol intake of men and women varied greatly, with average male consumption of cholesterol exceeding recommended levels and virtually unchanged at 350 milligrams per day since 2000, in contrast to levels of 240 milligrams per day for women over this period.

Table D3.9 shows the percent of calories from fat as unchanged since 1990, with mean SFA at 11 to 12 percent energy (above recommended 10%) and unchanged for the past 15 years. Similarly, levels of MUFA (12%) and PUFA (7%) have been stable over this time. Sex-specific data show no major differences in SFA, MUFA, and PUFA intake between men and women (for detailed tables, see http://www.ars.usda.gov/ba/bhnrc/fsrg).

Table D3.8. Mean intake of fats (grams/day) and cholesterol (mg/day), USDA national surveys of all persons in U.S., 1977-2006

Dietary Component	**NFCS 1977-78 (n=~30,000)[1] Mean (SE)[4]**	**CSFII 1989-91 (n=15,128)[1] Mean**	**CSFII 1994-96 (n=15,968)[2] Mean (SE)**	**NHANES 2001-02 (n= 9,033)[3] Mean (SE)**	**NHANES 2003-04 (n=8,273)[3] Mean (SE)**	**NHANES 2005-06 (n= 8,549)[3] Mean (SE)**
Total Fat (g)	84.6 (0.83)	71.8	74.4 (0.7)	81.0 (0.54)	82.7 (0.71)	81.9 (1.35)
SFA (g)	NA[5]	25.7	25.6 (0.3)	26.7 (0.25)	27.7 (0.24)	27.8 (0.49)
PUFA (g)	NA	13.8	14.6 (0.2)	16.1 (0.13)	17.2 (0.25)	17.0 (0.31)
MUFA (g)	NA	26.7	28.6 (0.3)	30.1 (0.22)	31.0 (0.29)	30.1 (0.48)
Cholesterol (mg)	NA	270	256 (3)	273 (2.7)	273 (4.6)	278 (3.3)

Data sources: Published USDA, ARS Reports What We Eat In America-National Health and Nutrition Examination Surveys (NHANES), Continuing Surveys of Food Intakes by Individuals (CSFII), and Nationwide Food Consumption Survey (NFCS), 1 day data. [1]Includes all persons from birth.
[2]Includes all persons from birth; excludes breast-fed children.
[3]Includes persons 2 years and over; excludes breast-fed children.
[4]SE= Standard error.
[5]Unpublished data from Food Surveys Research Group, ARS, USDA.
This table is available at: http://www.ars.usda.gov/ba/bhnrc/fsrg.

Table D3.9. Mean intake of fats as percent of energy, USDA national survey of all persons in U.S., 1977-2006

Dietary Component	**NFCS 1977-78 (n=~30,000)[1] Mean (SE)[4]**	**CSFII 1989-91 (n=15,128)[1] Mean**	**CSFII 1994-96 (n=15,968)[2] Mean (SE)**	**NHANES 2001-02 (n=9,033)[3] Mean (SE)**	**NHANES 2003-04 (n=8,273)[3] Mean (SE)**	**NHANES 2005-06 (n= 8,549)[3] Mean (SE)**
Total Fat (%)	40.1 (0.16)	34.4	32.8 (0.1)	33 (0.3)	33.4 (0.25)	33.6 (0.19)
SFA (%)	NA[5]	12.3	11.3 (0.1)	NA	11.2 (0.11)	11.4 (0.09)
PUFA (%)	NA	6.6	6.4 (0.01)	NA	7.0 (0.09)	7.0 (0.08)
MUFA (%)	NA	12.7	12.5 (0.1)	NA	12.5 (0.09)	12.3 (0.07)
Energy (kcal)	1854 (12.9)	1839	2002 (16)	2178 (16.1)	2195 (15.6)	2157 (29.0)

Data sources: Published USDA, ARS Reports What We Eat In America-National Health and Nutrition Examination Surveys (NHANES), Continuing Surveys of Food Intakes by Individuals (CSFII), and Nationwide Food Consumption Survey (NFCS), 1 day data. [1]Includes all persons from birth.
[2]Includes all persons from birth; excludes breast-fed children.
[3]Includes persons 2 years and over; excludes breast-fed children.
[4]SE= Standard error.
[5]Unpublished data from Food Surveys Research Group, ARS, USDA.
This table is available at: http://www.ars.usda.gov/ba/bhnrc/fsrg.

Recommended Intakes and Health Outcomes Related to Dietary Fat and Cholesterol

In the 2002 report *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids* (IOM, 2002), the IOM did not establish either an Adequate Intake (AI) or Recommended Dietary Allowance (RDA) for total fat intake. Rather, an AMDR of 20 to 35 percent of energy was established for total fat consumption for adults. Furthermore, the IOM did not set a tolerable Upper Intake Level (UL) for total fat because available evidence was insufficient to define a level at which adverse outcomes, such as obesity, occur. However, for SFA, although there is also no UL, the rationale was that there is no incremental level of SFA intake that does not incrementally increase CVD risk.

For dietary cholesterol, because cholesterol can be synthesized endogenously in sufficient amounts for metabolic and structural needs, there is no evidence for a dietary requirement for cholesterol; therefore, there is no AI, RDA, or AMDR for cholesterol. Similar to SFA, there is no UL set for dietary cholesterol. It should be noted, however, that both SFA and cholesterol are unavoidable in omnivorous diets, and attempts to reduce intake completely would require significant changes to dietary patterns and introduce undesirable effects, such as inadequate intakes of micronutrients and protein.

Given the state-of-the-art of our current knowledge regarding dietary fat and health, the DGAC 2010 has addressed the following questions for application to U.S. public health:

List of Questions

THE INFLUENCE OF DIETARY FATS ON CARDIOVASCULAR DISEASE (CVD) AND OTHER HEALTH OUTCOMES

1. What is the effect of saturated fat intake on increased risk of cardiovascular disease or type 2 diabetes (T2D), including effects on intermediate markers such as serum lipid and lipoprotein levels?
2. What is the effect of dietary cholesterol intake on risk of cardiovascular disease, including effects on intermediate markers such as serum lipid and lipoprotein levels and inflammation?
3. What is the effect of dietary intake of MUFA when substituted for SFA on increased risk of cardiovascular disease and T2D, including intermediate markers such as lipid and lipoprotein levels and inflammation? And what is the effect of replacing a high carbohydrate diet with a high MUFA diet in persons with T2D?
4. What is the effect of dietary intake of *n*-6 PUFA on risks of cardiovascular disease and T2D, including intermediate markers such as lipid and lipoprotein levels and inflammation?

SPECIFIC FATTY ACIDS THAT AFFECT PLASMA LDL, HDL, AND NON-HDL CHOLESTEROL LEVELS

5. What are the effects of dietary stearic acid on LDL cholesterol?
6. What effect does consuming natural (ruminant) versus synthetic (industrially hydrogenated) *trans* fatty acids have on LDL-, HDL- and non HDL cholesterol levels?

RELATIONSHIPS BETWEEN CONSUMPTION OF *n*-3 FATTY ACIDS AND HEALTH OUTCOMES

7. What is the relationship between consumption of seafood *n*-3 fatty acids and risk of CVD?
8. What is the relationship between consumption of plant *n*-3 fatty acids and risk of CVD?
9. What are the effects of maternal dietary intake of *n*-3 fatty acids from seafood on breast milk composition and health outcomes in infants?

CARDIOVASCULAR HEALTH EFFECTS RELATED TO CONSUMPTION OF SPECIFIC FOODS HIGH IN FATTY ACIDS

10. What are the health effects related to consumption of nuts?
11. What are the health effects related to consumption of chocolate?

Methodology

The DGAC 2010 first reviewed the 2005 DGAC Report to inform their review process. Several lines of evidence indicate that the type of fat is more important in decreasing metabolic and CVD risk than the total amount of fat in the diet; therefore, the committee focused their review on the metabolic effect of specific types of fats and fatty acids. (Questions related to the effect of macronutrient distribution in the diet are found in *Part D. Section 1: Energy Balance and Weight Management*.) Topics in this section on fatty acids and cholesterol that were considered by the 2005 DGAC include: saturated fat (SFA) (Question 1), cholesterol (Question 2), monounsaturated fatty acids (MUFA) (Question 3), *n*-6 polyunsaturated fatty acids (PUFA) (Question 4), stearic acid (Question 5), *trans* fatty acids (Question 6), *n*-3 fatty acids from seafood (Question 7), and plants (Question 8). New questions considered by the 2010 DGAC examined maternal intake of *n*-3 fatty acids from seafood and the effect on breast milk composition and infant health (Question 9) and health effects related to consumption of nuts (Question 10) and chocolate (Question 11).

Full NEL evidence-based reviews were conducted on Questions 1-6, 9, and 11; whereas, a combination of NEL and American Dietetic Association's (ADA) Evidence Analysis Library reviews were conducted for Questions 7, 8, and 10 (described below). A description of the NEL evidence-based systematic review process is provided in *Part C: Methodology*. Additional information about the search strategy and articles considered and included for each question can be found at www.NutritionEvidenceLibrary.gov. To address several issues about the feasibility and desirability of potential 2010 DGAC recommendations related to cholesterol (Question 2), stearic acid and cholesterol-raising (CR) fatty acids (Question 5), and seafood (Question 7), the subcommittee conducted several modeling exercises using the USDA food intake patterns. Summaries of these analyses are presented here, and a description of the approach used is described in *Part C: Methodology*. The full modeling analyses reports can be found online at www.dietaryguidelines.gov.

For Question 1 on SFA effects on CVD risk and Questions 3 and 4 on MUFA and *n*-6 PUFA, the conclusions expressed in the 2010 DGAC Report are informed by evidence compiled for the 2005 DGAC Report, but are based primarily on NEL evidence gathered and reviewed since 2004. As described in the Review of Evidence section, for some questions, the search was extended back further to capture a larger body of evidence, particularly related to diabetic-risk populations. Conclusions to Question 1 on SFA effects on T2D risk, Question 5 on stearic acid, Question 6 on *trans* fatty acids, Question 9 on maternal *n*-3 fatty acid intake, and Question 11 on chocolate are based on literature published since 2000. Although Questions 3 and 4 on MUFA and *n*-6 PUFA did not go back to 2000, the results from Question 1 on SFA and T2D risk also strengthen the evidence for these questions, as SFA was replaced by MUFA or PUFA. The conclusion to Question 2 on dietary cholesterol is based on literature published since 1999. Results of a NEL search since 2004 for question 7 on seafood are supplemented by the findings of an earlier evidence review conducted by the ADA Evidence Analysis Library on health benefits related to consumption of fish or fish-derived *n*-3 fatty acids, covering the literature published from 2004 to 2007 (http://www.adaevidencelibrary.com). Question 8 on plant-derived *n*-3 fatty acids is also based on this earlier systematic review conducted by the ADA that included health benefits related to consumption of plants or plant-derived *n*-3 fatty acids. The NEL updated this search from 2007 to 2009 for this question. The review for Question 10 on nuts was also informed by a previous review conducted by the ADA on almonds that covered the literature published from 2001 through 2004 (http://www.adaevidencelibrary.com).

Prior DGACs made recommendations about dietary fat consumption targeting atherosclerotic CVD as the primary disease of concern. The 2010 DGAC continues this focus, but considered additional disease outcomes and intermediate markers of these outcomes. Atherosclerotic CVD includes coronary heart disease (with major clinical presentations as angina pectoris, acute myocardial infarction, or sudden cardiac death), atherothrombotic stroke, and peripheral arterial disease. T2D, as affected by dietary fat, is a new consideration for the 2010 DGAC. In contrast to CVD, T2D is clearly increasing in prevalence and incidence. T2D is a strong risk factor for atherosclerotic disease, but also carries a high burden of disability and healthcare costs, with diabetic nephropathy, retinopathy, and neuropathy as major sequelae. Because of this, T2D and T2D risk were included as disease outcomes related to fatty acid and cholesterol consumption.

The relationships of fatty acids or cholesterol to various cancers were also considered but have very recently been reviewed by the World Cancer Research Fund/American Institute for Cancer Research Report (WCRF/AICR, 2007). The evidence regarding cancer is less conclusive than that related to CVD and T2D. Population-wide recommendations, therefore, have been driven by the public health impact of CVD and T2D.

A series of intermediate markers have been examined because of their strong etiologic association with atherosclerotic CVD and T2D, and their use as outcomes in prospective studies and randomized clinical trials. These measures include blood lipids and lipoproteins, glucose intolerance, insulin resistance, blood pressure, and biomarkers of inflammation. These intermediate markers are linked to risk of both CVD and T2D, as indicators of altered metabolism. This is manifested most clearly by metabolic syndrome that is clinically characterized by five criteria: blood pressure, waist circumference, fasting triglyceride levels, HDL cholesterol, and fasting blood glucose. Metabolic syndrome is considered an intermediate stage in the progression to full-blown T2D.

For each of the NEL review questions in this chapter, the following general criteria applied. Study designs included systematic reviews, meta-analyses, randomized controlled trials, prospective cohort studies, and case-control studies. Research was conducted in developed nations and participants were healthy adults and those at elevated risk of chronic disease, including CHD/CVD and T2D, with related conditions including hyperlipidemia, insulin resistance, and associated metabolic disturbances. Study participants with CVD were included in Questions 7 and 8, and individuals with T2D were included in Questions 1 to 4. Pregnant and lactating women and infants were included in the review of the literature related to maternal intake of DHA and infant health outcomes.

THE INFLUENCE OF DIETARY FATS ON CARDIOVASCULAR DISEASE (CVD) AND OTHER HEALTH OUTCOMES

The 2005 DGAC addressed the issue of total fat intake as a determinant of major health outcomes, body weight, blood lipid concentrations, and other metabolic parameters, based on the IOM report *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids* (IOM, 2002). Based on this review, the recommendation was to avoid very low fat diets (<20% of energy from fat) to reduce the risk of inadequate intakes of fat-soluble vitamins and the essential fatty acids, LA and ALA. The 2005 DGAC also recommended avoidance of very high fat diets (>35% of energy from fat), as such diets are associated with increased caloric intake and related weight gain. Therefore, total fat intake of 20 to 35 percent of calories was recommended for adults, 25 to 35 percent for children ages 4 to 18 years, and 30 to 35 percent for children ages 2 to 3 years. Since the 2005 DGAC Report, there has been little evidence in adults to contradict this as a healthy range of total fat as percent of calories. The issue of children, ages 2 to 18 years, is more challenging to evaluate because of the limited number of studies and the difficulty in tracking and documenting diet in this age group. Pediatric guidelines are currently under review by the National Heart, Lung, and Blood Institute (NHLBI).

Most studies with higher percentages of energy from fat also include higher levels of SFA both in absolute units and in percent of energy. The 2010 DGAC, therefore, has focused on the quality of fats within the 20 to 35 percent AMDR range. Because there are major etiologic links between dietary consumption of fats or cholesterol and cardiovascular disease, lipids and lipoproteins are important intermediate markers in the study of dietary fats and cholesterol. In keeping with the 2010 DGAC's focus on a broader range of intermediary and disease outcomes, the following questions were considered for evidence-based analysis.

Question 1: What Is the Effect of Saturated Fat Intake on Increased Risk of Cardiovascular Disease or Type 2 Diabetes, Including Effects on Intermediate Markers Such as Serum Lipid and Lipoprotein Levels?

Conclusion

Strong evidence indicates that intake of dietary SFA is positively associated with intermediate markers and end point health outcomes for two distinct metabolic pathways: 1) increased serum total and LDL cholesterol and increased risk of CVD and 2) increased markers of insulin resistance and increased risk of T2D. Conversely, decreased SFA intake improves measures of both CVD and T2D risk. The evidence shows that 5 percent energy decrease in SFA, replaced by MUFA or PUFA, decreases risk of CVD and T2D in healthy adults and improves insulin responsiveness in insulin resistant and T2D individuals.

Implications

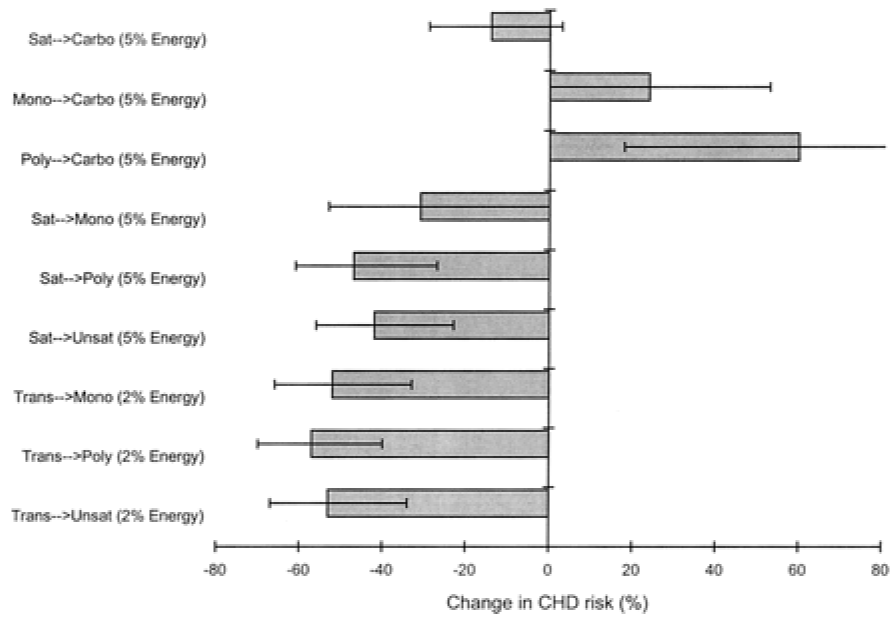
As the evidence indicates that a 5 percent energy decrease in SFA, replaced by MUFA or PUFA, results in meaningful reduction of risk of CVD or T2D, and given that in the U.S. population 11 to 12 percent of energy from SFA intake has remained unchanged for over 15 years, a reduction of this amount resulting in the goal of less than 7 percent energy from SFA should, if attained, have a significant public health impact. As an interim step toward this less than 7 percent goal, all individuals should immediately consume less than 10 percent of energy as saturated fats. This impact would not only be limited to a reduction in heart disease and stroke, but also in T2D, a disease currently rising in incidence and prevalence. This substitution of MUFA and PUFA for SFA assumes no change in energy intake. The age of onset of T2D is substantially younger than that of CVD and increasingly frequent in adolescence. Reduction in SFA in children and young adults may provide benefits decades earlier than currently appreciated. The growing data to support a risk of T2D from SFA consumption supports the need for fat-modified diets in persons with pre-diabetes, including those with metabolic syndrome, and those with established diabetes. Early signs of atherosclerotic CVD are also seen in children and a number of studies indicate that the atherosclerotic process begins in childhood and is affected by high blood cholesterol levels. Therefore, reduction in SFA in children and young adults may provide benefits decades earlier than currently appreciated relative to both CVD and T2D incidence.

Review of the Evidence

The NEL systematic review of the literature published since 2004 identified 12 studies assessing the relationship between SFA intake and CVD risk in healthy adults or those at elevated chronic disease risk. Studies were conducted in the U.S., Europe, and South America and overall, 10 randomized controlled trials, one non-randomized trial and an analysis of 11 pooled cohorts with meta-analysis were identified. The intervention studies ranged in sample size from 14 to 191 participants and the pooled analysis included 344,696 participants. Of the 12 studies, eight were methodologically strong (Azadbakht, 2007; Berglund, 2007; Chen, 2009; Furtado, 2008; Jakobsen, 2009; Kralova, 2008; Lefevre, 2005; Lichtenstein, 2005), and four were methodologically neutral (Buenacorso, 2007; Bourque, 2007; Chung, 2004; Dabadie, 2005). Most methodologically strong studies were feeding trials with an "average American" diet at baseline, which involved a reduction in SFA through replacement with MUFA, PUFA, or, to a lesser extent, carbohydrates. Dietary SFA replacement (5 to 7% of energy) with either MUFA (Berglund, 2007; Lichtenstein, 2005) or PUFA (Chung, 2004; Kralova, 2008; Lichtenstein, 2005) significantly decreased total and LDL cholesterol. Replacement of SFA with carbohydrates decreased plasma total and LDL cholesterol. However, compared to MUFA or PUFA, carbohydrate decreased HDL cholesterol and increased serum triglycerides (Berglund, 2007). A study by Lefevre et al. (2005) included two levels of total fat (30% and 25%) and SFA (9% and 6%) in the Step I and Step II diets, respectively, and demonstrated a dose-response effect in lowering LDL cholesterol. However, compared to the average American diet, the Step I and Step II diets also decreased HDL cholesterol levels and raised triglyceride levels in the blood. Furthermore, these authors showed that individuals who were insulin resistant responded less favorably to the STEP II diet than did those with normal insulin sensitivity. A study by Kralova et al. (2008) examined changes in cholesterol efflux to determine whether reduced HDL cholesterol, on a high PUFA/low SFA diet, had a negative effect on reverse cholesterol transport. The study showed no change in cholesterol efflux.

One meta-analysis examined effects of SFA reduction on incident coronary heart disease (CHD) outcomes by estimating the anticipated effects from statistical models where SFA is exchanged for equal energy from MUFA, PUFA, or carbohydrates (Jakobsen, 2009). These authors examined 11 American and European cohort studies and found a significant inverse association for PUFA (with 5% substitution for SFA) and coronary events (hazard ratio = 0.87, 95% CI, 0.77-0.97, and coronary death hazard ratio = 0.74, 95% CI, 0.61-0.89). They also found a positive association between substitution of MUFA or carbohydrates for SFA and risk of coronary events, but not risk of coronary deaths. To provide further context for the question of SFA replacement with other healthy fats or carbohydrates and CVD risk, a review by Hu et al. (2001) was helpful. Figure D3.1 shows the estimated changes in risk of coronary heart disease associated with isocaloric substitution of SFA (at 5% energy) with healthy fats such as MUFA or PUFA or carbohydrates, as well as substitution of *trans* fatty acids (at 2% energy). In all cases of isocaloric SFA or *trans* fatty acid substitution, there is a decrease in CHD risk. However, it should be noted that when MUFA or PUFA are substituted by any kind of carbohydrates, CHD risk increased.

Figure D3.1. Saturated fatty acid substitution and coronary heart disease risk



Note: Estimated changes (percent with 95% confidence intervals) in risk of coronary heart disease (CHD) associated with isocaloric dietary substitutions. Adjusted for coronary risk factors and total energy intake. Sat=SFA, Carbo=carbohydrate, Mono=MUFA, Poly=PUFA, *Trans*=*trans* fatty acids, Sat-Carbo=substitute carbohydrates for SFA.
Source: Hu et al., 2001. *J Amer Col Nutr* 20:5-19. Used with permission, the American College of Nutrition.

The NEL review of the literature published since 2000 on the association of dietary SFA and T2D identified 12 studies conducted in the U.S., Europe, Canada, and China that examined the effect of dietary SFA on altered glucose metabolism, markers of insulin resistance, and T2D risk. Two were methodologically strong review articles including one which evaluated 15 trials, nine trials in 358 non-diabetic participants and six trials in 93 participants with T2D (Galgani, 2008), and one reviewing 14 prospective cohort and five cross-sectional studies (Hu, 2001). Nine were randomized clinical trials ranging in size from 11 to 522 participants, including six methodologically strong studies (Han, 2001; Lindstrom, 2006a, 2006b; Lopez, 2008; Perez-Jimenez, 2001; and Vesby, 2001) and three methodologically neutral studies (Paniagua, 2007; Shah, 2007; and St-Onge, 2003). The one prospective cohort study with 84,204 participants from the Nurses' Health Study was methodologically strong (Salmeron, 2001). The Galgani review of randomized controlled trials indicated that three studies provided evidence that MUFA or PUFA replacement of SFA improved insulin sensitivity, including one high-powered study that indicated a 10 percent decrease in insulin sensitivity on high SFA, versus high MUFA, diets. However, nine studies showed no effect of MUFA or PUFA replacement. The Hu review concluded that higher intake of PUFA (and potentially long-chain *n*-3 PUFA) were beneficial; whereas, higher intakes of SFA and *trans* fatty acids impaired glucose metabolism and increased insulin resistance. Four randomized controlled trials showed MUFA-enriched diets improved glucose uptake and insulin sensitivity: Lopez et al. (2008) showed that increased dietary MUFA improved insulin sensitivity and promoted pancreatic beta cell function; Paniagua et al. (2007) showed a diet high in MUFA improved blood glucose and Homeostatic Model Assessment (HOMA) – Insulin Resistance (IR) (HOMA-IR) scores over both SFA and carbohydrates in insulin resistant individuals; Perez-Jinenez et al. (2001) showed a MUFA-enriched diet improved glucose uptake in peripheral tissues and insulin sensitivity; and Vesby et al. (2001) showed SFA decreased, whereas MUFA did not change, insulin sensitivity. Three studies provided evidence that decreased SFA intake may decrease risk of T2D; two large randomized controlled trials (Lindstrom, 2006a, 2006b) and one prospective cohort study (Salmeron, 2001). One randomized controlled trial by Shah et al. (2007) showed that insulin responsiveness was improved with either MUFA- or PUFA-enriched diets in individuals with T2D.

Question 2: What Is the Effect of Dietary Cholesterol Intake on Risk of Cardiovascular Disease, Including Effects on Intermediate Markers Such as Serum Lipid and Lipoprotein Levels and Inflammation?

Conclusion

Moderate evidence from epidemiologic studies relates dietary cholesterol intake to clinical CVD endpoints. Many randomized clinical trials on dietary cholesterol use eggs as the dietary source. Independent of other dietary factors, evidence suggests that consumption of one egg per day is not associated with risk of CHD or stroke in healthy adults, although consumption of more than seven eggs per week has been associated with increased risk. An important distinction is that among individuals with T2D, increased dietary cholesterol intake is associated with CVD risk.

Implications

Overall, the evidence shows that consumption of dietary cholesterol in the amount of one egg per day is not harmful and does not result in negative changes in serum lipoprotein cholesterol and triglyceride levels. Neither does consumption of eggs at this level increase risk of CVD in healthy individuals. Eggs also are a good source of high quality protein and numerous micronutrients. However, in individuals with T2D, egg consumption (at one egg/day) does have negative effects on serum lipids and lipoprotein cholesterol levels and does increase risk of CVD. Furthermore, consumption of more than seven eggs per week is not recommended for the general public. Overall, limiting dietary cholesterol to less than 300 milligrams per day, with further reductions of dietary cholesterol to less than 200 milligrams per day for persons with or at high risk for CVD and T2D, is recommended.

Review of the Evidence

The NEL systematic review identified 16 studies published since 1999 that evaluated the effect of dietary cholesterol intake on CVD risk conducted in the U.S., Europe, Mexico, and Japan. Eight randomized controlled trials, including two methodologically strong studies (Ballesteros, 2004; Knopp, 2003) and six methodologically neutral studies (Goodrow, 2006; Greene, 2005; Harman, 2008; Mutungi, 2008; Reaven, 2001; Tannock, 2005) with sample size ranging from 28 to 201 participants were reviewed. Five prospective cohort studies, including four methodologically strong studies (Djousse, 2008; Hu, 1999; Qureshi, 2007; Tanasescu, 2004) and one methodologically neutral study (Nakamura, 2006) ranging in size from 5,687 to 80,082 participants, were reviewed. And one meta-analysis of 17 studies that was methodologically strong (Weggemans, 2001), and two systematic reviews, one methodologically strong pooled analysis of 167 cholesterol feeding studies in 3,519 participants (McNamara, 2000) and one methodologically neutral review of eight prospective cohort studies on dietary cholesterol and six prospective cohort studies on eggs (Kritchevsky and Kritchevsky, 2000) met the eligibility criteria and were reviewed. The majority of these articles reported on comparisons of egg versus egg substitute or no egg intake. In studies comparing eggs versus egg substitute, one randomized controlled trial (Ballesteros, 2004) and one pooled analysis (McNamara, 2000) showed that LDL cholesterol and HDL cholesterol increased in hyper-responders, but did not change in hypo-responders; overall, the LDL:HDL did not change in hypo- or hyper-responders. Identification of hypo-and hyper-responders showed inter-individual variation to dietary cholesterol that may result in differing health outcomes for individuals with different genetic predispositions.

Harman et al. (2008) found that LDL cholesterol decreased in both egg and egg substitute groups, and two studies in elderly adults (Greene, 2005; Goodrow, 2006) indicated that LDL cholesterol and HDL cholesterol were not affected by egg intake. Two randomized controlled trials showed an increase in LDL diameter in the egg group (Ballesteros, 2004; Greene, 2005). Two randomized controlled trials in 65 insulin-sensitive and 75 insulin-resistant individuals determined that egg consumption was associated with increased LDL cholesterol, but only in insulin-sensitive individuals (Knopp, 2003; Tannock, 2005). However, Reaven et al. (2001) found that high cholesterol intake did not increase LDL cholesterol in either insulin-sensitive or insulin-resistant subgroups. All studies that measured HDL cholesterol found that HDL cholesterol was increased with egg consumption, and one such study was in a carbohydrate-restricted diet background (Mutungi, 2008). One study assessed markers of inflammation and found increased C-reactive protein and serum amyloid A with high egg consumption, but found no difference in circulating cytokines (Tannock, 2005). One meta-analysis of 17 studies indicated that high dietary cholesterol intake increased the total:HDL cholesterol ratio. However, this effect was attenuated in the low SFA subgroup (Weggemans, 2001).

In the prospective cohort studies, Djousse et al. (2001) found that egg consumption up to six eggs per week in the Physicians' Health Study was not associated with risk of all-cause mortality, but consumption of more than seven eggs per week was associated with a 23 percent increased risk of death. In the Japan Public Health Center study, egg consumption was not associated with CHD incidence (Nakamura, 2006). In NHANES I, no relationship was established between egg consumption (>6 eggs/wk) and risk of stroke or ischemic stroke, and risk of myocardial infarction and all-cause mortality was not different between egg and non-egg consumption groups (Qureshi, 2007). A combined analysis of the Health Professionals Follow-up Study (HPFS) and the Nurses' Health Study (NHS), found no significant association between egg consumption and risk of CHD or stroke in men or women (Hu, 1999). A review of epidemiological studies (Kritchevsky and Kritchevsky, 2000) showed there was no association between consumption of one egg per day and risk of CVD, but only in non-diabetic men and women. Furthermore, three methodologically strong prospective cohort studies warned that egg consumption was associated with increased CVD risk in individuals with T2D (Djousse, 2001; Hu, 1999; Tanasescu, 2004) and this warrants further investigation.

Dietary Cholesterol Modeling

The USDA Food Patterns were designated to meet adequacy and reduction goals, and the 2005 DGAC recommended cholesterol intakes of less than 300 milligrams per day for persons not at risk for CVD. A food pattern modeling analysis was carried out to identify nutrient amounts that would change and the nutrient goals that would be met or not met for the patterns at each calorie level when dietary cholesterol is limited to less than 200 milligrams per day. (See the Cholesterol report, online Appendix E3.8, available at www.dietaryguidelines.gov). To meet the lower criteria of less than 200 milligrams of cholesterol per day, all patterns were modified as follows. Eggs were limited to less than two per week. The amounts of meat and chicken were decreased by about 20 percent, and nuts and soy products were substituted to maintain the same total amount from the meat and bean group in each pattern. The amounts of solid fats, which include fats in milk products as well as meats and poultry, were capped at 10 grams per day, and oils were substituted isocalorically. With these modifications, dietary cholesterol was reduced 23 to 31 percent. These modified patterns also showed a 3.5 percent reduction in protein, a 10 percent reduction in choline, a 2 to 7 percent reduction in vitamins A and D, a 21 percent reduction in EPA (20:5 *n*-3), and a 3 percent reduction in DHA (22:6 *n*-3). In contrast, vitamin E increased 4 to 25 percent, thiamin increased 13 to 19 percent, LA increased 3 to 20 percent, and ALA increased 8 percent. The resulting patterns had adequate protein, but amounts of choline, and vitamin D (which were below AI levels set by the IOM in the patterns containing 300 mg/dl per day) were even less adequate in the patterns containing less than 200 milligrams of cholesterol per day. The health implications of a lower choline diet are not well defined.

Diets with less than 200 milligrams per day of cholesterol can be constructed for those for whom such a diet has a positive benefit-to-cost ratio. This diet can be achieved by reducing eggs, meat, chicken, and solid fats (including fats in milk products), and replacing them with unsalted nuts, soy products, and oils.

Question 3: What Is the Effect of Dietary Intake of MUFA When Substituted for SFA on Increased Risk of Cardiovascular Disease and Type 2 Diabetes, Including Intermediate Markers Such as Lipid and Lipoprotein Levels and Inflammation? And What Is the Effect of Replacing a High Carbohydrate Diet With a High MUFA Diet in Persons with Type 2 Diabetes?

Conclusion

Strong evidence indicates that dietary MUFA are associated with improved blood lipids related to both CVD and T2D, when MUFA is a replacement for dietary SFA. The evidence shows that 5 percent energy replacement of SFA with MUFA decreases intermediate markers and the risk of CVD and T2D in healthy adults and improves insulin responsiveness in insulin resistant and T2D individuals. Moderate evidence indicates that increased MUFA intake, rather than high carbohydrate intake, may be beneficial for persons with T2D. High MUFA intake, when replacing a high carbohydrate intake, results in improved biomarkers of glucose tolerance and diabetic control.

Implications

At the current level of 11 to 12 percent of energy from SFA, healthy American adults would benefit substantially by replacing 5 percent of that total energy with MUFA (e.g., 12 percent SFA reduced to 7 percent SFA, 12 percent MUFA increased to 17 percent MUFA). Beneficial outcomes would include reduced rates of CVD and T2D as well as improved lipids and lipoproteins, inflammatory markers, and measures in insulin resistance. Persons with a predisposition to T2D or established T2D may especially benefit from a high MUFA diet, both as a substitute for SFA and as a substitute for carbohydrates. Given the high prevalence of T2D and the metabolic syndrome in the U.S., such benefits would have a large public health impact.

Review of the Evidence

Thirteen studies published since 2004 and conducted in the U.S., Europe, and Australia were reviewed to determine the effect of MUFA on health outcomes. These included one methodologically strong meta-analysis evaluating 11 prospective cohort studies (Jakobsen, 2009) and 11 randomized controlled trials ranging from 14 to 162 participants, including six methodologically strong studies (Appel, 2005; Berglund, 2007; Due, 2008; Lopez, 2008; Thijssen and Mensink, 2005; and Thijssen, 2005), and five methodologically neutral studies (Allman-Farinelli, 2005; Binkoski, 2005; Clifton, 2004; Paniagua, 2007; and Rasmussen, 2006). The reviewed studies also included one methodologically strong prospective cohort study of 5,672 participants from the Nurses' Health Study who reported a diagnosis of T2D (Tanasescu, 2004). Overall, MUFA replacing SFA in the diet as percent of energy leads to a decrease in LDL cholesterol (Allman-Farinelli, 2005; Appel, 2005; Berglund, 2007), a decrease in serum triglycerides (Allman-Farinelli, 2005), a decrease in markers of inflammation (Allman-Farinelli, 2005), and a decrease in CVD risk (Appel, 2005; Rasmussen, 2006). Increasing MUFA intake, rather than replacing SFA with MUFA, also leads to a decrease in total cholesterol (Haban, 2004), LDL cholesterol (Haban, 2004), LDL:HDL ratio (Due, 2008), serum triglycerides (Brunerova, 2007), inflammatory markers (Brunerova, 2007), and fasting insulin and HOMA-IR scores (Brunerova, 2007; Due, 2008). However, Clifton et al. (2004) found a greater decrease in total cholesterol and HDL cholesterol in women who consumed a very low-fat diet, compared with a high MUFA diet, and no difference in the LDL:HDL ratio between the two diets (Clifton, 2004). Replacing SFA with MUFA, compared to replacement with carbohydrates, decreased serum triglycerides (Appel, 2005) and increased HDL cholesterol (Appel, 2005; Berglund, 2007). Lastly, a prospective cohort study involving a T2D subpopulation within the Nurses' Health Study found that replacing 5 percent energy from SFA with equivalent energy from MUFA was associated with a 27 percent lower risk of CVD. The authors conclude that replacing SFA with MUFA may be more protective against CVD than replacement with carbohydrate (Tanasescu, 2004).

Comparing substitution of SFA with MUFA versus PUFA showed a greater decrease in total and LDL cholesterol with PUFA substitution (Binkoski, 2005). Furthermore, a pooled analysis of 11 prospective cohort studies showed that risk of coronary events and coronary death was lowest with 5 percent energy substitution of SFA with PUFA; PUFA substitution resulted in the greatest decrease, with MUFA showing somewhat less, and carbohydrate showing the least improvement when substituted for SFA (Jakobsen, 2009). In a comparison of individual fatty acids, oleic acid was no different than stearic or linoleic acid in its effect on measures of serum lipids or lipoproteins and markers of inflammation (Thijssen and Mensink, 2005; Thijssen, 2005).

To determine the effects of replacing a high carbohydrate diet with a high MUFA diet in persons with T2D, five randomized controlled trials published since 2004 were reviewed. These randomized controlled trials were conducted in the U.S. and Europe and ranged in size from 11 to 95 participants. Two studies were methodologically strong (Brehm, 2009; Gerhard, 2004) and three were methodologically neutral (Brunerova, 2007; Rodriguez-Villar, 2004; and Shah, 2005). In persons with T2D, a high MUFA diet compared to high carbohydrate diet decreased blood LDL cholesterol and triglycerides (Rodriguez-Villar, 2004), increased HDL cholesterol (Brunerova, 2007), and decreased fasting blood glucose and HbA1c (Brunerova, 2007). On the other hand, when high MUFA and carbohydrate diets were also low calorie or weight loss diets, the results were more difficult to interpret. Brehm et al. (2008) found no significant differences in fasting glucose, insulin, hemoglobin A1c, or HDL cholesterol between the MUFA and carbohydrate groups. Both groups improved compared to baseline due to decreased caloric intake (200-300 kcal/d). Gerhard et al. (2004) did not find any significant difference in blood lipids or glycemic control in a comparison of high MUFA versus high carbohydrate diets in T2D individuals; however, in this case, the two diet interventions were not isocaloric and the MUFA diet was a higher calorie diet. Shah et al. (2005) measured the effects of high MUFA versus carbohydrate on blood pressure in persons with T2D and found that long-term consumption of a high-carbohydrate diet may modestly raise blood pressure in persons with T2D.

Question 4: What Is the Effect of Dietary Intake of *n*-6 PUFA on Risks of Cardiovascular Disease and Type 2 Diabetes, Including Intermediate Markers Such as Lipid and Lipoprotein Levels and Inflammation?

Conclusion

Strong and consistent evidence indicates that dietary PUFA are associated with improved blood lipids related to CVD, in particular when PUFA is a replacement for dietary SFA or *trans* fatty acids. Evidence shows that energy replacement of SFA with PUFA decreases total cholesterol, LDL cholesterol and triglycerides, as well as numerous markers of inflammation. PUFA intake significantly decreases risk of CVD and has also been shown to decrease risk of T2D.

Implications

All recommendations assume an isocaloric replacement of SFA or *trans* fatty acids with PUFA. In this setting, both CVD and, potentially, T2D may be reduced with PUFA replacement. The mechanisms of CVD reduction, including improvement in serum lipid levels and reduced markers of inflammation, may have additional health benefits. PUFA consumption in the U.S. is lower than that of SFA or MUFA, although the only essential fatty acids are PUFA, so a reduction of SFA from 12 percent to 7 percent of energy through an increase in PUFA alone would increase PUFA from 7 percent to 12 percent of energy. This, or replacing SFA with some combination of PUFA and MUFA, should yield significant public health benefits.

Review of the Evidence

Ten studies published since 2004 were reviewed to determine the effect of PUFA on health outcomes. These studies were conducted in the U.S., Canada, Europe, and Australia. These included one methodologically strong pooled analysis of 11 prospective cohort studies (Jakobsen, 2009); five randomized controlled trials, including two methodologically strong studies (Thijssen and Mensink, 2005; and Thijssen, 2005) and three methodologically neutral studies (Liou, 2007; St-Onge, 2007; and Zhao, 2004) ranging in size from 23 to 45 participants; and four prospective cohort studies ranging in size from 1,551 to 78,778 participants. Of these cohort studies, three were methodologically strong (Laaksonen, 2005; Mozaffarian, 2005; and Oh, 2005) and one was methodologically neutral (Hodge, 2007). Randomized controlled trials that investigated the effects on serum lipid and lipoprotein levels of replacing SFA with PUFA showed that PUFA improved serum lipid profiles (St. Onge, 2007; Zhao, 2004). Zhao et al. (2004) found that high LA or high ALA diets compared to the average American diet decreased serum total cholesterol, LDL cholesterol, and triglycerides similarly. St-Onge et al. (2007) reported that replacing snacks high in SFA or *trans* fats with snacks high in PUFA reduced LDL cholesterol concentrations, total cholesterol, and triglycerides. However, varying LA, with SFA held constant, showed that high or low LA did not influence total cholesterol, LDL cholesterol, or HDL cholesterol levels (Liou, 2007). Comparing individual fatty acids, diets providing 7 percent of energy from linoleic acid, stearic acid, or oleic acid showed no significant differences in serum LDL or HDL cholesterol (Thijssen and Mensink, 2005).

Studies that examined markers of inflammation or measures of oxidative stress showed PUFA improved inflammatory marker levels. Zhao et al. (2004) reported that while both high ALA and LA diets decreased C-reactive protein, the finding was significant only for ALA. Additionally, while both high-PUFA diets similarly decreased intercellular cell adhesion molecule-1 (ICAM-1) versus the average American diet, the ALA diet decreased vascular cell adhesion molecule-1 (VCAM-1) and E-selectin more than the LA diet. The comparison of high versus low LA, with SFA constant, showed no difference in C-reactive protein, interleukin-6, or platelet aggregation (Liou, 2007). Comparison of linoleic acid, stearic acid, or oleic acid showed that, in men, platelet aggregation time was favorably prolonged with consumption of LA versus stearic acid, but was not different compared to oleic acid (Thijssen, 2005).

Four prospective cohort studies showed that higher PUFA intake was associated with lower risk of CHD and total mortality (Hodge, 2007; Laaksonen, 2005;

Mozaffarian, 2005; Oh, 2005). A pooled analysis of 11 prospective cohort studies showed that risk of coronary events and coronary death was lowest with 5 percent energy substitution of SFA with PUFA>MUFA> carbohydrate (Jakobsen, 2009).

The NEL review for this question included a prospective study with nested case-cohort analyses on the effects of a dietary PUFA on T2D risk. The authors reported an inverse association between dietary LA and T2D, compared to a positive association for stearic acid and total saturated fatty acids (Hodge, 2007). In addition, the review for this question is supplemented by evidence from question 1 on SFA and T2D risk that reviewed the literature from 2000. This, and the fact that blood lipids are intermediate markers of risk for both CVD and T2D, further supports the association between PUFA intake and decreased T2D risk.

SPECIFIC FATTY ACIDS THAT AFFECT PLASMA LDL, HDL, AND NON-HDL CHOLESTEROL LEVELS

More than 50 years of research has defined the impact of fatty acids on cholesterol metabolism, yet stearic acid is still categorized as a SFA and *trans* fatty acids are categorized as PUFA, based on their respective chemical properties. However, as more evidence becomes available showing that stearic acid has different metabolic effects than other SFA and does not raise blood cholesterol, and that elaidic acid and other *trans* fatty acids do raise blood cholesterol similar to SFA, a better classification of fatty acids with deleterious health effects would be “cholesterol-raising FA.” This category would consist of SFA with carbon chain lengths from C12-C16 (i.e., excluding stearic acid and smaller SFA) and *trans* fatty acids. The 2010 DGAC reviewed recent evidence on the effects of these particular fatty acids on blood cholesterol and lipoprotein levels.

Question 5: What Are the Effects of Dietary Stearic Acid on LDL Cholesterol?

Conclusion

Moderate evidence from a systematic review indicates that when stearic acid is substituted for other SFA or *trans* fatty acids, plasma LDL cholesterol levels are decreased; when substituted for carbohydrates, LDL cholesterol levels are unchanged; and when substituted for MUFA or PUFA, LDL cholesterol levels are increased. Therefore, the impact of stearic acid replacement of other energy sources is variable regarding LDL cholesterol, and the potential impact of changes in stearic acid intake on cardiovascular disease risk remains unclear.

Implications

Since stearic acid is not known to raise LDL cholesterol, the DGAC is recommending that stearic acid not be categorized with known “cholesterol-raising fats,” which include C12, C14, C16 SFA and *trans* fatty acids. Foods that are high in stearic acid, such as dark chocolate and shea nut oil, need not be considered as problematic as foods high in other SFA or *trans* fatty acids. In addition, setting the recommended percent of energy from these cholesterol-raising fats to a less than 5 to 7 percent will help to maintain blood cholesterol at desirable concentrations.

Review of the Evidence

Background

Stearic acid consumption in the U.S. varies considerably between men (mean 8.8 g/d) and women (mean 5.9 g/d), with modest increases between 1994 and 2006 (USDA/ARS, 1997-2008). The foods that contribute the most stearic acid to the diets of Americans are listed in Table D3.10.

Table D3.10. Top food sources of stearic acid among U.S. population, 2005-2006 NHANES

Food Item	**Contribution to Intake %**	**Cumulative Contribution %**
Grain-based desserts	8.3	8.3
Regular cheese	6.1	14.4
Sausage, franks, bacon, and ribs	6.0	20.4
Chicken and chicken mixed dishes	5.7	26.1
Pizza	5.7	31.8
Burgers	5.1	36.9
Beef and beef mixed dishes	4.8	41.7
Mexican mixed dishes	4.4	46.1
Dairy desserts	4.3	50.4
Candy	4.2	54.5
Pasta and pasta dishes	3.3	57.8
Fried white potatoes	3.2	61.1
Eggs and egg mixed dishes	3.2	64.2
Reduced fat milk	3.0	67.2
Whole milk	2.6	69.9
Yeast breads	2.5	72.3
Cold cuts	2.2	74.5
Butter	2.2	76.7

Source: Sources of Saturated Fat, Stearic Acid, and Cholesterol Raising Fat Among the U.S. Population, 2005-2006. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/foodsources Updated November 9, 2009. Accessed April 16, 2010.

Evidence Summary

A NEL review of the evidence since 2000 resulted in one systematic review with univariate and multivariate regression analysis of all selected studies. This review examined the effect of stearic acid on blood LDL cholesterol when substituted for SFA, MUFA, PUFA, carbohydrate, or *trans* fatty acids (Hunter, 2010). Although this systematic review provided broad qualitative and quantitative analysis, it was scored as methodologically neutral based on one limitation: the selected studies included in the review were not individually graded. However, this review provided the most updated evidence and covered all aspects of stearic acid replacements and risk/benefit outcomes related to LDL cholesterol and CVD risk. Overall, this review covered three epidemiologic studies that examined stearic acid specifically, and 20 randomized controlled trials that examined high stearic acid intake as a replacement of other dietary fats or carbohydrate. The randomized controlled trials were grouped according to comparisons with (1) high SFA (palmitic acid, myristic acid, or butterfat) (Aro, 1997; Becker, 1999; Bonanome and Grundy, 1988; Denke and Grundy, 1991; Dougherty, 1995; Judd, 2002; Kelly, 2001, 2002; Kris-Etherton, 1993; Nestel, 1998; Snook, 1999l; Sundram, 2007; Schwab, 1996; Tholstrup, 1994, 1995); (2) high carbohydrate (Nestel, 1998; Judd, 2002; Kris-Etherton, 1994); (3) high unsaturated fat (oleic acid or linoleic acid) (Bonanome and Grundy, 1988; Denke and Grundy, 1991; Dougherty, 1995; Hunter, 2000; Zock and Katan, 1992; Mensink, 1992; Kris-Etherton, 1993; Judd, 2002; Thijssen and Mensink, 2005; Berry, 2007; Louheranta, 1998); and (4) baseline (or habitual) diet (Snook, 1999; Schwab, 1996; Kelly, 2001, 2002). Four studies assessed the effect of substituting stearic acid for *trans* fatty acids in the diet (Aro, 1997; Judd, 2002; Sundram, 2007; Zock and Katan, 1992).

Overall, the results showed that in comparison with SFA, stearic acid lowered LDL cholesterol, was neutral with respect to HDL cholesterol, and lowered the ratio of total to HDL cholesterol. In comparison with unsaturated fatty acids, MUFA and PUFA, stearic acid tended to raise LDL cholesterol, lower HDL cholesterol, and increase the ratio of total to HDL cholesterol. Univariate regression analysis of the data substituting stearic acid for cholesterol-raising SFA indicated that the LDL cholesterol concentration decreases as dietary stearic acid increases. The univariate regression coefficient for this relation was -0.036 ($p=0.034$). The regression coefficient suggests that for each 1 percent of energy increase in stearic acid, when substituted for cholesterol-raising SFA, the LDL-cholesterol concentration could decrease by 0.036 millimoles (mmol)/L. When multivariate regression analysis was done (with adjustments for both between-study, and within-study variation), the multivariate regression coefficient for this relation was 0.043 ($p<0.001$), suggesting that for each 1 percent energy increase in cholesterol-raising SFA, when substituted for stearic acid, the LDL cholesterol concentration would increase by 0.043 mmol/L.

A one-to-one substitution of stearic acid for *trans* fatty acids showed a decrease or no effect on LDL cholesterol, an increase or no effect on HDL cholesterol, and a decrease in the ratio of total to HDL cholesterol. Replacing industrial *trans* fatty acids with stearic acid could increase stearic acid intake from 3 percent to 4 to 5 percent of energy in the U.S. population.

Although not part of the formal NEL review, the 2002 IOM report is consistent with Hunter et al. (2010). The IOM report emphasized that stearic acid has been shown to have a neutral effect on LDL cholesterol levels (Bonanome and Grundy, 1988; Denke, 1994; Hegsted, 1965; Keys, 1965, Yu, 1995; Zock and Katan, 1992), in comparison to palmitic, lauric, and myristic acids that increase LDL cholesterol levels (Mensink, 1994). Stearic acid was indicated to be similar to oleic acid in its effects (Kris-Etherton, 1993).

Cholesterol-raising Fatty Acids Modeling

Food pattern modeling analyses were carried out to answer the question, “What would the impact be on food choices and overall nutrient adequacy if the cholesterol-raising fatty acids were limited to (a) less than 7 percent of total calories and (b) less than 5 percent of total calories?” (see the Reducing Cholesterol-Raising Fatty Acids report, online Appendix E3.9, available at www.dietaryguidelines.gov). Cholesterol-raising fatty acids were defined as total SFA minus stearic acid. *Trans* fatty acids are not available in the USDA food composition databases because levels in foods have been rapidly changing, however, they are captured in the solid fat values.

Changes in the base food patterns needed to bring cholesterol-raising fats to less than 7 percent and less than 5 percent of calories were identified, and the impact on food selections and other nutritional goals was assessed. In the base patterns, stearic acid constitutes 2.2 to 2.6 percent of calories, and cholesterol-raising fatty acids provide 6.0 to 6.8 percent of calories, so no changes were needed to achieve the goal of less than 7 percent. If all solid fats were removed and isocalorically replaced with oils, total SFA would be decreased to 7.0 to 7.5 percent of calories and cholesterol-raising fatty acids would be decreased to 5.0 to 5.5 percent of calories.

Question 6: What Effect Does Consuming Natural (Ruminant) Versus Synthetic (Industrially Hydrogenated) *Trans* Fatty Acids Have on LDL-, HDL- and Non HDL Cholesterol Levels?

Conclusion

Limited evidence is available to support a substantial biological difference in the detrimental effects of industrial *trans* fatty acids (iTFA) and ruminant *trans* fatty acids (rTFA) on health when rTFA is consumed at 7 to 10 times the normal level of consumption.

Implications

The level of daily intake of rTFA is quite small with the U.S. adult population’s average daily intake approximating 1.2 grams (1.5 g for men and 0.9 g for women).[2] This represents less than 0.5 percent of total daily energy intake. This is a relatively minor exposure in the diet regardless of its metabolic effect.

[2] Estimated by the Food and Drug Administration in: Food Labeling; *Trans* Fatty Acids in Nutrition Labeling; Final Rule and Proposed Rule. Vol. 68, No. 133, p. 41470, July 11, 2003, http://www.fda.gov/Food/LabelingNutrition/Labelclaims/NutrientContentClaims/ucm110179.htm from CSFII food intake data reported in Smicklas-Wright, 2002.

The very limited data available provide insufficient evidence to suggest rTFA and iTFA be considered differently in their metabolic effects. Total *trans* fatty acid intake should be considered the target for dietary change. Total elimination of rTFA would require elimination of red meat and dairy products from the diet. Although total elimination of iTFA may be desirable, the elimination of rTFA would have wider implications for dietary adequacy and is not recommended. It is best to avoid iTFA while leaving small amounts of rTFA in the diet. Overall, *trans* fatty acid levels in the U.S. food supply have decreased dramatically following mandatory *trans* fatty acids labeling regulations, which went into effect in 2006. Continued reductions in iTFA are to be encouraged.

Review of the Evidence

Based on the 2002 IOM review covering 20 controlled trials and 11 epidemiologic studies, as well as the National Cholesterol Education Program (NCEP) Adult Treatment Panel Review (NCEP 2002) and seven additional publications, the 2005 DGAC concluded that the relationship between *trans* fatty acid intake and LDL cholesterol is positive and HDL cholesterol is inverse, increasing the risk of CHD. The 2005 DGAC's recommendation was that *trans* fatty acids consumption should be kept as low as possible, defined as less than 1 percent of energy. An obstacle to removing *trans* fatty acids altogether has been its dual source in the food supply. The great majority comes from hydrogenation of unsaturated fats industrially, but about 1 to 2 percent is found naturally in the gastrointestinal tracts of ruminant animals, ending up in meats and dairy products. The 2010 DGAC therefore considered the question of whether rTFA, which are structurally different from iTFA, have different effects from iTFA on serum lipid and lipoprotein levels.

A NEL review of the evidence from 2000 found two methodologically strong randomized controlled cross-over trials (Motard-Belanger, 2008; Chardigny, 2008) and one methodologically neutral review (Jakobsen, 2006) that compared the effects of iTFA and rTFA on plasma lipid concentrations and CVD risk. Chardigny et al. (2008) compared experimental diets containing 11 to 12 grams per day (about 5% of daily energy) of rTFA and iTFA in 40 healthy normolipidemic individuals in France and found no difference in effect in men and that *trans* fatty acids from natural sources significantly increased HDL cholesterol and LDL cholesterol in women. This level of intake of rTFA is far above current U.S. rTFA consumption, which is small compared to iTFA consumption (IOM Report, 2002). Motard-Belanger et al. (2008) evaluated four isocaloric experimental diets in 38 normolipidemic men: (1) high rTFA (10.2 g/2500 kcal); (2) moderate rTFA (4.2 g/2500 kcal); (3) high iTFA (10.2 g/2500 kcal); (4) low TFA from any source (control) (2.2 g/2500 kcal). The investigators found plasma LDL cholesterol was significantly higher after the high iTFA diet as compared to the moderate rTFA diet, and after the high rTFA diet compared to moderate rTFA or control diets. Plasma HDL cholesterol concentrations were significantly lower after the high rTFA diet compared to the moderate rTFA diet. These results indicate that moderate rTFA intake has neutral effects on plasma lipids related to CVD risk.

One methodologically neutral review (Jakobsen, 2008) evaluated results from three prospective cohort studies and one case-control study which assessed the effect of consumption of rTFA on CHD outcomes and reported no statistically significant association. A prospective cohort study included in the Jakobsen review (Oomen, 2001) assessed the association between *trans* fatty acid intake and CHD in 667 Dutch men between the ages of 64 and 84 years with no history of CHD. These investigators found a non-significant association between rTFA or iTFA and risk of CHD. Relative risks of CHD for an increase of 0.5 percent energy from rTFA and iTFA were 1.17 (95% CI 0.69-1.98) and 1.05 (95% CI 0.99-1.15), respectively.

The risk of CVD associated with *trans* fatty acids is due, in part, to *trans* fatty acid effects on LDL and HDL cholesterol, inflammatory processes, as well as interference with fat metabolism. In countries like Denmark, dramatic declines in CVD of about 60 percent have been attributed to diverse factors including progress made in lowering the intake of *trans* fatty acids from commercial sources (Leth, 2006; Stender, 2008), following the passage of legislation limiting their use. Although simultaneous advances in the prevention and treatment of CVD have played a role, the importance of eliminating iTFA cannot be overlooked. Mozaffarian et al. (2006) estimated that reducing commercial *trans* fatty acid intake from 2.1 percent of energy to 1.1 percent or 0.1 percent of energy could have prevented 72,000 or 228,000 CVD deaths per year, respectively. The FDA suggested that removal of *trans* fatty acids in just 3 percent of breads and cakes and 15 percent of cookies and crackers would save up to $59 billion in health care costs in the next 20 years.

Accordingly, a number of U.S. companies are taking innovative steps to reduce *trans* fatty acids in their food products (Table D3.11).

Table D3.11. Mean *trans* fatty acid levels in certain foods from Food Label and Package Surveys (FLAPS) 2006–2007 and mean *trans* fatty acid levels of comparable food products

Food	**2004**[a]	**FLAPS 2006-2007**[a]
Cakes		
Number of samples	n = 10	n = 11
Mean TFA levels g/100 g (SE)[b]	2.85 (1.03)	0.98 (0.47)
Biscuits		
Number of samples	n = 5	n = 5
Mean TFA levels g/100 g (SE)	4.40 (0.25)	5.41 (0.70)[d]
Margarines and Spreads		
Number of samples	n = 7	n = 9
Mean TFA levels g/100 g (SE)	12.24 (1.06)	4.37 (2.36)[c]
Cookies		
Number of samples	n = 12	n = 14
Mean TFA levels g/100 g (SE)	4.5 (0.62)	1.9 (0.84)
Crackers		
Number of samples	n = 11	n = 17
Mean TFA levels g/100 g (SE)	5.20 (0.51)	0.71 (0.39)[c]
Potato Chips		
Number of samples	n = 8	n = 10
Mean TFA levels g/100 g (SE)	0.45 (0.45)	0.0 (0) NS[e]
Tortilla Chips		
Number of samples	n = 8	n = 9
Mean TFA levels g/100 g (SE)	1.76 (0.6)	0.0 (0)[c]
Frozen Potato Products		
Number of samples	n = 6	n = 7
Mean TFA levels g/100 g (SE)	1.97 (0.48)	0.74 (0.24)[c]
Cereal and Granola		
Number of samples	n = 8	n = 9
Mean TFA levels g/100 g (SE)	1.70 (0.8)	0.0 (0)[c]
Tortillas		
Number of samples	n = 6	n = 7
Mean TFA levels g/100 g (SE)	0.76 (0.39)	0.22 (0.22)[f]

[a] *Trans* fat levels for 2004 are from Satchithanandam et al. 2004a, and were analyzed from food products. The levels from FLAPS are values from food labels.
[b] SE = Standard error.
[c] Significant decrease at $p < 0.05$.
[d] Significant increase at $p < 0.05$.
[e] NS = Not significant.
[f] Mean is NS, but median is significant decrease at $p < 0.05$.
Source**:** Mossoba et al. (2009). *J. of AOAC International*, 92 (5), 1284-1300. Used with permission, AOAC International.

RELATIONSHIPS BETWEEN CONSUMPTION OF *n*-3 FATTY ACIDS AND HEALTH OUTCOMES

This question had been reviewed extensively by several expert panels and the 2005 DGAC. As *n*-3 PUFA are derived from two sources, plant and marine, the 2010 DGAC examined both sources for benefits impacting primary and secondary prevention of CVD. Although most expert panels have focused on *n*-3 supplements, this review examined the consumption of *n*-3 PUFA in whole foods (dietary supplement interventions were excluded) in individuals with and without CVD. In addition to the potential beneficial effects of *n*-3 PUFA on CVD risk in adults, significant findings have emerged on the benefits of maternal long-chain *n*-3 PUFA intake during pregnancy and lactation related to improved neurodevelopment in the infant and child.

Question 7: What Is the Relationship Between Consumption of Seafood *n*-3 Fatty Acids and Risk of CVD?

Conclusion

Moderate evidence shows that consumption of two servings of seafood per week (4 oz per serving), which provide an average of 250 milligrams per day of long-chain *n*-3 fatty acids, is associated with reduced cardiac mortality from CHD or sudden death in persons with and without CVD.

Implications

An increase in seafood intake to two servings per week at 4 ounces per serving, is advised for high-risk (those with CVD) and average-risk persons, especially as the first presentation of CVD (myocardial infarction, stroke) is frequently fatal or disabling. The quantity and frequency of seafood consumption is important, but the type of seafood (those providing at least 250 mg of long-chain *n*-3 fatty acids per day) also is critical. Increased consumption of seafood will require efficient and ecologically friendly strategies be developed to allow for greater consumption of seafood that is high in EPA and DHA, and low in environmental pollutants such as methyl mercury (see *Part D.8: Food Safety and Technology* for a detailed discussion of the risks and benefits of seafood consumption).

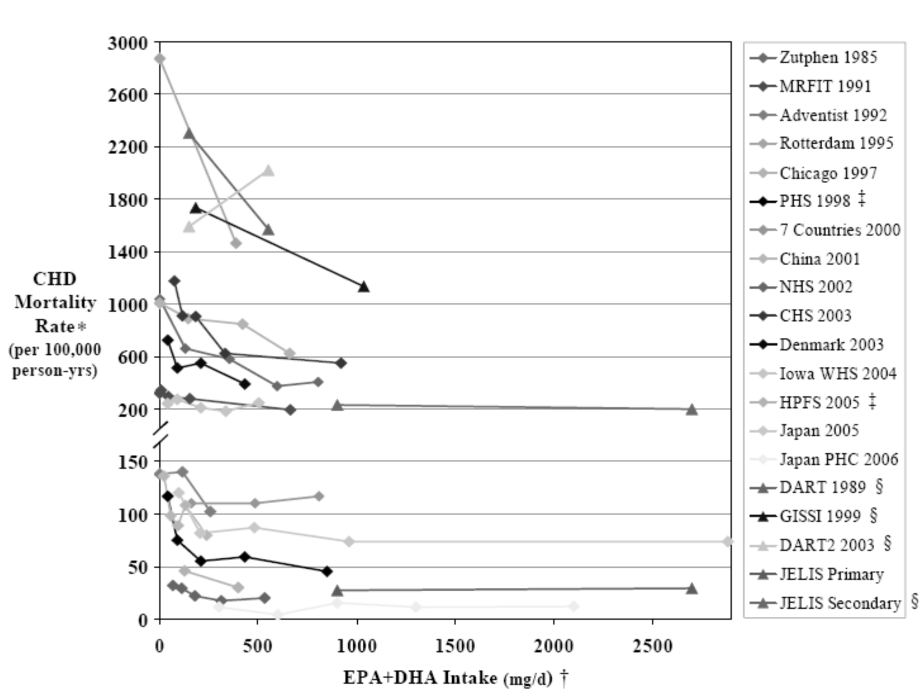
Review of the Evidence

The 2010 DGAC conducted a full NEL search of the literature from 2004 to evaluate the association of seafood consumption and CVD risk. Results of this review were supplemented by an earlier evidence review of the literature from 2004 to 2007 conducted by the ADA on health benefits related to consumption of fish or fish-derived *n*-3 fatty acids in individuals without or with CVD. Taken together, the NEL and ADA evidence reviews identified 25 studies published since 2004 assessing the health benefits of seafood consumption in persons without CVD. These included six systematic reviews/meta-analyses, including four methodologically strong reviews with meta-analyses of randomized controlled trials and prospective cohort studies (He, 2004; Konig, 2005; Mozaffarian 2008; Mozaffarian and Rimm, 2007), one methodologically strong systematic review of 14 randomized controlled trials, 25 prospective cohort studies, and seven case-control studies (Wang, 2006) and one methodologically neutral meta-analysis of 14 cohort and five case-control studies (Whelton, 2004). These also included four randomized controlled trials ranging in size from 33 to 48 participants conducted in the U.S. and Finland, including two methodologically strong study (Lara, 2007; Seierstad, 2005) and two methodologically neutral studies (Lindqvist, 2009; Lankinen, 2009). Lastly, this included 15 prospective cohort studies conducted in the U.S., Europe, Japan, and China, ranging in size from 300 to 57,972 participants, including eight methodologically strong (Brouwer, 2006; Frost and Vestergaard, 2005; Iso, 2006; Järvinen, 2006; Mozaffarian, 2004, 2005; Virtanen, 2008, 2009) and seven methodologically neutral studies (Albert, 2002; Folsom and Demissie, 2005; Levitan, 2009; Pangiotakos, 2007; Streppel, 2008; Turunen, 2008; Yamagishi, 2008).

Three of the systematic reviews assessed both fish and long-chain *n-3* FAs (Mozaffarian 2008; Mozaffarian and Rimm, 2007; Wang, 2006) and three meta-analyses covered only fish (Konig, 2005; Whelton, 2004; He, 2004). The systematic reviews and meta-analyses were consistent in showing that fatty fish consumption at about two servings per week (about 250 mg EPA+DHA/d) decreases risk of CVD events. Intakes above this level appeared to result in no significant additional decreases in risk of CVD events, as shown in Figure D3.2a and D3.2b.

The randomized controlled trial evidence showed an inverse protective association between fish intake and intermediate markers of CVD risk and CVD health outcomes. The interventions were fish-specific and included the following: one study that showed herring significantly increased serum HDL levels (Lindqvist, 2009); two studies on salmon that showed salmon versus no fish intake improved serum lipids and blood pressure (Lara, 2006), and intake of salmon with different levels of EPA + DHA showed the high EPA + DHA salmon improved serum lipids and markers of inflammation (Seierstad, 2005); and one study comparing fatty versus lean fish showed that fatty fish consumption improved serum lipid profiles and markers of insulin resistance and inflammation (Lankinen, 2006).

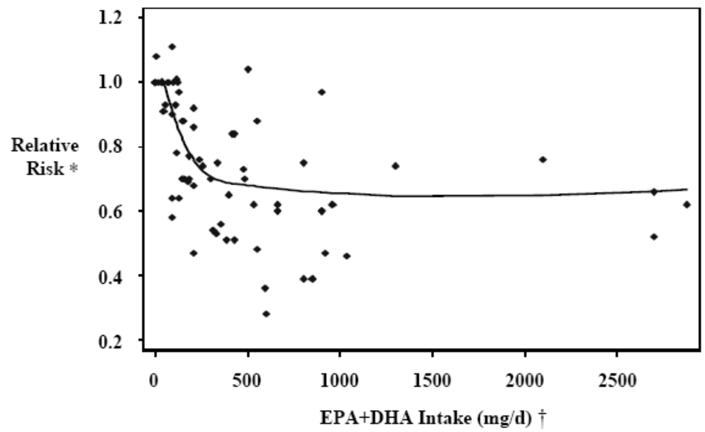
Figure D3.2a. Relationship between intake of fish or fish oil and relative risks of CHD death in prospective cohort studies and randomized clinical trials



Note: Absolute coronary heart disease (CHD) mortality rates vary more than 100-fold across different populations (due to differences in age, prior CHD, and other risk factors), but the relative effects of intake of fish or fish oil are consistent, whether for primary or secondary prevention, for cohort studies or randomized trials, or for comparing populations at higher or lower absolute risk. Compared with little or no fish intake, modest consumption (~250-500 mg/d eicosapentaenoic acid [EPA] plus docosahexaenoic acid [DHA]) is associated with lower risk of CHD death, while at higher levels of intake, rates of CHD death are already low and are not substantially further reduced by greater intake.

Source: Mozaffarian and Rimm, *JAMA* 2006;296:1885-1899. Used with permission, American Medical Association, Chicago, IL.

Figure D3.2b. Relative risk of coronary heart disease death by dose of EPA+DHA



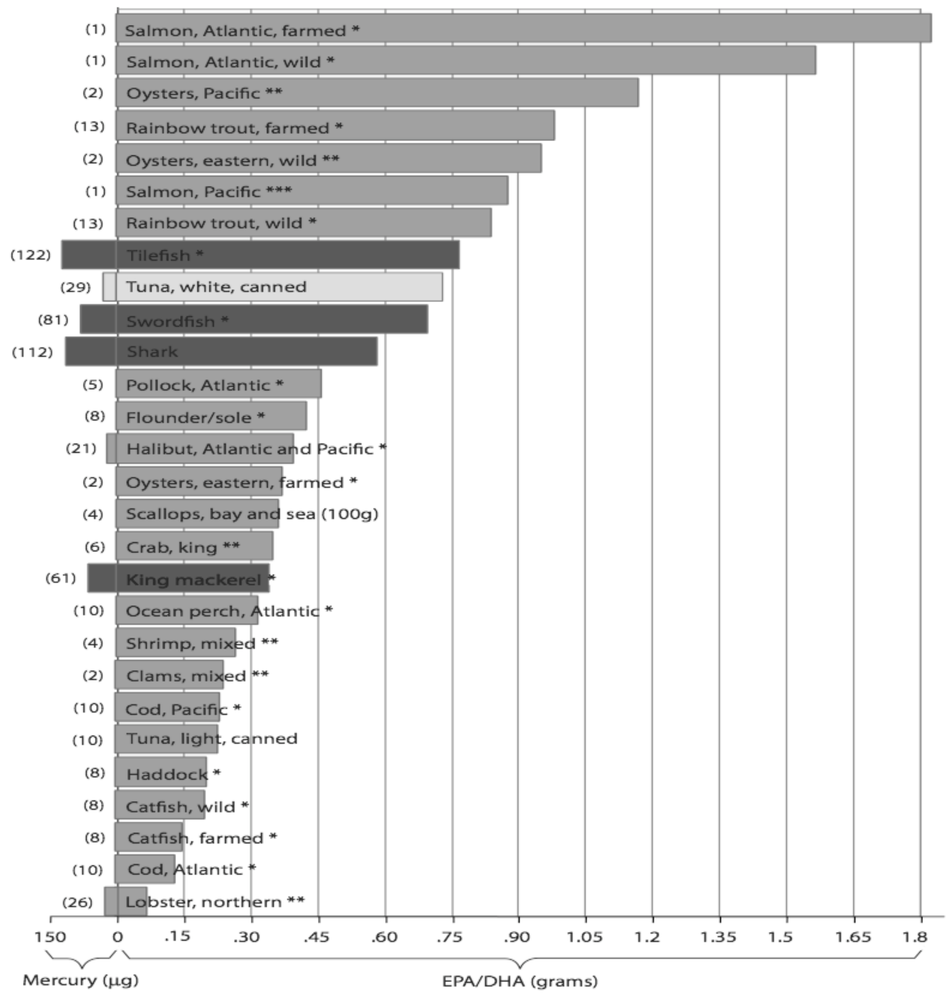
Note: The relationship between intake of fish or fish oil and relative risk of coronary heart disease (CHD) death in a pooled analysis of the prospective studies and randomized trials show that fatty fish consumption at about two servings per week (about 250 mg EPA+DHA/d) decreases risk of CVD events. Intakes above this level appeared to result in no significant additional decreases in risk CVD events.
Source: Mozaffarian and Rimm, *JAMA* 2006;296:1885-1899. Used with permission, American Medical Association, Chicago, IL.

Evidence from prospective cohort studies was substantial and focused on primary CVD prevention in healthy adults. Ten prospective cohort studies examined the association between fatty fish and CVD outcomes and found a positive association between seafood and seafood-derived *n*-3 fatty acid consumption and decreased CVD incidence/risk (Levitan, 2009; Virtanen, 2008; Yamagishi, 2008; Streppel, 2008; Turunen, 2008; Järvinen, 2006; Iso, 2006; Mozaffarian, 2005; Lemaitre, 2003; Albert, 2002). Three prospective cohort studies examined fish and fish-derived fatty acid consumption and atrial fibrillation and found either no association between fish *n*-3 fatty acid intake and reduced risk of atrial fibrillation (Brouwer, 2006; Frost and Vestergaard, 2005) or a inverse association between consumption of tuna or other broiled or baked fish (but not fried fish) and incidence of atrial fibrillation (Mozaffarian, 2004). Virtanen et al. (2009) reported *n*-3 fatty acids (especially DHA) to be effective in reducing atrial fibrillation in men. One prospective cohort study examined the association between fatty fish intake and intermediate markers of CVD risk and found moderate intake of fatty fish was inversely associated with serum lipids and blood pressure (Panagiotakos, 2007). One prospective cohort study assessed fish *n*-3 FA intake on CVD and CHD mortality and found no independent association with CHD or stroke mortality (Folsom and Demissie, 2005). One prospective cohort study found a positive association between fish intake and increased incidence of T2D (Kaushik, 2009). This is the only observational evidence regarding risk of T2D, but the randomized controlled trial on fatty vs. lean fish by Lankinen et al. (2009) examined markers of insulin resistance and can be added to the evidence regarding T2D.

The 2005 DGA indicated there was sufficient evidence to suggest that *n*-3 PUFA consumption provided protection for persons with existing CVD. For the current 2010 review, conclusions related to persons with CVD relied on the ADA evidence-based review referred to above, as a NEL search did not yield additional studies that met the inclusion criteria. Four studies were reviewed by the ADA that addressed the relationship between consumption of fish-derived *n*-3 fatty acids and risk of CVD events in persons with CVD. One was a methodologically strong meta-analysis covering 11 randomized controlled trials (Bucher, 2002) and three studies were methodologically strong prospective cohort studies conducted in the U.S. with cohort size ranging from 228 to 415 participants (Erkkila, 2003, 2004, 2006). All of these articles provided evidence of the protective effects of consuming long-chain *n*-3 fatty acids on risk of CVD events in persons with known CVD. Erkkila et al. (2003) found blood levels of ALA, EPA and DHA were associated with a reduction in risk of all-cause mortality, but associations with combined fatal and nonfatal CVD events specifically were not significant, suggesting a totally different mechanism. Erkkila et al. (2004) and Erkkila et al. (2006) found fish-derived *n*-3 fatty acids exerted protective effects against progression of coronary artery arteriosclerosis. Women who ate two or more servings of fish per week had significantly fewer new lesions, and women with plasma DHA levels above the median exhibited less atherosclerosis progression than those below the median. A meta-analysis that included two diet intervention trials (Bucher, 2002) assessed the effect of a diet high in long-chain *n*-3 fatty acids from fish (compared to control) and found long-chain *n*-3 fatty acids decreased the relative risk of myocardial infarction, sudden death, and overall mortality in persons with coronary artery disease.

Figure D3.3 shows examples of seafood and their respective content of EPA and DHA and methyl mercury (see *Part D.8: Food Safety and Technology* for a detailed discussion of the risks and benefits of seafood consumption.)

Figure D3.3. Estimated EPA/DHA content and methyl mercury content of 3 oz. portions of seafood



* = cooked, dry heat.
** = cooked, moist heat.
*** = EPA and DHA content in Pacific salmon is a composite of chum, coho, and sockeye.
Source: Institute of Medicine (IOM). Seafood Choices, 2006. Used with permission, National Academies Press, Washington, DC.

Seafood Modeling

The implications for nutrient adequacy of increasing seafood in the USDA Food Patterns was studied by modeling three scenarios of differing levels of seafood consumption, using the reference 2000 calorie per day food intake pattern:

- Scenario 1: 4 ounces per week of seafood high in *n*-3 fatty acids.
- Scenario 2: 8 ounces per week of seafood, including seafood both low and high in *n*-3 fatty acids in proportions to those currently consumed by Americans.
- Scenario 3: 12 ounces per week of seafood low in *n*-3 fatty acids.

One goal of this modeling analysis was to quantify seafood consumption recommendations for the general public—something not done previously because of a lack of strong evidence on the role of seafood consumption in population health. The three scenarios were modeled to determine the amounts of foods to include in the Meat and Beans group so as to meet nutrient recommendations without altering the calorie level of the patterns. (See the Seafoods report, online Appendix E3.10, available at www.dietarygsuidelines.gov). The analysis showed that the amounts of seafood in the base USDA Food Patterns could be increased to 8 ounces per week without any negative impact on nutrient adequacy. The total amounts of EPA and DHA for the three seafood scenarios modeled were 292 milligrams per day for 4 ounces of high *n*-3 seafood (Scenario 1); 253 milligrams per day for 8 ounces of the current mixture of low and high *n*-3 seafood (Scenario 2); and 201 milligrams per day for 12 ounces of low *n*-3 seafood (Scenario 3). This analysis did not incorporate the methyl mercury content of fish included in the patterns; however, the amounts of methyl mercury found in the seafood varieties used in the patterns are zero to minimal (see *Part D.8: Food Safety and Technology* for a detailed discussion of the risks and benefits of seafood consumption.)

Question 8: What Is the Relationship Between Consumption of Plant *n*-3 Fatty Acids and Risk of CVD?

Conclusion

ALA intake of 0.6 to 1.2 percent of total calories will meet current recommendations and may lower CVD risk, but new evidence is insufficient to warrant greater intake beyond this level. Limited but supportive evidence suggests that higher intake of *n*-3 fatty acids from plant sources may reduce mortality among persons with existing CVD.

Implications

Evidence is currently insufficient to make a formal guideline to increase *n*-3 intake from plant sources without additional evidence from randomized clinical trials and prospective observational studies among participants with a broad range of *n*-3 intake. As relatively little ALA converts to EPA and DHA, evidence is lacking that plant-derived *n*-3 fatty acids alone will provide the same cardioprotective effects as EPA and DHA consumed at the recommended level discussed above. This increases the need for efficient and ecologically friendly strategies to allow for greater consumption of seafood *n*-3 fatty acids, unless plant-derived sources of EPA or DHA can be developed.

Review of the Evidence

The NEL conducted an evidence review to determine the relationship between consuming plant-derived *n*-3 PUFA and the risk of CVD events. This review relied upon an evidence-based review conducted by the ADA on the relationship between *n*-3 fatty acids and CVD, covering the literature from 2004 to 2007 (ADA, 2008). Overall, five studies were reviewed by ADA that addressed this question. These included two methodologically strong case control studies (Lemaitre, 2003, Rastogi, 2004), and three prospective cohort studies (two were methodologically strong [Albert, 2005; Mozaffarian, 2005] and one was methodologically neutral [Folsom and Demissie, 2005]). In addition, the NEL reviewed three studies since 2008, including one methodologically strong case-control study conducted in the U.S. (Lemaitre, 2009), one methodologically strong prospective cohort study covering 2,682 men in Finland (Virtanen, 2009), and one methodologically strong systematic review of 14 randomized controlled trials, 25 prospective cohort studies, and seven case-control studies (Wang, 2006).

Lemaitre et al. (2009) reported that an increase in red blood cell membrane ALA corresponding to 1 standard deviation was associated with 32 percent higher risk of sudden cardiac arrest (odds ratio = 1.32, 95% confidence interval: 1.07 - 1.63) after adjusting for confounding variables. Virtanen et al. (2009) found that red blood cell membrane ALA and intermediate chain *n*-3 PUFA did not have any association with atrial fibrillation. Wang et al. (2006) conclude from their systematic review that increased intake of *n*-3 fatty acids from fish or fish-oil supplements, but not of ALA, reduces the rates of all-cause mortality, cardiac and sudden death.

Two studies of persons with CVD were part of the 2008 ADA review. One methodologically neutral randomized controlled trial (Baylin, 2003) and one methodologically neutral case control study (De Lorgeril, 1999) found a diet high in plant-derived *n*-3 fatty acids protective against recurrence of myocardial infarction. Both studies used biomarkers. Baylin et al. (2003) found an inverse relationship between adipose tissue ALA and risk of nonfatal acute myocardial infarction. The greatest protection was found in those individuals who also had low total *trans* fatty acids in adipose tissue. Study participants in the top quintiles of adipose tissue ALA (0.72% of fatty acids) had a lower risk of myocardial infarction than those in the lowest quintile (0.35% of fatty acids). The difference in adipose tissue ALA corresponds to approximately 0.3 gram per day of dietary intake. De Lorgeril et al. (1999) found a decreased rate of cardiac death and nonfatal myocardial infarction in those following a Mediterranean diet versus a Western diet (1.24 vs. 4.07 per hundred patients per year). The experimental group had a significantly lower intake of total lipids and SFA, and increased intake of oleic acid, LA and ALA. The plasma concentration of ALA and DHA tended to be inversely associated with recurrence of myocardial infarction.

Question 9: What Are the Effects of Maternal Dietary Intake of *n*-3 Fatty Acids From Seafood on Breast Milk Composition and Health Outcomes in Infants?

Conclusion

Moderate evidence indicates that increased maternal dietary intake of long chain *n*-3 PUFA, in particular docosahexaenoic acid (DHA), from at least two servings of seafood per week during pregnancy and lactation is associated with increased DHA levels in breast milk and improved infant health outcomes, such as visual acuity and cognitive development.

Implications

There has been controversy and concern over the consumption of fish during pregnancy and lactation with regard to exposure of the fetus and infant to heavy metals during the most sensitive period of neurodevelopment. The current evidence, however, favors consumption of fish for pregnant and lactating women, particularly in the context of women making educated choices to consume seafood that is high in *n*-3 fatty acids and low in environmental pollutants. The benefits of fish consumption are maximized with fatty fish high in EPA and DHA but low in methyl mercury. These conclusions are consistent with those found in the discussion of seafood benefits and risks in *Part D.8: Food Safety and Technology*. The previously described modeling analysis of seafood identified scenarios of type and quantity of fish that provide 250 milligrams per day of EPA + DHA.

Review of the Evidence

Since the 2005 DGAC Report, a number of organizations have rendered expert opinions on the subject of *n*-3 PUFA supplements during pregnancy and lactation, including a Cochrane Database Systematic Review (Makrides, 2009), ADA Evidence Analysis Library review (Kaiser, 2008), and the European Union Perinatal Lipid Intake Working Group assessment (Koletzko, 2007). The 2010 DGAC reviewed these reports as well as a background paper by Brenna and Lapillonne (2009), which provided context on the effects of supplemental long-chain *n*-3 PUFA during pregnancy and lactation. This background paper covered 23 randomized controlled trials on supplemental DHA at physiological and pharmacologic levels, and highlighted the benefits of maternal DHA consumption on infant/child intelligence scores, among other positive outcomes.

For the purposes of this review, the DGAC excluded studies with long chain *n*-3 PUFA given in "supplement" form (e.g., fish oil, cod liver oil, fish oil capsules). This removed most randomized clinical trials during pregnancy and lactation from consideration. Also not included were breast feeding versus infant formula feeding studies (before DHA addition), and studies of pre-term versus full-term infants.

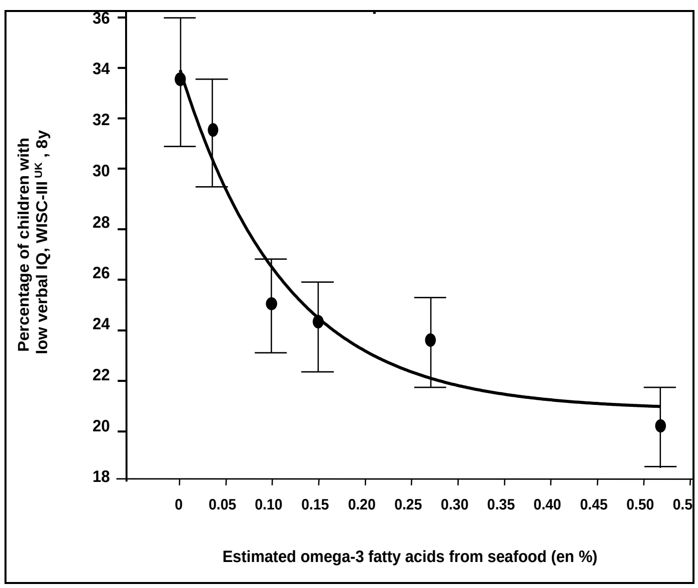
Overall, nine articles were reviewed since 2000 to determine the effect of *n*-3 fatty acids on breast milk composition and infant health outcomes. There were seven methodologically strong prospective cohort studies conducted in the U.S., Europe, and Canada in healthy women with low-risk pregnancies, healthy mother/infant pairs, or healthy children up to 8 years in cohort sizes ranging from 211 to 50,276 participants

(Drouillet, 2009; Hibbeln, 2007; Innis, 2001; Oken, 2005, 2008a, 2008b; Olsen, 2006). In addition, the evidence included one methodologically strong randomized controlled trial of 350 mother/infant pairs in the U.S. (Colombo, 2004) and one methodologically strong meta-analysis of 65 international studies (Brenna, 2007).

The prospective cohort studies focused on maternal DHA consumption during pregnancy and, overall, the evidence for benefits from maternal DHA consumption during pregnancy was strong. Because randomized controlled trials with DHA supplements were excluded, there were fewer studies on maternal DHA intake during lactation. However, one study examined both pregnancy and duration of breastfeeding with improved infant cognitive outcomes (Oken, 2008b) and another measured breastfeeding with associated DHA biomarkers in infants with improved cognitive outcomes (Innis, 2001).

One prospective cohort study showed that low maternal fish intake was associated with increased risk of children being in the lowest quartile for verbal intelligence quotient (IQ), and increased risk of suboptimal outcomes for fine motor skills and communication/social development scores (Hibbeln, 2007). Hibbeln et al. (2007) estimated incidence of suboptimal verbal IQ in children eight years of age as a function of maternal seafood consumption during pregnancy in 11,875 women. The study was conducted in British women and analysis controlled for 28 potentially confounding variables, such as birth weight, alcohol use during pregnancy, and smoking. Children of mothers reporting the highest seafood consumption, estimated using a food frequency questionnaire and estimated *n*-3 intake, were significantly less likely to score in the lowest quartile for verbal IQ compared to women who reported no seafood consumption during pregnancy (Figure D3.4).

Figure D3.4. Effect on children's verbal IQ of maternal seafood consumption during pregnancy



Note**:** Prevalence of children with low verbal IQ according to mothers' consumption of *n*-3 fatty acids from seafood. Estimated maternal consumption of long chain *n*-3 fatty acids is expressed as proportion of total calories (en %). Maternal seafood consumption was grouped into six categories: mothers with no reported consumption plus five equal groups of the remaining population. Means and 95% CI for proportion of children in the lowest quartile for verbal IQ.
Source**:** Hibbeln et al., 2007 *Lancet*. Feb 17;369(9561):578-85. Used with permission from Elsevier, publisher of *The Lancet,* Oxford, UK.

Two reports from Project VIVA on maternal seafood intake and infant cognition showed that higher fish consumption in pregnancy was associated with better infant cognition, but if the fish consumed resulted in higher mercury levels, this was associated with lower cognition. The visual recognition memory scores were highest among infants of women who consumed more than two weekly fish servings, but had mercury levels less than 1.2 parts per million (ppm) (Oken, 2005). No benefit was associated with fish consumption of less than two servings per week (Oken, 2008a).

The effect of maternal fish consumption during pregnancy and duration of infant breastfeeding on child developmental milestones in participants of the Danish National Birth Cohort showed that higher maternal fish intake and greater duration of breastfeeding were associated with higher child developmental scores at ages 6 and 18 months (Oken, 2008b). Related to maternal fish consumption and biomarkers during lactation, increased red blood cell phosphatidylethanolamine DHA in infants was associated with improved visual acuity and speech perception (Innis, 2001).

Maternal fish consumption was also associated with improved perinatal outcomes. A prospective cohort study in Denmark showed that mean gestation length was shorter and odds of preterm delivery were increased in subjects who never consumed fish, compared with those who consumed fish at least once per week (Olsen, 2006). A study of the EDEN mother-child cohort in France showed that high fish intake during pregnancy was not associated with increased fetal growth, but in a sub-population of overweight women, high fish intake was associated with increased fetal growth and head circumference (Drouillet, 2009).

One randomized controlled trial using high DHA eggs (133 mg DHA/d) fed during pregnancy showed infants with improved measures of visual habituation and attention span, compared to mothers on low DHA eggs (Colombo, 2004).

One meta-analysis of 65 international studies measured distribution of DHA and arachidonic acid (AA) concentrations in breast milk. Brenna et al. (2007) found that in mothers worldwide, DHA concentrations were lower and more variable than AA concentrations in breast milk. The highest DHA concentrations were found in coastal populations and associated with seafood consumption. Overall, compared to AA, breast milk DHA content was more sensitive to dietary intake.

CARDIOVASCULAR HEALTH EFFECTS RELATED TO CONSUMPTION OF SPECIFIC FOODS HIGH IN FATTY ACIDS

Specific whole foods high in fat content were examined for effects on cardiovascular health. The two foods selected for inclusion are nuts and chocolate. The health effects of consuming other high-fat, high-calorie foods, such as full-fat dairy products and meats are discussed in other chapters (see, for example, *Part D.2. Nutrient Adequacy*).

Question 10: What Are the Health Effects Related to Consumption of Nuts?

Conclusion

There is moderate evidence that consumption of unsalted peanuts and tree nuts, specifically walnuts, almonds, and pistachios, in the context of a nutritionally adequate diet and when total calorie intake is held constant, has a favorable impact on cardiovascular disease risk factors, particularly serum lipid levels.

Implications

Most nut consumption is in the form of peanuts, though tree nuts (walnuts, almonds, pecans, pistachios) are frequently used in cooking and as snack foods. Peanuts are also an important source of plant protein. Many nuts (e.g., peanuts, almonds, cashews) are sold with added salt as snack foods; thus, the recommendations for consumption are limited to unsalted nuts as a means to reduce sodium intake. It also is important to note that nuts should be consumed in small portions, as they are high in calories and can contribute to weight gain.

Review of the Evidence

Background

Nuts are a commonly consumed food in the U.S., and certain varieties, such as peanuts, walnuts, almonds, pecans, and pistachios, are often used in cooking and as snack foods (Table D3.12). Peanuts and other nuts also are an important source of plant protein (Table D3.13). See *Part D. Section 4: Protein* for additional information on the contribution of plant sources of protein to the diet.

In recent years, investigators have examined the potential cardiovascular benefits associated with certain foods high in fat. Nuts are a primary example of these foods. Because nuts, especially peanuts, are so frequently consumed in the U.S., the 2010 DGAC decided to review the evidence on this issue.

Table D3.12. Estimated mean daily intakes of tree nuts and peanuts[1] by adults 20 years and over, U.S. 2005-2006

Gender Groups	Sample Size	Mean[2] Intake of Nuts (grams)	Mean[2] Energy from Nuts (kcal)	Mean Energy from Nuts (%)
Men	2163	9.7±0.87	57±5.2	2.2
Women	2357	5.6±0.51	34±3.1	1.9
All adults	4520	7.5±0.46	45±2.7	2.1

[1]Includes tree nuts and peanuts eaten out of hand, either alone or in nuts mixtures containing dried fruits and/or seeds, and peanut butter eaten alone or in sandwiches. Nuts in baked products, such as muffins and cakes, and nuts in candies are *not* included.
[2]Mean±standard error.
Source**:** USDA, Agricultural Research Service, Food Surveys Research Group.2010. Tree nuts and peanuts. Available at http://www.cnpp.usda.gov/Publications/DietaryGuidelines. Accessed May 5, 2010.

Table D3.13. Nutrient composition of nuts per 1.5 ounces (43 g)

Type	Energy (kcal)	Total Fat (g)	Saturated Fatty Acids (g)	Monounsaturated Fatty Acids (g)	Polyunsaturated Fatty Acids (g)	Protein (g)
Almonds	254	22.5	1.7	14.3	5.4	9.4
Brazil nuts	279	28.2	6.4	10.4	8.8	6.1
Cashews	244	19.7	3.9	11.6	3.3	6.5
Hazelnuts	275	26.5	1.9	19.8	3.6	6.4
Macadamias	305	32.4	5.1	25.2	0.6	3.3
Peanuts	249	21.1	2.9	10.5	6.7	10.1
Pecans	302	31.6	2.7	18.7	8.7	4.0
Pistachios	243	19.6	2.4	10.3	5.9	9.1
Walnuts, English	278	27.7	2.6	3.8	20.1	6.5

Source**:** USDA, Agricultural Research Service, USDA Nutrient Data Laboratory. 2009. USDA National Nutrient Database for Standard Reference, Release 22. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

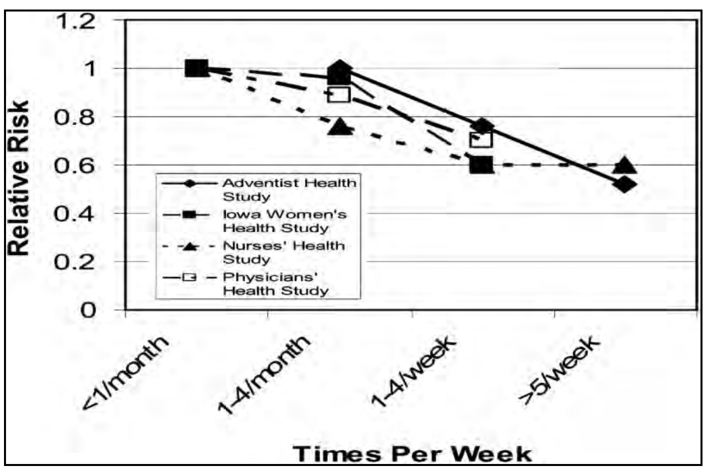
Evidence Summary

The NEL reviewed the literature from 2000 and was informed by studies from a previous systematic review on almonds conducted by the ADA's Evidence Analysis Library. Overall, 17 studies were identified since 2000. These studies included four methodologically strong prospective cohort studies conducted in the U.S. and Europe ranging in cohort size from 6,309 to 51,118 participants (Bes-Rastrollo, 2007, 2009; Djousse, 2009; Li, 2009); 10 randomized controlled trials conducted in the U.S. ranging from 15 to 1,224 participants (four methodologically strong (Sabate, 2005; Salas-Salvado, 2008a, 2008b; Wien, 2003) and six methodologically neutral (Gebauer, 2008; Griel, 2008; Kurlandsky and Stote, 2006; Olmedilla-Alonso, 2008; Rajaram, 2009; Sheridan, 2007); and three methodologically strong reviews covering international randomized controlled trials (Banel and Hu, 2009; Mukuddem-Petersen, 2005; Phung, 2009). These 17 studies were further subdivided based on studies of nuts in general (including peanuts) and studies of specific types of nuts in particular and are listed below. Overall, this review provided evidence that consumption of nuts collectively and walnuts, almonds, and pistachio nuts individually, in the context of a healthy diet and when calorie intake is constant, has a favorable impact on CVD risk factors, particularly serum lipid levels. The evidence was strongest for walnuts. Insufficient evidence was available to address the health effects of macadamia nuts or cashews.

Six studies on nuts in general, including peanuts, were reviewed to determine their health benefits. Overall, the studies indicated beneficial effects of nut consumption on intermediate markers and CVD risk. These studies included one systematic review with meta-analysis (Mukuddem-Petersen, 2005) covering 13 randomized controlled trials that showed decreased total and LDL cholesterol in study participants consuming nuts compared to participants consuming control diets. In two prospective cohort studies in high risk populations, one found that consumption of at least five servings per week of nuts or peanut butter was significantly associated with lower total, LDL, non-HDL cholesterol and apoB-100 concentrations, as well as a lower risk of CVD (Li, 2009), and one showed that a Mediterranean diet high in nuts resulted in the most significant improvement in inflammatory markers related to endothelial function (Salas-Salvado, 2008). Two prospective cohort studies indicated that nut consumption (≥ 2 servings/week) was associated with decreased incidence of weight gain and obesity (Bes-Rastrollo, 2007, 2009). Djousse and colleagues found an inverse relationship between nut consumption and hypertension in lean participants, but not in overweight or obese participants in the Physicians' Health Study (Djousse, 2009).

For additional context regarding nuts in general, two meta-analyses demonstrated consistent and dose-responsive changes in coronary disease risk with increasing doses of nuts per month for four prospective studies (Kris-Etherton, 2008; Sabate, 2009) (Figure D3.5).

Figure D3.5. Frequency of nut consumption and coronary heart disease risk reduction in a dose-response manner



Note**:** Results are from four epidemiologic studies.
Source**:** Sabaté J, Ang Y. *Am J Clin Nutr* 2009;89:1643S-1648S. Used with permission, American Society for Nutrition.

Evidence analysis was also conducted on specific types of nuts including almonds, walnuts, macadamia nuts, and pistachios. Overall, studies showed that almond consumption improved total cholesterol (Phung, 2009; Wein, 2003), decreased LDL cholesterol and the LDL:HDL cholesterol ratio (Wein, 2003), or was neutral regarding LDL and LDL:HDL cholesterol ratio (Phung, 2009; Kurlandsky and Stote, 2006). Regarding walnuts, studies showed that walnut consumption improved total cholesterol, LDL cholesterol and the LDL:HDL cholesterol ratio (Banal and Hu, 2009; Rajaram, 2009; Olmedilla-Alonso, 2008). Olmedilla-Alonso et al. (2008) found that meat products with walnuts decreased body weight. However, one randomized crossover trial found that a walnut supplemented diet (12% energy from walnuts) provided more calories per day and increased body weight and BMI (Sabate, 2005). Energy-adjusted results were not significant, indicating that care must be taken to accommodate the caloric content of nuts in the diet. Lastly, studies focused on macadamia nuts (Griel, 2008) or pistachios (Sheridan, 2007; Gebauer, 2008) showed that both decreased total cholesterol, LDL cholesterol, and the LDL:HDL cholesterol ratio.

Question 11: What Are the Health Effects Related to Consumption of Chocolate?

Conclusion

Moderate evidence suggests that modest consumption of dark chocolate or cocoa is associated with health benefits in the form of reduced CVD risk. Potential health benefits need to be balanced with caloric intake.

Implications

Chocolate as currently consumed is a small component of the total diet, and benefits or risks will likely be minimal. Potential health effects need to be balanced with caloric intake, as chocolate is a calorie dense product. The predominant fat in chocolate is stearic acid, which has been shown to not raise blood cholesterol. Different formulations of chocolate vary in their content of dairy fat, with darker chocolate containing less dairy fat. Beneficial effects of chocolate have been attributed to polyphenolic compounds, in particular flavonoids. Many plant-based foods contain polyphenolic compounds and chocolate is a minor source. Formulations of chocolate are known to have different polyphenolic profiles, and, if this is the mechanism of chocolate's beneficial actions, different forms of chocolate may confer different benefits.

Review of the Evidence

The current evidence regarding chocolate and health outcomes primarily focuses on flavonoids as bioactive constituents of chocolate and their relation to CVD risk. Flavonoids are a subgroup of polyphenols and within the flavonoid chemical hierarchy the flavan-3-ols (flavanols) are particularly high in dark chocolate and cocoa. The flavan-3-ols in dark chocolate and cocoa are primarily catechins, epicatechins (monomers), and procyanidins (polymers).

A NEL search of the literature since 2000 identified a total of 13 studies that addressed the question on health effects of chocolate consumption. Three methodologically strong systematic reviews of international randomized controlled trials and prospective cohort studies (Desch, 2010; Ding, 2006; Hooper, 2008) were identified. Eight randomized controlled trials conducted in the U.S., Europe, Australia, and Japan, covering from 25 to 297 participants, that were methodologically strong (Allen, 2008) and methodologically neutral (Baba, 2007; Crews, 2008; Davidson, 2008; Farouque, 2006; Kurlandsky and Stote, 2006; Monagas, 2009; Tuabert, 2007) were identified. And one methodologically strong prospective cohort study of 876 males in the Netherlands (Buijsse, 2006) and one methodologically neutral population-based case-control study conducted in Sweden (Janszky, 2009) were included to address this question.

The systematic review and meta-analysis by Desch et al. (2010) covered 10 randomized controlled trials and showed that high-flavanol chocolate or cocoa significantly lowered systolic and diastolic BP (Desch, 2010). Hooper et al. (2008) included six randomized controlled trials in their meta-analysis and showed that dark chocolate or cocoa improved flow mediated dilation both acutely and chronically. Ding et al. (2006) included 21 randomized controlled trials and 11 prospective cohort studies and both flavonoids and stearic acid were examined for association with intermediate markers and CVD outcomes. Overall, the randomized controlled trials suggested that cocoa and chocolate have beneficial effects on blood pressure, inflammatory markers, anti-platelet function, serum HDL, and LDL oxidation. The prospective cohort studies showed that flavonoids in chocolate were positively associated with decreased risk of CHD and myocardial infarction mortality. Overall, the evidence from these systematic reviews and meta-analyses was strengthened by the consistency of findings across studies.

The randomized controlled trials in this evidence analysis were focused on flavonoids and intermediate markers of CVD risk. Studies showed that dark chocolate or cocoa consumption decreased serum total cholesterol and LDL cholesterol, increased HDL cholesterol, delayed LDL oxidation (Baba, 2007), decreased serum triglycerides, and improved inflammation markers (Kurlandsky and Stote, 2006). However, one study found no effect of dark chocolate consumption on serum cholesterol levels (Kurlandsky and Stote, 2006). Regarding BP, dark chocolate or cocoa consumption decreased systolic blood pressure (Allen, 2008; Tuabert, 2007), diastolic blood pressure

(Davidson, 2008), and decreased prevalence of hypertension (Tuabert, 2007). However, one randomized controlled trial found no effect of dark chocolate or cocoa consumption on blood pressure (Crews, 2008). A more detailed analysis of inflammation markers showed that cocoa consumption decreased monocyte expression of numerous cell adhesion molecules (Monagas, 2009). Additionally, high-flavonol cocoa (versus low flavonol cocoa) increased flow-mediated dilation, both acutely and chronically, and reduced insulin resistance (Davidson, 2008). High-flavonol cocoa was also tested in individuals with coronary artery disease and did not improve any markers of arterial blood flow or inflammation (Farouque, 2006).

The evidence regarding chocolate and CVD health outcomes contains relatively few epidemiologic studies. Overall, this evidence included populations in the U.S., Europe, Japan, and Australia, participating in both primary prevention and, to a lesser extent, secondary prevention studies. Sample sizes ranged from relatively small randomized controlled trials to 470 participants in the Zutphen Elderly Study (Buijsse, 2006) and 1,169 participants in the Stockholm Heart Epidemiology Program (SHEEP) (Janszky, 2009).

A prospective cohort study in the Netherlands examined cocoa intake and found it inversely associated with blood pressure and CVD mortality in male participants from the Zutphen Elderly Study (Buijsse, 2006). A population-based case-control study assessed the effects of chocolate consumption in patients with established CHD in the SHEEP study where people who had had myocardial infarctions were followed for 8 years. In this study, chocolate consumption had a significant inverse association with cardiac mortality (Janszky, 2009).

Chapter Summary

Dietary fatty acids and cholesterol are major determinants of two major causes of morbidity and mortality in Americans, namely CVD and T2D. The health impacts of dietary fats and cholesterol are mediated through levels of serum lipids, lipoproteins, and other intermediary factors. The consumption of harmful types and amounts of fatty acids and cholesterol has not changed appreciably since 1990. In order to reduce the population's burden from CVD and T2D, and their risk factors, the preponderance of the evidence indicates beneficial health effects associated with:

1. Limiting saturated fatty acid intake to less than 7 percent of calories, replacing these calories with those from mono- or polyunsaturated fatty acids, rather than carbohydrates. As an interim step toward this less than 7 percent goal, all individuals should immediately consume less than 10 percent of energy as saturated fats.
2. Limiting dietary cholesterol to less than 300 milligrams per day with further reductions of dietary cholesterol to less than 200 milligrams per day in persons with or at high risk for CVD or T2D.
3. Avoiding *trans* fatty acids from industrial sources in the American diet, leaving small amounts of *trans* fatty acids from natural (ruminant) sources.
4. Redefining cholesterol-raising fats as saturated fats (exclusive of stearic acid) and *trans* fatty acids, with a recommended daily intake of less than 5 percent of energy.
5. Consuming two servings of seafood per week (4 oz cooked, edible seafood per serving), which provide an average of 250 milligrams per day of *n*-3 fatty acids from marine sources.
6. Ensuring maternal dietary intake of long-chain *n*-3 fatty acids, in particular DHA, during pregnancy and lactation through two or more servings of seafood per week, with emphasis on types of seafood high in *n*-3 fatty acids and with low methyl mercury content.

Needs for Future Research

Saturated Fatty Acids

1. Determine the benefits and risks of MUFA versus PUFA as an isocaloric substitute for SFA (see below). Confirm the metabolic pathways through which dietary SFA affect serum lipids, especially as some SFA (e.g., stearic acid) do not appear to affect blood lipid levels.

   Rationale: The growing data to support a risk of T2D from SFA consumption indicates the need for fat-modified diets in persons with pre-diabetes, including those with metabolic syndrome, and with established diabetes. Since the ages of onset of T2D now include childhood, studies from adolescence through middle age would be useful to define when SFA-reduced diets would be most effective.

2. Conduct feeding studies using cholesterol from sources other than eggs and funded by non-industry sponsors. Conduct research on low- and high-risk consumers of dietary cholesterol and determine a better definition of hypo- and hyper-responders to dietary cholesterol with respective underlying genetic polymorphisms. Identify additional subgroups in which dietary cholesterol appears especially harmful with regard to cardiovascular risk.

   Rationale: Most of the feeding studies with serum lipid and lipoprotein endpoints used eggs as the primary source of cholesterol, and many of the studies were funded by industry. Since the proportion of dietary cholesterol in the U.S. diet supplied by eggs has declined to less than 25 percent, feeding trials on other dietary sources of cholesterol would be useful. Persons with T2D appear to be a subgroup in which dietary cholesterol is particularly harmful and better understanding of the mechanisms and magnitude of risk would be essential, as eggs are an important, low fat source of protein in T2D patients.

3. Determine the mechanism by which dietary MUFA improve serum lipids, glucose metabolism, insulin levels, Homeostatic Model Assessment (HOMA) scores, inflammatory markers, and blood pressure in both healthy persons and in persons with T2D. Studies of replacing carbohydrates or other dietary fat with MUFA should include isocaloric substitutions, so as not to be confounded by differences in energy.

   Rationale: Understanding the mechanism by which MUFA improve risk of CVD and T2D will enhance our ability to make specific recommendations for MUFA consumption in healthy and at-risk individuals.

4. Determine the mechanism by which dietary PUFA improve serum lipids, glucose metabolism, insulin levels, HOMA scores, inflammatory markers, and blood pressure in both healthy persons and in persons with T2D. Studies of replacing carbohydrates or other dietary fat with PUFA should include isocaloric substitutions, so as not to be confounded by differences in energy.

   Rationale: Understanding the mechanism by which PUFA improve risk of CVD and T2D will enhance our ability to make specific recommendations for PUFA consumption in healthy and at-risk individuals. PUFA and MUFA have similar benefits as substitutes for SFA and *trans* fatty acids. Additional isocaloric comparisons of MUFA versus PUFA on metabolic intermediates and especially on clinical outcomes are needed to differentiate these two classes of fatty acids.

5. Examine stearic acid for its benefits as a solid fat, in contrast to liquid oils high in MUFA and PUFA; include other potential metabolic effects of stearic acid, such as inflammation and coagulation.

   Rationale: The benefit of stearic acid is that it has a high melting point and therefore is solid at room temperature, unlike other FAs which do not raise blood cholesterol (e.g., MUFA, PUFA). Comparisons of intermediate markers and other effects of stearic acid versus MUFA and PUFA would clarify ways that it could be best used in a calorie and nutrient-balanced diets.

6. Characterize the difference in metabolic effects and intermediate markers between industrial and ruminant *trans* fatty acids.

   Rationale: Since ruminant and industrial *trans* fatty acids have different chemical structures, better characterization of their metabolic effects though further feeding studies would be warranted.

7. Conduct randomized controlled trials and prospective observational studies in persons with and without CVD on plant compared to marine *n*-3 fatty acids. Examine diets rich in plant *n*-3 fatty acids in individuals with and without adequate intake of *n*-3 fatty acids from marine sources. Examine the mechanism of action of marine vs. plant *n*-3 fatty acids for synergies and/or inhibition.

   Rationale: Although there are consistent data on the benefits of *n*-3 fatty acids from seafood consumption, there is no research on comparing marine versus plant *n*-3 fatty acids on intermediate markers and CVD outcomes.

8. Investigate further the opposing interactions of high EPA and DHA versus high methyl mercury, especially in dietary patterns in which these consumptions coexist. Investigate high versus low DHA-consuming mothers and infants and the long-term effects on intelligence and other cognitive outcomes.

Rationale: All aspects of the risk to benefit ratio of consumption of EPA + DHA and methyl mercury, both of which can be present in varying amounts in different types of seafood, should be further elucidated. DHA appears to be the active nutrient in seafood that provides benefits in infant development. Further studies of the role of DHA in neurodevelopment and dose-response relationships between DHA and health/development outcomes would be useful.

9. Conduct randomized controlled trials comparing different types of nuts on intermediate markers, such as serum lipids, and classify each specific type of nut as more or less associated with CVD risk reduction.

   Rationale: Additional randomized trials will be required over longer periods of time to determine if nuts confer long-term benefits. It is difficult to distinguish benefits to health and to intermediate metabolites between different types of nuts.

10. Elucidate further the role of polyphenolic compounds as major active ingredients in the health benefits of chocolate. Test different chocolate formulations that are commonly consumed by the general public.

    Rationale: Many chocolate and cocoa studies used formulations of chocolate that are not readily available to the consumer and were sponsored by industry. In order to determine the real health benefits of chocolate consumption, chocolate formulations that are available to, and consumed by, the general public need to be tested.

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Part D. Section 4: Protein

Introduction

Protein is the major structural component of all cells in the body and functions as enzymes, hormones, and other important molecules. Protein is one of the major macronutrients and an important source of calories. Both protein and non-protein energy (from carbohydrates and fats) must be available to prevent protein-energy malnutrition (PEM). Proteins are made of amino acids and if the amino acids are not present in the right balance, the body's ability to use protein will be affected. If amino acids needed for protein synthesis are limited, the body may break down body protein to obtain needed amino acids. Protein deficiency affects all organs and is of particular concern during growth and development. Adequate intake of high-quality protein is essential for health.

Because average protein intakes in the United States (U.S.) are more than adequate, protein was not considered as a separate topic by past Dietary Guidelines Advisory Committees. However, the 2010 DGAC decided to focus on dietary protein for many important reasons. First, many consumers have recently adopted high-protein diets for weight loss purposes and the Committee wanted to evaluate the scientific basis of this approach. Secondly, consumer comments addressed the health benefits of vegetarian eating styles (see *Part D. Section 2: The Total Diet: Combining Nutrients, Consuming Food* for a discussion of the nutrient adequacy of vegetarian diets). Finally, as Americans decrease total calorie intake to combat obesity, the optimal percentage of calories derived from protein in the diet may rise. The Committee wanted to review data on the use of high-protein diets and determine whether such diets limit other nutrients (see *Part D. Section 1: Energy Balance and Weight Management* for a discussion of the relationship between macronutrient proportion and body weight, including the safety aspect of high-protein diets).

Background on Protein

Nomenclature

Protein sources vary widely in their nutritional value. The quality of a protein depends on its ability to provide the nitrogen and amino acid requirements necessary for growth, maintenance, and repair. Protein quality is determined by two factors—digestibility and amino acid profile. Amino acids can be divided into categories based on the body's ability to produce them (Table D4.1). Nine amino acids cannot be synthesized in the body and are known as indispensable, or essential, amino acids. These must be consumed in the diet. The remaining amino acids are either dispensable or conditionally indispensable. Five amino acids are dispensable, meaning that they can be produced in the body from other amino acids or nitrogen-containing compounds. An additional six amino acids are conditionally indispensable. Under most circumstances, these amino acids can be synthesized in the body. However, in certain conditions, the body cannot synthesize adequate amounts to meet metabolic needs. Subsequently, a dietary source of the conditionally indispensable amino acids becomes necessary (Institute of Medicine [IOM], 2005).

The Recommended Dietary Allowance (RDA) for both men and women (19 years and older) is 0.80 gram of good-quality protein per kilogram of body weight per day and is based on careful analyses of available nitrogen balance studies (Dietary Reference Intakes [DRI], 2006). Data were insufficient to set a Tolerable Upper Intake Level (UL) for protein or amino acids. Recommended Dietary Allowances (RDAs) for protein increase at certain times during the lifespan. For example, protein RDAs for children are higher on a gram per bodyweight basis than for adults: ages 1 to 3 years, 1.05 grams/kilogram per day; ages 4 to 13 years, 0.95 gram/kilogram per day; ages 14 to 18 years, 0.85 gram/kilogram per day. RDAs for protein also are increased in pregnancy (1.1 g/kg/d) and lactation (1.3 g/kg/d).

The IOM-established Acceptable Macronutrient Distribution Range (AMDR) for protein is 5 to 20 percent of total calories for children ages 1 to 3 years, 10 to 30 percent of total calories for children ages 4 to 18 years, and 10 to 35 percent of total calories for adults older than age 18 years (IOM, 2002/2005). For men and women, protein typically provides about 15 percent of total calories (National Cancer Institute [NCI], 2010).

Table D4.1. Categories of amino acids

Essential	**Conditionally Essential**	**Non-Essential**
Histidine	Arginine	Alanine
Isoleucine	Cysteine	Aspartic acid
Leucine	Glutamine	Asparagine
Lysine	Glycine	Glutamic acid
Methionine	Proline	Serine
Phenylalanine	Tyrosine	
Threonine		
Tryptophan		
Valine		

As calorie intake decreases, however, it is essential to increase the percentage of calories from protein so as to consume the RDA for protein. Thus, the wide recommended range of 10 to 35 percent of total calories coming from protein for adults is based on the large range of calories consumed, which depends on physical activity and body size. For example, low-calorie, protein-sparing, modified fast diets contain mostly protein as it is necessary to get the RDA for protein. In contrast, extremely active people, such as endurance athletes, consume high-calorie diets and their RDA for protein does not change. A lower percentage of energy from protein is therefore appropriate for them and these additional calories would typically come from carbohydrates.

The data are conflicting on the potential for high-protein diets to produce gastrointestinal effects, change nitrogen balance, alter mineral absorption, or affect chronic diseases, such as osteoporosis or renal stones.

Food allergies exist for protein foods including milk, eggs, peanuts, tree nuts, soy, fish, and shellfish (DRI, 2002). Gluten-free diets are recommended for those with gluten intolerance, which limits intake of wheat and certain other grain products. Lactose intolerance, although not medically diagnosed, can limit consumption of dairy products. Care must be taken to determine the cause of the intolerance to a food product (e.g., is the individual sensitive to the sugar in milk or the protein in milk) and make appropriate dietary changes. Often, children allergic to one protein source develop allergies to other protein sources. Many protein sources, including milk, wheat, or soy, must be avoided as a result. As protein allergies can be very severe, careful food selection is essential. If high-quality protein sources cannot be consumed in the diet, other options for high-quality protein sources must be explored (see *Part D. Section 8. Food Safety and Technology*).

Food Sources of Proteins

Diets adequate in protein can be designed in many ways and are reflected in eating patterns around the world. Since the adults (19 years and older) RDA for protein is 0.8 gram/kilogram body weight, a 150-pound adult would require 54 grams of high quality protein daily. Three ounces (the recommended serving size) of lean meat or poultry contain about 25 grams of protein, while 1 cup of milk or yogurt contains 8 grams of protein. Cereals, grains, nuts, and vegetables contain about 2 grams of protein per serving. When protein needs are high, as during growth and development, consumption of animal products will provide both greater quantity and quality of protein than plant products. Plant products can be combined to improve protein quality, but the number of calories that must be consumed to get adequate intakes must be considered.

Thus, proteins are the most important macronutrient in the diet because they provide both essential amino acids and are a source of energy. They are particularly important during growth and development.

List of Questions

ANIMAL AND PLANT PROTEINS AND HEALTH OUTCOMES

1. What is the relationship between the intake of animal protein products and selected health outcomes?
2. What is the relationship between vegetable protein and/or soy protein and selected health outcomes?
3. How do the health outcomes of a vegetarian diet compare to that of a diet which customarily includes animal products?

PROTEIN-RELATED FOOD GROUPS AND HEALTH OUTCOMES

4. What is the relationship between the intake of milk and milk products and selected health outcomes?
5. What is the relationship between the intake of cooked dry beans and peas and selected health outcomes?

Methodology

For the first time, the 2010 DGAC included a chapter focusing solely on the relationship between protein and health. Most of the questions addressed here cover new topics. The Committee reviewed evidence from January 2000 to 2009. Because the 2005 DGAC reviewed the topic of milk and milk products, the 2010 Committee agreed with those recommendations and provided here only an updated review of evidence from June 2004 to 2009.

All of the questions addressed in this section were answered using a Nutrition Evidence Library (NEL) evidence-based systematic review. A description of the NEL evidence-based review process can be found in *Part C: Methodology*. For each question considered in this section, the following general criteria applied. With minor exceptions noted below, all study designs were originally included in the searches, but cross-sectional studies were later excluded from the review if there was sufficient evidence from studies with stronger designs. Also, original research articles included in systematic reviews or meta-analyses were not included as individual articles in the review, so as not to count the study twice. Finally, the Committee excluded studies that considered only participants diagnosed with chronic disease, hyperlipidemia, hypertension, and related health conditions. Additional information about the NEL search strategies and criteria used to review each question can be found online at www.NutritionEvidenceLibrary.gov.

Recent literature has begun to examine the relationship between protein and health outcomes. The Committee addressed this topic in three separate questions: animal protein products, vegetable protein, and vegetarian versus animal-based diets. Question 1 considers animal protein products, including red meat, processed meat, and poultry. Although milk and milk products are sources of animal protein, their relationship to selected health outcomes is addressed separately in Question 4. Seafood, another source of animal protein, is discussed in detail in *Part D. Section 3. Fatty Acids and Cholesterol* and in *Part D. Section 8. Food Safety and Technology*. The health outcomes considered in Question 1 were type 2 diabetes (T2D), cardiovascular disease (CVD), hypertension, body weight, and cancer. For many sections of this Report, the relationship between dietary intakes and cancer outcomes are discussed using conclusions from the World Cancer Research Fund/American Institute for Cancer Research report (WCRF/AICR, 2007). The WCRF/AICR report examined the relationship between meat and numerous types of cancer in a thorough review of the literature of various study designs with humans and animals. However, some controversy has surrounded the WCRF/AICR conclusions for red meat and colorectal cancer. Thus, the Committee decided to conduct a review parallel to other reviews in this Report and included only prospective cohort studies with humans published since 2000. In addition to colorectal cancer, prostate and breast cancers were reviewed.

Question 2 concerns the relationship of vegetable protein and selected health outcomes and was conducted to complement the Committee's review of animal protein products. Because much of the research on vegetable protein has focused on soy protein, soy protein was included in the search as a separate term. However, articles examining soy foods, rather than soy protein specifically, were considered under the Committee's review of cooked dry beans and peas (Question 5). The Committee considered a variety of health outcomes in the vegetable protein search, but available evidence was sufficient to permit only a review of chronic disease, blood pressure, blood lipids, and body weight.

Question 3 considers research that directly compares health outcomes among individuals consuming a diet which customarily includes animal products to those consuming a vegetarian, including vegan, diet. The Committee recognized that additional research on this topic was published before 2000, but felt research published since 2000 represented current plant-based dietary patterns and provided sufficient context to discuss the relationship between these dietary patterns and health. For an in-depth discussion of the relationship between various dietary patterns and health outcomes, see *Part D. Section 2: The Total Diet: Combining Nutrients, Consuming Food*.

As noted, Questions 4 and 5 address specific food groups. Milk and milk products and cooked dry beans and peas are significant protein sources in the American diet, and they also are important sources of other nutrients. Additional information about other nutrient contributions of these food groups can be found in *Part D. Section 2: Nutrient Adequacy*. It should be noted that the Committee considered only studies that directly assessed the relationship between food group intake and health; studies examining dietary patterns that were high in a particular food group were considered as dietary patterns, not under reviews for the individual food groups. The review of milk and milk products considered bone health, cardiovascular outcomes, metabolic syndrome, T2D, and body weight. All the evidence reviews covered children and adults, except for body weight, which included only adults. The relationship between the consumption of milk and milk products and childhood adiposity is discussed in *Part D. Section 1: Energy Balance and Weight Management*. Outcomes considered in the review of cooked dry beans and peas were body weight, CVD, and T2D. Although “legumes” includes dry beans and peas as well as peanuts, peanuts were not considered in this question but are a part of the review of nuts in *Part D. Section 3: Fatty Acids and Cholesterol*.

ANIMAL AND PLANT PROTEINS AND HEALTH OUTCOMES

Question 1: What Is the Relationship Between the Intake of Animal Protein Products and Selected Health Outcomes?

Conclusion

Limited evidence from prospective cohort studies shows inconsistent relationships between intake of animal protein products and CVD with somewhat more positive evidence for processed meats and CHD. Moderate evidence found no clear association between intake of animal protein products and blood pressure in prospective cohort studies. Limited inconsistent evidence from prospective cohort studies suggests that intake of animal protein products, mainly processed meat, may have a link to T2D. Insufficient evidence is available to link animal protein intake and body weight. Moderate evidence reports inconsistent positive associations between colorectal cancer and the intake of certain animal protein products, mainly red and processed meat. Limited evidence shows that animal protein products are associated with prostate cancer incidence. Limited evidence from cohort studies shows there is no association between the intake of animal protein products and overall breast cancer risk. However in subgroups of breast cancer patients, limited evidence suggested a relationship between the intake of animal protein products and risk of developing breast cancer.

Implications

Americans may choose animal products as part of their diet based on the body of evidence showing a general lack of relationship between animal protein consumption and selected health outcomes. However, attention should be given to quantity and preparation, as some forms of meat (well done and processed) may be linked to specific cancers. In addition, animal protein products contain saturated fat and proportionately, a high calorie load, so serving sizes should be appropriate.

Review of the Evidence

Intake of animal protein products shows few links to negative health outcomes in epidemiologic studies. Most people consume protein from both animal and plant sources, making separation of protein intake into animal and plant sources difficult in epidemiologic studies. The WCRF/AICR report (WRCF/AICR, 2007) examined the relationship between meat, poultry, and eggs and a variety of different cancers including colorectal, prostate, and breast. They concluded that the evidence that red meats and processed meats are causally related to colorectal cancer is convincing. Additionally, they found that limited evidence suggests that processed meat is causally related to prostate cancer, and there was limited suggestive evidence that foods containing animal fat are associated with postmenopausal breast cancer.

In a systematic review and meta-analysis published subsequent to our review, Micha et al. (2010) examined the association between the consumption of red and processed meat and the risk of incident CHD and T2D. They found that intake of red meat was not associated with CHD or T2D. However, processed meat was associated with a 42 percent higher risk of CHD and 19 percent higher risk of T2D. Associations for total meat intake and these outcomes were intermediate.

The review provided below summarizes the evidence from literature published since 2000 related to animal protein products, specifically total meat, red meat, processed meat, poultry, and eggs, acknowledging the wide variation in how types of meat and meat products were grouped and analyzed.

Animal Protein Products and Cardiovascular Disease

Prospective cohort studies show inconsistent relationships between intake of animal protein products and cardiovascular disease. The evidence review for this question included seven articles (Djousse, 2008; Halton, 2006; Keleman, 2005; Nakamura, 2004, 2006; Qureshi, 2007; Sinha, 2009), which represented prospective cohorts from the U.S. and Japan published since 2000. Regarding the relationship between the intake of total animal protein and coronary heart disease, no relationship was observed in the Nurses' Health Study (Halton, 2006) or Iowa Women's Health Study (Keleman, 2005). However, a positive association between red meat and processed meat and CVD mortality was observed in the National Institutes of Health-AARP (NIH-AARP) Diet and Health Study (Sinha, 2009), and substituting red/processed meat (combined) for carbohydrate-dense foods was positively associated with coronary heart disease (CHD) mortality in the Iowa Women's Health Study (Keleman, 2005). Studies found no association between egg intake and CVD (Djousse, 2008; Nakamura, 2006, 2004; Qureshi, 2007). Thus, limited information is available on this relationship, and risk may depend on type of meat or meat products consumed and the type of CVD.

Animal Protein Products, Blood Pressure, and Hypertension

No clear association was found between intake of animal protein products and blood pressure in prospective cohort studies. This conclusion is based on the review of six articles (Alonso, 2006; Miura, 2004; Steffen, 2005; Wagemakers, 2009; Wang, 2008b, 2008c) representing prospective cohorts from the U.S., United Kingdom, and Spain published since 2000. No relationship between intake of animal protein and hypertension was observed in the Seguimiento Universidad de Navarra (SUN) cohort in Spain (Alonso, 2006). Similarly, no association between intake of animal protein and systolic or diastolic blood pressure was observed in the PREMIER Study (Wang, 2008b), and no association between the intake of red or processed meat and systolic or diastolic blood pressure was observed in a cohort in the United Kingdom (Wagemakers, 2009).

In contrast, in the Women's Health Study (Wang, 2008c), total red meat intake was positively associated with risk of developing hypertension. In addition, each individual unprocessed and processed red meat item, including hot dogs, hamburgers, and bacon, beef, or lamb as a main dish was positively associated with the risk of developing hypertension. Similarly, the CARDIA study (Steffen, 2005) found a positive association between consumption of total meat and red and processed meat (combined) and risk of developing elevated blood pressure. The Chicago Western Electric Study also showed a positive association between systolic and diastolic blood pressure and red meat, but observed no association with processed meat.

Differences in dietary assessment methodology likely affected the results in this review. Assessment methods included 24-hour recalls, 5-day diaries, diet histories, interviews, and food frequency questionnaires. Studies that used 24-hour recalls (Wang, 2008b) and 5-day diaries (Wagemakers, 2009) observed no associations between animal protein products and systolic or diastolic blood pressure.

Animal Protein Products and Body Weight

Few studies exist to link animal protein products and body weight. After applying our review criteria, only three articles (Mahon, 2007; Wagemakers, 2009; Xu, 2007) published since 2000 were identified that examined the relationship between animal protein products and body weight. Inconsistent findings were reported in a cohort of British adults (Wagemakers, 2009) on whether meat intake was associated with body mass index (BMI) and waist circumference who were studied between 1989 and 1999. Red and processed meat consumed in 1999 was significantly associated with increased BMI in women only. In a cross-sectional study in China (Xu, 2007), red meat consumption was associated with excess body weight. In the only U.S. study found (Mahon, 2007), overweight postmenopausal women were successful in weight loss with either a meat-containing or vegetarian protein intervention. Thus, existing research is sparse and finds little link between meat intake and body weight, and meat-containing diets work as well as calorie controlled vegetarian diets in enhancing weight loss in intervention studies.

Animal Protein Products and Type 2 Diabetes

Prospective cohort studies suggest that intake of animal protein products, mainly processed meat, may have a link to T2D, although results are not consistent. This review included seven articles (Djousse, 2009; Fung, 2004; Halton, 2008; Schulze, 2003; Song, 2004; van Dam, 2002; Vang, 2008) published since 2000 representing prospective cohorts from the U.S. In the three studies examining total animal protein intake, two reported a positive association with T2D (Song, 2004; Vang, 2008) and one reported no association (Halton, 2008). All five studies that reported on the relationship between the intake of processed meats and T2D reported a positive association (Fung, 2004; Schulze, 2003; Song, 2004; van Dam, 2002; Vang, 2008). Inconsistent findings were reported related to the intake of red meat and poultry. Some of the reported risk found in these studies may be attributed to obesity or weight gain, but controlling for this supported meat intake as an important risk factor for diabetes. Other dietary factors, such cereal fiber, fat, and total calories, also are strong in this relationship and the association between T2D and animal protein is attenuated when there is adjustment for these factors.

Animal Protein Products and Colorectal Cancer

Inconsistent positive associations have been reported between colorectal cancer and the intake of certain animal protein products, mainly red and processed meat. This review included 13 studies (Chao, 2005; Cross, 2007; English, 2004; Flood, 2003; Jarvinen, 2001; Kojima, 2004; Larsson, 2005; Lee, 2009b; Norat, 2005; Oba, 2006; Sato, 2006; Wei, 2004; Wu, 2006) representing prospective cohorts from the U.S., Europe, Australia, Finland, Japan, China, and Sweden published since 2000. In studies examining total meat intake, none reported a relationship with overall colorectal cancer risk (Flood, 2003; Jarvinen, 2001; Lee, 2009b; Oba, 2006; Sato, 2006) or risk associated with specific subsites (Lee, 2009b; Sato, 2006; Wu, 2006).

However, more varied results were reported for red and processed meats. For example, in the NIH-AARP Diet and Health Study, positive associations between red meat and processed meat and colorectal cancer were observed (Cross, 2007). However, no associations were observed between red or processed meats and colorectal cancer in the Breast Cancer Detection Demonstration Project (Flood, 2003). The European Prospective Investigation into Cancer and Nutrition (EPIC) study observed no association between red meat and colorectal cancer, but did observe a positive association for processed meat. Further risk may vary depending on subsite. Some studies found a relationship with rectal cancer and red meat intake (Chao, 2005; English, 2004), while others found no association (Kojima, 2004; Larsson, 2005; Lee, 2009b; Wei, 2004; Wu, 2006).

Studies also report inconsistent results for the intake of poultry and colorectal cancer at various subsites, with studies reporting a positive association (Jarvinen, 2001; Kojima, 2004; Sato, 2006), no association (Flood, 2003; Lee, 2009b; Norat, 2005; Wu, 2006), or an inverse association (Chao, 2005; English, 2004; Larsson, 2005).

In general, the studies showed no consistent findings on type of meat or meat product and colorectal cancer. Little information also is available about how much meat is consumed, and the association may differ depending on amount as well as the way it is cooked. Further, although it has been suggested that animal protein products have a different effect in different sites of the colon and rectum, no consistent findings are available. Future studies should consider the subsite of the cancer.

Animal Protein Products and Prostate Cancer

Little evidence is available that animal protein products are associated with prostate cancer incidence. The Committee reviewed six articles (Cross, 2005; Koutros, 2008; Michaud, 2001; Park, 2007; Rodriguez, 2006; Rohrmann, 2007) examining the relationship between animal protein products and incidence of prostate cancer published since 2000. All of the studies represented prospective cohorts from the U.S. Most studies reported no association between total, red, processed, or white meat consumption, meat-cooking method and risk of total prostate cancer, incident cancer, or advanced disease. However, in the Health Professionals Follow Up Study (Michaud, 2001), positive associations between metastatic prostate cancer and red and processed meats were observed. Also, in the Cancer Prevention Study (Rodriguez, 2006), red meat (including processed red meat) and cooked processed meats were positively associated with prostate cancer in Black, but not White, men. Rohrmann and colleagues (2007) reported a positive association between the intake of processed meat and total and advanced prostate cancer but did not observe relationships between cancer and other animal protein products.

Mixed results were observed regarding the level of doneness of meat. Well and very well done meat were associated with prostate cancer in the Prostate, Lung, and Colorectal and Ovarian (PLCO) Screening Trial (Cross, 2005) and the Agricultural Health Study (Koutros, 2008), but level of doneness was not related to cancer risk in the Multiethnic Cohort Study (Park, 2007) or Cancer Prevention Study (Rodriguez, 2006). Thus, cohort studies of animal protein products and prostate cancer since 2000 show little link between total meat intake and prostate cancer although there may be a link between processed meat products as well as well done meat and prostate cancer.

Animal Protein Products and Breast Cancer

Cohort studies show little association between intake of animal protein products and overall breast cancer risk. However, in premenopausal and estrogen receptor positive individuals, meat intake may alter risk of certain types of breast cancer. This review included six studies published since 2000 (Cho, 2006; Ferrucci, 2009; Fung, 2005; Kabat, 2009; Linos, 2008; Taylor, 2007). Results were often reported based on menopausal status (premenopausal or postmenopausal) and/or estrogen receptor status (positive or negative). In the Nurses' Health Study (Cho, 2006), overall, there was no association between total meat intake and risk of breast cancer. However, there was a positive association for ER (estrogen receptor)+/PR (progesterone receptor)+ breast cancer and no association for ER-/PR-. Similarly, they reported positive associations between ER+/PR+ breast cancer and individual red and processed meats, but not for ER-/PR-. Ferrucii et al. (2009) found a stronger association between red meat intake and ER+/PR+ breast cancer compared to negative receptor status in the PLCO Screening Trial.

In additional analyses from the Nurses' Health Study, Linos et al. (2008) found a positive association between premenopausal breast cancer and red meat, and this relationship was stronger among estrogen receptor positive participants. In the UK Women's Cohort Study (Taylor, 2007), positive associations between total meat and premenopausal and postmenopausal breast cancer were observed. Non-processed meat also was positively associated with premenopausal breast cancer. However, postmenopausal but not premenopausal breast cancer was associated with the intake of red meat and processed meat. Thus, results are conflicting and future research should further investigate the relationship between the intake of animal protein products and breast cancer specifically related to menopausal and receptor status.

Question 2: What Is the Relationship Between Vegetable Protein and/or Soy Protein and Selected Health Outcomes?

Conclusion

Few studies are available, and the limited body of evidence suggests that vegetable protein does not offer special protection against T2D, coronary heart disease, and selected cancers. Moderate evidence from both cohort and cross-sectional studies show that intake of vegetable protein is generally linked to lower blood pressure. Moderate evidence suggests soy protein may have small effects on total and low density lipoprotein cholesterol in adults with normal or elevated blood lipids, although results from systematic reviews are inconsistent. A moderate body of consistent evidence finds no unique benefit of soy protein on body weight. A limited and inconsistent body of evidence shows that soy protein does not provide any unique benefits in blood pressure control.

Implications

Our review indicated that intake of vegetable protein is generally linked to lower blood pressure, but this could be due to other components in plant foods, such as fiber, or other nutrients. Individual sources of vegetable protein have no unique health benefits so choice of plant protein sources can come from a wide range of plant-based foods. Consumption of plant proteins of lower quality is generally fine as long as calorie needs are met and effort is made to complement the incomplete vegetable proteins. Consumption of lower-quality or incomplete protein is of greater concern when protein needs are high. Thus, consumption of lower-quality vegetable protein must be carefully considered during pregnancy, lactation, and childhood. Additionally, recommendations to lower calorie intake to combat obesity by increasing plant-based food intake must be linked to cautionary messages to maintain protein total intake of sufficient quality at recommended levels.

Review of the Evidence

Background

Smit et al. (1999) estimated intakes of animal plant protein intake in U.S. adults, based on the Third National Health and Nutrition Examination Survey (NHANES III), 1988–1999. The main protein source in the American diet is animal protein (69%). Meat, fish, and poultry protein combined contributed the most to animal protein (42%), followed by dairy protein (20%). Grains (18%) contributed the most to plant protein consumption. Results found that the percentage of total energy from protein was similar among race-ethnicities and between men and women, their sources of protein were different. But, typically animal protein provides about 70 percent of the protein in the American diet.

In epidemiologic studies, food frequency questionnaires are often used to assess dietary intake and protein-rich foods are often divided into vegetable and animal sources. Most people consume both types of protein, so this division is often complicated (see Question 3 for a discussion of protein and vegan eating patterns). Additionally, sources of vegetable protein are typically also associated with intake of dietary fiber and other potentially beneficial phytonutrients, thereby confounding true, isolated comparisons of protein type.

Soy protein has been the focus of much published research. Based on earlier studies reporting that large intakes of soy protein (25 g) were required to lower serum lipids in the U.S., the U.S. Food and Drug Administration established a health claim stating that 25 grams per day of soy protein can lower serum lipids, including total cholesterol and low-density lipoprotein (LDL) cholesterol (FDA approves health claim labeling for foods containing soy protein. JADA 2000;100:292). No statement regarding isoflavone content or form of soy protein was issued.

The existing health claim for soy requires that each food contain at least 6.25 grams of soy protein, based on the need for 25 grams of soy protein to show significant lowering of serum total cholesterol and LDL-cholesterol. Soy foods that meet the 6.25 gram level include 4 ounces of whole soybeans, 8 ounces of soy milk, 3.5 ounces soy flour, 8 ounces textured soy protein, 4 ounces tofu, and 4 ounces tempeh (FDA approves health claim labeling for foods containing soy protein. JADA 2000; 100:292).

Vegetable Protein and Chronic Disease

Few studies are available, and the limited data collectively suggest that vegetable protein does not offer special protection against T2D, coronary heart disease (CHD), and selected cancers. This conclusion was based on seven studies, including six prospective cohort studies (Halton, 2006, 2008; Keleman, 2005; Sluijs, 2010; Song, 2004; Lee, 2009a) and one ecological study (Nagata, 2000). Five studies addressed vegetable protein (Halton, 2006, 2008; Keleman, 2005; Sluijs, 2010; Song, 2004) and two studies focused on soy protein (Lee, 2009a; Nagata, 2000). Five of the seven studies only included women (Halton, 2006, 2008; Keleman, 2005; Song, 2004; Lee, 2009a).

Three studies examined the relationship between vegetable protein and CHD. In the Nurses' Health Study, no association was found with vegetable protein intake and risk of CHD (Halton, 2006). In the Iowa Women's Health Study, intake of vegetable protein in the highest quintile decreased CHD mortality by 30 percent with isocaloric substitution of vegetable protein for carbohydrate (Keleman, 2005). An ecological study in Japan found no relationship between the intake of soy protein and heart disease mortality (Nagata, 2000).

Three studies examined the relationship between vegetable protein intake and the risk of T2D. No association was found with vegetable protein intake in the Nurses' Health Study (Halton, 2008), Women' Health Study (Song, 2004), or the Dutch cohort of the EPIC study (Sluijs, 2010).

Substituting vegetable protein for carbohydrate or animal protein did not affect risk for cancer and was not associated with all-cause mortality in the Iowa Women's Health Study (Keleman, 2005). In the Shanghai Women's Health Study, vegetable protein was protective against premenopausal but not postmenopausal breast cancer, although only soy protein intake was evaluated (Lee, 2009a). Small protective effects of soy protein were found in men against stomach cancer in the Japanese ecological study (Nagata, 2000). However, intake of soy protein was not associated with breast, prostate, or lung cancer mortality in this study, and intake of soy protein increased colorectal cancer mortality (Nagata, 2000).

In summary, few studies have examined the relationship of vegetable protein intake and chronic diseases and the results from prospective studies report no relationship to diabetes, most cancers, and all-cause mortality. Results are inconsistent for CHD.

Vegetable Protein and Blood Pressure Among Adults Without Hypertension

Intake of vegetable protein is associated with lower blood pressure. This conclusion is based on the review of six studies, including four prospective observational and two cross-sectional studies (Alonso, 2006; Elliott, 2006; Stamler, 2002; Steffen, 2005; Umesawa, 2009; Wang, 2008b). Alonso et al. (2006) reported in the SUN cohort in Spain that vegetable protein intake was associated with less hypertension. In the Chicago Western Electric Study, intake of vegetable protein was linked to lower systolic and diastolic blood pressure (Stamler, 2002). In the CARDIA study, an inverse relationship between the consumption of plant foods and elevated blood pressure was observed (Steffen, 2005). In the PREMIER trial, plant protein had a beneficial effect on blood pressure and was associated with a lower risk of hypertension at 6 months, but not at 18 months (Wang, 2008b). Cross-sectional studies (Elliott, 2006; Umesawa, 2009) also report lower systolic and diastolic blood pressure links to vegetable protein intake.

Soy Protein and Blood Pressure Among Adults Without Hypertension

Some data suggest soy protein may lower blood pressure in adults with normal blood pressure. This conclusion is based on review of three RCTs (He, 2005; Liao, 2007; Teede, 2002), one prospective cohort study (Yang, 2005), and one cross-sectional study (Pan, 2008) published since 2000. All studies were published outside of the U.S. He et al. (2005) and Teede et al. (2002) conducted RCTs that included 40 grams of soy protein consumed per day over 3 months. In both studies, participants receiving soy protein supplementation experienced a significant decrease in systolic blood pressure and diastolic blood pressure compared to the control groups. Liao et al. (2007) did not observe significant changes in systolic blood pressure or diastolic blood pressure among participants consuming soy protein as the only protein source versus a control diet with animal and plant protein for 8 weeks. The groups consumed an isocaloric diet providing 1200 kilocalories per day.

In the Shanghai Women's Health Study, systolic blood pressure and diastolic blood pressure were lower in women who consumed 25 grams or more of soy protein per day than in women consuming less than 2.5 grams per day (Yang, 2005). In cross-sectional analyses of the Nutrition and Health of Aging Population Project in China, soy protein intake and elevated blood pressure were inversely associated in men, but not women (Pan, 2008); median soy protein in quartile 1 and quartile 4 of this study were 3 grams per day and 16 grams per day, respectively. Thus, while data suggest that vegetable protein plays a role in blood pressure, the data specifically for soy protein are limited and inconsistent. Soy protein does not appear to have any unique benefits in blood pressure control.

Soy Protein and Body Weight

Soy protein had no advantage over other proteins when consumed in isocaloric studies on body weight as based on one systematic review (Cope, 2008) and three primary citations (Liao, 2007; McVeigh, 2006; Pan, 2008). Cope et al. (2008) completed a systematic review including 91 international references with data from in vitro, animal, epidemiologic, and clinical studies evaluating the relationship between soy foods, including soy protein, and weight loss. The authors reported that studies with overweight and obese individuals suggest that soy, as a source of dietary protein, may be used to achieve significant weight loss. However, there is no convincing evidence to show whether soy protein is better than other protein sources to achieve weight loss when prescribed in isocaloric levels.

Three additional studies identified in the NEL review support the conclusion by Cope et al. (2008). No differences in weight loss were found when a soy diet was compared to a traditional low-calorie diet (McVeigh, 2006). Pan et al. (2008) examined the effect of soy protein on risk of metabolic syndrome in a cross-sectional study of older Chinese individuals and found no differences in body weight. Liao et al. (2007) conducted a randomized, controlled trial with obese adults, examining the effect of soy protein on weight loss in obese adults and found no effect. Thus, studies consistently find no unique benefit of soy protein with weight loss.

Soy Protein and Blood Lipids Among Adults Without Hyperlipidemia

Soy protein may have small effects on total and LDL-cholesterol in adults with normal or elevated blood lipids, although systematic reviews report inconsistent results. This conclusion is based on four meta-analyses (Harland, 2008; Reynolds, 2006; Weggemans, 2003; Zhan, 2005) and consideration of an additional randomized, controlled trial (Liao, 2007) and a cross-sectional study (Pan, 2008). Results from the meta-analyses are somewhat inconsistent. Harland et al. (2008) concluded that 25 grams of soy protein lowered total cholesterol, LDL cholesterol, and triglycerides, with no change in HDL-cholesterol in adults without hyperlipidemia. Reynolds et al. (2006) suggested that soy protein supplementation (20 to >61 g/d) lowered total cholesterol, LDL-cholesterol, triglycerides, and actually increases HDL cholesterol. Zhan et al. (2005) concluded that soy protein with isoflavones lowered total cholesterol, LDL-cholesterol, triglycerides, and had no effect on HDL-cholesterol. In contrast, Weggemans et al. (2003) reported that soy-associated isoflavones and soy protein have no effect on either LDL-cholesterol or HDL-cholesterol. However, unlike others, this review compared soy protein with isoflavones only with studies in which control groups consumed dairy or other animal protein sources. The role of isoflavones in lowering lipids is discussed in many of these reviews, but it remains unclear whether the protein in soy-associated substances (isoflavones, other phytonutrients or substitution for animal protein) causes lipid lowering.

Liao et al. (2007) reported a significant decrease in total cholesterol and LDL cholesterol in their weight loss study with soy protein, but no changes in triglycerides or HDL cholesterol were observed. A cross-sectional study in China (Pan, 2008) found no relationship between soy protein intake and elevated triglycerides. Overall, conclusions suggest that soy protein may have small effects on total and LDL cholesterol in adults with normal or elevated blood lipids but neither the etiology nor the potential importance of isoflavones in this relationship have been clarified.

Question 3: How Do the Health Outcomes of a Vegetarian Diet Compare to That of a Diet Which Customarily Includes Animal Products?

Conclusion

Limited evidence is available documenting that vegetarian diets protect against cancer. However, it suggests that vegetarian, including vegan, diets are associated with lower BMI and blood pressure. Vegan diets may increase risk of osteoporotic fractures. The effect of vegetarian diets on cardiovascular disease, stroke, and mortality are discussed further in *Part B. Section 2: The Total Diet: Combining Nutrients, Consuming Food.*

Implications

Most people consume diets containing both animal and plant foods. Few studies exist on the nutritional or health status of vegetarians and/or vegans. Individuals who restrict their diet to plant foods may be at risk of not getting adequate amounts of certain indispensable amino acids because the concentration of lysine, sulfur amino acids, and threonine are sometimes lower in plant than in animal food proteins. Nutrients of concern in vegan diets include calcium, iron, B_{12}, zinc, and long-chain *n*-3 fatty acids. Vegetarian diets that include complementary mixtures of plant proteins can provide the same quality of protein as that from animal protein. Education is needed for those designing diets containing complementary proteins for consumers switching to a more plant-based diet. Additionally, individuals consuming vegetarian, particularly vegan, diets should ensure adequate intake of all nutrients.

Review of the Evidence

Background

The nitrogen requirement for adults eating high-quality plant food proteins is not significantly different than animal protein or protein from a mixed diet. Most consumers eat protein from a variety of sources and few cohort studies include enough vegetarians or vegans to draw any conclusions. Also, many self-described vegetarians consume milk products or eggs or even consume processed foods that contain animal protein. Thus, there is limited accurate data to answer questions about health differences between vegetarians and non-vegetarians.

In general, plant proteins are less digestible than animal proteins, but digestibility can be improved with certain processing methods and food preparation techniques. Vegetarians typically consume less protein than non-vegetarians and Hadded et al. (1999) found that 10 of 25 vegan women had potentially inadequate intakes.

Most available evidence relates to the nutritional content and health effects of the average diet of well-educated vegetarians living in Western countries (Key, 2006). Vegetarian diets are rich in carbohydrates, *n*-6 fatty acids, dietary fiber, carotenoids, folic acid, vitamin C, vitamin E, and magnesium and relatively low in protein, saturated fat, *n*-3 fatty acids, vitamin B_{12}, and zinc. Vegans have particularly low intakes of vitamin B_{12}, iron, and calcium. Most data find little differences in major causes of death or all-cause mortality when comparing vegetarians with non-vegetarians from the same population (Key, 2006b). Animal protein intake was linked to greater muscle mass index in a Finnish study (Aubertin-Leheudre & Adlercreutz, 2009) and there is concern about protein intake during growth and development. Nutrients of concern on vegan diets include calcium, iron, B_{12}, zinc, and long-chain *n*-3 fatty acids. Because some vegetarian diets are low in protein, calcium, and other nutrients, research has examined the relationship between plant-based diets and bone health. It is possible to consume complementary plant proteins and have an adequate intake of protein, but education is needed on how to design adequate diets.

We examined studies published since January 2000 with no limits to study design to address these questions. Few cohort studies were available and there were no randomized, controlled trials. A limitation of this area is the small number of vegans and semi-vegetarians in the cohorts studied. For a more in-depth discussion of vegetarian and vegan eating patterns, including review of articles published before 2000 and using additional search strategies, see *Part B. Section 2: The Total Diet: Combining Nutrients, Consuming Food*.

Health Outcomes of a Vegetarian Diet Compared to a Diet Which Customarily Includes Animal Products

Eighteen studies published since 2000 were reviewed that represented eight countries (Alewaeters, 2005; Appleby, 2002, 2007; Baines, 2007; Chen, 2008; Dos Santos Silva, 2002; Grant, 2008; Hung, 2006; Key, 2009a, 2009b; Newby, 2005; Nakamoto, 2008; Rosell, 2006; Spencer, 2003; Teixeira, 2007; Thorpe, 2008; Wang, 2008d; Yen, 2008). Most studies in this review were of a weaker design, including cross-sectional and case-control studies. Only five articles were prospective cohort studies and no Randomized Controlled Trials (RCTs) were identified. Six articles provided results from the EPIC study from the United Kingdom, and four studies were conducted in Taiwan. Other countries represented were the U.S., Australia, Japan, Sweden, Belgium, and Brazil. Vegetarian diets varied greatly among countries, and classifications of plant-based diets were inconsistent among studies. However, all studies compared the health outcomes observed between individuals who regularly consumed animal products to those who occasionally, rarely, or never consumed animal products.

In the EPIC cohort, vegetarian, particularly vegan, diets were associated with lower BMI and lower levels of obesity than diets that included meat (Spencer, 2003). Similar results were found in the Swedish Mammography Cohort (Newby, 2005). Rosell et al. (2006) reported on 5-year changes in weight in the EPIC cohort by dividing participants into groups based on their eating patterns. Specifically, they examined whether participants maintained the same diet (e.g., vegan) over time, or reverted from a vegan or vegetarian diet to a diet containing meat, or converted from eating meat to a vegetarian or vegan diet. Among those who had not changed their eating patterns over time, the largest weight gain was seen in meat-eaters. The smallest weight gain was observed in participants who converted to a vegetarian or vegan diet, and the highest weight gains were among participants classified as reverted, but mean weight gains were not different than weight gains in meat eaters.

Meat eaters had the highest prevalence of hypertension and vegans the lowest in the EPIC cohort (Appleby, 2002), and vegetarians had lower blood pressure than omnivores in small studies in Taiwan (Chen, 2008) and Brazil (Teixeira, 2007). Studies from Taiwan and Brazil also showed improvement in cardiovascular biomarkers, such as total cholesterol, between individuals consuming vegetarian compared to omnivorous diets (Chen, 2008; Teixeira, 2007; Yen, 2008).

Vegans were found to have a higher risk of fractures than vegetarians and meat eaters in the EPIC cohort, which was related to the lower mean calcium intake in this group (Appleby, 2007). However, those on a vegetarian diet in Taiwan did not differ from non-vegetarians in bone mineral density or risk of osteoporosis (Wang, 2008d). In a review of women from the Adventist Health Study (Thorpe, 2008), greater intake of foods rich in protein, whether from animal or plant sources, was associated with reduced wrist fractures.

Data on cancer are inconsistent with one recent study finding more colorectal cancer in vegetarians compared to meat eaters (Key, 2009a). However, the risk of female breast, prostate, ovarian, and lung cancer were not significantly different between vegetarians and non-vegetarians.

Overall, Key and colleagues (2009b) found no differences in mortality rates between vegetarians and non-vegetarians in the EPIC cohort.

PROTEIN-RELATED FOOD GROUPS AND HEALTH OUTCOMES

Question 4: What Is the Relationship Between the Intake of Milk and Milk Products and Selected Health Outcomes?

Conclusion

Strong evidence demonstrates that intake of milk and milk products provide no unique role in weight control. Moderate evidence indicates that the intake of milk and milk products is linked to improved bone health in children. Limited evidence suggests a positive relationship between the intake of milk and milk products and bone health in adults, but results are inconsistent due to variability in outcomes considered. Moderate evidence shows that intake of milk and milk products are inversely associated with cardiovascular disease. A moderate body of evidence suggests an inverse relationship between the intake of milk and milk products and blood pressure. Moderate evidence shows that milk and milk products are associated with a lower incidence of T2D in adults. Limited evidence is available showing intake of milk and milk products are associated with reduced risk of metabolic syndrome. Insufficient evidence is available to assess the relationship between intake of milk and milk products and serum cholesterol levels.

Implications

Currently, many children and adults are not consuming adequate amounts of milk and milk products. NHANES 2005-2006 reported that the mean consumption of calcium does not meet the recommended DRIs for any age group older than age 12 (Moshfegh, 2009). Research since 2004 shows that the underconsumption of milk and milk products may lead to an increase in cardiovascular disease and T2D, as well as an increased risk for poor bone health and related diseases.

Consumption of the recommended daily amounts of low-fat or fat-free milk and milk products (2 cups for children ages 2 to 8 years, 3 cups for those ages 9 years and older) should be promoted. It is especially important to establish milk drinking in young children, as those who consume milk as children are more likely to do so as adults. Those who choose not to consume milk and milk products should include other foods in the diet that contain the nutrients provided by the milk and milk products group, protein, calcium, potassium, magnesium, vitamin D, and vitamin A.

Review of the Evidence

Background

In addition to providing protein, milk and milk products are a source of many important nutrients, including calcium, potassium, magnesium, vitamin D, and vitamin A (DGAC, 2005; p. 183). This topic is further discussed in *Part D. 2 Nutrient Adequacy*. Previous research, as reviewed by the 2005 DGAC, has established the positive relationship between milk and milk products and bone mineral content or bone mineral density. Also milk product consumption has been linked with overall diet quality and the adequacy of many nutrients (DGAC, 2005, p. 183).

Calcium maintains the strength and density of the bones, with 99 percent of the calcium in the body found in bones and teeth. Bone undergoes constant remodeling, a process in which existing bone is broken down and replaced with new bone. Without sufficient calcium in the diet, there is inadequate formation of new bone, resulting in osteoporosis or other bone disease (IOM, 1997). When dietary intake of calcium is too low, the body will draw upon the calcium stored in the bones which can lead to low bone mass.

Some of the most bioavailable sources of calcium are in milk and milk products. Calcium also is found in dark green vegetables, whole grains, beans, and soy protein, but it is not as well absorbed due to the oxalic or phytic acid found in these foods. Other foods may be fortified with calcium and numerous calcium supplements are available. However, calcium naturally occurring in foods is the recommended source. Absorption of calcium varies based on a number of factors, such as the amount consumed at any one time, the age of the individual, and other foods consumed including dietary fiber, phytic acid, and oxalic acid. Calcium status is also affected by the intake of vitamin D, phosphorus, and protein. Vitamin D is especially important in the absorption of calcium.

Dietary guidance has recommended reduction in dairy fats because they contain high levels of saturated fats and cholesterol. In general, studies show that the higher the saturated fat intake is, the higher the serum total and LDL-cholesterol concentrations will be. Serum total and LDL-cholesterol concentrations have a positive linear relationship with the risk of CHD or mortality from CHD. Fat-free dairy products are devoid of saturated fats, but still contain protein, calcium, and the other nutrients found in milk products.

The WCRF/AICR report (WCRF/AICR, 2007) examined the relationship between milk and dairy products and the risk of cancer. The WCRF/AICR Panel concluded that milk probably protects against colorectal cancer, and limited evidence suggests that milk protects against bladder cancer. There is limited evidence suggesting that high consumption of milk and dairy products is a cause of prostate cancer.

The relationship between milk intake and weight management was reviewed in 2005 and it was reported that there was insufficient data to conclude that milk and milk products have an impact on weight. However the importance of milk and milk products in the diet was emphasized. The review provided below provides an update to the literature reviewed by the 2005 DGAC, focusing on studies published since 2004 that have examined milk and milk products and their impact alone on health outcomes.

Milk and Milk Products and Bone Health

Research since 2004 indicates that the intake of milk and milk products is linked to improved bone health in children. Results in adults are mixed. The conclusion reached for this question is based on a review of three systematic reviews or meta-analyses (Alvarez-Leon, 2006; Huncharek, 2008; Kanis, 2005), three primary research studies conducted since the reviews (Budek, 2007; Kristensen, 2005; McCabe, 2004), one longitudinal study (Rockell, 2005), one case-control study (Konstantynowicz, 2007), and one cross-sectional study (Al-Zahrani, 2006), all published since 2004.

The results of the systematic reviews and meta-analyses are inconsistent when children and adults are considered together. In a meta-analysis focused on children, Huncharek et al. (2008) examined the relationship between dairy and calcium intake and bone mineral content. Their review of 21 studies concluded that increased dairy/calcium intake, with or without vitamin D supplementation, results in significantly higher total body and lumbar spine bone mineral content among children with low baseline intakes of dairy, calcium, and/or vitamin D. In a small, short-term study among prepubertal boys consuming equal amounts of protein, Budek et al. (2007) found that a high intake of milk, but not meat, decreased bone turnover. However, the relevance of reduced turnover for peak bone mass is unclear.

A longitudinal study conducted in New Zealand (Rockell, 2005), assessed 2-year changes in bone and body composition in young children with a history of prolonged milk avoidance. The authors concluded that young milk avoiders demonstrated persistent height reduction, overweight, and osteopenia at the ultradistal radius and lumbar spine over 2 years of follow-up.

Alvarez-Leon et al. (2006) reviewed literature on the associations between the consumption of dairy products and health outcomes, including two review papers on bone health. They concluded that there is weak evidence of the protective capacity of dairy products on bone health, noting that limitations in studies examining this relationship make it difficult to make firm conclusions about the effect of dairy products on bone health.

Kanis et al. (2005) reviewed six prospectively studied cohorts from European, Australian, and Canadian research. They examined calcium intake, measured by milk consumption, and its association with the risk of fracture. They found no significant relationship between low intake of calcium and fracture risk. This study did not include other sources of dietary calcium besides milk and did not account for variations in vitamin D intake or sunlight exposure. Therefore, the authors caution that these findings should not be misinterpreted as suggesting that calcium is not causally related to fracture risk nor that calcium does not play a role in fracture prevention.

Results from three intervention studies supported the role of dairy products in bone health. McCabe et al. (2004) found that calcium supplementation protected study participants from bone loss and that higher dairy product consumption was associated with greater hip bone mineral density in men, but not in women. In a small study of Caucasian males who replaced milk with cola beverages in their diet for 10 days, Kristensen et al. (2005) concluded that replacement of cola for milk results in a low calcium intake, which may negatively affect bone health.

In summary, these reviews support that calcium and milk and milk products play an important role in bone mineral content in children. Results from adult trials are mixed.

Milk and Milk Products and Cardiovascular Disease

Recent studies report that intake of milk and milk products are protective against cardiovascular disease.

The conclusion reached for this question is based on review of two systematic reviews/meta-analyses (Alvarez-Leon, 2006; Elwood, 2008) and one case-control study (Kontogianni, 2006).

Alvarez-Leon et al. (2006) systematically reviewed papers on the associations between consumption of dairy products and health outcomes, including CVD. The systematic review of these papers found an inverse association between the intake of dairy products and stroke.

Elwood et al. (2008) performed a systematic review and meta-analysis to investigate the literature on milk and dairy consumption and risk of vascular disease. The final review included 15 prospective studies on ischemic heart disease and stroke and four case-control studies on myocardial infarction. The data showed a reduction in risk associated with the highest level of milk consumption for myocardial infarction. There was also a reduction of about 10 to 15 percent in the incidence of ischemic heart disease and a 20 percent reduction in stroke events in the individuals who had reported drinking the most milk, relative to those drinking the least milk within each cohort. The authors concluded that the data provides support for the beneficial effects of milk and dairy consumption on risk for cardiovascular disease.

Finally, in a case-control study, Kontogianni et al. (2006) examined the association between dairy consumption and the prevalence of a first, non-fatal event of an acute coronary syndrome in Greek adults. They reported an inverse relationship between dairy product consumption and the odds of having acute coronary syndrome. An increase of one portion of a dairy product per week was associated with a 12 percent lower likelihood of having acute coronary syndrome.

Milk and Milk Products and Type 2 Diabetes

In a recent systematic review with meta-analysis (Elwood, 2008) of four prospective studies on diabetes, relative risk for T2D was estimated to be 10 percent lower in people who had a high milk intake relative to those with low consumption.

Milk and Milk Products and Metabolic Syndrome

Intake of milk and milk products is associated with reduced risk of metabolic syndrome and may even be protective in certain population groups. The conclusion reached for this question is based on one systematic review with meta-analysis (Elwood, 2008), one prospective cohort study (Snijder, 2008), and two cross-sectional studies (Beydoun, 2008; Ruidavets, 2007).

Elwood et al. (2008) performed a systematic review and meta-analysis and the data showed a reduction in risk associated with the highest level of milk consumption for metabolic syndrome (RR=0.74; 95% CI: 0.64, 0.84) compared to the risk in those with low consumption.

Snijder et al. (2008) conducted a prospective cohort study investigating the association between dairy consumption and changes in weight and metabolic disturbances. The authors concluded that dairy consumption was not associated with changes in metabolic variables in a Dutch elderly population. Two cross-sectional studies (Beydoun, 2008; Ruidavets, 2007) looked at milk and milk product consumption and metabolic syndrome. The French study by Ruidavets et al. (2007) determined that the intake of dairy products was associated with a lower probability of insulin resistance syndrome. No significant associations between whole milk (per 100 g), low-fat milk (per 100 g), or skim milk (per 100 g) and metabolic syndrome were observed in a study of NHANES 1999-2004 data (Beydoun, 2008).

Milk and Milk Products and Blood Cholesterol

Few studies have been conducted on the relationship between the intake of milk and milk products and blood cholesterol, although the high saturated fat content of milk fat would theoretically support a positive association with whole milk products. Three articles published since 2004 were reviewed on this topic: a randomized trial (Bowen, 2005), a prospective cohort study (Snijder, 2008) and a cross-sectional study (Houston, 2008).

In the dairy product feeding study (Bowen, 2005), intake of milk products was associated with reduced blood cholesterol, although this was associated with weight loss in the study. In a study of Dutch elderly (Snijder, 2008), baseline dairy consumption was not associated with changes in serum lipid levels over 6.4 years. A study of NHANES III data found that in women, more frequent cheese consumption was associated with higher HDL-cholesterol and lower LDL-cholesterol (p for trend < 0.05), while in men, more frequent cheese consumption was associated with higher BMI, waist circumference, HDL-cholesterol, and LDL-cholesterol (p for trend < 0.05). Thus, intake of milk and milk products in recent studies did not always show expected increases in total blood cholesterol, and may be linked to increased HDL-cholesterol.

Milk and Milk Products and Blood Pressure

Based on the current review of research of literature published since 2004, there is little evidence that supports an independent relationship between the intake of milk and milk products and blood pressure. This conclusion is based on one systematic review (Alvarez-Leon, 2006), one RCT (Bowen, 2005), six prospective cohort studies (Alonso, 2005; Engberink, 2009a, 2009b; Snijder, 2008; Toledo, 2009; Wang, 2008a), and five cross-sectional studies (Azadbakht, 2005; Beydoun, 2008; Djousse, 2006; Houston, 2008; Ruidavets, 2006).

The systematic review by Alvarez-Leon et al. (2006) concluded that an inverse association exists between the intake of dairy products and hypertension. In the Bowen et al. (2005) RCT, the authors determined that weight loss following energy-restricted, high-protein diets is not affected by dietary calcium or protein source. Also, weight loss, not dietary calcium, was shown to improve blood pressure.

Results were reviewed from six prospective studies conducted in the Netherlands, Spain, and the U.S. In the Women's Health Study (Wang, 2008a), decreased risk of hypertension was associated with low-fat dairy products, calcium, and vitamin D. In the SUN cohort in Spain, Alonso et al. (2005) reported a 54 percent reduction in hypertension in participants with the highest consumption of low-fat dairy products compared to those with the lowest consumption, and they found no association between whole-fat dairy or total calcium intake and incident hypertension. Likewise, the Toledo et al. (2009) study in Spain found no significant relationship between high-fat dairy and blood pressure, but blood pressure was significantly lower among the highest consumers of low-fat dairy products.

In general, studies from the Netherlands did not show as strong a relationship between the intake of milk and milk products and blood pressure. Engberink et al. (2009a) followed more than 20,000 participants for 5 years in the Netherlands and concluded that dairy intake has little effect on population blood pressure. Snijder et al. (2008) concluded that dairy consumption was not associated with changes in metabolic variables in their study with a Dutch elderly population. Engberink et al. (2009b) followed older Dutch participants for 6 years, and they concluded that low-fat dairy may be related to hypertension prevention, but high-fat dairy and cheese did not show the same effect.

Five cross-sectional studies (Azadbakht, 2005; Beydoun, 2008; Djousse, 2006; Houston, 2008; Ruidavets, 2006) conducted in Iran, France, and the U.S. also were reviewed, and all showed some positive impact of milk and milk product consumption on blood pressure, although the results were not consistent for all population groups. Using data from NHANES 1999-2004, Beydoun et al. (2008) found that among all study participants, and among men in particular, fluid milk was inversely related to blood pressure (systolic and diastolic), and yogurt was associated with better systolic blood pressure. In contrast, cheese was positively associated with systolic blood pressure. Using data on the intake of cheese from NHANES III, Houston et al. (2008) found that systolic blood pressure was not different across categories of cheese consumption, but diastolic blood pressure was higher among men in the highest category of cheese consumption compared to non-consumers. In a cross-sectional analysis of almost 5,000 participants from the National Heart, Lung, and Blood Institute Family Heart Study, there was an inverse association between dairy intake and the prevalence of hypertension that was independent of calcium intake and seen mainly among participants consuming less saturated fat. A cross-sectional analysis of 1,500 participants in Iran (Azadbakht, 2005) showed an inverse relationship between dairy consumption and hypertension. Finally, the French study by Ruidavets et al. (2006) concluded that the consumption of dairy products may be associated with reduced blood pressure.

Evaluating the research on this topic is complicated by the types of milk products consumed in the various studies, potential confounding with calcium intakes from other food sources, and the known relationship of blood pressure to weight loss.

Milk and Milk Product Intake and Body Weight

The Committee reviewed 18 studies conducted since 2004 that examined the link between the intake of milk and milk products and body weight and concluded that evidence supporting the hypothesis of a relationship between intake of milk and milk products and decreased body weight is not convincing. This conclusion is based on one systematic review (Lanou, 2008), one RCT (Bowen, 2005), four prospective cohort studies (Rajpathak, 2006; Rosell, 2006; Snijder, 2008; Vergnaud, 2008), and eight cross-sectional studies (Azadbakht, 2005; Beydoun, 2008; Brooks, 2006; Houston, 2008; Marques-Vidal, 2006; Mirmirin, 2005; Murakami, 2006; O'Neil 2009). The Committee also reviewed three studies that looked at energy intake as an outcome (Dove, 2009; Harper, 2007; Hollis, 2007), and one study (Olsen, 2007) that addressed pregnancy.

Lanou et al. (2008) reviewed the body of evidence on the effect of dairy product or calcium intake, with or without energy restriction, on body weight or adiposity. Of the 49 randomized clinical trials reviewed, 42 found no effect on weight of dairy or calcium consumption, and only four trials showed a potential effect of dairy products or calcium on weight loss. Of the 16 clinical trials, 15 showed no difference in body fat change between consumers of high and low levels of dairy or calcium. One study found greater fat loss among high-dairy consumers compared to low-dairy consumers. Overall, their review does not support a connection between dairy or calcium consumption and weight or fat loss.

In the Bowen et al. (2005) RCT, the effects on weight, body composition, metabolic parameters, and risk markers of two isocaloric, energy-restricted high-protein diets that differed in dietary calcium and protein source on weight loss and body composition in healthy, overweight adults were compared. The authors concluded that weight loss following energy-restricted, high protein diets is not affected by dietary calcium or protein source.

The following four prospective cohort studies did not strongly support the hypothesis that increasing milk and milk products would result in a decrease in weight. Rajpathak et al. (2006) evaluated the association between calcium and dairy intakes and 12-year weight change among men in the U.S. Their results indicate that increasing calcium or dairy consumption is not associated with lower long-term weight gain in men. Rosell et al. (2006) examined the association between changes in dairy product consumption and self-reported weight change over 9 years among women. They concluded that the association between the intake of dairy products and weight gain differed according to the type of dairy product and the body weight status at baseline. Snijder et al. (2008) investigated the association between dairy consumption and 6.4-year changes in weight and metabolic disturbances in an elderly Dutch population. They concluded that higher dairy consumption does not protect against weight gain and the development of metabolic disturbances over time. Vergnaud et al. (2008) investigated the relationship between dairy consumption and calcium intake with 6-year changes in body weight and waist circumference in a French population. The authors concluded that sex, overweight status at baseline, and type of dairy product influences the associations between dairy product consumption and anthropometric changes. Eight cross-sectional studies (Azadbakht, 2005; Beydoun, 2008; Brooks, 2006; Houston, 2008; Marques-Vidal, 2006; Mirmirin, 2005; Murkami, 2006; O'Neil, 2009) were reviewed, and were more likely to support that calcium and/or dairy consumption was related to lower BMI.

Other studies included in the review measured whether consumption of milk or milk products was related to energy intake as an outcome. Dove et al. (2009) concluded that consumption of skim milk, in comparison with a fruit drink, leads to increased perceptions of satiety and to decreased energy intake at a subsequent meal. Harper et al. (2007) conducted a randomized cross-over design study to compare the effect on appetite and energy intake of consuming either a sugar-sweetened beverage (cola) or chocolate milk drink. The authors concluded that consuming chocolate milk increased subjective ratings of satiety and fullness compared with cola and decreased hunger and later consumption of food. However, this enhanced satiety did not translate into differences in ad libitum energy intake. Hollis and Mattes (2007) assessed the effect of daily intake of one or three portions of dairy foods on energy intake and appetite. The authors concluded that increasing dairy consumption from one to three portions each day led to increased energy intake. Thus, dairy foods may have some benefit for satiety when compared to fruit drinks, but increased consumption of any extra calories (versus substitution), including dairy products, will lead to increased energy intake.

Olsen et al. (2007) examined whether milk consumption during pregnancy is associated with greater infant size at birth in the Danish National Birth Cohort. Milk consumption was inversely associated with the risk of small-for-gestational age birth and directly with both large-for-gestational age birth and mean birth weight.

Question 5: What Is the Relationship Between the Intake of Cooked Dry Beans and Peas and Selected Health Outcomes?

Conclusion

Limited evidence exists to establish a clear relationship between intake of cooked dry beans and peas and body weight. There is limited evidence that intake of cooked dry beans and peas lowers serum lipids. Limited evidence is available to determine a relationship between the intake of cooked dry beans and peas and T2D.

Implications

Legumes and soybeans, including dried beans and peas, are typically recommended foods because of their content of dietary fiber, protein, vitamins, and minerals (Mesina, 1999). Because soybeans are particularly high in isoflavones, a phytoestrogen, they have been more extensively studied than other legumes. Legumes are also promoted as a complementary protein source to grains since legumes are low in methionine and grains are low in lysine. Thus, legumes play an important role in vegan diets for enhancing protein quality. They may also provide a beneficial contribution to the general population in part to increase total vegetable consumption and dietary fiber intake.

Review of the Evidence

Background

Beans and peas are sources of protein, dietary fiber, minerals, and vitamins. As dietary fiber is linked to lower body weight, intake of beans and peas would be expected to also be linked to lower body weight. Consumption of dry beans, peas, and lentils is low in the U.S., with only 8 percent of adults consuming dry beans and peas on any one day (Mitchell, 2009), making it difficult to see relationships in existing cohorts. Dry beans and peas are concentrated sources of soluble dietary fiber, which is known to lower serum lipids. Vegetable protein from legumes has also been found to lower serum lipids, and the U.S. has an existing health claim for the ability of soy protein to lower serum lipids. Most of the research in the lipid-lowering benefits of soy protein was done in hyperlipidemic individuals.

Unfortunately, few consumers include cooked dry beans and peas in their daily diet, and soy products are also not commonly consumed in the U.S. This makes it difficult to determine the protectiveness of intake of cooked dry beans and peas and soy when most prospective cohort studies include few participants who are consuming these products.

Soluble fibers are thought to slow absorption of carbohydrates and lower the glycemic index of foods. In the original studies of glycemic index, intake of legumes was associated with the lowest glucose response. Independent of glycemic index and load, cooked dry beans and peas show promise for use in control of blood glucose for individuals with T2D.

We examined studies from January 2000 to present for this review. Overall, our review suggests that little evidence is available on the relationship between intake of cooked dry beans and peas and health outcomes.

Cooked Dry Beans and Peas and Body Weight

The few intervention studies on the relationship between intake of cooked dry beans and peas (not including soy) and body weight find mixed results. This conclusion is based on the review of one meta-analysis (Anderson and Major, 2002), one systematic review (Williams, 2008), four trials (Crujeiras, 2007; Pittaway, 2006, 2007, 2008), and one cross-sectional study (Papanikolaou, 2008) for beans and peas. Additionally, the Committee reviewed one systematic review (Cope, 2008) and one cohort study (Maskarinec, 2008) specifically pertaining to soy foods.

In a meta-analysis of 11 studies, Anderson and Major (2002) found that the intake of non-soy legumes was associated with decreased body weight. In a systematic review examining the role of whole grains and legumes in preventing and managing overweight and obesity, Williams et al. (2008) concluded that weight loss is achievable with energy-controlled diets high in legumes but felt there was insufficient evidence to draw conclusions about the protective effect of legumes on weight.

Results from feeding trials with beans and peas are mixed, but diet treatments with beans and peas are generally no more successful in weight loss than the control or comparison treatment. In two randomized crossover trials comparing chickpea- to wheat-supplemented diets, no significant differences between dietary interventions was observed (Pittaway, 2006, 2007). In a study that included chickpea-supplemented ad libitum, a non-significant decrease in body weight was observed during the chickpea phase compared to the control phase (Pittaway, 2008). In a RCT comparing hypocaloric diets high in non-soybean legumes to a diet without legumes, both groups lost weight with greater weight loss achieved by those consuming legumes. A comparison of bean eaters from NHANES 1999-2002 suggest that bean consumers had lower body weights, and waist circumferences in comparison to non-consumers (Papanikolaou, 2008).

In a systematic review of soy foods and weight loss, Cope et al. (2008) concluded that there was limited evidence to support the hypothesis that soy foods increase weight loss when fed at isocaloric levels or that soy foods affect caloric intake when included as part of a diet. In a cohort study, women consuming more soy during adulthood had a lower BMI, but the relation was primarily observed for Caucasian and postmenopausal participants (Maskarinec, 2008).

Cooked Dry Beans and Peas and Cardiovascular Outcomes

Limited evidence exists that dry beans and peas have unique abilities to lower serum lipids; most of the lipid lowering seen in studies is related to the soluble fiber content of these products. The conclusion reached for this question is based on the review of one meta-analysis (Anderson and Major, 2002), five trials (Crujeiras, 2007; Finley, 2007; Pittaway, 2006, 2007, 2008), two prospective cohort studies (Bazzano, 2001; Steffen, 2005), one case-control study (Kabagambe, 2005), and one cross-sectional study (Papanikolaou, 2008). The Committee also considered one randomized crossover trial (Welty, 2007), one prospective cohort study (Kokubo, 2007), and one longitudinal study (Nagata, 2000) regarding soy foods.

Anderson and Major (2002) quantitatively analyzed changes in serum lipoprotein levels resulting from intake of non-soya pulses. The authors concluded that regular consumption of pulses may have important protective effects on risk for CVD, including decreases in serum cholesterol, LDL-cholesterol, and triacylglyercols, and increases in HDL-cholesterol.

In the intervention studies, dry beans and peas lowered serum lipids as expected based on soluble fiber content. In a series of studies including the daily consumption of more than 100 grams of chickpeas per day for 5 to 12 weeks, Pittaway et al. (2006, 2007, 2008) observed improvements in serum total cholesterol and LDL-cholesterol compared to a control diet without legumes. Similar improvements in total cholesterol were observed following an 8-week weight loss intervention that included non-soybean legumes four days each week, and the decrease in total cholesterol was directly correlated with increased fiber intake (Crujeiras, 2007).

Bazzano et al. (2001) found a strong and independent inverse association between dietary intake of legumes and risk of CHD in the Nutrition Examination Survey Epidemiologic Follow-up Study (NHEFS), which is a prospective cohort study of the First NHANES (NHANES I) from 1971 to 1975. Legume consumption four or more times per week compared with less than once a week was associated with a 22 percent lower risk of CHD and an 11 percent lower risk of CVD. In the Coronary Artery Risk Development in Young Adults (CARDIA) Study (Steffen, 2005), tertiles of legume intake were less than 0.1, 0.1 to 0.2, and more than 0.2 times per day, supporting extremely low usual intake of legumes. The authors noted that limited consumption of legumes and insufficient statistical power precluded definitive conclusions from being drawn about the relationship between intake of legumes and elevated blood pressure. However, it is unclear whether null findings were due to the lack of association or limited range in consumption. In a case-control study in Costa Rica, Kabagambe et al. (2005) observed an inverse association between myocardial infarction and the intake of one serving of beans per day (1/3 cup of cooked beans) in adjusted analyses. However, no additional benefit was observed with more than one serving per day.

In more than 12 years of follow-up of the Japan Public Health Center-Based Study Cohort I (Kokubo, 2007), investigators saw a decrease in the risk of myocardial infarction, cerebral infarction, and CVD mortality among women consuming soy at least five times per week compared to those consuming soy zero to two times per week. However, no associations were observed for men. In a longitudinal study in Japan, Nagata et al. (2000) also observed an inverse correlation between soy product intake and heart disease mortality in women, but not men.

In a randomized crossover trial in which hypertensive, prehypertensive, and normotensive postmenopausal women consumed the Therapeutic Lifestyle Changes (TLC) diet alone or with 1/2 cup unsalted soy nuts (25 g soy protein) replacing 25 grams of non-soy protein, benefits to blood pressure and LDL-cholesterol were greater for the hypertensive women than the normotensive participants (Welty, 2007).

Cooked Dry Beans and Peas and Type 2 Diabetes Mellitus

Evidence is insufficient to determine a relationship between dry beans and peas and T2D. Only one study was found that measured the relationship between dry beans and peas and T2D. The association between the consumption of legume and soy foods and T2D was examined over an average follow-up of approximately 5 years in the Shanghai Women's Health Study (Villegas, 2005). Average daily intake of individual food items was combined for the following food groups: total legumes and three mutually exclusive groups—

soybeans (dried and fresh), peanuts, and other legumes. The median intake of total legumes was 30.5 grams per day, for soybeans was 11.0 grams per day, for peanuts was 0.7 gram per day, and for other legumes was 15.5 grams per day. Total legume consumption and consumption of soybeans and other legumes were each associated with a decrease in risk of T2D.

Chapter Summary

Proteins are unique because they provide both essential amino acids to build body proteins and are a calorie source. Because the RDA of protein for any person is based on their ideal body weight (0.8 g protein/kg body weight/day for ages 19 and above), lower-calorie diets require higher percentage of protein intake. Protein quality varies greatly and is dependent on the amino acid composition of the protein and the digestibility. Animal sources of protein, including meat, fish, milk, and egg, are the highest quality proteins. Plant proteins can be combined to form more complete proteins if combinations of legumes and grains are consumed. As most Americans consume too many calories, the percentage of calories from protein may be higher—up to 35 percent of calories can come from protein on very low calorie diets. Higher-protein diets tend to assist in initial weight loss, but long term studies of weight loss or maintenance of weight loss find no differences among diets lower or higher in protein.

Needs for Future Research

1. Develop standardized definitions for vegetable proteins and improve assessment methods for quantifying vegetable protein intake to help clarify outcomes in epidemiologic studies in this area.

   Rationale: Assessing vegetarian eating patterns and their protein content is complex and current methodologies do not capture critical variations. Therefore, investigators' ability to quantify any possible association with health benefits is limited. Better standardized definitions and improved assessment methods will improve the ability to quantify health benefits associated with consumption of vegetable protein.

2. Develop better methods of conducting cohort studies of populations consuming plant-based diets compared to animal based diets, including defined classifications of vegetarian and "near vegetarian" eating patterns and more specific impacts of dried beans and peas on health.

   Rationale: Large U.S. cohorts do not include enough vegetarians and vegans to make comparisons on health outcomes including weight control and blood pressure. Widespread public interest and possible public health impacts of this dietary pattern raise the priority for this research.

3. Conduct studies of potential limitations of plant-based diet for key nutrients, including calcium, iron, vitamin B_{12}, and protein quality, especially in children and the elderly.

   Rationale: These data are needed to determine whether vegan children require dietary supplements to attain adequate nutrient status and growth.

4. Examine the role of dairy products in lipid profiles, especially through intervention trials in which all types of dairy products, both low and high fat, are fed. Bioactive components that alter serum lipid levels may be contained in milk fat.

   Rationale: Consumption of milk products may not have predictable effect on serum lipids, weight control, and metabolic syndrome. The ability of dairy consumption to increase HDL levels and their effect on weight gain or weight loss and metabolic syndrome is also of widespread public health interest and worthy of additional study.

5. Develop and investigate potential biomarkers for objective assessment of vegetable protein intake.

   Rationale: Few measures of protein status exist in healthy individuals, so it is difficult to compare protein status of participants in cohort studies with diverse protein intakes.

6. Develop better assessment tools to classify vegetarian patterns in epidemiologic studies.

   Rationale: No assessment methods are currently available to classify participants into the wide range of vegetarian eating patterns.

7. Conduct randomized controlled trials to answer the question whether intake of dairy products alters blood pressure.

Rationale: Results from prospective studies are inconsistent and suggest that many other variables that affect blood pressure, such as weight loss and other nutrients, will make associations difficult to determine.

8. Ensure that prospective cohort studies continue to track the association between intake of dairy products and metabolic syndrome.

   Rationale: Evidence to date does not suggest that high fat dairy products are more likely than low fat dairy products to induce metabolic syndrome. Whether there are other protective compounds in milk products, such as calcium, protein, fatty acids, etc., that provide protection requires further research.

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Part D. Section 5: Carbohydrates

Introduction

Carbohydrates (one of the three macronutrients) consist of sugars, starches, and fibers. The Institute of Medicine (IOM) (2002) set an acceptable macronutrient distribution range (AMDR) for carbohydrates of 45 to 65 percent of total calories. Thus, current dietary guidance recommends consumption of carbohydrate-containing foods, including vegetables, fruits, grains, nuts and seeds, and milk products. Carbohydrate foods are an important source of fiber and other nutrients.

Sugars and starches provide glucose, the main energy source for the brain, central nervous system, and red blood cells. Glucose also can be stored as glycogen (animal starch) in liver and muscle, or, like all excess calories in the body, converted to body fat. Dietary fibers are nondigestible forms of carbohydrates and lignin. Dietary fiber is intrinsic and intact in plants, helps provide satiety, and is important in promoting healthy laxation. Diets high in fiber also have been linked to reduced risk of diabetes, colon cancer, obesity, and other chronic diseases.

The role of carbohydrates in the diet has been the source of much public and scientific interest. These include the relationship of carbohydrates with health outcomes, including coronary heart disease (CHD), type 2 diabetes (T2D), body weight, and dental caries. The 2010 DGAC conducted Nutrition Evidence Library (NEL) evidence reviews on these and other carbohydrate-related topics. The Committee also relied on evidence contained in the 2002 Dietary Reference Intakes (DRIs) report and conducted a non-NEL review of recent literature to specifically examine the relationship of carbohydrates with CHD, T2D, behavior, and cognitive performance (Colditz, 1992; Dolan, 2010; IOM, 2002; Laville, 2009; Meyer, 2000; Stanhope, 2009; Wolraich, 1995). No detrimental effects of carbohydrates as a source of calories on these or other health outcomes were reported.

The energy value of digestible carbohydrates is generally accepted as 4 calories per gram for both sugars and starches. Research suggests that high-fiber diets can cause energy losses in the feces beyond the energy contained in the fiber source that escapes fermentation (Miller, 1984) and can aid in weight control through lower energy yield. Few studies have linked carbohydrates to obesity. Indeed, observational data generally report that higher carbohydrate intake is linked to lower body weight (National Health and Nutrition Examination Survey [NHANES], 2000-2005). Aspects of carbohydrate and body weight are discussed in detail later in this section and in other sections of this Report (see Question 5 for a discussion of sugar-sweetened beverages [SSB] and energy intake and body weight; *Part D. Section 1: Energy Balance and Weight Management* for discussions of macronutrient proportions and body weight and of SSB and body weight in children; and *Part D. Section 2: Nutrient Adequacy* for a discussion of added sugars as a food component overconsumed in the American diet).

Carbohydrates and dental caries also are a topic of public health importance. The 2005 DGAC concluded that carbohydrate intake contributes to dental caries by providing substrate for bacterial fermentation in the mouth. A combined approach of reducing the frequency and duration of exposure to fermentable carbohydrate intake and optimal oral hygiene practices is the most effective way to reduce caries incidence. Substantive research on the relationship of carbohydrates and dental caries has not occurred since the last DGAC Report, so the 2010 DGAC reaffirms the 2005 Committee’s conclusion.

This section continues with background information on the nomenclature and composition of carbohydrates and provides discussion of recommended intakes of carbohydrates and their food sources. Also provided are the NEL systematic evidence-based reviews of six questions and non-NEL literature review of three questions that cover a variety of issues related to intakes of dietary carbohydrates and health.

Background on Carbohydrates

Nomenclature

Carbohydrates are subdivided into several categories, based on the number of sugar units present and the way in which the sugar units are chemically bonded to each other. These categories include sugars, starches, and fibers. Sugars are intrinsic in fruits, fluid milk, and milk products. They also are added to foods during processing, preparation, or at the table. These "added sugars" (or extrinsic sugars) sweeten the flavor of foods and beverages and improve their palatability. Sugars are also used in food preservation and to confer functional attributes, such as viscosity, texture, body, and browning capacity. They provide calories but insignificant amounts of vitamins, minerals, or other essential nutrients. The Nutrition Facts label provides information on total sugars per serving, but does not distinguish between sugars naturally present in foods and added sugars.

Starches are made of many glucose units linked together. They are found naturally in a wide range of foods, including vegetables, cooked dry beans and peas, and grains. Most starches are broken down to sugars by digestive enzymes for use by the body, but some starches, such as those in cooked dry beans and peas and pasta, are resistant to digestive enzymes. Fibers, like starches, are made mostly of many sugar units bonded together. Unlike most starches, however, these bonds cannot be broken down by digestive enzymes and pass relatively intact into the large intestine. There, fiber can be fermented by the colonic microflora to gases such as hydrogen and carbon dioxide or it can pass through the large intestine and bind water, increasing stool weight. Although fibers are not converted to glucose, some short chain fatty acids are produced in the gut as fibers are fermented. Short chain fatty acids are absorbed and can be used for energy in the body. Fibers include both "dietary fiber," the fiber naturally occurring in foods, and "functional fibers," which are isolated fibers that have a positive physiological effect. No analytical measures exist to separate dietary fiber and functional fiber, so the Nutrition Facts label lists "Dietary Fiber"—which is actually total fiber.

Table D5.1 provides a summary of the carbohydrate categories, showing their chemical composition, how they are made, examples of each, and food sources.

Recommended Intakes and Food Sources

Recommended Intakes of Sugars and Starches—In its 2002 report *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids* (IOM, 2002), the IOM established a Recommended Dietary Allowance (RDA) for carbohydrate of 130 grams per day for adults and children age 1 year and older. This value is based on the amount of sugars and starches required to provide the brain with an adequate supply of glucose. Although the IOM set an AMDR for carbohydrate of 45 to 65 percent of total calories, it is very difficult to meet dietary fiber recommendations at the low end of this range, and high intake of total sugars (intrinsic and added) may be linked to elevated blood triglycerides. A comparison of the RDA to the AMDR shows that the recommended range of carbohydrate intake is higher than the RDA. For example, if an individual with a caloric intake of 2000 kilocalories per day consumes 55 percent of calories as carbohydrate (the mid-range of the AMDR) 1100 kilocalories would be from carbohydrate. This equates to 275 grams carbohydrate (1 g carbohydrate = 4 kcal), well above the RDA of 130 grams per day needed for brain function.

The DRI committee concluded that evidence was insufficient to set a Tolerable Upper Intake Level (UL) for carbohydrates (IOM, 2002). However, a maximal intake level of 25 percent or less of total calories from added sugars was suggested by the panel. This suggestion is based on dietary intake survey data showing that people with diets at or above this level of added sugars were more likely to have poorer intakes of important essential nutrients.

Table D5.1. Carbohydrates: nomenclature and special issues

	Composition	Examples	Special Issues	Found In
Sugars				
Monosaccharides	1 sugar unit	• Glucose • Fructose • Galactose	• Rarely found naturally in foods-except for fructose	• Apples (fructose) • Pears (fructose) • Honey (fructose)
Disaccharides	2 linked sugar units	• Sucrose (50% glucose, 50% fructose) • Lactose (50% galactose, 50% glucose) • Maltose (100% glucose-glucose bond) • High fructose corn syrup (HFCS) (generally 55% fructose – sometimes 42% fructose – varies)	• Occurs naturally in foods (sucrose, lactose) • Produced by starch digestion (maltose) • Hydrolysis of corn (HFCS)	• Fruit • Milk • Sweet potatoes
Oligosaccharides (OS)	3-10 linked sugar units	• Raffinose • Stachyose	• May cause intestinal gas	• Dry beans and peas • Onions • Breast milk • Added to food as inulin and other OS
Starches				
Polysaccharides	Many linked glucose units	• Starch • Glycogen – animal starch	• Most are broken down to glucose for absorption	• Starchy vegetables • Grains • Dry beans and peas • Nuts and seeds
		• Resistant starch	• Resistant starch does not undergo digestion in the small intestine	• Dry beans and peas • Pasta • Refrigerated cooked potatoes
Fibers				
Polysaccharides/Lignin	Many linked sugar units	• Dietary Fiber, i.e., nondigestible carbohydrates and lignin that are intrinsic and intact in plants • Functional Fiber, i.e., isolated nondigestible carbohydrates that have beneficial physiological effects in human beings • Total Fiber = Dietary Fiber + Functional Fiber	• Different chemical bonding; human enzymes cannot break bonds; pass relatively intact through upper digestive tract • Can be fermented by colonic microflora to gases and short-chain fatty acids	• Vegetables • Fruits • Whole grains • Dry beans and peas • Nuts and seeds

Recommended Intakes of Fiber—In its 2002 report, the IOM set an Adequate Intake (AI) value for fiber of 14 grams of fiber per 1000 kilocalories. This value is derived from data on the relationship of fiber consumption and CHD risk, although the IOM also considered the totality of the evidence for fiber decreasing the risk of chronic disease and other health-related conditions. Consequently, the IOM fiber recommendations are highest for populations who consume the most calories, namely young males. Fiber recommendations are lower for women and the elderly. Using this method for determining recommended fiber intake for children is problematic (e.g., intake of 19 g of fiber is recommended for 2 year old children, an implausible number). Past recommendations for children were based on the age plus 5 rule (e.g., a child aged 2 years should consume 7 g of fiber per day) (Williams, 1995).

Dietary fiber is listed on the Nutrition Facts panel, and 25 grams of dietary fiber is the recommended amount in a 2000 kilocalorie diet. Manufacturers are allowed to call a food a "good source of fiber" if it contains 10 percent of the recommended amount (2.5 g/serving) and an "excellent source of fiber" if the food contains 20 percent of the recommended amount (5 g/serving). Dietary fiber on food labels includes both dietary fiber and functional fiber.

Food Sources of Carbohydrates in the Diet

The amount of dietary carbohydrate that confers optimal health in humans is unknown (IOM, 2006). Adults should consume 45 to 65 percent of their total calories from carbohydrates, except for younger children who need a somewhat higher proportion of fat in their diets (IOM, 2006). Vegetables, fruits, whole grains, milk and milk products are the major food sources of carbohydrates. Grains and certain vegetables including corn and potatoes are rich in starch, while sweet potatoes are mostly sucrose, not starch (Anderson, 1982). Fruits and dark green vegetables contain little or no starch. Regular soft drinks, sugar-sweets, sweetened grains, and regular fruitades/drinks comprise 72 percent of the intake of added sugar (Marriott et al., 2010). Marriott et al. (2010) examined the intake of added sugars and selected nutrients from 2003-2006 NHANES data. Thirteen percent of the population had added sugars intake of more than 25 percent of calories. The mean gram equivalent (g-eq) of added sugars intake was 83.1 g-eq per day and the food sources of added sugars were comparable to the mid-1990s. Higher added sugars intakes were associated with higher proportions of individuals with nutrient intakes below the Estimated Average Requirement (EAR), but the overall high calorie and low quality of the U.S. diet remained the predominant issue.

Dietary fiber intake was particularly low in their analysis. With the exception of older women (51+ years), only 0 to 5 percent of individuals in all other life stage groups had fiber intakes meeting or exceeding the AI (Marriott et al., 2010). Fiber intake is closely linked to calorie intake. Thus, recommendations to reduce calorie intake will make increasing fiber intake particularly challenging (Slavin, 2008).

To reduce calories in response to the epidemic obesity crisis in the U.S., non-nutrient-dense carbohydrate sources should be reduced. Because fiber has known health benefits, it is advisable to select foods high in dietary fiber, whole grain breads and cereals, legumes, vegetables, and fruit whenever possible. For more information on food sources of fiber, see *Part D. Section 2. Nutrient Adequacy*. Typically, vegetables and fruits are not the most concentrated fiber sources, but these are important foods to encourage because they contribute important micronutrients. Similarly, milk and milk products, which contain lactose, generally do not contain fiber but these too are important because they contribute calcium, vitamin D, protein, potassium, magnesium, and riboflavin.

List of Questions

CARBOHYDRATES AND HEALTH OUTCOMES

1. What are the health benefits of dietary fiber?
2. What is the relationship between whole grain intake and selected health outcomes?
3. What is the relationship between the intake of vegetables and fruits, not including juice, and selected health outcomes?
4. What is the relationship between glycemic index or glycemic load and selected health outcomes?
5. In adults, what are the associations between intake of SSB and energy intake and body weight?

OTHER RELATED TOPICS

6. How are non-caloric sweeteners related to energy intake and body weight?
7. What is the impact of liquids versus solid foods on energy intake and body weight?

8. What is the role of carbohydrate, fiber, protein, fat, and food form on satiety?
9. What is the role of prebiotics and probiotics in health?

Methodology

The Committee first reviewed the 2005 DGAC Report to inform their review process in 2010. Various topics in this section were also considered by the 2005 DGAC, including fiber (Question 1), whole grains (Question 2), vegetables and fruits (Question 3), glycemic index and load (Question 4), added sugars (Question 5), and liquids versus solids (Question 7). New questions considered by the 2010 Committee include non-caloric sweeteners (Question 6), satiety (Question 8), and prebiotics and probiotics (Question 9). NEL evidence-based systematic reviews were conducted for Questions 2 to 7. The Committee addressed the remaining topics in the DGAC Report, but given limited time and resources, the systematic review methodology was not applied. Rather, the most current or representative evidence was applied. For example, the dietary fiber question was primarily answered using the 2002 DRI Report (IOM, 2002) and a recent position paper on fiber from the American Dietetic Association (ADA) (Slavin, 2008). These were supplemented by an updated literature review. Questions on satiety and pre- and probiotics also were answered using a general literature search.

For each of the NEL systematic review questions in this chapter, the following general criteria applied. All study designs were originally included in the searches, but cross-sectional studies were later excluded from the review if there was sufficient evidence from studies with stronger study designs. The Committee excluded studies that only included participants diagnosed with chronic disease, hyperlipidemia, hypertension, and related health conditions. A description of the NEL evidence-based systematic review process is provided in *Part C: Methodology*. Additional information about the NEL search strategies and criteria used to review each question can be found online at www.NutritionEvidenceLibrary.gov.

Many systematic reviews and meta-analyses of primary research articles were considered by the Committee, and care was taken not to review the same study twice in the NEL evidence-based review. For most questions, systematic reviews and meta-analyses were included, and primary research articles included in the reviews were excluded. However, systematic reviews and meta-analyses were excluded from the review on glycemic index/load (Question 4) because many studies on the topic had been published since 2004 and the Committee wanted to focus their review on primary research articles.

For Questions 2, 3, 4, 5, and 7, the conclusions expressed in the 2010 DGAC Report are informed by the evidence compiled for the 2005 DGAC Report, but are based primarily on the NEL evidence gathered and reviewed since 2004. As described below, for some questions, the search was extended back further to capture a larger body of evidence.

Question 2 examined the relationship between the consumption of whole grains and the incidence of cardiovascular disease (CVD), T2D, and measures of adiposity. These outcomes were selected because they represent leading causes of morbidity and mortality in the U.S. The Committee extended this search back to 1995, so that literature reviewed by the 2005 DGAC could also be considered.

Question 3 examined the relationships between intake of vegetables and fruits, not including juice, and body weight, cardiovascular outcomes, and T2D in adults. The Committee only considered studies that directly assessed the relationship between the intake of vegetables and fruit and health outcomes; studies examining the intake of vegetables and fruits as a part of specific dietary patterns are considered in *Part D. Section 2: The Total Diet: Combining Nutrients, Consuming Food*. The childhood adiposity section in *Part D. Section 1: Energy Balance and Weight Management* provides additional information about vegetables and fruits and 100 percent juice, and *Part D. Section 2: Nutrient Adequacy* discusses vegetables and fruits as food groups of concern for the American population. Cancer was not considered in the NEL evidence-based systematic review because the Committee chose to address this topic using the World Cancer Research Fund/American Institute for Cancer Research report (WCRF/AICR, 2007).

Similar to 2005, the review of glycemic index/load (Question 4) included the outcomes of body weight and incidence of T2D, CVD, and cancer. Reviews for CVD and T2D were extended to January 2000 because insufficient evidence was available to draw conclusions from publications since 2004.

Although added sugars (Question 5) was considered by the 2005 DGAC, the Committee extended the search for this topic to 1990. This section of the Report only considers the literature pertaining to adults (*Part D. Section 1: Energy Balance and Weight Management* addresses SSB and childhood adiposity). The original search for this question was broad and included terms such as "added sugars," "dietary sucrose," and "candy" as well as various terms for SSB. However, few studies were identified that looked at added sugars other than SSB; thus, SSB are the focus of this review. Additional information about intake of added sugars is provided in *Part D. Section 2: Nutrient Adequacy*.

Liquids versus solids (Question 7) was considered an "unresolved issue" in 2005; therefore, the Committee extended the search for this review to January 2000. This review only included studies that compared a liquid to a solid or semi-solid form. Further, only articles that considered energy intake and/or body weight were reviewed. Although additional research on food form and appetite, hunger, and related outcomes are available, these outcomes were not addressed in this aspect of the review.

Non-caloric sweeteners (Question 6) was not considered in previous iterations of the DGAC Report. The review of non-caloric sweeteners was an update to a previous systematic review conducted by the ADAs Evidence Analysis Library on non-caloric sweeteners and energy intake and body weight. The ADA review addressed literature published from January 1985 through March 2006, and the Committee updated this search from March 2006 to present.

CARBOHYDRATES AND HEALTH OUTCOMES

Question 1: What Are the Health Benefits of Dietary Fiber?

Conclusion

A moderate body of evidence suggests that dietary fiber from whole foods protects against cardiovascular disease, obesity, and T2D and is essential for optimal digestive health.

Implications

Dietary fiber is underconsumed across all segments of the American population. The development of many risk factors that are associated with incidence of several highly prevalent chronic diseases could be reduced by increasing consumption of naturally-occurring plant-based foods that are high in dietary fiber, including whole grain foods, cooked dry beans and peas, vegetables, fruits, and nuts.

Review of the Evidence

Background

The 2002 DRIs defined dietary fiber as non-digestible carbohydrates and lignin that are intrinsic and intact in plants. Functional fiber consists of the isolated non-digestible carbohydrates that have beneficial physiological effects in human beings (IOM, 2002). Total fiber is the sum of dietary fiber and functional fiber. Since data were inadequate to determine an EAR and thus calculate a RDA for Total Fiber, an AI was instead developed. AI was based on the median fiber intake associated with the lowest risk of CHD in prospective, cohort studies. Fiber recommendations are calculated as 14 grams fiber per 1000 kilocalories of usual intake, so higher fiber intakes are recommended for men compared to women. The Nutrition Facts label suggests an intake of 25 grams of dietary fiber for a 2000 kilocalorie diet.

Most Americans seriously underconsume dietary fiber with usual intakes averaging only 15 grams per day (NHANES, 2005-06; NCI, 2009). Concentrated dietary fiber sources include whole grains, cooked dry beans and peas, vegetables, nuts, and dried fruits (see Table D2.16 in *Part D. Section 2. Nutrient Adequacy*). The major sources of dietary fiber in the American diet are white flour and potatoes, not because they are concentrated fiber sources but because they are widely consumed (Slavin, 2008).

The following summary is based on a non-NEL review of the literature. It highlights conclusions from the ADA position paper on dietary fiber and covers other recently published findings.

Dietary Fiber and Cardiovascular Disease

The ADA published a position paper which presents the findings of the ADA's Evidence Analysis Library systematic review on the health implications of dietary fiber (Slavin, 2008). This review found fair evidence (Grade II) that "dietary fiber from whole foods or supplements may lower blood pressure, improve serum lipids, and reduce indicators of inflammation. Benefits may occur with intakes of 12 to 33 grams fiber per day from whole foods or up to 42.5 grams fiber per day from supplements."

Other recent studies reported a range of cardiovascular benefits associated with dietary fiber. Demoura et al. (2009) evaluated the effect of applying the Food and Drug Administration's (FDA, 2006) definition of whole grains (see whole grain section that follows) to the strength of scientific evidence that supports whole grain health claims for CVD risk reduction. The authors concluded that when a broader whole grain definition was used, such that studies of individual whole grains (barley, oats, or rye) that did not explicitly define whole grains in the manuscript as well as studies that added bran and germ with whole grains were included, there was sufficient evidence for a CVD health claim. Flint (2009) reported that cereal fiber was associated with reduced blood pressure in adults. The longitudinal STRIP study in children (Ruottinen, 2010) found that serum cholesterol concentrations decreased with increasing fiber intake.

Dietary Fiber and Obesity Prevention

According to the ADA position paper (Slavin, 2008), high-fiber diets provide bulk, are more satiating, and have been linked to lower body weights. Three recent prospective studies and two cross-sectional studies provide additional support for the role of dietary fiber in obesity prevention. Du et al. (2010) followed a large cohort for 6.5 years and found that total fiber and cereal fiber were inversely associated with subsequent increases in weight and waist circumference. Fruit and vegetable fiber was also inversely associated with waist circumference change, but not with weight change. Likewise, a 20-month, prospective cohort study (n=252) (Tucker and Thomas, 2009) found that for each 1 gram increase in total fiber consumed, weight decreased by 0.25 kilogram and percent body fat decreased by 0.25 percentage points. A longitudinal study of dietary intake on metabolic risk factors in Latino youth (Davis, 2009b) concluded that adolescents who increased total dietary fiber intake (3 g/1000 kcal) decreased their visceral adipose tissue (VAT), whereas adolescents who decreased in dietary (3 g/1000 kcal) and insoluble fibers increased VAT. *Part D. Section 1: Energy Balance and Weight Management* provides a review of dietary fiber and adiposity in children.

Dietary Fiber and Type 2 Diabetes

The ADA position paper on the health implications of dietary fiber (Slavin, 2008) concluded that limited evidence suggested that "diets providing 30 to 50 grams fiber per day from whole food sources consistently produce lower serum glucose levels compared to a low fiber diet." Hopping et al. (2010) examined the association between dietary fiber and T2D in a large multiethnic cohort in Hawaii over a 14-year period. Study participants in the top quintile of grain fiber intake had a 10 percent reduction in diabetes risk, while diabetes risk was reduced by 22 percent among men in the highest quintile of vegetable fiber intake.

Dietary Fiber and Bowel Health

In 2005, the DGAC examined the role of fiber in laxation and bowel health. In developed countries, chronic constipation is a common disorder for adults and children. Dietary fiber from whole foods increases stool weight and improves transit time, thereby reducing constipation (DGAC, 2005). The ADA systematic review of the health implications of dietary fiber concluded that there was a lack of data examining the impact of fiber from whole foods on outcomes in gastrointestinal diseases. This may be due to the complexity and cost of these studies (Slavin, 2008). The 2002 DRIs recommended that dose-response studies be conducted to determine the amount of fiber that needs to be ingested to promote optimum laxation so that in the future this could form the basis for a recommendation for fiber intake and provide a basis for determining functional fibers. Few fiber supplements have been studied for physiological effectiveness, so the best advice is to consume fiber in foods (Slavin, 2008).

Question 2: What Is the Relationship Between Whole Grain Intake and Selected Health Outcomes?

Conclusion

A moderate body of evidence from large prospective cohort studies shows that whole grain intake, which includes cereal fiber, protects against cardiovascular disease. Limited evidence shows that consumption of whole grains is associated with a reduced incidence of T2D in large prospective cohort studies. Moderate evidence shows that intake of whole grains and grain fiber is associated with lower body weight.

Implications

Currently most Americans are not consuming adequate amounts of whole grains, which are an important source of dietary fiber and other nutrients. Enriched and fortified grains provide important nutrients; hence, individuals are encouraged to consume grains as both fiber-rich whole grains and enriched grains. To ensure nutrient adequacy, especially for folate, individuals who consume all of their grains as whole grains should include some that have been fortified with folic acid.

Total grains servings are typically overconsumed in the U.S., so recommendations to consume more grains are not supported by this review. Advice should be to make more grain choices as fiber-rich whole grains, rather than eat more grains. The lack of standards for whole grain foods and measuring whole grain content of foods also make any recommendations difficult to implement.

Review of the Evidence

Background

The 2005 DGA and the FDA (2006) defined whole grains, saying: "Whole grains, as well as foods made from them, include the entire grain seed, usually called the kernel. The kernel consists of three components—the bran, germ and endosperm. If the kernel has been cracked, crushed, or flaked, then it must retain the same relative proportions as they exist in the intact grain." FDA, recognizing the benefit of whole grains, established a whole grain health claim, which includes the requirement that 51 percent or more of the product weight be a whole grain ingredient. Food manufacturers can also make factual statements about whole grains on the label of their products, such as "10 grams of whole grains," "½ ounce of whole grains," and "100 percent whole grain oatmeal" (FDA, 2006). There is urgent need for an international definition for whole grain and methods to measure the whole grain content of foods (Frolich and Aman, 2010).

The 2005 DGAC focused on the relationship between whole grain consumption and three health outcomes—CHD, diabetes, and obesity. The 2005 DGAC reviewed 12 prospective cohort studies to ascertain the whole grain intake levels associated with the greatest health benefit. The 2005 DGAC committee concluded that consuming at least three servings (equivalent to 3 oz in a 2000 calorie diet) of nutrient-rich whole grains per day can reduce the risk of diabetes and CHD and helps with weight maintenance.

For this Report, the Committee reviewed literature published since June 2004 on the relationship between whole grains and three health outcomes: CVD, T2D, and body weight.

Whole Grain Intake and Cardiovascular Disease

Seven articles (DeMoura, 2009; Kelly, 2007; Mellen, 2008; Brownlee, 2010; Djousse, 2007; Flint, 2009; Nettleton, 2008) met the inclusion criteria and were reviewed to determine the effect of whole grain consumption on CVD (two systematic reviews, one meta-analysis, one randomized controlled trial [RCT], and three prospective cohort studies). The importance of the need for an agreed upon definition for whole grains was noted in the DeMoura et al. (2009) review. Their initial inclusion criteria required studies to explicitly state 51 percent of weight being whole grains, to be eligible for review. Using this standard, only two RCTs, one prospective cohort study, and one cross-sectional study were identified for review.

A second, broader set of inclusion criteria used a minimum level of 25 percent of whole grain by dry weight to assign values for whole grains and added bran and/or germ along with whole grains. RCTs conducted with individual whole grains, such as whole grain barley, oats, and rye, were included in the broader definition group. Six RCTs found a beneficial effect of oats on CVD outcomes and five found no significant changes. Four RCTs with barley showed reduction in plasma total cholesterol and LDL cholesterol. The authors concluded that, for the restricted assessment, while two observational studies found a significant reduction in CVD-related surrogate endpoints, there were not supporting intervention studies, and thus, insufficient evidence to support a whole grain health claim for CVD risk reduction. Using the broader definition that included added bran and/or germ along with whole grains, the authors concluded that the evidence supported a whole-grain health claim for reduced risk of CVD.

Two systematic reviews/meta-analyses found a protective effect of whole grains on CVD. Kelly et al. (2007), in a systematic review and meta-analysis of nine RCTs (eight oat, one rye), reported a significantly lower total cholesterol and LDL-cholesterol with higher whole grain (oat, rye) intake. Mellen et al. (2008), in a meta-analysis of seven prospective cohort studies, also reported a protective effect of whole grains on CVD. Mellen (2008) did not evaluate the criteria that the studies used to quantify whole grain intake. It is likely that a minimum content of 25 percent whole grain by weight, the Jacobs algorithm (AJCN, 1999), was used in most cases.

More recent studies have attempted to use grams of whole grains as the measure of whole grains in foods. Flint et al. (2009) used weight of whole grain in their hypertension analysis and found that both whole grains were protective for incident hypertension.

Brownlee et al. (2010) examined markers of cardiovascular risk in a large (n=266) intervention study with high-risk participants (Body Mass Index [BMI]>25 kg/m^2). Participants who routinely consumed few whole grain products were randomized to consume 60 grams whole grains per day for 8 weeks or 60 grams whole grains per day for 8 weeks and then 120 grams whole grains per day for 8 more weeks. Markers of CVD risk were measured at baseline, 8, and 16 weeks. Outcome data for the two intervention groups was averaged and then compared to the control group. There were no differences in fasting plasma lipid profile, indicators of inflammation, coagulation, or endothelial function.

Two prospective cohort studies examined whole grain intake and the incidence of heart failure (HF). Djousse and Graziano (2007) concluded that there was an inverse association between whole grain breakfast cereal consumption and the risk of HF. Similarly, Nettleton et al. (2008) concluded that in their large population-based cohort of the ARIC study (n = 14,153 African-American and White adults) whole-grain intake was associated with lower HF risk. The multivariate-adjusted HF risk for whole-grain intake was 0.93 (p<0.05) for each one serving per day increase in whole grain consumption.

Whole Grain Intake and Type 2 Diabetes

Four articles (DeMunter, 2007; Priebe, 2008; Kochar, 2008; Brownlee, 2010) were reviewed to determine the effect of whole grain consumption on the incidence of T2D. The four papers included a systematic review/meta-analysis of six prospective cohorts, as well as a separate prospective cohort study (DeMunter, 2007), a systematic review of 12 studies (one RCT and 11 prospective cohort studies of which five were relevant to this question; Priebe, 2008), a randomized controlled trial (Brownlee, 2010), and a prospective cohort study (Kochar, 2008).

Both systematic reviews reported that whole grain intake was inversely associated with risk of T2D. They included a common subset of five prospective cohorts; one conducted a pooled analysis and the other did not. The systematic review/meta-analysis (DeMunter et al., 2007) pooled the data of six prospective cohort studies (n = 286,125 predominantly Black and White male and female participants with 10,944 incident cases of T2D) and found that a two-serving-per-day increment in whole grain consumption was associated with a 21 percent decrease in risk of T2D after adjustment for potential confounders and BMI (p<0.001).

Priebe (2008), reported on five prospective cohort studies that examined the effect of whole grain foods and found an inverse association ranging from a relative risk of 0.67 to 0.79. After excluding studies that did not correct for family history of diabetes (Meyer, 2000; Montonen, 2003) and physical activity (Montonen, 2003), the observed effect in the remaining three studies was a relative risk of 0.70, 0.73, and 0.73.

A prospective cohort study, with 19 years of follow-up, compared the highest and lowest category of ready-to-eat whole grain breakfast cereal consumption and found that the relative risk for T2D was 0.63 (p< 0.0001) (Kochar, 2008), although the authors noted problems with their simplified food frequency questionnaire which did not collect data that would allow them to control for total energy intake and other nutrients such as fiber and magnesium.

Some randomized trials have measured biomarkers of interest in diabetes with intake of whole grains. An example is the WHOLEHeart study, which found no differences in serum glucose or insulin with consumption of whole grain foods (Brownlee, 2010).

Whole Grain Intake and Body Weight

Eight studies were reviewed to examine the relationship between whole grain consumption and body weight (Harland and Garton, 2007; Williams, 2008; Behall, 2006; Katcher, 2008; Brownlee, 2010; Lutsey, 2007; McKeown, 2009; Van der Vijver, 2009). The two large systematic reviews provide evidence that whole grain intake is associated with lower BMI and protects against weight gain and adiposity, but did include cross-sectional studies. Pooled analysis of 15 observational studies found a difference in BMI (p<0.0001), reduced waist circumference (p= 0.03), and lower waist:hip ratio (p=0.0001) with higher whole grain intakes (Harland and Garton, 2007). Williams et al. (2008) examined 20 studies, including 11 studies of dietary patterns, five RCTs, and four observational studies and concluded that there was strong evidence that a diet high in whole grains was associated with lower BMI, smaller waist circumference, and reduced risk of being overweight.

Behall (2006) compared the effects of feeding three whole-grain diets on blood pressure with weight as an ancillary outcome. Participants (n=25) consumed a controlled Step I diet for 2 weeks after which approximately 20 percent of energy was replaced with whole wheat/brown rice, barley, or half wheat-rice/half barley, for 5 weeks each. Participants lost approximately 1 kilogram during the study. In the RCT by Katcher et al. (2008), overweight participants (n=50) were advised to avoid whole grains foods or obtain all of their grain servings from whole grains for 12 weeks. Body weight, waist circumference, and percentage body fat decreased significantly in both groups over the study period, but there was a significantly greater decrease in percentage body fat in the abdominal region in the whole grain group compared to the refined grain group.

Three recent cross-sectional studies also found that whole grain intakes were associated with lower BMI and adiposity. Analysis of a MESA study of men and women comparing the extreme quintiles of whole grain intake found a difference in BMI (Lutsey, 2007). Similarly, McKeown et al. (2009) found that in older adults, after multivariate adjustment comparing the extreme quartiles of consumption, whole-grain intake was inversely associated with BMI percent body fat, and percent trunk fat mass measured by whole-body dual-energy X-ray absorptiometry. In the Netherlands, Van de Vijver et al. (2009) assessed the association of whole-grain and cereal fiber intake with BMI and the risk of being overweight in older adults. They reported an inverse association between whole-grain consumption and BMI. Fiber and cereal fiber intake were inversely associated with BMI in men only.

In the WHOLEHeart study (Brownlee, 2010), no differences were found in BMI, percentage body fat, or waist circumference with up to 16 weeks of self-reported consumption of whole grain foods compared to refined grain foods in *ad libitum* participants.

Question 3: What Is the Relationship Between the Intake of Vegetables and Fruits, Not Including Juice, and Selected Health Outcomes?

Conclusion

Consistent evidence suggests at least a moderate inverse relationship between vegetable and fruit consumption with myocardial infarction and stroke, with significantly larger, positive effects noted above five servings of vegetables and fruits per day. Notwithstanding prior work on dietary patterns that emphasize vegetables and fruits, insufficient evidence published since 2004 is available to assess the independent relationship between vegetable and fruit intake and blood pressure or serum cholesterol. The evidence for an association between increased fruit and vegetable intake and lower body weight is modest with a trend towards decreased weight gain over 5+ years in middle adulthood. No conclusions can be drawn from the evidence on the efficacy of increased fruit and vegetable consumption in weight loss diets. Limited and inconsistent evidence suggests an inverse association between total vegetable and fruit consumption and the development of T2D. Evidence also indicates that some types of vegetables and fruits are probably protective against some cancers.

Implications

Vegetables and fruits are nutrient-dense and relatively low in calories. In order to meet the recommended intakes, Americans should emphasize vegetables and fruits in their daily food choices, without added solid fats, sugars, starches or sodium to maximize health benefits. Significant favorable associations between vegetable and fruit consumption and health outcomes appear to be linked to a minimum of five servings per day and positive linear effects may be noted at even higher consumption levels. While the impact of increased vegetable and fruit consumption per se is unclear for some chronic diseases and markers (blood lipids, glucose control, T2D, and weight loss), improvements in preventing CVD and certain cancers, especially cancers of the alimentary tract, may occur with increased consumption of these foods. Additionally, there is evidence that vegetables and fruits, when considered as part of a dietary pattern, are associated with improved weight and health outcomes (see *Part D. Section 2: The Total Diet: Combining Nutrients, Consuming Food* for a discussion on dietary patterns and *Part D. Section 1: Energy Balance and Weight Management* for a discussion on energy density).

Review of the Evidence

Background

Vegetable and fruit consumption has long been associated with good health probably due to their high vitamin, mineral, fiber, and phytochemical content, yet the research is surprisingly sparse on the documented associations between vegetables and fruits and specific health outcomes. Several mechanisms for action were hypothesized in the 2005 DGAC Report, including that certain nutrients may directly improve CVD risk factors or protect against cancer; that vegetables and fruits may displace or reduce intake of saturated fat, cholesterol, and total calories; or that they may influence glucose metabolism. The study of vegetables and fruits on human health is complicated by many factors, including their large variety globally, varying dietary patterns, different effects for vegetables versus fruits, and interactions with other dietary components. However, most Americans, in all age-sex groups, consume substantially fewer vegetables and fruits than is recommended.

The 2005 DGAC Report noted that increased vegetable and fruit intake was associated with a reduced risk of stroke and perhaps other CVD. Moreover, the report emphasized the role of vegetables and fruits in protecting against cancer, but noted that it is difficult to distinguish the role of vegetables and fruits per se (versus their fiber content) in preventing T2D or glucose intolerance. Additionally, vegetables and fruits were noted to have a protective effect against weight gain probably mediated through reduced calorie intake.

Since 2004, a relatively small volume of work has been published regarding vegetables and fruits. The evidence from 2004 to 2009 is summarized below.

Vegetable and Fruit Intake and Cardiovascular Disease

Evidence suggests at least a moderate inverse relationship between vegetable and fruit consumption with myocardial infarction and stroke, with significantly larger, positive effects noted above five servings of vegetables and fruits per day. This evidence is based on 12 reports, including four meta-analyses (Dauchet, 2005, 2006; He, 2006, 2007) of U.S. and European participants; six prospective studies, four of which were conducted in the U.S. (Genkinger, 2004; Hung, 2004; Joshipura, 2009; Tucker, 2005) and two in Japan (Nakamura, 2008; Takachi, 2008), and two international case-control studies (Galeone, 2009; Nikolic, 2008). Results varied by sex, with a significant decrease for men and women reported in all-cause cardiovascular death (Genkinger, 2004; Hung, 2004; Joshipura, 2009), for men only (Tucker, 2005), for men only in terms of vegetable intake (Nakamura, 2008), and for women only in terms of fruit intake (Nakamura, 2008). In addition, Takachi (2008) found significant results for higher fruit (but not vegetable) intake in men and women. Risk for CVD is highest at consumption levels below three servings per day, results are ambiguous at three to five servings of vegetables and fruits per day, and lowest risk is associated with consumption levels above five servings per day (Dauchet, 2006; He, 2007), suggesting a linear relationship between vegetable and fruit consumption and CHD. Overall, risk reduction for CHD was estimated to be as much as 4 percent and 11 percent for stroke alone for each serving of vegetables and fruits added per day (Dauchet, 2006).

Five studies investigating blood pressure and vegetable and fruit intake were identified in the NEL search. These included the PREMIER prospective cohort study in the U.S. (Wang, 2008), one prospective study in Spain (Nuñez-Cordoba, 2009),cross-sectional studies in Iran (Mirmiran, 2009), Japan (Utsugi, 2008), and India (Radhika, 2008). Two studies showed no association between total vegetable and fruit intake and blood pressure (Mirmiran, 2009) and hypertension (Nuñez-Cordoba, 2009). Utsugi et al. (2008) showed a significant positive relationship with vegetable and fruit consumption and lower risk of home-measured hypertension. The Wang et al. (2008) study showed vegetable and fruit consumption was inversely associated with both systolic and diastolic blood pressure at 6 months but not at 18 months.

The U.S. results support the work reviewed in the 2005 DGAC Report, but the international studies do not. The variation in results may be due to differences between these international population samples and typical American patterns in baseline consumption levels of vegetables and fruits, types of vegetables and fruits consumed, and overall dietary patterns.

Blood lipids are traditionally used as an intermediate indicator or marker for CVD. The evidence testing the effect of vegetable and fruit intake on blood lipids is sparse, but suggests an associative trend between an increased consumption of vegetables and fruits with lower total and LDL-blood cholesterol levels. The evidence is based on three reports since 2004, including one limited trial (Kelley, 2006) and two cross-sectional studies (Mirmiran, 2009; Radhika, 2008). The trend is apparent for total and LDL-cholesterol, and persists even after adjustment for education, physical activity, and fat intakes. However, significance occurs only when the highest levels of vegetable and fruit intake are compared to the lowest levels of intake and the mechanisms of action are unknown.

Vegetable and Fruit Intake and Body Weight

A modest association with decreased weight gain over 5 or more years in middle adulthood has been reported with increased vegetable and fruit intake. However, based on current studies, no conclusions can be drawn about the efficacy of increasing vegetable and fruit consumption in achieving weight loss nor can any distinction be made about the relative influence of fruits versus vegetables on weight status.

The review of evidence regarding weight gain and vegetable and fruit consumption was based on 11 studies (Bes-Rastrollo, 2006; Buijee, 2009; Davis, 2006; Fujioka, 2008; Goss, 2005; He, 2004; Ortega, 2006; Radhika, 2008; Tanumibardjo, 2009; Vioque, 2008; Xu, 2007). These studies were conducted around the globe and varied considerably in length of observation. Two of the RCTs (Fujioka, 2008; Ortega, 2006) collected data at an endpoint of only 6 weeks; a third RCT evaluated participants at 3, 12, and 18 months. All indicated small, but significant, and nonsustainable weight loss over time with an intensive addition of vegetables and fruits to the diet. Similar results showing weak inverse relationships between vegetable and fruit consumption and weight gain were noted in the prospective (Buijsee, 2009; He, 2004; Vioque, 2008), case control (David, 2006), and cross-sectional studies (Bes-Rastrollo, 2006; Goss, 2005; Radhika, 2008) that followed participants over a longer time. The evidence is insufficient to ascertain the value of vegetable and fruit consumption in weight loss diets.

Vegetable and Fruit Intake and Type 2 Diabetes

In a review of five articles describing prospective cohort studies, the evidence is inconsistent but suggests an inverse association between the development of T2D and total vegetable and fruit consumption (Liu, 2004), a direct association with potato (French fry) consumption (Halton, 2006b), and no significant effect of tomato-based products (Wang, 2006). Another study indicated that total vegetables as well as vegetable subgroups, but not fruit, may have a preventive effect (Villegas, 2008). Conversely, the Nurses' Health Study (Bazzano, 2008) indicated no association between T2D risk and total vegetable and fruit consumption, but total fruit and green leafy vegetables were inversely associated. The number of vegetable and fruit servings in these five studies ranged from about 2.5 servings to more than 10 servings per day and sample sizes were large in all five cohort studies ranging from 35,000 to 84,000 participants (Bazzano, 2008; Halton, 2006b; Liu, 2004; Villegas, 2008; Wang, 2006). The effect size was variable ranging from a multivariate relative risk of 0.82 (Bazzano, 2008) to 1.04 (Wang, 2006) and 1.21 (Halton, 2006b) when comparing lowest quintiles to highest quintiles. However, the evidence is insufficiently strong to draw firm conclusions.

Vegetable and Fruit Intake and Cancer

The DGAC chose not to conduct an independent systematic review of vegetables and fruits and cancer due to the comprehensive and recent report by the WCRF/AICR (2007). The DGAC chose instead to review the WCRF/AICR findings (see summary Table D4.2 at the end of the chapter). Types of cancer examined by the WCRF/AICR Panel include cancers of the esophagus, stomach, colorectum, pancreas, liver, prostate, cervix, endometrium, ovary, breast, skin, and mouth, pharynx, larynx, and nasopharynx. Broadly speaking, there is no general agreement on classification of vegetables and fruits to drive comparisons in the research questions. The WCRF/AICR Panel examined the evidence by starchy and non-starchy vegetables. In their analysis, starchy vegetables were combined with cereal grains, roots, tubers, and plantains. The non-starchy vegetables were categorized into subtypes (cruciferous, allium [e.g., garlic], green leafy, tomatoes, and white or pale vegetables) and whether they are eaten in raw (salad) or cooked forms. Studies also were separated by whether the conclusions were based on vegetable intakes alone or vegetables and fruits combined. In addition, evidence was examined in vegetables and fruits containing certain micronutrients, including folate, carotenoids (spinach, kale, butternut squash, pumpkin, red bell pepper, carrots, tomatoes, cantaloupe, and sweet potatoes), lycopene (tomatoes), other flavinoids or phytochemicals, vitamin C, and other vitamins.

The WCRF/AIRC Panel found that non-starchy vegetables as a group as well as non-starchy vegetables and fruits in combination had a significant and consistent protective effect against cancer of the mouth, pharynx, and larynx, as well as esophageal cancer at least among the highest consumers of vegetables and fruits. Some studies suggested a dose response. Cruciferous vegetables, green leafy vegetables, and tomatoes did not have a significant association for these cancers as a separate exposure, but 16 of 18 cohort studies of carrot consumption indicate a statistically significant effect. Raw vegetables show a consistent association (16 of 16 case-control studies) with decreased risk of esophageal cancer. A decreased risk of stomach cancer was associated with green-yellow vegetables, but not with green, leafy vegetables, tomatoes, or white or pale vegetables. Data about an association with nasopharyngeal cancer are too sparse and the data relating non-starchy vegetables to colorectal cancer are too inconsistent to draw a firm conclusion. Limited evidence suggests that non-starchy vegetables protect against lung, ovarian, and endometrial cancers. The evidence is sparse but fairly consistent that allium vegetables (such as onions, garlic, leeks, and chives) probably protect against stomach and colorectal cancer and that carrots may protect against cervical cancer.

In their analysis, the WCRF/AICR Panel combined starchy vegetables with other starchy plant foods, including grains, tubers (including potatoes), plantains (excluding bananas), and roots, recognizing that these foods have to be prepared or cooked in some way to make them edible. The panel concluded that all foods in the starchy vegetable group as well as starchy vegetables and fruits in combination have an insubstantial effect on the risk of any cancer.

According to the WCRF/AICR Panel, fruits as a group, including fruit subtypes, show consistent evidence suggesting that they protect against mouth, pharynx, larynx, and esophageal cancer, though most of the studies are case-control designs. The evidence for a protective effect of fruits on lung cancer is convincing with a dose-response relationship. Evidence linking fruits to nasopharyngeal cancer, pancreatic cancer, colorectal, and liver cancer is too sparse and/or inconsistent to draw conclusions.

Micronutrients in vegetables and fruits that have been studied for risk of cancer include beta-carotene and lycopene, folate, vitamin C, vitamin D, vitamin E, quercetin, pyridoxine, and selenium (see *Part D. Section 2: Nutrient Adequacy* for additional information on folate and health outcomes). Foods containing carotenoids probably protect against cancers of the mouth, pharynx, larynx, and esophagus as well as lung cancer with a dose-response relationship, but they are unlikely to have a substantial effect on prostate cancer or non-melanoma skin cancer. Foods containing folate probably protect against pancreatic cancer. A substantial amount of consistent evidence indicates that foods containing lycopene, especially cooked tomato products, probably protect against prostate cancer.

Studies about the effect of dietary vitamin E show non-significant decreased risk of esophageal and prostate cancer and much of the evidence is of poor quality. A sparse amount of evidence for foods containing selenium suggest this mineral may protect against lung cancer and stomach cancer, whereas a substantial amount of data indicate it may protect against colorectal cancer, but these studies are from case-control designs only.

Part of the healthful effect of vegetables and fruits, including protection against cancer risk, may be due to the effect of phytochemicals. Technically, phytochemicals are not essential to the diet, so no daily requirement has been established for them, but they are bioactive and there may be as many as 100,000 different compounds. Future research will require assessment of these compounds and the possible mechanisms that may be associated with health. Only then can the amounts needed for a public health effect be noted, both in foods and in herbs and spices.

Question 4: What Is the Relationship Between Glycemic Index or Glycemic Load and Body Weight, Type 2 Diabetes, Cardiovascular Disease, and Cancer?

Conclusion

Strong and consistent evidence shows that glycemic index and/or glycemic load are not associated with body weight and do not lead to greater weight loss or better weight maintenance. Abundant, strong epidemiological evidence demonstrates that there is no association between glycemic index or load and cancer. A moderate body of inconsistent evidence supports a relationship between high glycemic index and T2D. Strong, convincing evidence shows little association between glycemic load and T2D. Due to limited evidence, no conclusion can be drawn to assess the relationship between either glycemic index or load and cardiovascular disease.

Implications

When selecting carbohydrate foods, there is no need for concern with their glycemic index or glycemic load. What is important to heed is their calories, caloric density, and fiber content.

Review of the Evidence

Background

There has been a great deal of interest as to whether glycemic index and glycemic load can predict the risk of chronic disease. The Committee felt that the question should be investigated further by looking at any new data available since the 2005 DGAC Report. The glycemic index is a classification system proposed to quantify the relative blood glucose response to consumption of carbohydrate-containing foods. Operationally, it is the area under the curve for the increase in blood glucose after the ingestion of a set amount of carbohydrate in a food (e.g., 50 g) during the 2-hour postprandial period, relative to the same amount of carbohydrate from a reference food (white bread or glucose) tested in the same individual under the same conditions and using the initial blood glucose concentration as a baseline.

The glycemic load is an indicator of the blood glucose response or insulin demand that is induced by total carbohydrate intake. It is calculated by multiplying the weighted mean of the dietary glycemic index of the diet of an individual by the percentage of total energy from carbohydrate.

Glycemic Index or Load and Body Weight

Current evidence shows that the glycemic index and/or glycemic load are not associated with body weight and do not lead to greater weight loss or better weight maintenance. Evidence from RCTs shows no difference between high glycemic index and low glycemic index diets on weight loss in studies longer than 8 weeks. Evidence from fewer RCTs show the same for high glycemic load versus low glycemic load. The Committee reviewed 22 studies published since 2005. Of these, 13 were RCTs, two were prospective cohort studies, and seven were cross-sectional studies.

Seven RCTs compared high versus low glycemic index or high versus low glycemic load in a reducing diet protocol. Of these, two studies (Abete, 2008; de Rougemont, 2007) showed a significant weight loss difference of 2.3 kilograms and 0.8 kilogram after 8 and 5 weeks with a greater drop in the low glycemic index diet. The other five RCTs (Phillipou, 2009; Pittas, 2005; Raatz, 2005; Sichieri, 2007; Sloth, 20004) showed no difference in weight loss in much longer studies lasting from 16 to 76 weeks. Three RCTs (Ebbeling, 2007; Maki, 2007; Pereira, 2004) compared low glycemic load diets versus low-fat diets. They did not show any differences in weight loss between the diets. One RCT (Pal, 2008) compared the effect of a high glycemic index versus low glycemic index breakfast and found no difference in weight after 3 weeks. One RCT (McMillan-Price, 2006) compared four diets, two of which were high carbohydrate and two were high protein, with either high or low glycemic index. No difference in weight loss was found with any of the diets over 12 weeks. In summary, the RCTs overwhelmingly report no difference between low and high glycemic index diets in achieving weight loss during reducing diet programs or maintenance diet programs. The data on glycemic load are less numerous but report similar results.

Two prospective cohort studies also examined this issue (Deienlein, 2008; Hare-Bruun, 2006). The first was a gestational diabetes study that found glycemic load not to be associated with gestational weight gain or weight gain ratio. The second followed normal weight participants for 6 years and showed no significant association between glycemic load and change in weight in either men or women. It showed no association between glycemic index and change in weight in men, but did show an association of glycemic index with lower weight gain in women. These studies suggest that in men there is no relation between either glycemic index or load and weight, and in women there is no relation of glycemic load and weight, but a possible relation of glycemic index and weight.

Seven cross-sectional studies also have been carried out, comprising a total of 21,231 participants, both children and adults. Of these, six (Hui, 2006; Lau, 2006; Liese, 2005; Mendez, 2009; Milton, 2007; Nielsen, 2005) showed no association between glycemic index or load and weight or BMI. One study (Murakami, 2007) did show a positive correlation between glycemic index and glycemic load with BMI in young lean Japanese women. These cross-sectional studies support the conclusion that glycemic index or load and weight are not associated.

Glycemic Index or Glycemic Load and Type 2 Diabetes

Evidence is mixed as to whether there is an association between a high glycemic index and T2D. Little evidence suggests that a high glycemic load is associated with T2D. This conclusion is based on 10 longitudinal prospective observational studies published since 2000 (Barclay, 2007; Halton, 2008; Hodge, 2004; Krishnan, 2007; Mosdol, 2007; Sahyoun, 2008; Schulz, 2006; Schulze, 2004; Stevens, 2002; Villegas, 2007). No RCTs were reported. Of the 10 prospective observational studies, glycemic index was positively associated with T2D in five reports (Halton, 2008; Krishnan, 2007; Schulz, 2006; Schultze, 2006; Villegas, 2007). Four other longitudinal studies reported no association of glycemic index with T2D (Barclay 2007; Mosdol 2007; Sahyoun 2008; Steven

2002). One longitudinal study reported an inverse association (Hodge, 2004).

Of the 10 prospective observational studies, one study reported a significant, positive association between glycemic load and risk of T2D during 20 years of follow-up in comparison of extreme deciles (Halton, 2008). Six studies found no relationship (Barclay, 2007; Hodge, 2004; Krishnan, 2007; Sahyoun, 2008; Schulz, 2006; Stevens, 2002). Two studies found an inverse association (Mosdol, 2007; Villegas, 2007).

Glycemic Index or Glycemic Load and Cardiovascular Disease

Although the evidence for an association between high glycemic index or high glycemic load and CVD is more negative than positive, the evidence available is inadequate to come to a firm conclusion on this question.

Eight reports have been published since 2000 (Beulens, 2007; Kaushik, 2009; Levitan, 2007; Liu, 2000; Halton, 2006a; Oh, 2005; Tavani, 2003; van Dam, 2000). Of these, three are from the same Nurses' Health Study. After 10 years of follow-up, Liu et al. (2000) reported glycemic index was associated with CVD. A high glycemic load was associated with CVD in women with a BMI greater than 23 but not with a BMI less than 23 kg/m^2. After 20 years of follow-up, Halton (2006a) reported both a high glycemic index and load to be associated with CVD. Oh (2005) reported on the associations between dietary carbohydrate, glycemic index, glycemic load, and stroke. They found no association between glycemic index and stroke. They found a positive association between glycemic load and total stroke in women with a BMI greater than 25 but not in those with a BMI less than 25 kg/m^2.

Five other reports are available. Of these, Beulens (2007) found a positive trend for an association between glycemic load and stroke, but not for glycemic index and stroke. He found a positive trend between glycemic index and CHD and between glycemic load and CHD only for women with a BMI greater than 25 k/m^2.

Kauschik (2009) found an association between both glycemic index and glycemic load and death from stroke. Levitan (2007) found no association between glycemic index or glycemic load with myocardial infarction, ischemic stroke, or all-cause mortality. van Dam (2000) found no association of either glycemic index or glycemic load and CHD.

One case-control study (Tavani, 2003) reported on the relation between glycemic index and glycemic load and the risk of non-fatal acute myocardial infarction. No significant association was found.

Glycemic Index or Glycemic Load and Cancer

The epidemiological evidence for an association between glycemic index or load and cancer is overwhelmingly negative. Twenty-eight reports have been published since 2005. Of these, 20 are prospective longitudinal observation studies, one is a cross-sectional observation study, five are case-control studies, and two are case-cohort studies.

Of the 20 prospective longitudinal observational studies, 18 studied the association between glycemic index and cancer. One showed a very weak positive association between glycemic index and total cancer risk (George, 2009), while 13 studies found no association between glycemic index and specific types of cancer including pancreatic (Heinen, 2008; Johnson, 2005; Nothlings, 2007; Patel, 2007; Silvera, 2005), breast (Giles, 2006; Lajous, 2008; Sieri, 2007; Silvera, 2005), endometrial (Cust, 2007; Larsson and Friberg, 2007) stomach (Larsson, 2006), and ovarian (Silvera, 2007) cancers. Varying results were found for colorectal cancer with no association reported in three studies (Larsson, 2007; McCarl, 2006; Michaud, 2005) and an inverse association reported by Strayer et al. (2007).

Of the 20 prospective longitudinal observational studies, all studied the association between glycemic load and cancer. Two showed a positive association for total cancer (George, 2009) and ovarian cancer (Silvera, 2007). However, most studies reported no association between glycemic load and cancer, including pancreatic (Heinen, 2008; Johnson, 2005; Nothlings, 2007; Patel, 2007; Silvera, 2005), breast (Giles, 2006; Lajous, 2008; Sieri, 2007; Silvera, 2005), endometrial (Cust, 2007; Larsson and Friberg, 2007), and stomach (Larsson, 2006) cancers. Similar to glycemic index, there were mixed results regarding the relationship between glycemic load and colorectal cancer with five studies finding no association (Kabat, 2008; Larsson, 2007; McCarl, 2006; Michaud, 2005; Strayer, 2007) and one study reporting an inverse association (Howarth, 2008).

The two case-cohort studies reported no association of either glycemic index or load with pancreatic (Kabat, 2008) or colorectal (Weijenberg, 2008) cancers. Similarly, one cross-sectional observational study showed no association between either glycemic index or load and colorectal adenomas (Flood, 2006a).

The five available case-control reports reported mixed results. Of these, three found glycemic index to be significantly associated with prostate (Augustin, 2004), gastric (Bertuccio, 2009), and thyroid (Randi, 2008) cancers, and two found no association with breast cancer (Lajous, 2005; McCann, 2007). Similarly, three found glycemic load to be significantly associated with cancer of the breast (Lajous, 2005), prostate (Bertuccio, 2009), or thyroid (Randi, 2008) and found no association for breast (McCann, 2007) and prostate (Augustin, 2004) cancers.

Question 5: In Adults, What Are the Associations Between Intake of Sugar-sweetened Beverages and Energy Intake and Body Weight?

Conclusions

Limited evidence shows that intake of sugar-sweetened beverages (SSB) is linked to higher energy intake in adults. A moderate body of epidemiologic evidence suggests that greater consumption of SSB is associated with increased body weight in adults. A moderate body of evidence suggests that under isocaloric controlled conditions, added sugars, including SSB, are no more likely to cause weight gain than any other source of energy.

Implications

Added sugars, as found in SSB, are not different than other extra calories in the diet for energy intake and body weight. Thus, reducing intake of all added sugars, including sucrose, corn sweetener, fructose, high fructose corn syrup, and other forms of added sugars, is a recommended strategy to reduce calorie intake in Americans. Intake of caloric beverages, including SSB, sweetened coffee and tea, energy drinks, and other drinks high in calories and low in nutrients should be reduced in consumers needing to lower body weight. While still moderate, recent evidence is stronger than prior evidence available to assess the relationship between SSB and increased body weight.

Review of the Evidence

Background

The 2005 DGAC asked the following question: “What is the significance of added sugars intake to human health?” Their conclusion was, “Compared with individuals who consume small amounts of foods and beverages that are high in added sugars, those who consume large amounts tend to consume more calories but smaller amounts of micronutrients. Although more research is needed, available prospective studies suggest a positive association between the consumption of SSB and weight gain. A reduced intake of added sugars (especially SSB) may be helpful in achieving recommended intakes of nutrients and in weight control.”

The role of dietary sugars in the current obesity epidemic is much debated, with many opposing views. A review by Saris (2003) concluded that the fat content of the diet is the most important contributor to overconsumption of calories and that the carbohydrate content, regardless of carbohydrate type, is relatively benign, with little evidence for direct negative effects of dietary sugar on body weight. Another recent review by the same group (van Bakk, 2008) concluded that there is insufficient evidence that an exchange of sugar for non-sugar carbohydrates in the context of a reduced fat *ad libitum* diet or energy-restricted diet results in lower body weight. They also noted that observational studies suggest a possible relationship between consumption of SSB and body weight, but that current supporting evidence from RCTs of sufficient size and duration was insufficient to support a difference between liquid and solid sugar intake in bodyweight control.

Most reviews have asked the question whether intake of SSB is linked to obesity. As described by Olsen and Heitmann (2009), the prevalence of obesity has increased in the past 30 years, and at the same time consumption of soft drinks has increased sharply. They reviewed the literature on calorically-sweetened beverages and obesity, relative to adjustment for energy intake. No cross-sectional studies were included. They concluded that a high intake of calorically-sweetened beverages can be regarded as determinant for obesity. However, there seems to be no support for an association between intake of calorically-sweetened beverages and obesity as mediated through increased energy intake, suggesting that alternative biological explanations should be explored. Other studies that examined obesity risk and intake of SSB in adults in U.S. as measured with CSFII and NHANES datasets found no association between obesity risk and sugar intake (Sun, 2007).

Intake of SSB and adiposity was reviewed by Bachman et al. (2006). They described four mechanisms to explain the possible association between sweetened beverages and increased overweight or obesity, including excess caloric intake, glycemic index and glycemic load, lack of effect of liquid calories on satiety, and displacement of milk. They report inconsistent results across studies. The strongest support was for the excess caloric intake hypothesis, but the findings were not conclusive. They suggest that assigning possible links between sweetened beverage consumption and adiposity requires research that compares and contrasts specific mechanisms, especially in populations at risk of obesity, while controlling for likely confounding variables.

Based on these existing reviews, the 2010 DGAC asked the questions whether intake of SSB was related to energy intake and body weight in adults. The Committee included systematic reviews and primary research studies in the NEL review. Because studies with stronger methodology were available in 2010, the Committee excluded cross-sectional studies. However, some of the systematic reviews included in the NEL review considered cross-sectional studies. The Committee therefore places more confidence in the reviews that excluded cross-sectional studies in our conclusions.

Methodological Challenges

Sugar is a ubiquitous term, but one that is not easy to define and measure. Analytical methods can measure total sugar in foods and nutrient databases and Nutrition Facts labels include values for total sugars. Added sugars are typically calculated values and can be added to dietary assessment tools in nutrition studies. As described by Ruxton et al. (2010), exact definitions of sugar are often omitted from studies, making it difficult to determine exactly what was under investigation. This hinders the ability to compare studies. Studies can report specific sugars—sucrose, glucose, fructose, or just say "sugar" to mean mono- and disaccharides. "Total sugars" means all dietary sugars whether added or naturally occurring. "Sugar-containing" is thought to mean foods and beverages that contain sugar. In epidemiologic studies, it is often easier to assess intake of SSB as these can be counted in food frequency instruments. This tends to be non-specific because fruitades, fruit punches, sport drinks, energy drinks, and juices that are not 100 percent juices may or may not be counted in these systems.

Two studies in the United Kingdom used non-milk extrinsic sugars (NMES) and reported an inverse relationship between NMES and BMI (Gibson, 2007a, 2007b) though no relationship was found between body weight status and sugar intake in a New Zealand population (Parnell, 2008). Thus, assessment of "added sugars" or "extrinsic sugar" is challenging because no analytical methods exist with which to measure sugars added to foods. Additionally, studies use different techniques to assess added sugars intake. Reliable and standardized measures of exposure to added sugars are necessary to draw meaningful conclusions. Currently, the best assessments involve counting frequency of intake of SSB in epidemiologic studies.

Sugar-sweetened Beverages and Energy Intake

To answer this question the Committee reviewed one meta-analysis (Vartanian, 2007) and four trials (Flood, 2006b; Reid, 2007; Soenen, 2007; Stookey et al., 2007) published since 1990. Vartanian et al. (2007) conducted a meta-analysis that examined the association between soft drink consumption and various health outcomes, including energy intake. It should be noted that this analysis included some unpublished data as well as cross-sectional studies. However, they conducted separate analyses based on study design and outcomes. Of the 88 studies in the review, three longitudinal studies and 11 experimental studies examined the relationship between soft drink consumption and energy intake in adults. Although effect size was small, the authors concluded that there was a clear positive association between soft drink intake and energy intake.

Two additional primary studies also support a relationship between the intake of SSB and increased energy intake. Flood et al. (2006b) examined the impact of beverage type (cola, diet cola, or water) and size (12 or 18 fl oz) on intake at an *ad libitum* lunch. Energy intake from food consumed at lunch did not differ across conditions. However, when the energy from beverages was added to the energy consumed from food, mean total energy intake at lunch was greater when regular cola was served as compared to the other beverages, regardless of portion size.

Reid et al. (2007) compared the effects of supplementary soft drinks sweetened with sucrose or aspartame added to the diet over 4 weeks on dietary intake in normal-weight women. Participants consumed four 250 milliliter bottles of drink per day. Sucrose supplements provided 430 kilocalories per day and aspartame supplements provided less than 20 kilocalories per day. For those consuming the sucrose drink, daily energy intake was higher during the intervention phase than at baseline; women consuming the SSB consumed about 200 kilocalories more energy each day.

Stookey et al. (2007) compared four weight loss diets and predicted that replacing sweetened caloric beverages with water would save 200 kilocalories per day over 12 months. Although weight loss might be expected due to lower energy intake, the study by Stookey et al. (2007) was not an intervention trial and thus did not measure change in body weight.

Soenen and Westerterp-Platenga (2007) examined the satiating effects of high fructose corn syrup (HFCS) and sucrose in comparison with milk and a diet drink. In this trial, participants completed four test sessions that included an *ad libitum* meal served after one of four beverages: one containing sucrose, one HFCS, one milk, and one a diet drink. All four drinks were isovolumetric (800 mL). The energy drinks were isocaloric. Test meal energy intake was lower after consumption of preloads containing sucrose or HFCS or milk (with no differences between the energy-containing preloads) compared to the diet drink preload. Total energy intake (preload + meal) with the energy-containing preloads was significantly higher than total energy intake with the diet drink preload. During the meal, energy intake from the beverage was partly compensated for. However, compensation for energy intake from the preloads containing sucrose, HFCS, or milk did not differ significantly and ranged from 30 percent to 45 percent. This study indicated that although energy intake was higher following the drinks sweetened with HFCS and sucrose compared to a diet drink preload, energy intakes were not different than the milk preload, indicating that the added sugar did not have a unique effect on energy intake.

Sugar-sweetened Beverages and Body Weight

The Committee addressed this question by reviewing four systematic reviews (Gibson, 2008; Malik, 2006; Ruxton, 2010; Vartanian, 2007), four RCTs (Raben, 1997; Reid, 2007; Stanhope, 2009; Surwit, 1997), and three prospective observational studies (Chen, 2009; Dhingra, 2007; Palmer, 2008).

The studies included in the systematic reviews did not use consistent methods to evaluate added sugars. Typical search terms were soft drinks, SSB, liquid sugar, and soda. The systematic reviews used different criteria to review the literature, and three reviews (Gibson, 2008; Malik, 2006; Vartanian, 2007) included cross-sectional studies, as there were limited prospective studies on the topic. Malik et al. (2006), attempted a meta-analysis, but the degree of heterogeneity among study designs made a more qualitative assessment necessary. Vartanian et al. (2007) attempted to separate out the effects in different study designs. Studies with experimental designs (five studies) showed no association with added sugar intake for body weight for adults. Significant relationships were found in longitudinal studies (three studies) for a relationship between added sugar intake and body weight, although the effect size was small. Similarly, Malik et al. (2006) concluded that epidemiologic and experimental data indicated a greater consumption of SSB is associated with weight gain and obesity. In contrast, Gibson (2008) reviewed six longitudinal studies and one intervention study with adults and concluded that SSB are a source of energy, but that little evidence showed that they are any more obesogenic than any other source of energy. In a recent review, Ruxton et al. (2010) concluded that recent evidence does not suggest a positive association between BMI and sugar intake. However, some studies, specifically on sweetened beverages, highlight a potential concern in the relation to obesity risk. The methods used for these systematic reviews varied and may explain the discrepancies in results.

The four trials included in the NEL review varied greatly in design. In general, when calorie intake was controlled, there were no differences in weight gain when participants consumed diets with a higher percent of calories from added sugars compared to diets with a lower percent of intake from added sugars (Raben, 1997; Stanhope, 2009; Surwit, 1997). When energy intake was not controlled, Reid et al. (2007) found a non-significant trend for weight gain among normal-weight women consuming four regular soft drinks per day compared to those consuming diet soft drinks. In a trial by Stanhope et al. (2009) that included 25 percent of energy from beverages sweetened with glucose or fructose, weight gain was observed when participants consumed self-selected diets in an outpatient setting.

The Committee also reviewed three prospective studies. Lower consumption of soft drinks was linked to weight loss in the PREMIER study (Chen, 2009). A reduction in SSB intake of one serving per day was associated with a weight loss of approximately 0.5 kilogram at 6 months and 18 months, and a significant dose-response trend between change in body weight and change in SSB intake also was observed. Over a mean follow-up of 4 years in the Framingham Heart Study (Dhingra, 2007), consumption of one or more soft drinks per day was associated with increased odds of developing obesity and increased waist circumference compared to drinking none.

Palmer et al. (2008) included sugar-sweetened soft drinks and fruit drinks in their analysis of T2D in a prospective cohort study of African-American women. Participants gained weight during the study, but the lowest mean weight gain occurred among those who decreased their consumption of soft drinks.

Thus, there are mixed results on this topic. RCTs report that added sugars are not different from other calories in increasing energy intake or body weight. Prospective studies report some relationship with SSB and weight gain, but it is not possible to determine if these relationships are merely linked to additional calories, as opposed to added sugars per se. The systematic reviews in this area are also inconsistent, probably based on different measures used to determine added sugars intake or intake of SSB.

OTHER RELATED TOPICS

Question 6: How Are Non-caloric Sweeteners Related to Energy Intake and Body Weight?

Conclusion

Moderate evidence shows that using non-caloric sweeteners will affect energy intake only if they are substituted for higher calorie foods and beverages. A few observational studies reported that individuals who use non-caloric sweeteners are more likely to gain weight or be heavier. This does not mean that non-caloric sweeteners cause weight gain—rather that they are more likely to be consumed by overweight and obese individuals.

Implications

The replacement of sugar-sweetened foods and beverages with sugar-free products should theoretically reduce body weight. Yet many questions remain, as epidemiologic studies show a positive link with use of nonnutritive sweeteners and BMI. Additionally, whether use of low calorie sweeteners is linked to higher intake of other calories in the diet remains a debated question.

Review of the Evidence

Background

Replacing sugar with low-calorie sweeteners is a common strategy to facilitate weight control (Bellisle, 2007). Intense sweeteners help lower energy density of beverages and foods, which should result in lower energy intakes. Mattes and Popkin (2008) estimate that 15 percent of the U.S. population ingests nonnutritive sweeteners, but that percentage is increasing. Concern about negative effects of diet soft drink consumption on energy intake came from animal studies that suggested an increased food intake and weight gain following prolonged exposure to saccharin-sweetened yogurt (Swithers, 2008). This study suggested that artificial sweeteners “uncouple” a relationship between sweet taste and energy, which promoted the rats to consume more food and gain weight.

The use of non-caloric sweeteners has increased greatly over the past three decades while the incidence of obesity also has risen. Thus, cross-sectional studies suggest that intake of non-caloric sweeteners is positively associated with increased obesity. If non-caloric sweeteners are used as substitutes for higher energy yielding sweeteners, they have the potential to aid in weight management, but whether they will be effective in this regard is not found in existing literature.

The DGAC answered this question using a partial NEL review. The ADA Evidence Analysis Library (EAL) conducted a search from January 1985 through March 2006 on the question, “In adults, does using foods or beverages with non-nutritive sweeteners (saccharin, aspartame, acesulfame-K, sucralose, neotame) in a calorie-restricted or *ad libitum* diet affect energy balance?” (ADA, 2009).

For adults, the conclusion was, “Using non-nutritive sweeteners in either a calorie restricted or *ad libitum* diet will affect overall energy balance only if the non-nutritive sweeteners are substituted for higher calorie food and beverages (Grade II).” For children, they concluded, “Studies do not support that the use of non-nutritive sweeteners causes weight gain. If non-caloric beverages, including non-nutritive sweeteners, are substituted for SSB, there is a potential for energy savings in adolescents (Grade III).”

Additionally, ADA conducted a review of aspartame and body weight in 2008 that included articles reviewed in 2006. In this review, they asked the question, “In adults, does aspartame affect energy balance (weight)?" The conclusion was "Use of aspartame by individuals consuming a hypocaloric diet may be associated with increased weight loss. In some cases aspartame did not affect weight loss (Grade I)."

Non-caloric Sweeteners and Energy Intake and Body Weight

If non-caloric sweeteners are substituted for higher-calorie food or beverages, they are associated with weight loss. Observational studies find that individuals who use non-caloric sweeteners are more likely to gain weight or be heavier. This does not support that non-caloric sweeteners cause weight gain—only that they are more likely to be used by overweight and obese individuals. The ADA EAL review of non-nutritive sweeteners in both adults and children served as the foundation for this review. This conclusion also is based on review of one meta-analysis (de la Hunty et al., 2006), a randomized crossover study (Flood, 2006b), and a prospective cohort study (Fowler et al., 2008) published since 2006.

The meta-analysis by de la Hunty et al. (2006) supports a significant reduction in energy intakes with aspartame compared with all types of control diets except when aspartame was compared with non-sucrose controls such as water. For body weight, the analysis was conducted in three stages: (1) used all weight outcomes including follow-up weights, (2) excluded studies in which the control group gained weight, and (3) excluded follow-up periods. A significant reduction in weight was seen for all three analyses. The combined effect was approximately a 3 percent reduction in body weight. The authors concluded that using foods and drinks sweetened with aspartame instead of sucrose results in a significant reduction in both energy intakes and body weight. Further, using foods and drinks sweetened with aspartame instead of those sweetened with sucrose is an effective way to maintain and lose weight.

In a prospective cohort study, Fowler et al. (2008) reported a significant positive dose-response relationship between baseline artificially-sweetened beverage consumption and incidence of overweight/obesity, incidence of obesity, and BMI change; however, this association does not establish causality.

Flood et al. (2006b) examined the impact of beverage type (cola, diet cola, or water) and size (12 or 18 fl oz) on intake at an *ad libitum* lunch. Participants consumed significantly more energy at lunch when cola was provided versus diet cola or water.

Question 7: What Is the Impact of Liquid Versus Solid Foods on Energy Intake and Body Weight?

Conclusion

A limited body of evidence shows conflicting results about whether liquid and solid foods differ in their effects on energy intake and body weight except that liquids in the form of soup may lead to decreased energy intake and body weight.

Implications

In general, if total calorie content is held constant, there is little support for any effects on energy intake and body weight due to the calories consumed either as liquid or solid. Some studies suggest that whole foods may be more satiating than liquid foods. Food structure, specifically a whole food (apple, carrots), plays a role in satiety and decreasing food intake at subsequent meals, yet fiber added to a drink is not effective in reducing food intake at subsequent meals. Soup as a preload decreases food intake at a subsequent meal. Thus, Americans are advised to pay attention to the calorie content of the food or beverage consumed, regardless of whether it is a liquid or solid. Calories are the issue in either case.

Review of the Evidence

Background

The 2005 DGAC asked the question "What is the evidence to support caloric compensation for liquid versus solids foods?" They concluded that this was an unresolved issue and that evidence on whether liquid and solid foods differ in their effect on calorie compensation was conflicting.

The 2010 DGAC conducted a NEL review and examined literature from 2000 to present, comparing liquids to solid or semi-solid forms. In addition to examining the role of food form on energy intake and body weight, Question 8 includes additional information on food form and satiety.

Liquids Versus Solids and Energy Intake and Body Weight

No consistent relationships have been reported between the form of a food and energy intake and body weight. This review included 12 studies with no consistent experimental designs. One study examined liquid calories to solid calories in the PREMIER trial (Chen, 2009). Six of the studies were crossover trials that investigated the impact of a preload before breakfast (Stull, 2008) or lunch (Almiron-Roig, 2004; Flood-Obbagy, 2009; Mattes, 2009; Mourao, 2007; Tsuchiya, 2006) on *ad libitum* intake of a meal. An additional crossover trial (Moorhead, 2006) examined the intake of carrots in various forms with a meal rather than as a preload. DiMeglio et al. (2000) conducted a longer term crossover trial that included two, 4-week interventions with daily consumption of liquid (caffeine-free soda) or solid (jelly beans) food. Finally, three studies (Rolls, 2005; Flood, 2007; Bertrais, 2001) examined soup as the liquid form.

No standard protocol has been established to answer this question, and information on food form and consumption of liquid is not collected in prospective cohort trials. Most of the available evidence to answer this question is from preload studies, in which meals are controlled for total calories and macronutrient content, and then satiety is measured for 3 hours after the meal. Subsequent food intake is then measured by consumption of a buffet lunch and food intake for 24 hours may then be calculated.

In the one prospective study, Chen et al. (2009) examined beverage consumption in the PREMIER study at baseline, 6 months, and 18 months. Analyses considered changes in volume, calorie intake, and percentage of calories from beverages both overall and from seven categories (SSB; diet drinks; milk; 100 percent juices; coffee and tea with sugar; coffee and tea without sugar or with artificial sweeteners; and alcoholic beverages). A reduction of 100 kilocalories per day in liquid calorie intake was associated with an approximate 0.25 kilogram weight loss at 6 and 18 months. In comparison, a reduction in solid calorie intake by 100 kilocalories per day was associated with a less than 0.1 kilogram weight loss at 6 and 18 months. Reductions in liquid calorie intake had a stronger effect on weight loss than did a reduction in solid calorie intake, but the difference was statistically significant only at 6 months. A significant dose-response trend between change in body weight and change in liquid calorie intake was observed at 6 and 18 months.

Consumption of solid food compared to juice in a controlled caloric load may decrease energy intake at a subsequent meal. Flood-Obbagy and Rolls (2009) examined how consuming preloads of apples in different forms (apple, applesauce, and apple juice with and without added fiber) influenced energy intake of a meal. Study participants consumed fewer calories at lunch after consuming apples compared to equal calories as applesauce, apple juice, or apple juice with added fiber. In a similar study, whole carrots were associated with less calorie intake for the remainder of the day compared to carrot juice or a carrot juice cocktail that contained all the nutrients in carrots (Moorhead, 2006).

Mourao et al. (2007) investigated the independent effect of food form on appetite and energy intake in lean and obese adults using high carbohydrate, fat, or protein food stimuli. Treatments were matched beverage and solid food forms: high carbohydrate (watermelon and watermelon juice); high protein (cheese and milk); and high fat (coconut meat and coconut milk). Participants consumed the entire test food as part of an *ad libitum* meal. Regardless of the predominant energy source, the beverage form elicited a weaker compensatory dietary response than the matched solid food form. The authors concluded that inclusion of a caloric beverage in a lunch meal led to greater daily energy intake compared to customary intake or days where a solid version of the same food was ingested. This occurred regardless of the primary energy source, and there was no clear indication that the lean and obese differ in this regard.

Stull et al. (2008) assessed the effect of liquid versus solid meal replacements on appetite and subsequent food intake in healthy older adults. After an overnight fast, participants consumed meal replacement products as either a liquid or as a solid (bar) followed by *ad libitum* oatmeal. Participants consumed more calories from oatmeal after the liquid versus solid meal replacement product.

Other studies suggest that food form may affect food intake, although inconsistent study designs make it difficult to compare results. DiMeglio and Mattes (2000) examined the differential effects of matched liquid (soda) and solid (jelly beans) carbohydrate loads on diet and body weight. Participants were assigned to one of two dietary load conditions (solid: 450 kcal serving of jelly beans; liquid: 450 kcal serving of caffeine-free soda) for 4 weeks, followed by a 4 week washout period and subsequent participation in the other condition for 4 weeks. During the solid load condition, participants compensated for some of the energy in the test foods by reducing free-feeding intake such that the overall compensation score was 118 percent. However, when the liquid load was included in the diet, no compensation was observed, resulting in a compensation score of -17 percent. The authors concluded that liquid carbohydrate promotes positive energy balance, whereas a comparable solid carbohydrate elicits dietary compensation; further, body weight and BMI increased only with the liquid load.

In contrast, both Mattes and Campbell (2009) and Almiron-Roig et al. (2004) found no differences in subsequent food intake when they compared solid food to liquids in studies well controlled for macronutrients and calories. Mattes and Campbell (2009) assessed the effects of apple food form (apple, applesauce, apple juice) and timing of eating events (meal or snack) on appetite and daily energy intake. There were no treatment effects on daily energy intake.

Almiron-Roig et al. (2004) compared the impact on energy intakes of equal-energy preloads (300 kcal) of regular cola or fat-free cookies presented either 2 hours or 20 minutes before a tray lunch. Liquid or solid form had no impact on energy intakes during the test meal. Similarly, physical form had no effect when the sum of the energy intake of breakfast, preload, and lunch was considered.

In another crossover trial (Tsuchiya, 2006) participants consumed 200 kilocalorie preloads: semisolid peach yogurt with peach pieces, peach yogurt homogenized to liquid form, peach syrup and water, or a milk-based peach and apricot beverage followed by an *ad libitum* lunch. No significant differences in energy intakes were detected across the four conditions, either for lunch alone or for total energy consumed from breakfast, preload, and lunch.

Liquids in soup may have different effects as studies find that daily soup consumers have lower daily energy intake than those who consume little soup (Bertrais, 2001), and soup pre-loads reduce food intake at a subsequent meal (Flood, 2007). Rolls et al. (2005) tested the effect on weight loss of a diet incorporating one or two servings per day of foods equal in energy but differing in energy density. Participants followed an energy-restricted diet in a 1-year trial (6-month weight loss and 6-month weight maintenance); participants were randomized to one of four intervention groups. Participants were instructed to consume daily: one serving of soup, two servings of soup, or two servings of dry snack foods. Participants in the fourth group were not provided with any specific food to consume (comparison group). There were no significant differences in reported energy intake among the intervention groups at any time points. All four groups showed significant weight loss at 6 months that was well maintained at 12 months. The magnitude of weight loss, however, differed by group. At 1 year, weight loss in the comparison (8.1 ± 1.1 kg) and two-soup (7.2 ± 0.9 kg) groups was significantly greater than that in the two-snack group (4.8 ± 0.7 kg); weight loss in the one-soup group (6.1 ± 1.1 kg) did not differ significantly from other groups. The authors concluded that on an energy-restricted diet, consuming two servings of low energy-dense soup daily led to 50 percent greater weight loss than consuming the same amount of energy as high energy-dense snack food.

When macronutrient content of a liquid food and a solid food is balanced, there are few data that food form affects energy intake. These studies are difficult to design and conduct as the form of the food cannot be blinded (i.e., participants know that they are eating apples or drinking apple juice). In the acute studies of food intake, efforts are made to control variables, including the time allowed to consume the test food, but it is difficult to generalize these results to the eating environment of real life.

Food structure may play a role in food intake. Whole foods, such as apples and carrots, play a role in satiety and decrease food intake at a subsequent meal. When a non-viscous fiber was added to apple juice, the fiber-enriched apple juice was not as effective as the apple in reducing food intake at a subsequent meal. Thus, factors besides the fiber in whole foods may affect energy intake, including food structure and chewing.

The data with soup as a preload are often in conflict with other data on liquid calories. In a 1-year weight loss trial, consumption of two servings of soup per day led to greater weight loss than consuming the same amount of energy from two snack foods. Soup preload significantly reduced test meal and total meal energy intake in one study. Thus, the studies with soup as a liquid calorie source suggest that specific liquid calories can be an aid to weight loss and that liquid calories from soup result in reduced intake at a subsequent meal.

Question 8: What Is the Role of Carbohydrate, Fiber, Protein, Fat, and Food Form on Satiety?

Conclusion

Many factors affect satiety and most studies are conducted in laboratory settings to control for variables. Thus results may not be generalized to the more complicated eating environment of the outside world. Foods high in dietary fiber generally are more satiating than low fiber foods, although some fibers added to drinks have little impact on satiety. Overall, small changes in the macronutrient content of the diet do not significantly alter satiety.

Implications

Intakes of caloric preloads, whether carbohydrate, protein, or fat, typically increase satiety. Protein and carbohydrate may be more satiating than fat, although studies are not consistent. Dietary fiber, especially from whole foods, appears to enhance satiety in studies. Not all fibers added to beverages or foods are equally satiating. In fact, some functional fibers show no effect on satiety.

Review of the Evidence

Background

Satiation and satiety are part of the body's appetite control system and are involved in limiting energy intake. Benelam (2009) summarized satiation, satiety, and their effects on eating behavior in an extensive literature review. Satiation is the process that causes one to stop eating, while satiety is the feeling of fullness that persists after eating, suppressing further consumption. Satiation and satiety are controlled by a cascade of factors that begin when a food is consumed and continues as it enters the gastrointestinal tract and is digested and absorbed. As food moves down the digestive tract, signals are sent to the brain, and gut hormones are produced that affect energy balance in a variety of ways, including slowing gastric emptying, acting as neurotransmitters, and reducing gastrointestinal secretions. These effects are proposed to influence satiety. The terms satiety and satiation are often used differently in the literature and many methods to measure each exist.

Interest in satiety and its role in obesity prevention are great, so the 2010 DGAC examined satiety's relationship between carbohydrate, fiber, protein, and fat using a non-NEL literature review.

The most common study design for satiety studies uses a test preload in which variables of interest are carefully controlled. Generally, participants rate aspects of their appetite sensations, such as fullness or hunger, at intervals and then, after a predetermined time interval, a test meal at which energy intake is measured. Longer-term studies typically provide foods or drinks of known composition to be consumed *ad libitum* and use measures of energy intake and/or appetite ratings as indicators of satiety. Satiety tests are often conducted with liquids where differences in macronutrient content are more easily formulated. Other studies use muffins or bars. However, it is difficult to formulate and blind products that vary greatly in the content of fiber, protein, fat, and carbohydrate.

Measurement of satiety is complicated because many internal signals also influence appetite, such as bodyweight, age, sex, habitual diet, exercise, and dietary restraint. These acute studies are typically done in laboratory settings where variables can be controlled. It is extremely difficult to conduct satiety studies in free-living individuals, so most studies are conducted in a laboratory setting. Usually visual analogue scales are used to monitor hunger, fullness, and motivation to eat. Studying the effects of one variable in food or drink while keeping others constant is inherently difficult, especially if researchers do not want the differences to be obvious to participants. Adding fiber to foods decreases energy density and often palatability, both of which can affect satiety (Slavin and Green, 2007).

External factors that affect satiety include palatability, variety, portion size, sleep, physical activity, television viewing and other distractions, and social situations (Benelam, 2009).

Macronutrients have no consistent differences in satiety, although general statements are often given that protein is most satiating, followed by carbohydrate, and then fat. Recent studies on the relationship between macronutrients, fiber, and satiety are summarized below.

Carbohydrate and Satiety

The carbohydrate content of foods and drinks is diverse and includes digestible carbohydrates and fiber. In the 1950s, the glucostatic theory of appetite regulation was developed by Mayer (1953), who hypothesized that blood glucose levels determined appetite, initiating energy intake when low and causing satiety when increased. Glucose levels do affect satiety and thus intake of calories as carbohydrate must be controlled and balanced in satiety studies.

Both glucose and fructose preloads have been found to reduce subsequent energy intake and no consistent differences are found when comparing the two (Anderson, 2003). A number of studies have investigated whether drinks sweetened with HFCS compared with sucrose have different effects on satiety, and a significant difference between the two types of sweetener has not been found (Soenen, 2007). Alfenas and Mattes (2005) concluded that under controlled conditions, the glycemic index of foods does not affect satiety or energy intake. RCTs comparing low and high glycemic index diets find no differences in weight loss (Aston et al., 2008; Das et al., 2007).

Fiber and Satiety

Fiber includes a wide range of compounds and although fiber generally affects satiety, not all fibers are equally effective in changing satiety (Slavin and Green, 2007). Typically a large dose of fiber is required, such as 10 grams or more in a serving of food (an amount not naturally occurring in a single serving of food). Viscous fibers, such as guar gum, oat bran, and psyllium, are generally more effective, although insoluble fibers that survive gut transit, such as wheat bran and cellulose, also are known to alter satiety.

Willis et al. (2009) compared the satiety response when four different muffins were fed at breakfast. Resistant starch and corn bran had the most positive impact on satiety, whereas polydextrose had little effect and behaved like the low-fiber muffin. Generally, whole foods that naturally contain fiber are satiating. Flood-Obbagy and Rolls (2009) compared the effect of fruit in different forms on energy intake and satiety at a meal. Results showed that eating apple reduced lunch energy intake by 15 percent compared to control. Fullness ratings differed significantly after preload consumption, with apple being the most satiating, followed by applesauce, then apple juice, then the control food. The addition of a pectin fiber to the apple juice did not alter satiety.

Other fibers added to drinks do change satiety. Pelkman et al. (2007) added low doses of a gelling pectin-alginate fiber to drinks and measured satiety. The drinks were consumed twice a day over 7 days and energy intake at the evening meal was recorded. The 2.8 gram dose of pectin alginate caused a decrease of 10 percent in energy intake at the evening meal. Thus, it generally found that high-fiber foods are more satiating and that certain isolated fibers affect satiety while others are not effective. Clinical studies are needed to assess the effectiveness of isolated fibers on satiety as there are no measures of fiber chemistry (solubility, structure, etc.) that can predict fiber's effect on satiety.

Protein and Satiety

It is generally accepted that at sufficiently high levels, protein has a stronger effect on satiety than equivalent quantities of energy from carbohydrate or fat. Differences in study design make it difficult to pinpoint the optimum dose or percentage of energy needed to observe significant effects of protein on satiety. Anderson and Moore (2004) suggest that at least 50 grams of protein in a food or meal is necessary to see a significant effect on satiety, but note that information is insufficient to describe a dose-response relationship.

Other factors have been considered as potential mechanisms for protein's effect on satiety. Westerterp-Plantenga et al. (2007) described the relationship between diet-induced thermogenesis and satiety. Additionally, the role of ketosis as an explanation for the satiating effect of protein has been offered, although studies find inconsistent results for fullness and prospective food consumption when low and high protein diets are compared (Johnstone, 2008).

Fat and Satiety

Dietary fat affects satiety by slowing gastric emptying, stimulating the release of satiating gut hormones and suppressing the release of ghrelin (Little et al., 2007). Still, most reviews find that the effect of fat on satiety is weaker than that of either protein or carbohydrate (Benelam, 2009). Bell and Rolls (2001) compared the effects of meals containing different amounts of fat that were matched at different levels of energy density. When energy density was matched, the fat content of the diets did not affect energy intake, indicating that it was the energy density and not the fat content that influences satiety. In free-living individuals, high-fat foods have a higher energy density than high-protein or high-carbohydrate foods. The palatability of high-fat foods also may contribute to overconsumption of calories.

Food Form and Satiety

The physiological effects of solids versus liquids are covered in Question 7, but the satiety effects of liquid diets will be described here. Overall, inconsistent evidence suggests that energy from liquids is less satiating than energy from solids (Benelam, 2009). Soups appear to have a particularly satiating effect, which may be due to their lower energy density. Mattes (2005) has suggested that soups are seen as part of a meal and consumed in response to hunger, compared with drinks, which are consumed to address thirst or to accompany foods. The impact of intense sweeteners on satiety and energy intake, as reviewed by Drewnowski and Bellisle (2007), is mixed, with some studies finding increases in appetite and/or energy intake, some decreases, but most finding no significant effects. Differences in study design make it difficult to reach any overall conclusions about the effect of intense sweeteners on satiety, but it seems that intense sweeteners do not enhance satiety.

Thus, many factors affect satiety and most studies are conducted in laboratory settings to control for variables. Therefore, results may not be generalized to the more complicated eating environment of the outside world. Foods high in dietary fiber generally are more satiating than low-fiber foods, although some fibers added to drinks have little impact on satiety. Overall, small changes in the macronutrient content of the diet are unlikely to significantly alter satiety.

Question 9: What Is the Role of Prebiotics and Probiotics in Health?

Conclusion

Gut microflora play a role in health, although the research in this area is still developing. Foods high in prebiotics (wheat, onions, garlic) may be consumed, as well as food concentrated in probiotics (yogurt), within accepted dietary patterns.

Implications

The lack of epidemiologic studies that support a role for changes in gut microflora and health outcomes limits any specific dietary recommendations in this area. Foods high in prebiotics and probiotics are linked to health benefits. For example, fiber is a prebiotic linked to health benefits. Many probiotic-containing foods, such as dairy foods, also are linked to health benefits and are recommended for inclusion in the diet.

Review of the Evidence

Evidence that the intestinal microbiota is linked with overall health is emerging (Davis, 2009b). The adult human gut contains 100 trillion microbial organisms, which are referred to as the microbiota. Although the importance of the microbiota has been accepted for diseases of the large intestine, it is now thought that the microbiota play a role in obesity control and other chronic diseases such as autism. Because of these new ideas, consumer interest in altering the microbiota is high.

Prebiotics are defined as “a non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon, and thus improves host health” (De Vrese, 2008). Oligosaccharides such as fructo-oligosaccharides and galacto-oligosaccharides are generally accepted as prebiotics and are often added to infant formula and other food products.

Probiotics are defined viable microorganisms, sufficient amounts of which reach the intestine in an active state and thus exert positive health effects (De Vrese, 2008). Synbiotics are combinations of both probiotics and prebiotics. The idea to suppress and displace harmful bacteria in the intestine by orally administered “beneficial” ones and thus improve microbial balance, health, and longevity has been around for more than a century. Tissier (1906) recommended the administration of bifidobacteria to infants suffering from diarrhea, claiming that bifidobacteria supersede the putrefactive bacteria causing the disease. He showed the bifidobacteria were predominant in the gut of breast-fed infants, the rationale for adding prebiotics to infant formula. Nobel Prize winner Elie Metchnikoff (1907) also suggested that intake of lactobacilli-containing yogurt results in reduction of toxin-producing bacteria in the gut which increased longevity in the host.

For this review, we completed a non-NEL review since 2004 of systematic reviews on prebiotics and probiotics and health. We conclude that the importance of the gut microbiota is an important emerging area of research, but not enough research is available to make dietary recommendations for either prebiotics or probiotics. All prebiotics are dietary fibers, but not all dietary fibers are prebiotics. Recommended intakes of dietary fiber can provide prebiotics to the diet. Also, recommended foods, such as yogurt, are probiotics, so by observing guidelines for dairy food consumption and picking yogurt or other fermented dairy products, probiotics will be included in the diet.

Some of the proposed health benefits of prebiotics and probiotics include reduction in diarrhea incidence, improvements in gut health, elimination of allergies, and prevention of infections. It is accepted that the gut microflora have a potential role in immune function, but studies showing an improvement in immunity with consumption of either prebiotics or probiotics are limited. Despite the continued interest in enhancing the gut environment, there are no cohort studies where fecal samples have been collected and higher levels of bifidobacteria or lactobacillus in feces linked to improved health status.

A systematic review of randomized controlled trials evaluating the relationship between probiotics and constipation concluded that until more data are available, the use of probiotics for the treatment of constipation should be considered investigational (Chmielewska and Szajerska, 2010). Probiotics may play a role in preventing and treating acute diarrhea in both children and adults, although results are inconsistent (Cummings, 2009). A systematic review and meta-analysis of probiotics in the treatment of irritable bowel syndrome found that probiotics could potentially play a role in irritable bowel syndrome treatment, but results of trials are inconsistent and many questions remain on the type of probiotics, dose, and whether certain subgroups of patients are more likely to benefit from probiotics (Hoveyda, 2009).

The effect of prebiotics on immune function, infection, and inflammation was reviewed (Lomax and Calder, 2009a). Again, results are mixed in human trials. Ten trials involving infants and children have mostly reported benefits on infectious outcomes, while in 15 adult trials, little effect was seen. A similar review was conducted on probiotics (Lomax and Calder, 2009b). Overall, the data are mixed with large species and strain differences of probiotic treatments influencing results.

Thus, the DGAC believes that the gut microbiota do play a role in health, although the research in this area is still developing. No recommendations for intake of prebiotics or probiotics for the American people can be made, although foods high in prebiotics (wheat, onions, garlic) should be consumed, as well as food concentrated in probiotic (yogurt).

Chapter Summary

Healthy diets are high in carbohydrates. AMDR for carbohydrates are 45 to 65 percent from carbohydrates. A maximal intake level of 25 percent or less of total energy from added sugars is suggested, based on trends indicating that people with diets at or above this level of added sugars are more likely to have poorer intakes of important essential nutrients. Active Americans should consume diets at the high end of the AMDR range (65%) while Americans on low calorie diets will need to consume diets at the low end of the range (45%). Usually proteins will replace carbohydrate on low calorie diets.

Americans should choose fiber-rich foods such as whole grains, vegetables, fruits, and cooked dry beans and peas as staples in the diet. Dairy products are also a nutrient-dense source of carbohydrates in the diet and provide high quality protein, vitamins, and minerals.

Carbohydrates are the primary energy source for active people. Sedentary people, including most Americans, should decrease consumption of caloric carbohydrates to balance energy needs and attain and maintain ideal weight. The high-energy, non-nutrient-dense carbohydrate sources that should be reduced to aid in calorie control include SSB, desserts, including grain-based desserts, grain products, and other carbohydrate foods and drinks that are non-nutrient-dense.

Needs for Future Research

1. Develop and validate carbohydrate assessment methods. Explore and validate new and emerging biomarkers to elucidate alternative mechanisms and explanations for observed effects of carbohydrates on health.

   Rationale: Studies of carbohydrates and health outcomes on a macronutrient level are often inconsistent or ambiguous due to inaccurate measures and varying food categorizations and definitions. The science cannot progress without further advances in both methodology and theory.

2. Develop definitions for whole grain foods and criteria for whole grain foods that can be universally accepted.

   Rationale: At present, there is no consistent way that whole grain foods are defined and determined. Without clear definitions for whole grain foods, it is difficult to compare research studies examining the effectiveness of various whole grains on biomarkers of interest in CVD, diabetes, and obesity. Clear definitions would also help consumers identify foods that can help them meet the *Dietary Guidelines* recommendation.

3. Conduct intervention and research studies with strong designs that include sufficient sample sizes over time and specific measures of vegetable and fruit intake, including specific types of vegetables and fruits, overall dietary patterns, exercise, sex, and other confounding factors to evaluate the impact of consuming vegetables and fruits on health.

   Rationale: Rigorous methods of assessing dietary intake are needed along with rigorous measures of outcomes. Strong designs that control for confounding variables will provide deeper insight into the effect vegetables and fruits have on health. Plausible mechanisms for these effects also need to be studied in depth. Traditional markers, such as blood lipids, while useful for risk factor assessment, appear to have limited explanatory value.

4. Conduct long-term, randomized controlled trials to resolve whether use of nonnutritive sweeteners can actually aid weight loss or prevent weight gain.

   Rationale: Currently available data are insufficient to recommend non-nutritive sweeteners as an aid to weight loss, except on a theoretical basis for calorie reduction.

5. Develop standardized assessment tools to determine accurate intake of added sugars.

   Rationale: This is challenging because carbohydrate methods are also limited as total carbohydrate is measured "by difference." Unless efforts are made to define and measure carbohydrates and carbohydrate fractions with potential health benefits, it will be difficult to determine if different carbohydrates types have different health effects.

6. Develop innovative methods to evaluate "food form" as a variable in food intake studies for the field to progress.

   Rationale: Unless macronutrients are carefully controlled, it is not possible to answer the question on how food form affects energy intake. These questions will remain unless RCTs are conducted that measure differences in exposure to different carbohydrates (glucose, fructose, sucrose) and different forms (liquid, solid, whole food).

7. Develop methods for use in epidemiologic studies to measure accurately or quantify intake of liquids, either caloric or non-caloric.

   Rationale: There has been an increase in the number of beverages available, and it would be valuable to know how these beverages are contributing to satiety, energy intake, and body weight. Drinks can include a wide range of macronutrients and artificial sweeteners, and are difficult to assess with food frequency instruments. The type of drinks consumed now includes sport drinks, designer coffees and teas, smoothies and juices, and carbonated beverage with different sugars or artificial sweeteners.

8. Determine whether the effects of vegetables and fruits in the overall dietary pattern are due to displacement of other foods in the diet or to the action of vegetables and fruits per se on specific health outcomes.

   Rationale: The mechanism(s) of action for the effects of vegetables and fruits have not been determined and, therefore, may vary for different health outcomes. The observed effects could be a simple displacement of these foods with other foods that cause poorer outcomes or vegetables and fruits may contribute specific benefits or a combination of the above may explain the observations made thus far in the literature. Only further research can provide more definitive answers.

9. Identify whether a progressive, inverse relationship of fruits and vegetable consumption exists with the prevention of chronic disease(s) or whether there is a threshold effect that may vary depending on factors such as disease, sex, and dietary pattern.

   Rationale: The evidence suggests that there may be a threshold effect of vegetables and fruits, at least within the American dietary pattern, but further research is needed to verify this hypothesis and to test whether the threshold varies among a variety of dietary patterns and/or among the specific variety of vegetables and fruits consumed.

Table D5.2. Vegetables,[1] fruits,[1] pulses (legumes), nuts, seeds, herbs, spices, and the risk of cancer.
In the judgment of the Panel, the factors listed below modify the risk of cancer. Judgments are graded according to the strength of the evidence.

	Decreases Risk	Decreases Risk	Increases Risk	Increases Risk
	Exposure	**Cancer site**	**Exposure**	**Cancer site**
Convincing				
Probable	**Non-starchy vegetables[1]**	**Mouth, pharynx, larynx Oesophagus Stomach**		
	Allium vegetables[1]	**Stomach**		
	Garlic[1]	**Colorectum**		
	Fruits[1]	**Mouth, pharynx, larynx Oesophagus Lung Stomach**		
	Foods containing folate[2]	**Pancreas**		
	Foods containing carotenoids[2]	**Mouth, pharynx, larynx Lung**		
	Foods containing beta-carotene[2]	**Oesophagus**		
	Foods containing lycopene[2 3]	**Prostate**		
	Foods containing Vitamin C[2 4]	**Oesophagus**		
	Foods containing selenium[2 5]	**Prostate**		
Limited—suggestive	Non-starchy vegetables[1]	Nasopharynx Lung Colorectum Ovary Endometrium	Chilli[1]	Stomach
	Carrots[1]	Cervix		
	Fruits[1]	Nasopharynx Pancreas Liver Colorectum		
	Pulses (legumes)[7]	Stomach Prostate		
	Foods containing folate[2]	Oesophagus Colorectum		
	Foods containing pyridoxine[2 8]	Oesophagus		
	Foods containing vitamin E[2 6]	Oesophagus Prostate		

Table D5.2 (continued). Vegetables,[1] fruits,[1] pulses (legumes), nuts, seeds, herbs, spices, and the risk of cancer. In the judgment of the Panel, the factors listed below modify the risk of cancer. Judgments are graded according to the strength of the evidence.

	Decreases Risk	Decreases Risk	Increases Risk	Increases Risk
	Exposure	**Cancer site**	**Exposure**	**Cancer site**
Convincing				
	Foods containing selenium[2 5]	Lung Stomach Colorectum		
	Foods containing quercetin[2]	Lung		
Substantial effect on risk unlikely	Foods containing beta-carotene[9]: prostate; skin (non-melanoma)			

[1]Judgements on vegetables and fruits do not include those preserved by salting and/or pickling.
[2]Includes both foods naturally containing the constituent and foods which have the constituent added (see chapter 3.5.3).
[3]Mostly contained in tomatoes and tomato products. Also fruits such as grapefruit, watermelon, guava, and apricot.
[4]Also found in some roots and tubers—notably potatoes. See chapter 4.1.
[5]Also found in cereals (grains) and in some animal foods. See chapters 4.1 and 4.3.
[6]Also found in plant seed oils. See chapter 4.5.
[7]Including soya and soya products.
[8]Vitamin B6. Also found in cereals. See chapter 4.1.
[9]The evidence is derived from studies using supplements and foods containing beta-carotene: see chapter 4.10.
For an explanation of all the terms used in the matrix, please see chapter 3.5.1, the text of this section, and the Glossary.
Source: World Cancer Research Fund/American Institute for Cancer Research. Food, Nutrition, Physical Activity, and the Prevention of Cancer: a Global Perspective, Washington, DC: AICR 2007.

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Part D. Section 6: Sodium, Potassium, and Water

Introduction

Dietary intakes of sodium, potassium, and water have substantial health effects. Excessive sodium intake, especially when accompanied by inadequate potassium intake, raises blood pressure, a well-accepted and extraordinarily common risk factor for stroke, coronary heart disease, and kidney disease (see below for background information on the problem of elevated blood pressure and its control). Adverse effects of sodium on blood pressure appear to begin early in life. Because of worsening blood pressure levels in children in the United States (U.S.), the 2010 Dietary Guidelines Advisory Committee (DGAC) decided to evaluate available research on the health effects of sodium in children, as well as update the 2005 DGAC's review of research on the health effects of sodium in adults. Inadequate potassium intake raises blood pressure and increases the blood pressure response to excess sodium intake.

In addition to their effects on blood pressure, excessive sodium and insufficient potassium likely have other health consequences. Excess sodium intake has been linked to an increased incidence of gastric cancer. Inadequate potassium intake may increase the risk of kidney stones and perhaps osteoporosis. Americans consume excessive sodium and insufficient potassium across the lifespan.

Water is the single largest constituent of the human body and is required to maintain adequate hydration. In the U.S., water intake appears adequate, without evidence of chronic insufficient or excessive intake.

List of Questions

SODIUM

1. What are the effects of sodium intake on blood pressure in children and in adults?

POTASSIUM

2. What are the effects of potassium intake on blood pressure in adults?

WATER

3. What amount of water is recommended for health?

Methodology

The 2005 DGAC based its conclusions regarding these questions on evidence extracted from *Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate*, an extensive, systematic review of the scientific literature conducted by an expert panel for the Institute of Medicine (IOM) (IOM, 2005). The conclusions expressed in the 2010 DGAC Report are based on that evidence plus subsequent evidence, especially regarding diet and blood pressure in children. Thus, while the vast majority of research on the health effects of sodium, potassium, and water on adults was published before 2005 and synthesized in the 2005 Report, this 2010 Report builds upon those findings and adds relevant new literature from updated searches. Additional information about the search strategies and criteria used to review each question can be found online in the Nutrition Evidence Library (NEL) at www.NutritionEvidenceLibrary.gov. The new focus involves considerably more effort in reviewing the emerging and growing evidence on the blood pressure effects of sodium in children. The overall search strategies used to identify relevant literature and update scientific evidence appear in *Part C. Methodology*.

The following conversions may be useful:

- 2300 milligrams of sodium is equivalent to 100 millimoles of sodium and is the amount of sodium in 5.84 grams of salt (sodium chloride), about 1 teaspoon of table salt; and,
- 1500 milligrams of sodium is equivalent to 65 millimoles of sodium and is the amount of sodium

in 3.8 grams of salt (sodium chloride), about 2/3 teaspoon of table salt.

Question 1: What Is the Effect of Sodium Intake on Blood Pressure in Children and in Adults?

Conclusion

A strong body of evidence has documented that in adults, as sodium intake decreases, so does blood pressure. A moderate body of evidence has documented that as sodium intake decreases, so does blood pressure in children, birth to 18 years of age.

Implications

The projected health benefits of a reduced sodium intake are substantial and include fewer strokes, cardiovascular disease events, and deaths, as well as substantially reduced health care costs. In view of these potential benefits and the current very high intake of sodium in the general population, children and adults should lower their sodium intake as much as possible by consuming fewer processed foods that are high in sodium, and by using little or no salt when preparing or eating foods.

The current food supply is replete with excess sodium. Many foods contribute to the high intake of sodium. While some foods are extremely high in sodium, the problem of excess sodium reflects frequent consumption of foods that are only moderately high in sodium. The major sources of sodium intake among the U.S. population are yeast breads; chicken and chicken mixed dishes; pizza; pasta and pasta dishes; cold cuts; condiments; Mexican mixed dishes; sausage, franks, bacon, and ribs; regular cheese; grain-based desserts; soups; and beef and beef mixed dishes (National Cancer Institute [NCI], 2010a). Collectively, this group of foods contributes about 56 percent of the dietary sodium, or nearly 2000 milligrams per person per day.

A major new concern is the excessive sodium added to products such as poultry, pork, and fish through injections or marination; efforts to quantify the amount of sodium from this type of processing are warranted. Finally, an important determinant of sodium intake is calorie intake. Hence, efforts to reduce calorie intake should also lower sodium intake.

In 2005, the DGAC recommended a daily sodium intake of less than 2300 milligrams for the general adult population and stated that hypertensive individuals, Blacks, and middle-aged and older adults would benefit from reducing their sodium intake even further. Because these latter groups together now comprise nearly 70 percent of U.S. adults, the goal should be 1500 milligrams per day for the general population. Given the current U.S. marketplace and the resulting excessively high sodium intake, it will be challenging to achieve the lower level. In addition, time is required to adjust taste perception in the general population. Thus, the reduction from 2300 milligrams to 1500 milligrams per day should occur gradually over time. A recent IOM report (IOM Report, 2010) provided a roadmap to achieve gradual reductions in sodium intake. Because early stages of blood pressure-related atherosclerotic disease begin during childhood, both children and adults should reduce their sodium intake. Individuals should also increase their consumption of dietary potassium because increased potassium intakes helps to attenuate the effects of sodium on blood pressure.

Sodium Recommendations of Scientific and Public Health Agencies and Organizations

Numerous policymaking national agencies and professional public health organizations have recommended a reduced sodium intake as a means to lower blood pressure in the general adult population. In the United States, the National High Blood Pressure Education Program set a sodium intake goal of 2300 milligrams (100 mmol) per day as a means to prevent hypertension in non-hypertensive individuals (Whelton, 2002) and as first line and adjuvant therapy in hypertensive individuals (Chobanian, 2003). In 2009, the American Society of Hypertension adopted prior American Heart Association guidelines that called for an upper limit of intake of 2300 milligrams per day (Appel, 2009). In early 2010, the American Heart Association lowered its recommended goal to no more than 1500 milligrams per day in adults (Lloyd-Jones, 2010). The current Canadian recommendation is less than 2300 milligrams of sodium per day; a new policy is expected in June 2010. In Great Britain, the Scientific Advisory Committee on Nutrition in 2003 conducted an independent review of available evidence and set an upper limit of 2400 milligrams of sodium (6 g of salt) per day. In its report, *Diet, Nutrition and the Prevention of Chronic Diseases*, the World Health Organization (WHO) (2003), set an upper limit of 1600 milligrams (70 mmol) of sodium per day as a means to lower blood pressure.

Several U.S. public health agencies and two international organizations have established separate sodium recommendations for children. Generally, these recommendations are consistent with either the IOM Dietary Reference Intakes (DRI), Adequate Intake (AI), or Tolerable Upper Intake Level (UL) for sodium, and range by age from 400 milligrams for ages 1 to 3 years to 2300 milligrams for ages 14 years and older.

Table D6.1. Sodium recommendations of scientific and public health agencies and organizations

Organizations	Date Published	Sodium Recommendation
United States		
Adults		
American Heart Association	2010	Sodium: <1500 mg per day for adults; The recommendation for 1500 mg/d does not apply to individuals who lose large volumes of sodium in sweat, such as competitive athletes and workers exposed to extreme heat stress (e.g., foundry workers and fire fighters), or to those directed otherwise by their healthcare provider (Lloyd-Jones, 2010). Web reference (accessed 23 March 2010): http://circ.ahajournals.org/cgi/content/full/112/13/2061
American Society of Hypertension	2009	Lower sodium intake as much as possible, with a goal of no more than 2300 mg/d in the general population and no more than 1500 mg/d in Blacks, middle- and older-aged persons, and individuals with hypertension, diabetes, or chronic kidney disease (Appel, 2009). Web reference (accessed 23 March 2010): http://www.ash-us.org/assets-new/pub/pdf_files/DietaryApproachesLowerBP.pdf
National High Blood Pressure Education Program	2002; 2003	Reduce dietary sodium intake to no more than 100 mmol per day (2300 mg sodium or 6 g sodium chloride) as a means to prevent hypertension in non-hypertensive individuals (Whelton et al., 2002) and as first line and adjuvant therapy in hypertensive individuals (Chobanian, 2003). Web reference (accessed 23 March 2010): http://www.nhlbi.nih.gov/guidelines/hypertension/express.pdf
Children		
American Academy of Pediatrics	2006	Adopted American Heart Association Position. Sodium recommendation by age: 1-3 yrs <1500 mg; 4-8 yrs <1900 mg; 9-13 yrs <2200 mg; 14-18 yrs <2300 mg (AHA/Gidding et al., 2006). Web reference (accessed 9 March 2010): http://pediatrics.aappublications.org/cgi/content/full/117/2/544
American Dietetic Association	2008	The current recommendation for adequate daily sodium intake for children 4-8 yrs is 1200 mg/day and for older children 1500 mg/day (ADA, 2008). http://www.adajournal.org/article/S0002-8223(08)00496-3/abstract
American Heart Association	2005	Based on *Dietary Guidelines for Americans*, 2005/ IOM DRI Sodium UL by age: 1-3 yrs <1500 mg; 4-8 yrs <1900 mg; 9-13 yrs <2200 mg; 14-18 yrs <2300 mg (Gidding et al., 2005). Web reference (accessed 23 March 2010): http://circ.ahajournals.org/cgi/content/full/112/13/2061
International		
Adults or Mixed Populations		
Australia and New Zealand	2005	Recommends that Australian adults consume less than 2300 mg of sodium per day (NHMRC, 2005). Web reference (accessed 9 March 2010): http://www.nhmrc.gov.au/_files_nhmrc/file/publications/synopses/n36.pdf

Table D6.1 (continued). Sodium recommendations of scientific and public health agencies and organizations

Organizations	Date Published	Sodium Recommendation
International		
Adults or Mixed Populations		
Canada	2006	Current Health Canada statement is based on IOM DRI Report: People 14 yrs and older not exceed 2300 mg of sodium per day. Adequate Intakes (AIs) for good health range from 1000 mg/d sodium for people 1-3 yrs to 1500 mg/d for people 9-50 yrs. Sodium Reduction Working Group policy update expected in June 2010 (Health Canada, 2005). Web reference (accessed 9 March 2010): http://www.hc-sc.gc.ca/fn-an/nutrition/sodium/index-eng.php
European Union	2004	EU Framework for Salt Reduction incorporates WHO/FAO recommendation for reducing dietary salt intake to <5-6 g per day (2000-2300 mg/d); 21 of 30 nations directly adopted recommendation, 5 countries adopted a higher interim goal or range, 4 countries reported no dietary sodium guidance (EU, 2009). Web reference (accessed 9 March 2010): http://ec.europa.eu/health/archive/ph_determinants/life_style/nutrition/documents/national_salt_en.pdf
Food and Agriculture Organization (FAO)	2003	Population nutrient intake goals for preventing diet-related chronic diseases, Sodium chloride (sodium) <5 g per day (Sodium <2000 mg per day) (FAO, 2003). Web reference (accessed 9 March 2010): http://www.fao.org/docrep/005/AC911E/ac911e07.htm
Pan American Health Organization (PAHO)	2009	Member nations (n=46) acknowledged WHO/FAO recommendation to reduce dietary sodium intake to <2000 mg per day for cardiovascular disease prevention through dietary salt reduction (PAHO, 2009). Web reference (accessed 9 March 2010): http://new.paho.org/hq/index.php?option=com_content&task=view&id=2015&Itemid=1757
United Kingdom	2003	Food Standards Agency set a target to reduce the adult population’s average salt intake to 6g (sodium 2300 mg) per day by 2010 (UK, 2009). Web reference (accessed 9 March 2010): http://www.food.gov.uk/healthiereating/salt/salttimeline
World Health Organization	2003	Set an upper limit of 70 mmol (1700 mg) of sodium per day as a means to lower blood pressure. All individuals should be strongly encouraged to reduce daily salt intake by at least one-third and, if possible, to <5 g or <90 mmol per day (WHO, 2003). Web reference (accessed 9 March 2010): http://www.who.int/cardiovascular_diseases/guidelines/PocketGL.ENGLISH.AFR-D-E.rev1.pdf
Children		
Canada	2006	Adequate Intakes (AIs) of sodium for good health for people aged one year and over range from 1000 mg/day for children 1-3 yrs to 1500 mg/day for people 9 yrs and older (Health Canada, 2006). Web reference (accessed 9 March 2010): http://www.hc-sc.gc.ca/fn-an/nutrition/sodium/index-eng.php

Table D6.1 (continued). Sodium recommendations of scientific and public health agencies and organizations

Organizations	Date Published	Sodium Recommendation
United Kingdom	2003	The Food Standards Agency issues advice for parents on amounts of salt infants and children should consume: Children: 0-6 months <1 g (400 mg sodium); 6-12 months - 1g (400 mg sodium); 1-3 yrs - 2g/day (800 mg sodium); 4-6 yrs - 3 g/day (1200 mg sodium); 7-10 yrs - 5/g day (2000 mg sodium); 11-14 yrs - 6 g/day (2400 mg sodium) (UK, 2009). Web reference (accessed 9 March 2010): http://www.food.gov.uk/scotland/aboutus_scotland/pressreleases/2003/may/121253

Review of the Evidence: Sodium Intake and Blood Pressure in Children

Background

In the U.S. and most other countries, blood pressure slowly rises with age. The age-related increase in blood pressure begins early in childhood and increases thereafter. The annual increase during childhood is actually greater than during adult life, increasing 1.9 millimeters of mercury (mmHg) per year for boys, and 1.5 mmHg for girls, ages 1 to 17 years, compared with 0.6 mmHg per year for U.S. adults (Appel, 2008; National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents, 2004). These data should be viewed in the context of the high blood pressure epidemic. More than 90 percent of U.S. adults 50 years of age or older will develop hypertension in their lifetime (Vasan, 2002). Hence, most children, even those with blood pressure in the usual range during childhood, are still at high risk of hypertension as adults. Because high blood pressure is a well established risk factor for cardiovascular disease, preventing the gradual rise in blood pressure during childhood and adolescence could translate into substantial health benefits for Americans of all ages.

Blood pressure during childhood exhibits a significant tracking phenomenon. That is, children tend to retain their position in the blood pressure distribution over time, relative to their peers. Thus, children who tend to track in the high, borderline high, or high normal percentiles of blood pressure for age, sex, and height, are at greater risk of eventual hypertension than are children who tend to track in the lower ranges of blood pressure. Chen and Wang (2008) conducted a meta-analysis that included 50 pediatric cohort studies of blood pressure tracking, and found strong evidence for blood pressure tracking from childhood to adulthood. They concluded that childhood blood pressure is associated with blood pressure in later life, and therefore, early intervention is important.

Recent evidence shows that mean blood pressure levels have increased among U.S. children and adolescents over the past two decades. Muntner et al. (2004) compared the blood pressure of U.S. children, aged 8 to 17 years, in the National Health and Nutrition Examination Survey (NHANES) III (1988-94; n=3,496) with the blood pressure of similar-aged youth in NHANES 1999-2000 (n=2,086). In the latter survey, mean systolic blood pressure had increased by 1.4 mmHg, and mean diastolic blood pressure by 3.3 mmHg (after adjustment for age, race, and sex). After further adjustment for body mass index (BMI) distribution at each time period, the increase in systolic blood pressure was reduced by 29 percent and for diastolic blood pressure by 12 percent. Greater increases were seen among some subgroups of minority youth, especially boys. Among non-Hispanic Blacks, mean systolic blood pressure levels increased by 2.9 mmHg among boys and 1.6 mmHg among girls compared with non-Hispanic Whites. Among Mexican Americans, mean systolic blood pressure levels increased by 2.7 mmHg among boys and 1.0 mmHg among girls compared with non-Hispanic Whites. During the same time period, the prevalence of hypertension[1] increased

[1]Hypertension in children and adolescents is defined as systolic or diastolic blood pressure equal to or greater than the 95th blood pressure percentile of sex-, age- and height-specific blood pressure percentiles. Pre-hypertension is defined as systolic or diastolic blood pressure equal to or greater than the 90th percentile but less than the 95th percentile, or a blood pressure of greater than 120/80 but less

by 2.3 percent and the prevalence of pre-hypertension increased by 1.0 percent among children and adolescents (Din-Dzietham, 2007).

The shift in mean blood pressure levels toward higher values for U.S. youth, and the increased prevalence of hypertension and pre-hypertension are of public health concern, not only because of increased risk of cardiovascular disease (CVD) morbidity and mortality in adult life, but because studies have now shown that elevated blood pressure in childhood results in significant cardiovascular dysfunction and pathology during childhood itself (Daniels, 1998; Mahoney, 1996; McCarron, 2000; McGill, 2000; Soto, 1989; Tracy, 1995). For example, in a study of 130 hypertensive children and youth, ages 6 to 23 years, 55 percent were found to have left ventricular hypertrophy[2] (left ventricular mass index >90th percentile). Additionally, 14 percent had left ventricular mass index greater than the 99th percentile, and 8 percent had a left ventricular mass index above 51 g/m$^{2.7}$, a cut-point associated with a fourfold increase in risk of CVD endpoints in adults with hypertension (Daniels, 1998). The authors also report that sodium intake was significantly higher among youth with severe left ventricular hypertrophy compared with those with normal left ventricular mass (Daniels, 1998).

High blood pressure, as well as other CVD risk factors, when present in childhood, have been shown to be strongly associated with the extent of early atherosclerotic fatty streaks and fibrous plaques in the aorta and coronary arteries. The Bogalusa Heart Study group performed autopsies on 204 young people, aged 2 to 39 years, most of whom died from trauma. Investigators had data on childhood ante-mortem risk factor status for 93 of these individuals. Systolic blood pressure, diastolic blood pressure, BMI, and serum lipid and lipoprotein concentrations in childhood were all strongly associated with the extent of fatty streaks and fibrous plaques in the aorta and coronary arteries seen at autopsy (Berenson, 1998). Thus, high blood pressure in youth promotes the development of atherosclerosis, the progression of which is greatly enhanced in the presence of other CVD risk factors, such as obesity, dyslipidemia, and cigarette smoking.

As in adults, several dietary factors likely raise blood pressure in children. In addition to excess sodium intake, other possible factors include excess weight and insufficient potassium intake. Both systolic and diastolic blood pressure are higher on average among overweight children and adolescents, compared to normal weight peers (Sorof, 2004). Based on studies in adults, diets rich in potassium might lower blood pressure and lessen the adverse effects of sodium on blood pressure. As discussed below, the largest volume of research on dietary factors on blood pressure in children has focused on the effects of excess sodium intake.

Evidence on the Relationship Between Sodium Intake and Blood Pressure in Children

A systematic review of the literature identified 19 studies (15 trials and 4 prospective observational studies). Although the vast majority of studies were small (and therefore underpowered) or had another methodological limitation, they showed a consistent pattern of lower blood pressure in those groups with a reduced sodium intake.

Of the 15 trials, 14 were randomized controlled trials (RCTs) (Calabrese and Tuthill, 1985; Cooper, 1984; Gillum, 1981; Hofman, 1983; Howe, 1985,1991; Lucas, 1988; Myers, 1989; Palacios, 2004; Pomeranz, 2002; Sinaiko, 1993; Trevisan, 1981; Tuthill and Calabrese, 1985; Whitten and Stewart, 1980). Five of the RCTs were methodologically strong (Gillum, 1981; Hofman, 1983; Howe, 1991; Sinaiko, 1993), seven were methodologically neutral (some potential for bias) (Calabrese and Tuthill, 1985; Cooper, 1984; Howe, 1985; Myers, 1989; Palacioset al. 2004; Pomeranz, 2002; Whitten and Stewart, 1980), and two were methodologically weak (Lucas, 1988; Trevisan, 1981). The 15th trial, a methodologically strong study (Ellison, 1989), was the largest and longest trial, a two-period cross-over study conducted in two boarding schools.

Four other studies provided evidence that supported this conclusion. One, a methodologically strong study, was a 15-year follow-up of an infant RCT conducted by Hofman et al. (1983) in the Netherlands (Geleijnse, 1997). Three additional studies were prospective longitudinal cohort studies (Brion, 2008 [neutral quality]; Geleijnse, 1990 [positive quality]; and Smith, 1995 [negative quality]).

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than the 95th percentile of sex-, age- and height-specific blood pressure percentiles (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents, 2004).

[2]Left ventricular hypertrophy is an enlargement of the muscle tissue that makes up the wall of the left ventricle, the heart's main pumping chamber.

Ten of the 14 RCTs achieved contrasts in sodium intake of 40 percent or more between treatment groups or periods (Cooper, 1984; Hofman, 1983; Howe, 1985, 1991; Lucas, 1988; Myers, 1989; Palacios, 2004; Pomeranz, 2002; Tuthill and Calabrese, 1985; Whitten and Stewart, 1980). Two other RCTs achieved contrasts of 7 to 12 percent (Calabrese and Tuthill, 1985; Trevisan, 1981), and two achieved less than a 2 percent difference between treatment groups (Gillum, 1981; Sinaiko, 1993). Although the extent of sodium reduction often appeared large, the data often came from dietary recalls or dietary histories (in which intakes are often underreported), rather than from 24-hour urine collections, which are considered more accurate reflections of sodium intake.

Twelve of the 15 intervention studies showed a decrease in systolic blood pressure and or diastolic blood pressure on the low sodium diet (Calabrese and Tuthill, 1985; Cooper, 1984; Ellison, 1989; Hofman, 1983; Howe, 1985, 1991; Myers, 1989; Palacios, 2004; Pomeranz, 2002; Sinaiko, 1993; Trevisan, 1981; Whitten and Stewart, 1980). Three studies reported no change in blood pressure on a low sodium diet (Gillum, 1981; Lucas, 1988; Tuthill and Calabrese, 1985).

Of the 12 intervention studies that showed a decrease in systolic blood pressure and/or diastolic blood pressure on the low sodium diet, the decrease was statistically significant for all, or a subset, of the study population in eight of the studies (Calabrese and Tuthill, 1985; Ellison, 1989; Hofman, 1983; Howe, 1985; Myers, 1989; Pomeranz, 2002; Sinaiko, 1993; Trevisan, 1981).

Results from two of the three prospective cohort studies tend to support the results of the intervention trials. The studies by Brion et al. (2008) and Geleijnse et al. (1990) involved prospective cohorts that were followed for 7 years. In the study by Brion et al. (2008), higher sodium intake at age 4 months (but not at 7 months or 7 years) was associated with increased systolic blood pressure at age 7 years. This was consistent with infants younger than age 4 months having greater difficulty excreting a sodium load. In the cohort study by Geleijnse et al. (1990), a higher sodium/potassium ratio was associated with a greater increase in slope of blood pressure change over time. In the methodologically weak infant cohort study by Smith et al. (1995), neither the contrast in sodium intake, nor the actual blood pressure was provided. The authors indicate that in the multivariate analysis, the amount of sodium added to the diet approached clinical significance ($p=.0751$).

The final study included in this evidence review was a 15 year follow-up study by Geleijnse et al. (1997) of an RCT conducted among infants who participated in the initial trial between birth and age 6 months (Hofman, 1983). In this methodologically strong long-term follow-up study, systolic blood pressure and diastolic blood pressure at follow-up were still lower among children initially assigned to the low sodium diet during infancy, compared with the higher sodium group. The difference for systolic blood pressure was statistically significant ($p<0.05$) and for diastolic blood pressure was of borderline significance ($p=0.08$). These results support the hypothesis that a programming effect of sodium intake in early life on blood pressure may exist, because the difference in blood pressure between treatment groups persisted for 15 years, even though all infants resumed their usual diet when the double-blind trial ended at 6 months of age.

Infancy may be a particularly sensitive period with respect to the effect of dietary sodium on later blood pressure. Young infants, before the age of 4 to 6 months, are less able to respond physiologically to varying concentrations of salt solutions, thus are at greater risk of hypernatremia with higher intakes of dietary sodium. Human milk has a low concentration of sodium, at about 15 milligrams per 100 milliliter (Sutton, 2008). In a meta-analysis of 15 studies, breastfeeding during infancy was found to be associated with lower blood pressure at follow-up 3 to 60 years later, compared with bottle feeding (Martin, 2005). Although the differences were small (systolic blood pressure -1.4/ diastolic blood pressure -0.5 mmHg) they were statistically significant. The composition of commercial infant formulas, however, has changed significantly over the past several decades, and although sodium levels of formulas were higher than breast milk before approximately 1980, formulations with sodium levels comparable to human milk were introduced in the U.S. and elsewhere beginning in the mid-1970s (Martin, 2005). Several studies of infants born since 1980, however, still show a blood pressure-lowering effect of breastfeeding compared with formula feeding, suggesting that breastfeeding may benefit blood pressure through a complex variety of mechanisms in addition to the low sodium content of breast milk. The association of breastfeeding with healthier patterns of infant weight gain and decreased obesity is likely to be another blood pressure-protective mechanism (Arenz, 2004).

In aggregate, these data document that sodium reduction modestly lowers blood pressure in infants and children. While the degree of reported blood pressure lowering was usually modest, in the range of -1 to -5 mmHg, such an effect, if sustained over time, could translate into reduced blood pressure in adults, and thus reduced prevalence of hypertension. Furthermore, if a reduced sodium intake blunts the age-related rise in blood pressure in children, then the effects of sodium reduction will be greater than projected from these studies. Although most of the studies had one or more methodological limitations, particularly small sample size (and consequently, inadequate statistical power), brief duration (typically < 1 month), and inadequate or uncertain contrast in sodium intake, these data as a whole point to potential public health benefits of considerable magnitude.

Review of the Evidence: Sodium Intake and Blood Pressure in Adults

Background

High blood pressure is highly prevalent among American adults. According to the most recent national survey data (1999-2004), nearly a third (32%) of adult Americans have hypertension, and roughly another third are pre-hypertensive (Wang and Wang, 2004; Cutler, 2008). These data also show that the prevalence of hypertension is increasing. Rates of controlled hypertension remain low (< 40%) but are improving slightly (Cutler, 2008).

As stated earlier, in the U.S., blood pressure generally increases with age throughout the lifespan. As a result, hypertension typically occurs in middle-aged and older adults. Adults 50 years of age and older now have a 90 percent lifetime risk of becoming hypertensive (Vasan, 2002). Some populations are disproportionately affected by hypertension and its adverse health outcomes. For example, pre-hypertensive individuals are at high risk of developing hypertension (Vasan, 2001). Blacks generally have higher blood pressure than do other racial-ethnic groups in the U.S. (Fields, 2004). Blacks also have a higher risk of blood pressure-related complications, particularly stroke (Ayala, 2001; Giles, 1995) and kidney failure (Klag, 1996).

Hypertension is one of the leading causes of death around the world. This is because high blood pressure is a strong, consistent, continuous, independent, and etiologically relevant risk factor for cardiovascular and renal diseases (Chobanian, 2003). Notably, the risk of cardiovascular disease resulting from hypertension has no threshold. It increases progressively from normal blood pressure through pre-hypertension to hypertension (Lewington, 2002; Vasan, 2001). Nearly a third of blood pressure-related deaths from coronary heart disease occur in people who do not have hypertension (Stamler, 1993).

High blood pressure occurs as a result of environmental and genetic factors and their interactions. Available evidence indicates that dietary factors play a critical role. Although this chapter focuses on the adverse effects of excessive sodium and insufficient potassium intake on blood pressure, other dietary factors, such as overweight/obesity and excess alcohol consumption, raise blood pressure. In individuals without hypertension, dietary changes lower blood pressure and prevent hypertension, which can reduce the risk of related adverse health outcomes. In individuals with stage I hypertension (systolic blood pressure of 140-159 mmHg and/or diastolic blood pressure of 90-99 mmHg), dietary changes can be an initial therapeutic approach before blood pressure medication is prescribed. Among hypertensive individuals who already are on medication, dietary changes can further lower blood pressure and help reduce the number or amount of medications necessary. In general, dietary changes have a greater effect on blood pressure in people with hypertension than in those without. These individual changes could have a huge positive effect on the health of American adults if they translated into even a small reduction in blood pressure across the population.

Evidence on the Relationship Between Sodium Intake and Blood Pressure in Adults

The 2005 DGAC Report previously examined the relationship between sodium intake and blood pressure. As documented in that report, evidence included results of more than 50 clinical trials, as well as meta-analyses that synthesized results (see IOM, 2005, Tables 6-12, 6-13, 6-15, 6-16, and Appendix I). Several of those trials were dose-response studies that examined the relationship of progressively higher levels of sodium intake with blood pressure. A few large trials also tested the effects of sodium reduction as a means to prevent hypertension.

The 2010 DGAC performed an updated literature search to identify new research on the relationship between sodium intake and blood pressure. The NEL search identified 47 potential articles (15 reviews/meta-analyses and 32 primary studies). A total of 13 articles, 12 primary studies, and one systematic review/meta-analysis, met the eligibility criteria and were reviewed. Of the 12 primary studies, nine were randomized trials

(Cappuccio, 2006; China Salt Substitute Collaborative Group, 2007; Dickinson, 2009; Forrester, 2005; Gates, 2004; He, 2009; Makela, 2008; Pimenta, 2009; Swift, 2005), two (He, 2009; Schmidlin, 2007) were studies that tested different levels of sodium intake but in fixed order, and one was an observational analysis of a previously published trial (Cook, 2005). Of the 12 primary studies, eight were methodologically strong and four were methodologically neutral. Enrollment criteria differed substantially by study, with blood pressure criteria that often bridged traditional classification schemes. Still, it appears that five of the studies enrolled normotensive individuals, six enrolled hypertensive individuals, and one explicitly enrolled both normotensive and hypertensive individuals. Trials were conducted in Jamaica, Northern China, U.S., Australia, Finland, Great Britain, and Nigeria. Populations were demographically heterogeneous (e.g., enrolling Black, White, and Asian hypertensives living in Great Britain).

Because previous trials had already confirmed that sodium reduction lowers blood pressure, the individual trials typically addressed other issues, such as the effects of public health interventions in economically developing countries or the effects of sodium reduction on other variables (e.g., vascular function, arterial compliance, proteinuria, and heart rate variability). Nonetheless, each reported the effects of sodium reduction on blood pressure. In total, a significant reduction in either systolic or diastolic blood pressure occurred in all but one of these studies, and significant reductions in both systolic and diastolic blood pressure in five studies. The eight methodologically strong studies all showed a significant reduction in systolic or diastolic blood pressure, and significant blood pressure reduction in both systolic and diastolic blood pressure occurred in five of the studies. In several studies, relatively few blood pressure measurements were obtained. Hence, in some cases, the absence of significant findings might have resulted from imprecise or inadequate blood pressure measurement.

The methodologically strong systematic review/meta-analysis of 34 randomized controlled trials (He, 2004), which pooled data for 23 trials of hypertensive and 11 trials of normotensive subjects, demonstrated that a modest reduction in sodium intake for 4 or more weeks had a significant effect on blood pressure in both hypertensive and normotensive subjects. It also found a significant dose-response relationship between sodium reduction and both systolic and diastolic blood pressure. In this meta-analysis, a median reduction in urinary sodium of approximately 1.8 grams per day (78 mmol/d) lowered systolic/diastolic blood pressure by 2.0/1.0 mmHg in non-hypertensive and by 5.1/2.7 mmHg in hypertensive adults.

In aggregate, these studies reinforce and further strengthen the previous conclusions from the 2005 DGAC Report that sodium reduction lowers blood pressure and benefits extend to both non-hypertensive and hypertensive individuals. As discussed below, the effects of blood pressure reduction are heterogeneous.

Inter-individual Variability in Blood Pressure Response

Evidence from a variety of studies, including observational studies and clinical trials, has demonstrated heterogeneity in the blood pressure responses to sodium intake. Such a phenomenon is commonplace because the effects of dietary factors, not just sodium, vary by individual. Those individuals with the greatest reductions in blood pressure in response to decreased sodium intake have been termed “salt sensitive.” Despite the use of the terms “salt sensitive” and “salt resistant” to classify individuals in earlier research studies, the change in blood pressure in response to a change in sodium intake is not binary. Rather, the reduction in blood pressure from a reduced sodium intake has a continuous distribution across individuals. Because no standardized diagnostic criteria and tests exist and blood pressure is highly variable, it is impossible to classify individuals as salt sensitive or not. Nonetheless, some general observations about sodium sensitivity with respect to subgroups of the population can be made.

Individuals with hypertension, diabetes, and chronic kidney disease, as well as middle- and older-aged persons and Blacks tend to be more sensitive to sodium than their healthier, younger, White counterparts. Genetic factors also influence the blood pressure response to sodium. Each of the 14 identified genes that affect blood pressure affects renal sodium handling. Such evidence provides indirect support of an etiologic role of sodium in blood pressure homeostasis (Lifton, 2002).

Sodium sensitivity is modifiable. On average, the rise in blood pressure from increased sodium intake is attenuated in the setting of a high potassium intake (4700 mg of supplemental potassium per day in one trial [Morris, 1999]; 6700 mg per day in another trial [Schmidlin et al., 1999]). The rise in blood pressure from increased sodium intake is also attenuated in the setting of the DASH diet, which is rich in potassium

(4600 mg of potassium per day) as well as other minerals (Bray, 2004; Karanja, 1999; Sacks, 2001; Vollmer, 2001). Nonetheless, a dose-response relationship between sodium intake and blood pressure persisted.

Relevant Contextual Issues

Relationship Between Sodium Intake and Cardiovascular Disease

Evidence of a direct relationship between dietary sodium intake and cardiovascular disease in humans has been sparse, in large part, because of methodological challenges. Direct evidence includes results from clinical trials and prospective observational studies in which outcomes are cardiovascular disease events. To date, three trials conducted in general populations have reported the effects of reduced sodium interventions on such outcomes. Two of these trials tested lifestyle interventions that focused on reducing sodium intake, and one trial tested the effects of a reduced sodium/high potassium salt. In each instance, a 21 to 41 percent reduction in clinical cardiovascular disease events occurred in those who received a reduced sodium intervention (significant reduction in two trials [Chang, 2006; Cook, 2007] and non-significant trend in the third [Appel, 2001]). Hence, direct evidence from trials, albeit limited, is consistent with evidence on the blood pressure lowering effects of sodium reduction.

In a meta-analysis, Strazzullo et al. (2009) synthesized results from prospective observational studies that evaluated the relationship of sodium intake with stroke and CVD. In their analysis of 13 cohort studies with 19 independent samples, a higher sodium intake was associated with an increased risk of stroke and likely cardiovascular disease. Specifically, a 2000 milligrams per day increased intake of sodium was associated with a 23 percent higher risk of stroke (CI = 1.06-1.43; p=0.007). The relationship of CVD with sodium intake was not statistically significant (14% greater risk of CVD, CI = 0.99-1.32; p=0.07). However, in sensitivity analyses that excluded one study with particularly unreliable estimates of sodium intake, the corresponding effect size was 17 percent and the relationship was statistically significant (p=0.02).

The disparate and often poor quality of dietary sodium measurements likely contributed to the significant heterogeneity in study results observed by Strazzullo et al. (2009). Because of large day-to-day variation in sodium consumption, imprecise and inaccurate measurement techniques, and incomplete assessment of dietary intake, results from prospective observational studies have been inconsistent and occasionally paradoxical. The "gold standard" to assess dietary sodium intake is urinary excretion of sodium as assessed from multiple, complete 24-hour urine collections. Yet only four of the 13 studies collected 24-hour urines, and none of these studies obtained more than one collection. More importantly, several studies had evidence of substantial, non-systematic underreporting of sodium intake, and most other studies provided no data on the completeness of dietary assessment. In view of the methodological limitations of observational epidemiologic evidence, policy makers have relied on the robust body of evidence that links salt intake with blood pressure to guide policy.

Relationship Between Sodium Intake and Gastric Cancer

Beyond sodium and blood pressure research, observational studies have noted a close relationship of sodium intake and cancer of the stomach. For example, an ecologic analysis of 39 populations in 24 countries documented a direct association between urinary sodium excretion and mortality from stomach cancer (Joossens, 1996). High doses of sodium result in destruction of the mucosal barrier of the stomach such that the mucus membrane is easily invaded by carcinogens (Correa, 1975). The World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR), recently reviewed the available evidence and concluded that sodium chloride and foods high in sodium chloride are probable causes of stomach cancer (WCRF/AICR, 2007).

Relationships Between Sodium Intake and Other Health Outcomes

As documented by the IOM (IOM, 2005), an increased sodium intake might have adverse effects on additional health outcomes. These include subclinical cardiovascular disease (i.e., left ventricular mass), early kidney disease (i.e., proteinuria), and disordered mineral metabolism (e.g., increased urinary calcium excretion, potentially leading to osteoporosis). Cross-sectional studies consistently document an association between urinary sodium excretion and left ventricular mass, but only one small controlled trial assessed the effects of sodium reduction on this endpoint. At least two trials have documented that a reduced sodium intake lowers proteinuria (He, 2009; Swift, 2005). Numerous trials document that a reduced sodium intake lowers urinary calcium excretion (IOM, 2005, Table 6-19), but urinary calcium excretion, by itself, is not a well-accepted surrogate marker for bone mineral density or dietary induced osteoporosis.

Overall Public Health Impact of Reducing Sodium Intake

Several studies have estimated the potential overall health and cost benefits of a reduced sodium intake (Bibbins-Domingo, 2010; Danaei, 2009; Palar and Sturm, 2009; Smith-Spangler, 2010). A feature of these studies is the use of statistical modeling with a set of linked assumptions, namely that sodium reduction lowers blood pressure, and lower blood pressure reduces the risk of stroke and coronary heart disease. Although evidence of a direct effect of sodium reduction on CVD outcomes is preferred, policy makers consider blood pressure as one of the few surrogate outcomes that is sufficiently robust to guide policy.

Additional direct evidence of a link between sodium intake and CVD comes from prospective observational studies and the few available trials with clinical CVD outcomes (see above).

Studies that evaluated the potential benefits and costs of reducing sodium intake have reached the conclusion that the projected benefits are substantial and that sodium reduction is cost-effective. In the most recent and comprehensive of such analyses (Bibbins-Domingo, 2010), a national effort that reduces sodium intake by 1200 milligrams per day in the U.S. is projected to have substantial health benefits (Tables D6.2 and D6.3). Even if the intervention reduced sodium intake by just 400 milligrams per day, the benefits still would be substantial and warrant implementation. Importantly, such a program should generate cost savings.

Table D6.2. Annual projected benefits, costs, and cost-savings from sodium reduction: higher estimate of benefit

Benefit	**Sodium Reduction of 400 mg/day**	**Sodium Reduction of 1200 mg/day**
Heart attacks prevented	32,000	92,000
Strokes prevented	20,000	59,000
Deaths prevented	28,000	81,000
Costs (billions)	$0.3	$0.3
Savings (billions)	$7.0	$20.4
Dollars saved/Dollars spent	$26.1 saved per $1 spent	$76 saved per $1 spent

Source: Adapted from Bibbins-Domingo, 2010.

Table D6.3. Annual projected benefits, costs, and cost-savings from sodium reduction: lower estimate of benefit

Benefit	**Sodium Reduction of 400 mg/day**	**Sodium Reduction 1200 mg/day**
Heart attacks prevented	20,000	58,000
Strokes prevented	13,000	37,000
Deaths prevented	17,000	51,000
Costs (billions)	$0.3	$0.3
Savings (billions)	$4.1	$12.1
Dollars saved/Dollars spent	$15.4 saved per $1 spent	$45.2 saved per $1 spent

Source: Adapted from Bibbins-Domingo, 2010.

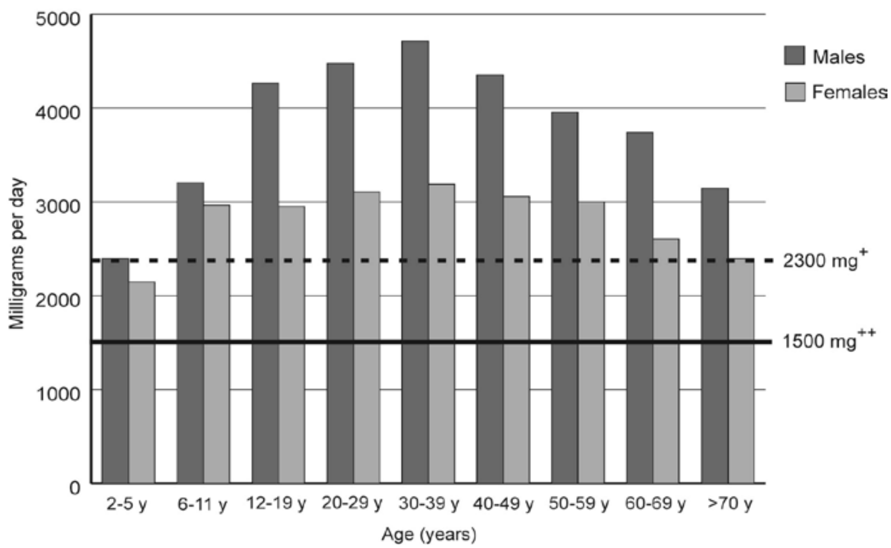
The above estimates do not include the projected long-term benefits from reducing sodium intake in children. As noted above, higher levels of blood pressure in children are strongly associated with early stages of atherosclerosis. Also, blood pressure exhibits a substantial tracking phenomenon—blood pressure levels in children track into adulthood. For these reasons, efforts to lower blood pressure in children through a reduced sodium intake should translate into additional health benefits, beyond those documented above for U.S. adults.

Sodium Intake

In 2005-2006, the estimated average intake of sodium for all persons in the U.S. ages 2 years and older was 3436 milligrams per day (USDA/ARS/FSRG, 2008a).

This includes sodium in water, but not salt added at the table or sodium in dietary supplements or medications. Figure D6.1 displays average daily sodium intake by age and sex. The higher sodium intake in men compared to women and the variation by age reflects the high correlation between intakes of sodium and calories (USDA/ARS/FSRG, 2010a). That is, as calorie intake rises, so does sodium intake. At all ages, mean intake exceeded 2300 milligrams per day as well as the 1500 milligrams per day limit that is recommended for middle- and older-aged adults, hypertensive individuals, and Blacks (currently about 70 percent of the adult population). Mean sodium intake was 3524 milligrams per day in non-Hispanic Whites, which was somewhat higher than the mean intake of 3257 milligrams per day in non-Hispanic Blacks and 3162 milligrams per day in Mexican-Americans (USDA/ARS/FSRG, 2008b).

Figure D6.1. Estimated mean daily sodium intake, by age/sex group, 2005-2006



*Includes water and excludes salt added at the table.
+ 2300 mg is the Upper Limit (UL) for sodium intake in adults set by the IOM. For children younger than 14 years old, the UL is less than 2300 mg/day.
++ 1500 mg is the recommended intake level for middle- and older-aged adults, hypertensive individuals, and Blacks in the 2005 U.S. *Dietary Guidelines*.
Source: U.S. Department of Agriculture, Agricultural Research Service (USDA, ARS), 2005-2006. What We Eat In America/National Health and Nutrition Examination Survey (WWEIA, NHANES). http:/www.ars.usda.gov/Services/docs.htm?docid=13793

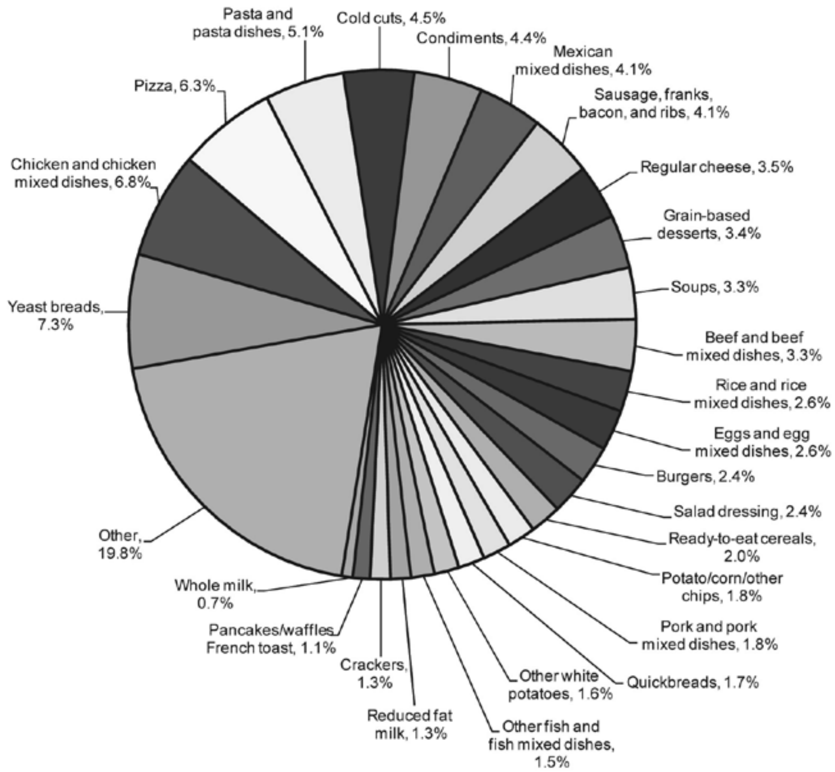
Previous NHANES results have indicated that the average daily sodium intake among persons in the U.S. ages 2 years and older increased from 3329 milligrams in 2001-2002, to 3436 milligrams in 2005-2006, exceeding in each period even the higher sodium intake limit of 2300 milligrams per day recommended in 2005.

Sources of Sodium

On average, the natural sodium content of food accounts for only 10 percent of total intake, while discretionary salt use (i.e., table and cooking salt) provides another 5 to 10 percent of total intake. The remaining 75 percent is derived from salt added in food processing by manufacturers (Mattes and Donnelly, 1991; Mattes, 1997). Sodium in water softeners and medications typically contributes a very small amount of sodium. When total intake of sodium is decreased, discretionary salt use is fairly stable, even when freely available (Mattes, 1997). Therefore, at the environmental level, programs for reducing the sodium consumption of a population should concentrate primarily on reducing the sodium used during food processing (IOM, 2010) and, at the individual level, focus on changes in food selection (e.g., more fresh, less-processed items, lower sodium foods) and preparation (Mattes, 1997).

Many foods contribute to the high intake of sodium. While some foods are extremely high in sodium, the problem of excess sodium reflects frequent consumption of foods that are only moderately high in sodium. As shown below, in 2005-2006, the major sources of sodium intake among the U.S. population were yeast breads; chicken and chicken mixed dishes; pizza; pasta and pasta dishes; cold cuts; condiments; Mexican mixed dishes; sausage, franks, bacon, and ribs; regular cheese; grain-based desserts; soups; and beef and beef mixed dishes. Each of these 12 food groups supply more than 100 milligrams sodium per person per day to the diet. Collectively, this group of foods contributes about 56 percent of the dietary sodium, or nearly 2000 milligrams per person per day in just these foods. Figure D6.2 shows the sodium contribution of these 12 food groups as well as the smaller contributions of other foods. It clearly shows that numerous types of foods contribute to the high intake of sodium by Americans.

Figure D6.2. Food sources of sodium



Source: Sources of Sodium Among the U.S. Population, 2005-2006. Risk Factor Monitoring and Methods Branch Website. Applied Research Program. National Cancer Institute. http://riskfactor.cancer.gov/diet/foodsources/sodium/. Updated January 2010. Accessed May 6, 2010a.

Sodium Modeling

The USDA Food Patterns are designed to meet the recommendations of the *Dietary Guidelines for Americans* and the recommendations of the IOM's DRIs. The DGAC conducted a modeling analysis to describe what the sodium levels of the USDA Food Patterns would be under three scenarios:

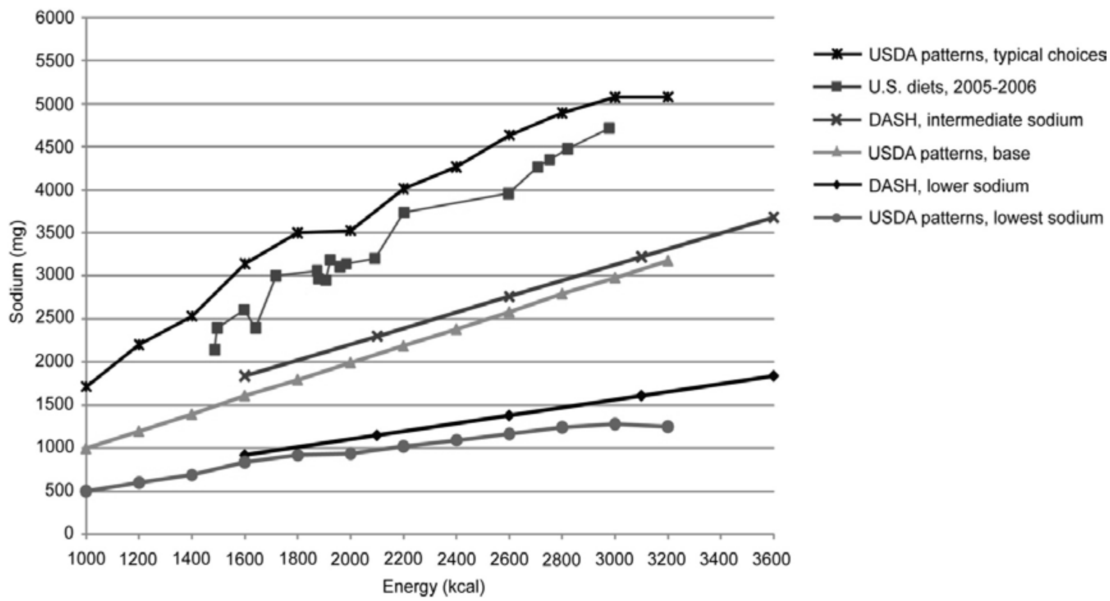
- Scenario 1: The "base" condition, in which nutrient-dense foods, most prepared without salt, are selected as representative foods;
- Scenario 2: A "typical" choices condition (higher than "base"); and
- Scenario 3: A "lower sodium" choices condition in which representative foods inherently high in sodium or with added salt are replaced with lower sodium foods; for example, substituting fresh meats, not those augmented with sodium solutions, for processed meats and using the lowest sodium value currently available on the market for both white breads and quick breads.

The following information summarizes the modeling analysis (see the online Appendix E3.11 at www.dietaryguidelines.gov, for details).

In the "base" USDA Food Pattern (Scenario 1), the sodium level, expressed on a per calorie basis, was about 40 percent lower than the estimated sodium intake levels in the U.S. in 2005-2006. Scenario 1 was similar to the intermediate sodium level in the DASH-Sodium trial and close to the recommended UL set by the IOM (2300 mg at about 2000 kcal). If typical, rather than ideal, food choices were to be made (Scenario 2), the sodium level of the patterns would be much higher. In contrast, if only foods with lower sodium content were to be chosen (Scenario 3), the sodium level could be reduced to a level similar to the lower sodium level tested in the DASH-Sodium trial, which is close to the 2005 *Dietary Guidelines* recommendation for high-risk individuals (1500 mg at about 2000 kcal). This level would be 70 percent below 2005-2006 sodium intake levels.

As shown in Figure D6.3, sodium and energy intakes in all three scenarios are highly correlated; sodium and energy intakes in the diets of Americans are highly correlated; and sodium levels in the DASH-Sodium diets are also highly correlated with energy intake.

Figure D6.3. Sodium and energy levels in U.S. diets, USDA Food Patterns at three levels of sodium and DASH diets at two levels of sodium



Source: USDA, ARS, Food Surveys Research Group, Correlations: Energy & Sodium and Energy & Potassium. 2010a. Available at http://www.cnpp.usda.gov/Publications/DietaryGuidelines/2010/Meeting5/Correlations-SodiumAndPotassium-2005-2006.pdf. Accessed April 15, 2010.

The correlation between sodium and energy intakes in the U.S. among free-living adults is estimated to be 0.80 (USDA/ARS/FSRG/2010a). The menus of controlled feeding studies, such as the DASH-Sodium trial, illustrate how sodium and potassium levels can be designed to be perfectly correlated with energy, that is, the goals for sodium and potassium in DASH-Sodium were set on a per calorie basis. Given the above considerations, it is therefore reasonable, for practical purposes, to adjust sodium targets based on calorie level, given the high correlation between sodium and energy intakes.

Salt Taste Preferences

Taste preference for sodium is neither fixed nor innate. Rather, it is a malleable trait that is influenced by dietary exposure. At birth, there is no indication that salty substances are distinguishable or preferred (Beauchamp, 1986). Initial appearance of preference for the salty taste occurs at about 4 months postnatal (Beauchamp, 1994, 1986; Harris and Booth, 1987) but based on the limited evidence available, sodium preferences in infants and children appear to be shaped by dietary exposure (Beauchamp, 1990; Stein et al., 1996). Likewise, sodium preferences in adults and children are influenced by dietary exposure. Studies have demonstrated that reducing dietary sodium intake over a time period of as little as 3 to 4 weeks can decrease preference for salty foods and increase acceptance of foods with reduced sodium content (Bertino, 1982; Cooper and Sanger, 1984).

Several studies document a temporary increased preference or craving for salt over the initial period when sodium intake is reduced (Bertino, 1981; McCance, 2001; Teow, 1985–1986; Yensen, 1959). However, subsequently, a shift in preference occurs such that by 8 to 12 weeks, or sooner in some individuals, preference for less salty foods is established (Bertino, 1982; Mattes and Donnelly, 1991; Mattes, 1997). This phenomenon also has been demonstrated in long-term studies lasting 1 year or more (Blais, 1986). In aggregate, such evidence argues for gradual, step-wise reductions in sodium intake to maximize acceptance of products that are reduced in sodium content.

Strategies to Reduce Sodium Intake

Recently, the IOM issued a report that provides a roadmap to lower the Americans' intake of sodium (IOM Report, 2010). This document noted that activities to reduce sodium intake of the U.S. population have been ongoing for more than 40 years. However, these efforts have been unsuccessful. A major reason is that these efforts were not broad enough in scope to fully address the public health problem of excessive sodium intakes. The current focus on individuals selecting lower-sodium foods and availability of reduced-sodium "niche" products cannot result in intakes consistent with the *Dietary Guidelines for Americans* by themselves. They must be accompanied by an overall reduction of the level of sodium in the food supply. In other words, the level of sodium to which consumers are exposed on a daily basis from processed and restaurant foods must be reduced. To date, efforts by food processors and the restaurant and foodservice sectors to voluntarily reduce the sodium content of the food supply face obstacles, are not consistently undertaken by all, are not readily sustained, and have proven unsuccessful in lowering overall sodium intake. The IOM made a series of recommendations, many of which involved regulatory actions to gradually lower the sodium content of the food supply. Given safety considerations as well as differences in the amount and function of sodium by type of food product, reductions in sodium intake will differ by foods (see *Part D. Section 8. Food Safety and Technology* for further information).

Question 2: What Is the Effect of Potassium Intake on Blood Pressure in Adults?

Conclusion

A moderate body of evidence has demonstrated that a higher intake of potassium is associated with lower blood pressure in adults.

Implications

Increasing dietary potassium intake can lower blood pressure. A higher intake of potassium also attenuates the adverse effects of sodium on blood pressure. Other possible benefits include a reduced risk of developing kidney stones and decreased bone loss. In view of the health benefits of adequate potassium intake and its relatively low current intake by the general population, increased intake of dietary potassium is warranted. The IOM set the AI for potassium for adults at 4700 milligrams per day. Available evidence suggests that Blacks and hypertensive individuals especially benefit from an increased intake of potassium.

Review of the Evidence

As documented in Question 1, elevated blood pressure is a highly prevalent, etiologically relevant, and modifiable risk factor for cardiovascular and renal diseases. A low intake of dietary potassium, especially in the presence of high sodium intake, has been implicated in the pathogenesis of elevated blood pressure. The 2005 DGAC reviewed available evidence from the relationship between potassium intake and blood pressure and concluded that an increased intake of potassium lowers blood pressure. The Committee included evidence from 36 clinical trials and 17 cohort studies (IOM, 2005) in their review. Most of these trials tested potassium supplements, not food sources, typically in the form of potassium chloride pills (Tables 5-4 and 5-5, IOM, 2005). On the basis of these data and in conjunction with other data showing that an increased potassium intake should attenuate the adverse effects of salt on blood pressure, reduce the risk of developing kidney stones, and possibly decrease bone loss, the IOM set the AI for potassium at 4700 milligrams per day for adults.

The 2010 DGAC performed a search of literature published since 2005 to identify new research on the relationship between potassium intake and blood pressure. A total of 10 new articles met the inclusion criteria and were reviewed. Of the 10 articles, five were systematic reviews/meta-analyses, four were randomized trials, and one was a three-period, non-randomized cross-over trial. The review by Burgess (1999) was not a formal meta-analysis. Two trials compared potassium chloride to potassium citrate; one of these trials did not have a placebo group. Potassium citrate is the form most similar to that provided naturally in food. Six studies were methodologically strong, and four were methodologically neutral.

Each study reported the effects of potassium intake, either from supplements or diet, on blood pressure in adults. Four of the five systematic reviews/meta-analyses found a significant reduction in either systolic or diastolic blood pressure, and three found a significant reduction in both. Three meta-analyses of these trials document that, on average, increased potassium intake lowers blood pressure (Cappuccio and MacGregor, 1991; Geleijnse, 2003; Whelton, 1997). In the meta-analysis by Whelton et al. (1997), average net systolic/diastolic blood pressure reductions from a net increase in urinary potassium excretion of 2 grams per day (50 mmol/d) were 4.4/2.5 mmHg among hypertensive individuals and 1.8/1.0 mmHg among nonhypertensive individuals. A meta-analysis (Dickinson, 2006) did not detect a significant effect of potassium on blood pressure, but this meta-analysis applied especially restrictive inclusion criteria and included only five trials. The blood pressure reductions tended to be greatest in hypertensive individuals and Blacks.

Relatively few trials tested the effects of potassium as provided in foods (IOM, 2004, Table 5-3). The potassium in vegetables and fruits is accompanied by bicarbonate precursors rather than chloride. In the initial DASH trial, a diet rich in fruit and vegetables (and therefore rich in potassium) lowered blood pressure (Appel, 1997). Another trial documented that increased vegetable and fruit consumption can significantly lower blood pressure (John, 2002), but that trial did not report the potassium intake of participants in the vegetable and fruit intervention.

Because virtually all trials used potassium chloride supplements, while observational studies assessed dietary potassium intake from foods (paired with nonchloride anions), the effect of potassium on blood pressure appears to result from potassium rather than its conjugate anion. No trial tested the effects of three or more levels of potassium intake on blood pressure; hence, the dose-response relationship is unclear. Still, blood pressure reductions from supplemental potassium occurred when baseline intake was low (e.g., 1.3 to 1.4 g of potassium per day in Brancati et al. [1996]) and when baseline intake was much higher (> 3.1 g of potassium per day in Naismith and Braschi [2003]).

Evidence from the observational studies and clinical trials has demonstrated heterogeneity in blood pressure responses to potassium intake. Blacks and hypertensive individuals are more sensitive to the effects of potassium than their non-Black and normotensive counterparts, respectively. Dietary sodium intake also modifies the effects of potassium on blood pressure. Specifically, the beneficial effects of potassium on blood pressure are greater when sodium intake is high than when sodium intake is low (for details, see DGAC, 2005, Table D7-1).

Some trials have assessed the effects of increased potassium intake on sodium sensitivity, that is, the pressor (blood-pressure raising) response to increased sodium intake. Study populations included nonhypertensive individuals, most of whom were Black (Morris, 1999; Schmidlin, 1999), and hypertensive individuals (Morgan, 1984). These trials are consistent in documenting that potassium attenuates the pressor effects of sodium. One dose-response trial documented that increasing potassium intake to 4700 milligrams per day reduced sodium sensitivity in nonhypertensive Blacks (Morris, 1999). In aggregate, these trials highlight the potential benefits of increasing potassium intake by Blacks, a group of individuals with a high prevalence of hypertension and of blood pressure-related cardiovascular and renal diseases.

Relevant Contextual Issues

Effect of Potassium Intake on Cardiovascular Disease Outcomes

It has been hypothesized that an increased intake of potassium should prevent stroke and coronary heart disease. These beneficial effects could be mediated indirectly through blood pressure (i.e. an increased intake of potassium should lower blood pressure, which in turn should prevent stroke and coronary heart disease) and directly (i.e., independent of blood pressure). To date, several observational studies suggest that increased potassium intake may prevent stroke and perhaps coronary artery disease (IOM, 2004, Table 5-6). However, the evidence is inconsistent and not sufficient to guide dietary recommendations. Recently, a trial documented that a reduced sodium/high potassium salt reduced CVD mortality and medical expenditures in Taiwanese veterans (Chang, 2006). However, it is uncertain whether the effect, if real, resulted from increased potassium, reduced sodium, or both.

Effect of Potassium in Preventing Bone Loss and Kidney Stones

A diet rich in potassium from vegetables and fruits favorably affects acid-base metabolism because these foods also are rich in precursors of bicarbonate (Sebastian, 1994, 2002). Acting as a buffer, the bicarbonate-yielding organic anions found in vegetables and fruits neutralize acids generated from meats and other high-protein foods. In the setting of an inadequate intake of bicarbonate precursors, bone titrates the excess acid in the blood. This results in demineralization of the bone. Increased bone breakdown and calcium-containing kidney stones are adverse consequences of excess acid derived from the diet. Therefore, diets rich in potassium with its bicarbonate precursors may help prevent kidney stones and bone loss.

To date, two observational studies have documented that high intakes of potassium (median of 4000 mg/d in men and 4700 mg/d in women) are associated with a reduced risk of incident kidney stones (Curhan, 1993, 1997). In a third observational study conducted in Finland, the relationship was statistically nonsignificant, perhaps because of the much higher usual levels of potassium consumed in this population (Hirvonen, 1999). In addition, one trial (Barcelo, 1993) documented that approximately 3.6 to 4.7 grams of supplemental potassium citrate reduced the risk of recurrent kidney stones. The potassium added to processed foods and the potassium in supplements typically has chloride as the conjugate anion. Because chloride cannot neutralize excess acid in the body, this form of potassium is not expected to help prevent kidney stones or bone loss.

Observational studies, including both cross-sectional studies and longitudinal studies, suggest that increased potassium intake is associated with increased bone mineral density (IOM, 2005, Table 5-7). Trials also have documented that supplemental potassium bicarbonate can reduce bone breakdown and increase bone formation (Sebastian, 1994). However, no trial has tested the effect of increased potassium or diets rich in potassium on bone mineral density or on clinical outcomes related to osteoporosis.

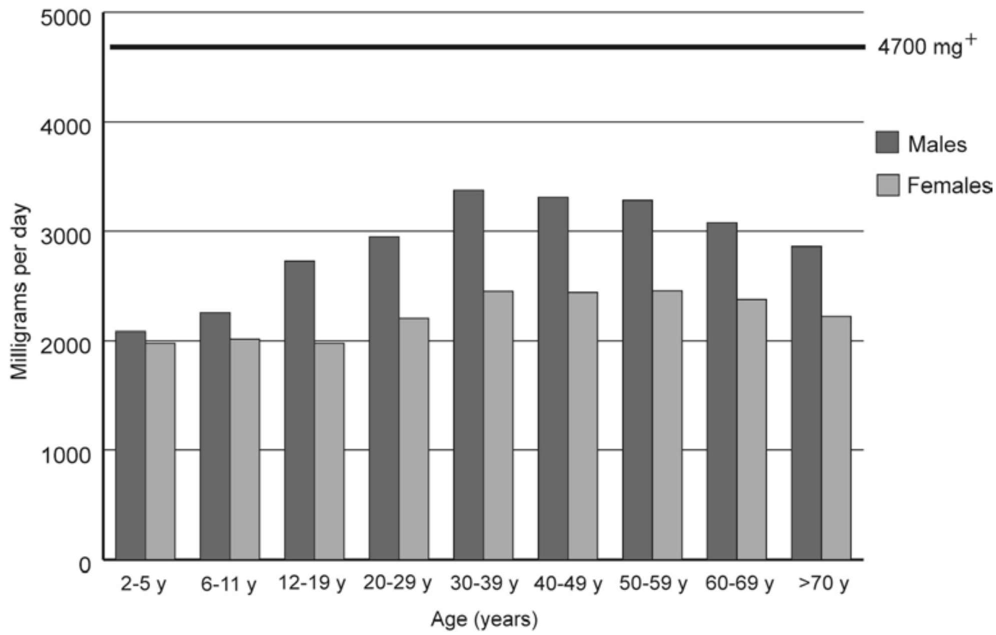
Safety Considerations

In a generally healthy population with normal kidney function, a potassium intake from foods that exceeds 4700 milligrams per day poses no threat of increased risk because excess potassium is readily excreted in the urine. Hence, the IOM did not set a UL for potassium (IOM, 2005). However, a potassium intake below 4700 milligrams per day is indicated for individuals whose urinary potassium excretion is impaired. Adverse cardiac effects (arrhythmias) can result from hyperkalemia, which is a markedly elevated serum level of potassium. Common drugs that can substantially impair potassium excretion are angiotensin-converting enzyme (ACE) inhibitors, angiotensin receptor blockers (ARB), and potassium-sparing diuretics. Medical conditions associated with impaired potassium excretion include diabetes, chronic kidney disease, end stage renal disease, severe heart failure, and adrenal insufficiency. As a group, elderly individuals are at increased risk of hyperkalemia because they often have one or more of these conditions or take one or more of the above medications.

Potassium Intake

At present, dietary intake of potassium by all groups in the United States is considerably lower than 4700 milligrams per day (Figure D6.4). In recent surveys, the mean intake of potassium by adults in the United States was approximately 3200 milligrams per day by men and 2400 milligrams per day by women. On average, non-Hispanic Blacks consume less potassium than non-Hispanic Whites. Among adults age 20 and older, mean potassium intake was approximately 2400 milligrams by non-Hispanic Blacks and 2800 milligrams by non-Hispanic Whites. Because Blacks have a relatively low intake of potassium and a high prevalence of elevated blood pressure and sodium sensitivity, this subgroup of the population would especially benefit from an increased intake of potassium.

Figure D6.4. Estimated mean daily potassium intakes, by age/sex group, 2005-2006



+ 4700 mg is the Adequate Intake (AI) for potassium intakes set by the IOM. For children younger than 14 years old, the AI is less than 4700 mg per day.
Source: USDA, ARS, 2005-2006. WWEIA, NHANES. http:/www.ars.usda.gov/ba/bhnrc/fsrg.

Food Sources of Potassium

Table D2.14 in *Part D. Section 2: Nutrient Adequacy* lists foods that are among the best sources of potassium, when considered in typically eaten portion sizes. However, consumption of many of these potassium sources is relatively low in the U.S., and therefore due to their frequency of consumption, other foods provide most of the potassium currently consumed. At present, the top five contributors of potassium for all persons, and their mean contribution to overall potassium intake, are reduced fat (2% and 1%) milk (154 mg/d), coffee (135 mg/d), chicken and chicken mixed dishes (119 mg/d), beef and beef mixed dishes (94 mg/d), and 100 percent orange/grapefruit juice (90 mg/d). Table D2.15 in *Part D. Section 2: Nutrient Adequacy* provides additional information about the major food sources of potassium in U.S. diets (NCI, 2010b).

Potassium Modeling

The DGAC examined potassium intakes by the U.S. population, the levels of potassium in the base USDA Food Patterns, and the levels of potassium in the DASH-Sodium trial diets. These intakes and levels were described in terms of absolute potassium intake (mg/d) and as milligrams per kilocalorie. Just as for sodium, there is a high correlation between energy intake and potassium intake (r=0.72) (USDA/ARS/FSRG, 2010a). This high correlation makes interpretation of cohort studies difficult. The following information summarizes the modeling analysis (see the online Appendix E3.12 at www.dietaryguidelines.gov, for details).

While the target level of potassium for all USDA base Food Patterns was 4700 milligrams per day; this level was not met at most calorie levels. Only at the 3000 and 3200 calorie levels was the target met. The potassium/energy ratios range from 1.5 to 1.9 milligrams per kilocalorie. An important feature of the patterns is the high correlation of potassium and energy (r = 0.98). Therefore, like sodium, the potassium in the USDA Food Patterns is effectively, but not intentionally, calorie adjusted. Unlike the targets for the USDA patterns, the potassium targets for the DASH diets were designed to be proportional to energy intake and provided 4258 milligrams potassium per 2000 kilocalories (Pao-Hwa, 2003). Therefore, for practical purposes, it is reasonable to adjust potassium targets based on calorie level, given the high correlation of potassium and calorie intakes in the population.

The menus developed for the DASH trials intentionally included vegetables and fruits that were especially high in potassium to meet the potassium targets. The USDA Food Patterns, on the other hand, use composite potassium values of all the fruits and each vegetable subgroup. These values reflect a weighted population mean intake of all vegetables and fruits in each subgroup. (They also reflect the weighted population mean intake of all other food groups and subgroups.) The potassium/calorie ratios in the DASH diets ranged from 1.9 to 2.5 milligrams per kilocalorie, somewhat higher than the USDA pattern ratios, which range from 1.5 to 1.9 milligrams per kilocalorie, and much higher than the current potassium average potassium/energy intake ratio (1.2).

The DGAC also determined the contribution of coffee and tea consumption on potassium intake. In 2005-2006, adults aged 19 years and older drank an average of about 18 fluid ounces of coffee or tea per day. These beverages provided an average of 247 milligrams of potassium per day. On a given day, 66 percent of adults drink coffee and/or tea, and 90 percent drink these beverages at least once in a year (USDA/ARS/FSRG, 2010b). The food pattern modeling analysis revealed that the potassium levels in the current USDA Food Patterns would be increased by 5 to 8 percent if the mean amounts of coffee and tea consumed by adults were assumed to be included in the patterns designed for adults (i.e., 1600 calories and higher).

Question 3: What Amount of Water Is Recommended for Health?

Conclusion

Based on an extensive review of evidence, an IOM panel in 2004 concluded that the combination of thirst and usual drinking behavior, especially the consumption of fluids with meals, is sufficient to maintain normal hydration. However, because water needs vary considerably and because there is no evidence of chronic dehydration in the general population, a minimum intake of water cannot be set.

Implications

In order to prevent dehydration, water must be consumed daily. Healthy individuals who have routine access to fluids and who are not exposed to heat stress consume adequate water to meet their needs. Purposeful drinking is warranted for individuals who are exposed to heat stress or who perform sustained vigorous physical activity. Although uncommon, heat waves are one setting of extreme heat stress that increases the risk of morbidity and mortality from dehydration, especially in older-aged persons. In view of the ongoing obesity epidemic, individuals are encouraged to drink water and other fluids with few or no calories.

Review of the Evidence

Recommendations for water are made to prevent the deleterious, primarily acute, effects of dehydration. These effects include impaired cognitive function and motor control. Although a low intake of water has been associated with an increased risk of kidney stones and other chronic diseases, this evidence was insufficient for the 2005 DGAC to establish quantitative recommendations for water consumption. The 2010 DGAC conducted exploratory literature searches on the relationship of water intake with hydration, kidney stones, body weight, and cancer. These searches revealed that for the purposes of identifying health problems related to water intake in the general population, little additional evidence on these topics has been published since the 2005 DGAC Report.

The primary indicator of hydration status is plasma or serum osmolality. Appendix G-1 of the 2004 IOM report (IOM, 2005) provides the serum osmolality by decile of total water intake in the third NHANES conducted in 1988-1994. Serum osmolality concentrations in each decile were essentially identical (the maximum range between the lowest and highest decile was only 3 millimoles (mmol) per kilogram in each age group. These data indicate that people in the lowest and highest deciles of total water intake were neither systematically dehydrated nor overhydrated. Importantly, this pattern of findings was evident throughout the lifespan. In infants and children as well as community-dwelling older-aged persons, no evidence of dehydration existed except when deprived of water due to illness or lack of mobility. Although it is well documented that older individuals have reduced ability to concentrate and dilute their urine (Brenner and Rector, 2007) and have reduced thirst in the setting of water deprivation (IOM, 2005; Farrell, 2008), there is no evidence that even older individuals experience dehydration, except under conditions of extreme heat stress. Overhydration is an uncommon medical problem that occurs in a few unusual settings, such as psychogenic polydipsia in patients with severe mental illness or forced water consumption as part of hazing rituals.

Although uncommon, heat waves are one setting of extreme heat stress that increases the risk of morbidity and mortality from dehydration, especially in older-aged persons. One of the worst heat waves occurred in France in 2003. Nearly 15,000 excess deaths occurred (Fouillet, 2006). While virtually all age groups were affected, older-aged persons (> 75 years old) were disproportionally affected. Risk factors for adverse outcomes included concurrent medical conditions, as well as social factors, such as living alone. Still, excess deaths occurred in older-aged persons living in institutional settings. Overall, these data indicate the need for purposeful drinking by broad segments of the population, not just older-aged persons, in the setting of extreme heat stress, such as heat waves.

Total water intake includes drinking water, water in beverages, and water contained in food. Because normal hydration can be maintained over a wide range of water intakes, the IOM set the AI for total water based on the median total water intake estimated from U.S. survey data (IOM, 2005). The AI for total water intake for men and women age 19 to 30 years is 3.7 liters and 2.7 liters per day, respectively. In NHANES III, fluids (drinking water and beverages) provided 3.0 liters (101 fl oz; approximately 13 cups) and 2.2 liters (74 fl oz; approximately 9 cups) per day for men and women age 19 to 30 years, respectively. Fluids represented approximately 81 percent of total water intake. Water contained in food provided the remaining 19 percent of total water intake.

The AI should not be interpreted as a specific requirement or recommended intake. Individual water requirements can vary greatly, even on a day-to-day basis, primarily because of differences in physical activity and environmental conditions and differences in diet. Dietary factors influence water requirements because total water consumption must be sufficient to excrete metabolites of protein and organic compounds, as well as excess electrolytes. Increased water intake is typically required by those individuals who are very physically active or who are exposed to high temperatures. In individuals who are neither physically active nor exposed to heat stress, daily consumption below the AI can be sufficient to maintain normal hydration.

Chapter Summary

At present, Americans consume excessive sodium and insufficient potassium. The health consequences of excessive sodium and insufficient potassium are substantial and include increased levels of blood pressure and its sequelae (heart disease and stroke). Water is needed to sustain life; except under unusual circumstances, there is no evidence that water intake is either excessive or insufficient.

Needs for Future Research

1. Conduct studies, including clinical trials, in children to determine the effects of sodium on blood pressure and the age-related rise in blood pressure.

   Rationale. The problem of elevated blood pressure begins in childhood, well before blood pressure levels cross the threshold that defines hypertension in adults (140/90).

2. Conduct trials that determine the effects of sodium reduction on clinically relevant non-blood pressure variables, such as left ventricular mass, proteinuria, and bone mineral density.

   Rationale. An inclusive body of evidence suggests that the benefits of lower sodium intake extend beyond reduced blood pressure. Evidence from cross-sectional studies has documented that sodium is directly associated with left ventricular mass and proteinuria. Clinical trials have also documented that a higher intake of sodium increases urinary calcium excretion.

3. Conduct controlled trials that test whether increased potassium intake through supplements or potassium-rich foods increases bone mineral density.

   Rationale. A consistent body of evidence from observational studies indicates that increased intake of potassium from foods is associated with greater bone mineral density and with evidence of reduced bone turnover. Data from small trials also have documented that increased intake of potassium reduces bone turnover.

4. Conduct dose-response trials that test the main and interactive effects of sodium and potassium intake, as well as possible impact of other minerals (e.g., calcium, magnesium) on blood pressure and other clinically relevant outcomes.

   Rationale. There remains a need for dose-response trials, particularly for potassium, that span a clinically relevant range of dietary intake. Also, the interactive effects of sodium and potassium are of considerable interest.

5. Investigate the role of increased total fluid intake as a means to prevent chronic diseases.

   Rationale. A few studies suggest that increased fluid consumption might reduce the risk of bladder cancer, urinary tract infections, kidney stones, and colon cancer. However, this evidence was insufficient to make recommendations on fluid intake.

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Part D. Section 7: Alcohol

Introduction

The hazards of heavy alcohol (ethanol) intake have been known for centuries. Heavy drinking increases the risk of liver cirrhosis, hypertension, cancers of the upper gastrointestinal tract, injury, and violence (USDA, 2000). A recent analysis of the preventable causes of mortality in the United States (U.S.) attributed 90,000 deaths a year to alcohol misuse (Danaei, 2009). However, the health consequences of consuming lesser amounts of alcohol are also important because of the large percent of the population that consumes alcohol at or below government recommendations on limits for intake. It is estimated that the benefits attributed to moderate alcohol consumption resulted in 26,000 fewer deaths from heart disease, stroke, and diabetes.

Estimates from the most recent national surveys, conducted 2003-2006, indicate that 76 percent of men and 65 percent of women consumed alcohol at least once in the last year (Guenther, 2010). The *Dietary Guidelines for Americans, 2005* defined moderate alcohol consumption as the consumption of up to one drink per day for women and up to two drinks per day for men (HHS/USDA, 2005). One drink was defined as 12 fluid ounces of regular beer, 5 fluid ounces of wine (12 percent alcohol), or 1.5 fluid ounces of 80-proof distilled spirits. Of concern is that a large number of individuals exceed the recommended upper limits of average intake. An estimated 9 percent of men consumed an *average* of more than two drinks per day and 4 percent of women consumed an *average* of more than one drink per day (Guenther, 2010). Furthermore, heavy drinking is also common. On any single day, 9 percent of men drank five drinks or more and 4 percent of women drank four drinks or more. These thresholds of heavy consumption in men and women are considered as a "heavy drinking day" and are used to identify an individual as "at risk" for adverse health outcomes (*National Institute on Alcohol Abuse and Alcoholism* [NIAAA], 2009).

The recent release of *Rethinking Drinking* by NIAAA provides guidelines that are consistent, in part, with the 2005 *Dietary Guidelines*, but also adds additional guidance on weekly patterns of consumption. This NIAAA booklet, which is also designed to help individuals drink less if they are heavy or "at risk drinkers," defines "low-risk" drinking as no more than 14 drinks a week for men and seven drinks a week for women with no more than four drinks on any given day for men and three drinks a day for women (NIAAA, 2009).

The 2010 Dietary Guidelines Advisory Committee (DGAC) largely agreed with this definition of moderation from the NIAAA because it implied that consumption was based on daily intake averaged over the week and also because the NIAAA guideline was generally consistent with the recommendation from the 2005 *Dietary Guidelines.* The DGAC further wanted to explore whether additional new information on alcohol drinking patterns and health supported a change in the guidelines. The DGAC explored whether there was a sufficient evidence base from large-scale human populations to apply guidelines on drinking patterns to the general U.S. population.

The beneficial and detrimental effects of alcohol consumption on health are well known and have been studied extensively as summarized in the *Dietary Guidelines for Americans, 2005* and updated below (HHS/USDA, 2005). The DGAC determined that for many of these chronic diseases there was not a meaningful incremental change in the research findings. However, because these associations, even for moderate consumption, are of great importance, they are summarized below.

- ***Cancer.*** The recent comprehensive summary from the World Cancer Research Fund/ American Institute for Cancer Research (WCRF/AICR, 2007) summarized the available evidence from epidemiological studies of alcohol and cancer.
  - ***Colon Cancer –*** There is convincing evidence that alcohol is associated with risk of colon cancer in a dose response manner, but this evidence is strongest for men and stronger for populations that drink on average in excess of two drinks a day.
  - ***Breast Cancer –*** There is also robust evidence from more than 100 studies that suggest a dose-response association between alcohol and breast cancer. A woman who drinks, on average, one

drink per day has a 10 percent elevated risk. However, alcohol is known to modestly suppress blood folate levels (Barak, 1993; Chiuve, 2005) and in some, but not all, studies of alcohol and breast cancer the elevated risk attributed to alcohol is attenuated among women with ample dietary folate (Baglietto, 2005; Beasely, 2010; Zhang, 1999).

— ***Liver Cancer –*** Liver cancer is rare in the U.S., especially among individuals who do not drink in excess. However; even moderate drinkers have a modest increase in risk compared to those who abstain. There are substantial differences between studies (WCRF/AICR, 2007), which suggests that other personal characteristics such as smoking, diet, or underlying viral infections may modify risk.

- ***Diabetes.*** Several studies have found that alcohol in moderation may increase insulin sensitivity and reduce fasting glucose levels (Shai, 2007). Further, results from comprehensive reviews and meta-analyses suggest that risk of diabetes is significantly lower among moderate drinkers than abstainers (Baliunas, 2009; Howard, 2004). The systematic review by Howard et al. (2004) covered 32 studies. Compared with no alcohol use, moderate consumption (1 to 3 drinks/day) was associated with a 33 percent to 56 percent lower incidence of type 2 diabetes (T2D) and a 34 percent to 55 percent lower incidence of diabetes-related coronary heart disease (CHD). Importantly, compared with moderate consumption, heavy consumption (>3 drinks/day) was associated with up to a 43 percent increased incidence of T2D. Despite the benefit of alcohol when consumed in moderation, when consumed in excess, alcohol can cause serious metabolic disturbances and increase diabetes risk.
- ***Hypertension and Stroke.*** Many studies have addressed the question of alcohol in relation to hypertension and stroke, and several meta-analyses have followed to summarize this information. In a meta-analysis of 35 observational studies, Reynolds et al. (2003) found that, compared with abstainers, consumption of more than four drinks per day was associated with an increased risk of total stroke, increased risk of ischemic stroke, and increased risk of hemorrhagic stroke. On the other hand, consumption of approximately one drink per day was associated with reduced risk of total stroke and ischemic stroke, and consumption of one to two drinks per day was associated with reduced risk of ischemic stroke. These results indicate that heavy alcohol consumption increases risk of stroke while light to moderate alcohol consumption may be protective against total and ischemic stroke. Since that publication, 10 prospective cohort studies have provided further evidence to support these findings. Most studies reported a beneficial effect of low to moderate alcohol consumption, but a detrimental effect with high alcohol consumption (Bazzano, 2007; Emberson, 2005; Elkind, 2006; Ikehara, 2008; Iso, 2004; Mukamal, 2005a, 2005b; Sundell, 2008). Iso et al. (2004) reported that alcohol consumption was positively associated with age-adjusted risk of total stroke with a 68 percent increased risk among drinkers (>450 g/week) compared with occasional drinkers; this risk was confined primarily to hemorrhagic stroke. Although fewer studies differentiate the stroke subclasses, the stronger positive association for heavier alcohol consumption and hemorrhagic stroke than for ischemic stroke is consistent in the literature. Most importantly for the proposed guidelines for alcohol, strong evidence indicates that moderate alcohol consumption does not elevate risk of either hypertension or stroke. It is also well documented that alcohol consumed in excess of moderation causes an increase in blood pressure and stroke (Reynolds, 2003; Taylor, 2009). For the growing percentage of the population with elevated blood pressure, reduction in alcohol is an effective treatment for lowering blood pressure; although this is most effective when included in a regimen with changes in diet and physical activity patterns (Dickinson, 2006).
- ***Total Mortality*****.** In most Western countries where chronic diseases such as CHD, cancer, stroke, and diabetes are the primary causes of death, results from large epidemiological studies consistently show that alcohol has a favorable association with total mortality, especially among middle-aged and older men and women. A recent updated meta-analysis of all-cause mortality demonstrated an inverse association between moderate drinking and total mortality (Di Castelnuovo, 2006). The relative risk of all-cause mortality associated with moderate drinking was approximately 0.80. The J-shaped curve, with the lowest mortality risk for men and women at the average level of one to two drinks per day, is likely due to the protective effects of moderate alcohol consumption on CHD, diabetes, and ischemic stroke as summarized in this chapter.
- ***Hepatic Effects*****.** Alcohol abuse is the leading cause of liver-related mortality in the U.S., likely accounting for a majority of cirrhosis deaths (CDC,

1993; Vong, 2004). Lower levels of alcohol intake can result in liver function abnormalities short of cirrhosis. For example, alcohol consumption may modulate pharmaceutical catabolism by liver enzymes and may potentiate the carcinogenic potency of hepatotoxins (NIAAA, 2003).

- ***Young Age.*** Children and adolescents should not consume alcohol. Alcohol consumption increases the risk of drowning, car accidents, and traumatic injury, which is the number one cause of death in this age group. Animal data on alcohol-related structural changes in the adolescent brain, while less compelling, illustrate why drinking is inappropriate for adolescents (Land, 2004; Markwiese, 1998).
- ***Pregnancy*.** Heavy drinking during pregnancy can produce a range of behavioral and psychosocial problems, malformations, and cognitive dysfunction in the offspring (NIAAA, 2003, 2009). Even daily moderate drinking during pregnancy, especially in the first few months or before the pregnancy is recognized, may have behavioral or neurocognitive consequences in the offspring. This effect may be from the direct toxic effects of alcohol or its metabolites or the effect that alcohol has on suppressing folate status—a known determinant of neural tube defects.
- ***Other Conditions.*** Alcohol consumption should be avoided by individuals who cannot restrict their drinking to moderate levels, individuals taking medications that can interact with alcohol, and persons with specific medical conditions, such as liver disease (NIAAA, 2009). NIAAA highlights specific advice and suggestions for individuals who cannot restrict their alcohol consumption (NIAAA, 2009).

Despite this lengthy list of diseases and conditions in which solid scientific evidence supports a cause and effect, the DGAC thought several questions should be further addressed. For most of the questions, the DGAC also wanted to explore whether there was enough information to make specific recommendations on patterns of consumption rather than on a simple daily limit. Unlike most other micronutrients and macronutrients which are consumed every day, most individuals do not drink every day. Thus, the DGAC surveyed the evidence to determine whether recommendations should continue to be based on a maximum number of drinks allowable on a single day or instead be based on an average consumed over the course of a week or even a month.

Methodology

The Committee recognized that alcohol affects many health outcomes due both to the acute effects of alcohol in the bloodstream and to the chronic effects of regular alcohol consumption. As noted above, many associations with disease are well known and well documented; therefore, only a few specific questions where a new evidence review could modify conclusions from previous DGAC Reports were examined. In addition, the Committee chose those specific health outcomes that would be most influenced by moderate alcohol consumption (up to one drink a day for women and two drinks a day for men), and where changes in recommendations would have the broadest impact.

Although the 2005 DGAC summary of the health effects of alcohol consumption were based on an evidence-based review, in many instances these reviews included a substantial number of cross-sectional studies. Since 2005, a large number of prospective studies of alcohol and chronic disease have been published. Thus, to refine the evidence search for each question, the DGAC limited the reviews to studies with greater methodological rigor and only conducted systematic reviews of observational prospective studies and randomized control trials. An exception was the question related to alcohol intake and unintentional injury because cross-sectional or case control studies are of equal or even better validity. For the question related to alcohol consumption and CHD, only systematic reviews and meta-analyses were used since the Nutrition Evidence Library (NEL) review found several recent studies.

Despite this lengthy list of diseases and conditions in which solid scientific evidence supports a cause and effect, the DGAC thought several questions should be further addressed, many of them specific to patterns of alcohol consumption that may potentially identify differential health effects based on more than just overall average alcohol intake (e.g., frequency of consumption or choice of beverage).

The methodology used in the search strategies varied depending upon the question. All questions, except for the breastfeeding sub-question related to offspring growth, included adults of legal drinking age (21 years and older). Other strategies used to identify relevant literature for the questions are discussed under each section. Additional information about the search strategies and criteria used to review each question can be found online in the NEL at www.NutritionEvidenceLibrary.gov. The overall search strategies used to identify relevant literature and to update scientific evidence appear in *Part C. Methodology*.

List of Questions

ALCOHOL INTAKE AND HEALTH OUTCOMES

1. What is the relationship between alcohol intake and weight gain?
2. What is the relationship between alcohol intake and cognitive decline with age?
3. What is the relationship between alcohol intake and coronary heart disease?
4. What is the relationship between alcohol intake and bone health?

ALCOHOL INTAKE AND UNINTENTIONAL INJURY

5. What is the relationship between alcohol intake and unintentional injury?

ALCOHOL INTAKE AND LACTATION

6. Does alcohol consumption during lactation have adverse health effects? What is the relationship between alcohol consumption and the quality and quantity of breast milk available for the offspring? What is the relationship between alcohol consumption and postnatal growth patterns, sleep patterns, and/or psychomotor patterns of the offspring?

Question 1: What Is the Relationship Between Alcohol Intake and Weight Gain?

Conclusion

Moderate evidence suggests that among free-living populations, moderate drinking is not associated with weight gain. However, heavier consumption over time is associated with weight gain.

Implications

Regardless of the alcoholic beverage, in general, all contain calories that are not a good source of nutrients and when consumed beyond an average of two drinks a day may lead to weight gain. Below this level of consumption, the results from most well designed large prospective studies suggest that individuals who drink in moderation do not gain weight at a faster rate than non-drinkers.

Review of the Evidence

Based on the literature dating back to November 1994, one randomized control trial (RCT) (Flechtner-Mors, 2004) and seven prospective observational studies (Koh-Banerjee, 2003; Liu, 1994; Sammel, 2003; Sherwood, 2000; Tolstrup, 2008; Wannamethee, 2004; Wannamethee and Shaper, 2003) from the U.S., Germany, Denmark, and the United Kingdom directly addressed the question of alcohol consumption and weight gain. The RCT was in the setting of an energy-restricted diet and was designed to test whether weight loss would be different if the energy-restricted diet contained 10 percent of energy from white wine or grape juice. The authors reported that everyone in the study lost weight as designed and the magnitude of the weight loss was similar between groups.

The remaining studies were mostly large scale prospective studies which followed people over time and examined whether a baseline report of alcohol was associated with subsequent weight gain after accounting for other lifestyle characteristics typically associated with body weight. For a subset of the first National Health and Nutrition Examination Study (NHANES), Liu et al. (1994) reported that drinkers were less likely to have either major weight gain or weight loss than nondrinkers over 10 years of follow-up. Similar results were reported in several other smaller studies (Sammel, 2003; Sherwood, 2000).

In the largest studies to examine this association, light to moderate drinkers did not have a significant increase in weight compared to abstainers. However, in these studies, significant weight gain was seen in men and women drinking more than two drinks per day (Wannamethee, 2003, 2004). In the two studies which specifically assessed changes in waist circumference, the results were similar (Koh-Banerjee, 2003; Tolstrup, 2008). Individuals who consumed on average one to two drinks per day did not have a significant increase in waist circumference when compared with non-drinkers. There is insufficient evidence to determine the relationship of drinking pattern or frequency of consumption to change in waist or weight; however, in each of the prospective studies, intake was based on average daily consumption typically over the past month or year.

Relevant Contextual Issue

Despite the lack of evidence to support a strong association between moderate alcohol consumption and weight gain, there is still concern that diets of individuals who drink may be inadequate if calories from alcoholic beverages replace calories from foods which may be more nutrient-dense. The NIAAA and the USDA Center for Nutrition Policy and Promotion used the Healthy Eating Index-2005 (a gauge of adherence to the 2005 *Dietary Guidelines*) to examine the relationship of alcohol consumption with nutrient intakes and diet quality, as measured by the Healthy Eating Index-2005 (HEI-2005). In this recently published cross-sectional study (Breslow, 2010) using data from NHANES, the authors described the following:

- Among men, there was not a clear difference between current drinkers and non-drinkers for total energy intake or HEI-2005 scores.
- Among women, current drinkers had significantly higher total energy and lower HEI-2005 scores.
- Among all drinkers, as the average number of drinks per day increased, total energy increased and HEI-2005 scores decreased.

This study was based on alcohol consumption over the past year, and a 24-hour dietary intake. It did not take into account physical activity as an important source of energy expenditure, but it does highlight the important concept that alcoholic beverages supply calories but few nutrients. The energy contribution from alcoholic beverages varies widely. Specifically, some alcoholic beverages, such as dessert wines and mixed drinks, provide almost three times as many calories as do the standard drink portions: 12 fluid ounces of regular beer, 5 fluid ounces of wine, or 1.5 fluid ounces of distilled spirits. Individuals who drink should be aware of the total calories of alcoholic beverages (see Table D.1.6 in *Part D. Section 1. Energy Balance and Weight Management* for a list of selected alcoholic beverages and their caloric content) and carefully assess how alcohol fits into their overall dietary pattern, especially with respect to the number of calories needed to maintain a healthy weight.

For those who choose to drink an alcoholic beverage, it is advisable to consume it with food to slow alcohol absorption. Data suggest that the presence of food in the stomach can slow the absorption of alcohol (Jones, 1997) and thereby mitigate the associated rise in blood alcohol concentration.

Question 2: What Is the Relationship Between Alcohol Intake and Cognitive Decline With Age?

Conclusion

Moderate evidence suggests that compared to non-drinkers, individuals who drink moderately have a slower cognitive decline with age. Although limited, evidence suggests that heavy or binge drinking is detrimental to age-related cognitive decline.

Implications

Alcohol, when consumed in moderation, did not quicken the pace of age-related loss of cognitive function. In most studies, it was just the opposite—moderate alcohol consumption, when part of a healthy diet and physical activity program, appeared to help to keep cognitive function intact with age. Despite the potential benefit at moderate consumption levels, heavy drinking and episodes of binge drinking impairs short- and long-term cognitive function and should be avoided.

Review of the Evidence

Over the past 10 years, a substantial new body of evidence has supported a modest beneficial association between alcohol consumption and cognitive function. The DGAC restricted its search to prospective studies to reduce bias associated with reverse causation of effect (i.e., the bias that individuals with reduced cognitive function may be less capable and less likely to drink). Based on the included literature dating back to 2001, one systematic review/meta-analysis (Peters, 2008) and seven additional U.S. and international prospective cohort studies (Bond, 2005; Deng, 2006; Mehlig, 2008; Ngandu, 2007; Solfrizzi, 2007; Stott, 2008; Wright, 2006) directly addressed the question related to alcohol intake and cognitive decline. Results from Peters et al. (2008), a systematic review and meta-analysis of 23 studies conducted primarily in the U.S., Canada, and Europe, found that in older adults, small to moderate amounts of alcohol consumption were associated with reduced incidence of dementia and Alzheimer's disease (Peters, 2008). Small amounts of alcohol may be protective against dementia and Alzheimer's disease, but not for vascular dementia or cognitive decline.

Several prospective cohort studies (Bond, 2005; Deng, 2006; Stott, 2008; Wright, 2006) found similar results that suggest that individuals who drink lightly to moderately have a decreased risk or reduced severity of dementia and/or cognitive decline especially in comparison to non-drinkers.

Question 3: What Is the Relationship Between Alcohol Intake and Coronary Heart Disease?

Conclusion

Strong evidence consistently demonstrates that compared to non-drinkers, individuals who drink moderately have lower risk of coronary heart disease. Insufficient evidence was available to determine if any one single drinking pattern was predictive of lower or higher risk of coronary heart disease, although there was moderate evidence to suggest that heavy or binge drinking is detrimental.

Implications

An average daily intake of one to two alcoholic beverages is associated with a low risk of coronary heart disease among middle-aged and older adults. Binge or heavy irregular drinking should be avoided.

Review of the Evidence

The issue of moderate alcohol consumption and risk of cardiovascular disease (CVD) was updated from the 2005 DGAC and also addressed alcohol consumption patterns. The NEL review searched published literature dating back to 1995 to 2009 and included six systematic reviews/meta-analyses conducted in the U.S. and internationally (Bagnardi, 2008; Britton, 2000; Cleophas, 1999; Corrao, 2000; Di Castelnuovo, 2002; Rimm, 1999). Overall, the evidence shows that compared to those who abstain from alcohol, regular light to moderate drinking can reduce the risk of CHD; whereas, heavy irregular or binge drinking increases risk of CHD.

The overall conclusion of general benefit from moderate intake of alcohol is also supported by the *State of the Science Report on the Effects of Moderate Drinking* (NIAAA, 2003), an extensive review of the literature conducted by scientific staff of the NIAAA and reviewed by 14 outside experts. In addition to recognizing the apparent mortality benefit of moderate alcohol consumption among middle-aged and older adults, the report concludes, "Except for those individuals at particular risk…, consumption of [up to] 2 drinks a day for men and 1 for women is unlikely to increase health risks" (NIAAA, 2003). Individuals at particular risk include persons who cannot restrict their drinking to moderate levels, children and adolescents, persons taking prescription or over-the-counter medications that can interact with alcohol, and individuals with special medical conditions (e.g., liver disease). In this 2010 DGAC Report, individuals who may be at risk (particularly with respect to unintentional injury and lactating women) are more clearly defined.

Many of the observational studies which have documented a benefit of moderate alcohol consumption on CVD prevention are summarized in the 2005 DGAC Report in Table D8-1, but are not summarized again here. The inverse association has been demonstrated in a variety of populations and is independent of many other cardiac risk factors, including age, sex, race/ethnic group, smoking habits, physical activity, diet, and body mass index (Corrao, 2000; Marmot, 2001; Mukamal, 2001). Similar to the evidence summarized above for alcohol and weight gain, the majority of prospective studies of alcohol and CHD assess average weekly intake over the past several months or year and are not based on a daily maximum of one to two drinks for the definition of moderate. On average, the relative risk of CHD associated with moderate drinking as defined by the DGAC is between 0.50 and 0.80 and is directly related to the benefits of alcohol on HDL-C, glucose, and clotting factors such as fibrinogen (Mukamal, 2001).

The DGAC pursued evidence to support a specific guideline for patterns of consumption. The same NEL review identified two meta-analyses (Bagnardi, 2008; Corrao, 2000) that addressed alcohol pattern consumption. Bagnardi et al. (2008) served as the strongest summary of the evidence. Based on somewhat similar measures of patterns of consumption from four prospective studies and two case-control studies, Bagnardi et al. (2008) concluded that among individuals who consumed alcohol on more than 2 days per week, risk of coronary heart disease was lowered even when alcohol was consumed at intake levels greater than two drinks a day. However, among irregular drinkers, moderate alcohol consumption was still inversely associated with CHD, but binge (or heavy) drinking was associated with an excess risk of CHD.

Question 4: What Is the Relationship Between Alcohol Intake and Bone Health?

Conclusion

Moderate evidence suggests a J-shaped association between alcohol consumption and incidence of hip fracture; there was a suggestion that heavy or binge drinking was detrimental to bone health.

Implications

There is insufficient evidence from epidemiological data to make a strong conclusion related to patterns of alcohol intake and bone health. However, it is very likely that the increased risk of fracture among individuals who drink more than one to two drinks per day on average is due to injuries that follow heavier consumption. What further complicates the interpretation of the existing studies is that moderate and heavy drinkers frequently were combined in the same category, making it impossible to disentangle potential benefits and risks. In addition, many studies failed to control adequately for physical activity, an important lifestyle characteristic beneficially related to bone density.

Review of the Evidence

The DGAC conducted a search for evidence published between 1995 and 2009. A recent systematic review and meta-analysis (Berg, 2008) involving 33 studies examined the association between ethanol intake and hip fracture and bone density mostly in White, European, or American adults. Studies were included if they used experimental, cohort, or case-control designs and included adults both exposed and not exposed to alcohol. The results from the meta-analysis involving 13 studies (8 prospective cohorts and 5 case-control) with a fair quality rating involving men and women over 20 years of age revealed a J-shaped relationship between alcohol consumption and hip fracture. Compared with abstainers, a lower risk of hip fracture was found among persons consuming up to 0.5 drinks per day (RR=0.84 [95% CI, 0.70-1.01]) and persons consuming 0.5-1.0 drinks per day (RR=0.80 [95% CI, 0.71-0.91]). Those consuming one to two drinks per day did not differ from abstainers (RR=0.91 [95% CI, 0.76-1.09]). However, persons consuming more than two drinks per day had an elevated risk for fracture (RR=1.39, [95% CI 1.08-1.79]).

In the meta-analysis of bone mineral density, a linear relationship existed between alcohol consumption and bone density of the femoral neck and vertebral spine. With limited data, the authors could not assess relative associations between alcohol consumption and bone density in moderate compared with heavy drinkers. Even though there is a positive effect of alcohol consumption on hip fracture and femoral neck/vertebral spine bone density, the exact range of alcohol consumption that is beneficial cannot be determined.

Question 5: What Is the Relationship Between Alcohol Intake and Unintentional Injury?

Conclusion

Strong evidence demonstrates that drinking in excess of current guidelines increases the risk of unintentional falls, motor vehicle crashes, and drowning. When alcohol is consumed in moderation, the evidence for risk of unintentional injury is less well established for activities such as driving, swimming, and athletic participation, but abstention from alcohol is the safest.

Implications

Adverse effects, in terms of unintentional injury, can occur even at levels of moderate alcohol consumption.

Review of the Evidence

This conclusion is based on 20 U.S. and international studies dating back to 2004, including four systematic reviews (Cherpitel, 2007; Driscoll, 2004; Gonzalez-Wilhelm, 2007; Kool, 2009), six prospective cohort studies (Bedford, 2006; Driscoll, 2004; Hall, 2009; Hingson, 2009; Johnson, 2004; Mukamal, 2004), five case-control studies (Kool, 2008; Kurzthaler, 2005; Sorock, 2006; Watt, 2004; Yoonhee, 2009), five cross-sectional studies (Hingson, 2009; Levy, 2004; McLean, 2009; Rehm, 2006; Watt, 2006).

All 20 studies reviewed found that alcohol consumption was positively associated with risk of unintentional injuries and found associations with a wide range of different types of injuries. For example, many studies focused specifically on head injuries, spinal cord injuries, and soft tissue injuries (Cherpitel, 2007; Hingson, 2009a, 2009b; Johnston, 2004; Levy, 2004; McLean, 2009; Rehm, 2006; Watt, 2006; Yoonhee, 2009); while others were related to fatal and non-fatal motor vehicle crashes (Bedford, 2006; Gonzalez-Wilhelm, 2007; Hingson, 2009a, 2009b; Levy, 2004; Sorock, 2006), boating incidents (Driscoll, 2004), and all-terrain vehicle crashes (Hall, 2009).

As discussed above in relation to bone health, there is evidence that even when consumed in moderation, alcohol consumption increases risk of falling (Kool, 2008, 2009; Kurzthaler, 2005; Mukamal, 2004; Sorock, 2006). Also, the specific reason that the DGAC chose to include swimming in the list of specific activities where alcohol should be avoided is because of the association between drinking alcohol and drowning (Driscoll, 2004a, 2004b; Levy, 2004). Other areas of unintentional injury linked to alcohol consumption include suicide, fire-related injuries, and violence-related injury.

Finally, while few studies had sufficient data, one study found evidence of a dose-response relationship between alcohol intake and injury (Kool, 2009), and several studies found that risk of unintentional injury tended to increase significantly after drinking two or more drinks per day (Kool, 2008; Mukamal, 2004; Watt, 2004).

Question 6: Does Alcohol Consumption During Lactation Have Adverse Health Effects? What Is the Relationship Between Alcohol Consumption and the Quality and Quantity of Breast Milk Available for the Offspring? What Is the Relationship Between Alcohol Consumption and Postnatal Growth Patterns, Sleep Patterns, and/or Psychomotor Patterns of the Offspring?

Conclusion

Moderate, consistent evidence shows that when a lactating mother consumes alcohol, alcohol enters the breast milk, and the quantity of milk produced is reduced, leading to reduced milk consumption by the infant. Although limited, evidence suggests that alcohol consumption during lactation is associated with altered post-natal growth, sleep patterns, and/or psychomotor patterns of the offspring.

Implications

The benefits of breastfeeding to the infant are well established. A woman who chooses to breast feed, however, need not completely abstain from alcohol. Because the level of alcohol in breast milk mirrors the mother's blood alcohol content, after latch-on has been perfected and a pattern of consistent breastfeeding has been established (i.e., around age 2 to 3 months), a mother could wait 3 to 4 hours after a single drink (the time it would take to metabolize the ethanol) before breastfeeding and the infant's exposure to alcohol would likely be negligible. It is not sufficient for a woman to express breast milk after alcohol consumption to prevent exposure to the infant because the concentration of alcohol in breast milk will remain at levels in the blood until all the alcohol is metabolized. Contrary to medical and cultural folklore, alcohol consumption does not enhance lactational performance and instead reduces milk production and decreases infant milk consumption in the 3 to 4 hours after alcohol is consumed. Finally, there is still insufficient evidence to conclude definitively that alcohol exposure to an infant during lactation affects the postnatal growth of the child, but nonetheless, alcohol exposure to the breastfeeding infant by breastfeeding too soon after consuming a single drink should be avoided.

Review of the Evidence

Background

The Committee felt strongly that the issue of alcohol and breastfeeding should be addressed because substantial evidence clearly demonstrates that breastfeeding is beneficial to the health of the infant. The DGAC did not want women to misinterpret the *Dietary Guidelines* and prematurely stop breastfeeding because they wanted to occasionally consume an alcoholic drink. In an effort to capture all available information on this new *Dietary Guidelines* topic, no date restrictions were imposed on the literature search.

Summary of Evidence

As briefly summarized above, there is substantial evidence that heavy drinking during pregnancy can cause serious health consequences to the unborn infant. Even daily moderate alcohol consumption among pregnant women may not be without risk and should be avoided. However, the DGAC has not previously adequately addressed the evidence for the health effects of alcohol among women who are breastfeeding and who may expose their child to alcohol indirectly through the breast milk. A limited number of U.S. and international studies have directly examined this relationship (Backstrand, 2004; Little, 1989, 2002; Mennella, 1998, 2001). In a small cohort in Mexico among women who consumed pulque (a "beer strength" alcoholic beverage from Mexico produced from fermented cactus sap), heavier pulque intake during lactation was associated with slower postpartum growth of the infant from 1 to 57 months (Backstrand, 2004).

In two separate studies of lactating women with regular exposure to moderate alcohol, the authors assessed infant motor development. In the first, Little et al. (1989) examined infants at 1 year of age and found a significant detrimental association with infant motor development among mothers who consumed on average two drinks per day compared to women who abstained. In a replication study by the same author the opposite association was reported; but the children were examined at 18 months, and the mothers consumed significantly less alcohol on average (Little, 2002).

Besides these potential longer term effects of alcohol on infant cognition, two studies examined the effects of alcohol during lactation on other characteristics of the infant. These studies reported that short-term exposure to small amounts of alcohol in mothers' milk produces distinctive adverse changes in the infants' sleep–wake patterning (Mennella, 1998, 2001).

Relevant Contextual Issues for the Entire Chapter

Abstention is an important option. Approximately one in three American adults does not drink alcohol. Moreover, studies suggest adverse effects at even moderate alcohol consumption levels in specific individuals and situations, as described above. People who should not drink include:

- Individuals who cannot restrict their drinking to moderate levels
- Children and adolescents
- Individuals taking prescription or over-the-counter medications that can interact with alcohol
- Individuals with specific medical conditions (e.g., liver disease, hypertriglyceridemia, pancreatitis)

In addition, alcohol should be avoided by:

- Women who are pregnant or who are unsure if they are pregnant
- Individuals who plan to drive, operate machinery, or take part in other activities that require attention, skill, or coordination or in situations where impaired judgment could cause unintentional injury (e.g., swimming)

Chapter Summary

An average daily intake of one to two alcoholic beverages is associated with the lowest all-cause mortality and a low risk of diabetes and CHD among middle-aged and older adults. Despite this overall benefit of moderate alcohol consumption, the evidence for a positive association between alcohol consumption and risk of unintentional injuries and breast and colon cancer should be taken into consideration. The DGAC recommends that if alcohol is consumed, it should be consumed in moderation, and only by adults. Moderate alcohol consumption is defined as *average* daily consumption of up to one drink per day for women and up to two drinks per day for men and no more than three drinks in any single day for women and no more than four drinks in any single day for men. One drink is defined as 12 fluid ounces of regular beer, 5 fluid ounces of wine, or 1.5 fluid ounces of distilled spirits.

The substantial epidemiological literature is based on studies where individuals report their "average" intake as drinks per day, month, or year. Because most U.S. citizens do not drink every day, the DGAC also recommends that the definition for moderation be based on this general "average" metric over the course of a week or month instead of an exact threshold of "1 drink per day for women or 2 drinks per day for men" each day. The Committee further explored whether there was compelling evidence to expand the definition of moderation to include a specific healthy pattern of consumption, but could not find one particular pattern of consumption that had a strong evidence base and could provide more clarity than the recommendation above. The DGAC did find strong evidence that heavy consumption, that is, four or more drinks a day for women and five or more drinks a day for men, had harmful health effects. A number of situations and conditions call for the complete avoidance of alcoholic beverages.

Needs for Future Research

1. Conduct a comprehensive set of studies in a controlled setting to assess the influences that alcohol may have on factors that affect energy intake and expenditure.

   Rationale: The effects of energy from alcohol on body weight are complex and not completely understood. These studies will clarify whether the lack of association between moderate alcohol consumption and weight gain is due to biological compensation or changes in other behaviors (e.g., diet or physical activity).

2. Conduct research to enhance the currently limited data on changes in markers of bone health in metabolic studies of alcohol consumption.

   Rationale: In large epidemiological studies, a better classification of drinking patterns and a better documentation of the traumatic or non-traumatic cause of fracture are needed, but equally important is the need to study prospectively changes in alcohol consumption and changes in intermediate markers of bone structure and integrity.

3. Focus further research to avoid unintentional injury on effective communication policies that expand current messages on drinking and driving to inform individuals of other unintentional risks associated with alcohol consumption.

   Rationale: The documented benefit of drunk driving campaigns is a public health success; yet alcohol related injury is still substantial in other areas and should be addressed with the same vigilance and governmental support.

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Part D. Section 8: Food Safety and Technology

Introduction

The 2005 *Dietary Guidelines for Americans* emphasized the importance of food safety. Since the release of the Guidelines, food safety concerns have escalated, with the apparent increase in voluntary recalls of foods contaminated with disease-causing bacteria and adulterated with non-food substances. These food safety issues affect commercial food products and food preparations in the home.

The basic four food safety principles identified to reduce the risk of foodborne illnesses remain unchanged. These principles—Clean, Separate, Cook, and Chill—are cornerstones in the Fight BAC!® (www.fightbac.org) educational messages developed by the Partnership for Food Safety Education, a collaboration with the Federal government. These messages are reinforced in the United States Department of Agriculture's (USDA) *Be Food Safe* (www.befoodsafe.gov) efforts to reduce foodborne illnesses. Other food safety education programs include the USDA's *Is It Done Yet?* (www.isitdoneyet.gov) and *Thermy*™ (http://origin-www.fsis.usda.gov/food_safety_education/thermy/index.asp) initiatives, which outline key elements in thermometer use and placement to ensure proper cooking of meat, poultry, seafood, and egg products. The primary food safety message from these education programs is "It's Safe to Bite When the Temperature is Right." This "temperature" message receives attention in this chapter. Additional consumer-friendly information on food safety is available at www.foodsafety.gov. In addition to the principles of Fight BAC!®, the importance of "avoiding risky foods[1]" is another relevant food safety education construct addressed (Medeiros, 2001).

Heightened food safety concerns have contributed to the development of new technologies and research directed at reducing the risk of microbial foodborne illness outbreaks and food contamination, while assisting the consumer in controlling the home food preparation and storage environment. Food technology is the application of food science to the processing of food materials into safe, wholesome, and nutritious food (Institute of Food Technologists [IFT], 2009). Thus, the 2010 Dietary Guidelines Advisory Committee (DGAC) was compelled to provide additional food safety guidance to the American public while introducing and discussing technological developments. The name of the subcommittee changed from the Food Safety to the Food Safety *and Technology* subcommittee.

This chapter updates the 2005 Report content related to risks from exposure to methyl mercury from the consumption of seafood, and, in addition, addresses the impact of exposure to persistent organic pollutants (POPs). The benefit-risk ratios are presented, weighing the benefits of consuming seafood against the risks on health, including reducing the risk of cardiovascular disease (CVD) and supporting child neurological development. The evidence assessment was particularly important in providing information about populations vulnerable to methyl mercury exposure, such as pregnant and nursing women and young children. What is known regarding the interaction of methyl mercury and selenium from seafood sources is briefly addressed, as is the influence of aquaculture practices on a safe and nutritious food supply.

During the deliberations of the DGAC, organic produce emerged as a topic of discussion. The DGAC agreed that current scientific evidence did not warrant a question on this topic, but that some clarification for the public was needed as to what "organic" means. Therefore, a short review of the topic by the Food Safety and Technology subcommittee is available online at http://www.cnpp.usda.gov/DGAs2010-DGACReport.htm.

[1] The DGAC defines a "risky food" as a food consumed in such a way (e.g., undercooked) that it poses a microbiological hazard for human health.

Lastly, food allergens were identified by the DGAC as an important food safety issue. The National Institute of Allergy and Infectious Disease (NIAID) of the National Institutes of Health (NIH) established a Coordinating Committee to oversee the development and approval of *Guidelines for the Diagnosis and Management of Food Allergy*. The Coordinating Committee used an Expert Panel of specialists from a variety of clinical, scientific, and public health arenas relevant to this topic. The Expert Panel used an independent systematic literature review, as well as expert opinion, when needed, to develop the guidelines. Due to the extensive literature review conducted through this NIAID initiative, the DGAC deferred completing an evidence review on food allergy. A draft report of the *Guidelines for the Diagnosis and Management of Food Allergy* was released by NIAID in March 2010 (www.niaid.nih.gov). A short review of the topic by the Food Safety and Technology subcommittee is available online at http://www.cnpp.usda.gov/DGAs2010-DGACReport.htm.

List of Questions

BEHAVIORS MOST LIKELY TO PREVENT FOOD SAFETY PROBLEMS AND THE EXTENT TO WHICH U.S. CONSUMERS FOLLOW THESE BEHAVIORS

1. CLEAN: What techniques for hand sanitation are associated with favorable food safety outcomes and to what extent do U.S. consumers follow them?

2. CLEAN: What techniques for washing fresh produce are associated with favorable food safety outcomes and to what extent do U.S. consumers follow them?

3. CLEAN: To what extent do U.S. consumers clean their refrigerators?

4. SEPARATE: What techniques for preventing cross-contamination are associated with favorable food safety outcomes?

5. COOK AND CHILL: To what extent do U.S. consumers follow adequate temperature control during food preparation and storage at home?

6. AVOID RISKY FOODS: To what extent do U.S. consumers eat raw or undercooked animal foods?

7. To what extent do specific subpopulations practice unsafe food safety behaviors?

FOOD SAFETY TECHNOLOGIES

8. To what extent are recently developed technological materials that are designed to improve food safety, effective in reducing exposure to pathogens and decreasing the risk of foodborne illnesses in the home?

SEAFOOD

9. What are the benefits in relationship to the risks for seafood consumption?

Methodology

The information used to develop the Food Safety chapter written for the 2005 DGAC was gleaned from a literature review and review of educational tools for conveying messages to consumers about safe food handling and preparation. The Committee emphasized information from the national food safety education campaign Fight BAC!®. Thus, unlike other chapters in the 2005 DGAC Report, which reflected evidence-based reviews, the food safety recommendations stemmed primarily from educational tools developed by the USDA. The 2010 DGAC emphasized systematic evidence-based assessments for all aspects of the Report, and leveraged, for the first time, the systematic review process using the Nutrition Evidence Library (NEL) and the careful quality weighing of that evidence. A description of the NEL evidence-based systematic review process is provided in *Part C: Methodology*.

Using the NEL system for the first time for the Food Safety and Technology chapter provided a platform for evaluating evidence that has not been previously available and sets the standard for future Committees. Through this process, research strengths and weaknesses were identified, thus providing significant direction for national policy development and guidance for future investigations in food safety and food technology.

The Food Safety and Technology subcommittee assessed the quality of the available evidence pertinent to the three primary families of questions focused on (a) in-home food safety behaviors, (b) new technologies related to food safety in the home, and (c) risks and benefits associated with seafood consumption. All NEL systematic evidence-based review materials are available at www.NutritionEvidenceLibrary.gov.

For both the 2005 and the 2010 DGAC Reports, questions involved reviewing evidence on food safety techniques for application in the home, including those on food storage, food preparation and handling, personal hygiene, and management of cooking utensils. In addition, the food safety questions in the 2010 DGAC Report went further to review substantive evidence on consumer behaviors related to favorable techniques for preventing foodborne illness. The literature search generally covered 2004 through 2009, with slight variations in date ranges by topic that can be found online in the NEL. For in-home food safety behaviors, an original set of nine subquestions was drafted for the literature search and sort plans. Some of these subquestions were worded very generally with the intention to cast a wide net on the available literature. However, after searches were completed, the questions were refocused where the evidence was most plentiful, resulting in the overarching in-home food safety question and seven subquestions as noted above. For the original list of research questions on in-home food safety, see Table D8.1[2].

The food safety questions of the 2005 DGAC Report evaluated topics that were not an integral part of Fight BAC!®, yet warranted attention. Since the 2005 Report, Fight BAC!® has further developed its guidance, and additional food safety materials from the Food and Drug Administration (FDA), and USDA's educational campaigns, www.isitdoneyet.gov and www.befoodsafe.gov, have greatly expanded the food safety messages available to consumers. Therefore, in the 2010 food safety discussion, information available from several USDA and HHS food safety educational programs are identified as points of reference to the findings of the literature reviewed. However, a research question did not specifically address these programs. In addition to the NEL evidence, the DGAC also used data summarized from the FDA and Food Safety and Inspection Service (FSIS) Food Safety Survey (2006).

While the basic pillars of food safety in the home remain unchanged, the Committee considered recent technological developments that may assist consumers in their food management practices. Thus, the second area of formal review encompassed common and emerging technologies associated with items such as thermometers, food contact surfaces, and sanitizers. This topic was not previously addressed by the 2005 DGAC, and the 2010 DGAC's literature search covered only 2004 through 2009 because information has emerged only recently. In addition to the questions stated previously, the 2010 DGAC conducted literature searches for two other questions on aspects of in-home technologies, (1) technological materials that may be effective in increasing the shelf life of foods, and (2) the accessibility and economical practicality of effective technological materials that are designed to improve food safety or increase shelf life. However, the evidence in these two areas was insufficient to draw any conclusions, and, therefore, they will not be discussed in the evidence review.

Originally presented in the 2005 DGAC Report, the current content also updates the evidence on methyl mercury exposure from seafood through a review of new evidence on the benefit-risk ratios associated with seafood consumption and health outcomes published since 2007. The impact of exposure to POPs also is addressed in the review of the literature for this question. A formal search of the evidence-based literature began in 2007 because a report published that year from the Institute of Medicine (IOM), *Seafood Choices–Balancing Benefits and Risks* (IOM, 2007), provided an evidence-based assessment of the methyl mercury and POPs issues from the 2005 Report through 2007. A second search on POPs alone was also done from 2004 to 2009. The Environmental Protection Agency (EPA)/FDA advisory, *What You Need to Know about Mercury in Fish and Shellfish* (EPA/FDA, 2004), the current Federal guidance at the time this Report was submitted, and analyses in food pattern modeling to explore the role of seafood in the total diet, were taken into consideration.

The subcommittee considered food safety-related information submitted by the public through the public comments process. Many of these topics were addressed through the evidence-based review. Other topics were not formally reviewed by the Committee, due, in part, to the complexity of the issue or the apparent limited availability of evidence related to the subject. To support the continued consideration of these topics for future DGACs and for public policy, the following are addressed through a review of contextual references:

[2] Tables D8.1 through D8.8 can be found at the end of this chapter.

- Seafood: Implications of dietary selenium and the potential health risks of methyl mercury exposure from seafood
- Seafood: Implications of aquacultural practices and a safe, nutritious food supply
- On-line resource (accessible at http://www.cnpp.usda.gov/DGAs2010-DGACReport.htm): http://www.dietaryguidelines.gov/Implications of food allergens and a safe food supply
- On-line resource (accessible at http://www.cnpp.usda.gov/DGAs2010-DGACReport.htm): Conventional and organically produced foods

BEHAVIORS MOST LIKELY TO PREVENT FOOD SAFETY PROBLEMS AND THE EXTENT TO WHICH U.S, CONSUMERS FOLLOW THESE BEHAVIORS

Annually, foodborne illness affects more than 76 million individuals in the U.S. leading to 325,000 hospitalizations and 5,200 deaths at a cost of $7 billion to the Nation (IOM, 2006). Because foodborne illness outbreaks are difficult to trace and characterize, the proportion of outbreaks that can be attributed to unsafe food safety practices at home remains unknown, although it is believed to be substantial (Redmond, 2003; Roseman, 2007). An indirect way of assessing this risk is by documenting consumers' food safety practices at home. This topic is of relevance as the vast majority of consumers has a refrigerator and a stove or microwave at home, and prepare and/or consume at least some of their meals at home (FDA/FSIS, 2006).

Foodborne illness continues to be a major public health threat to U.S. consumers who are aware of the importance of food safety for human health (Mead, 1999), but they do not believe that their home kitchens are an actual source of foodborne outbreaks (Levy, 2008; Miles, 2003; Redmond, 2004). Risky food safety behaviors at home are likely to translate into home-based foodborne illness outbreaks.

On the one hand, consumers are not aware, or they lack specific knowledge regarding pathogens (e.g., *Listeria*, *Campylobacter*) (Cates, 2006), food contamination vehicles and potential transmission routes (e.g., cross contamination) (Dharod, 2004), and proper cold storage temperatures and refrigerator cleaning (Bryd-Bredbenner, 2008; Godwin, 2006; Kilonzo-Nthenge, 2008; Kosa, 2007; Towns, 2006). For example, research conducted among Hispanic women in Connecticut has shown that few consumers are aware of the term "cross-contamination," even after exposure to the Fight BAC!® campaign (Dharod, 2004). This is a cause of public health concern because the risk of cross-contamination in home kitchens in some Hispanic (Dharod, 2007a) and other (FDA/FSIS, 2006) communities is substantial. Hands play a central role in the chain of transmission of microbial pathogens through food and other vehicles. Thus, proper hand hygiene before, during, and after food preparation is one of the key measures for preventing foodborne diseases. Hand hygiene can be based on hand washing with plain soap (i.e., detergents that do not contain antimicrobial agents or contain low concentrations of antimicrobial agents that are effective solely as preservatives, Centers for Disease Control and Prevention [CDC], 2002) and water (physical removal of microbes) and/or the use of rinse-free alcohol-based hand sanitizers (killing of microbes).

On the other hand, consumers often do not translate their food safety knowledge into safe practices (Abbot, 2009; Byrd-Bredbenner, 2007; Cates, 2006; Dharod, 2004, 2007a; Godwin, 2006; Kwon, 2008; Patil, 2005; Redmond, 2003; Towns, 2006; Trepka, 2007; Yarrow, 2009). This is perhaps explained at least in part by the "not in my kitchen" optimistic bias (Cates, 2006; Levy, 2008; Miles, 2003; Redmond, 2004; Roseman, 2006) and the lack of consumers' internal locus of control with regard to food safety, namely the belief that its mainly the responsibility of industry and government to prevent foodborne illness (Cates, 2006). Improvements in consumers' knowledge and also their attitudes and intentions toward reducing home-based food safety risks are needed.

Higher socio-economic status has been associated with more food safety knowledge, but often with the worst food safety behaviors (Patil, 2005). Being a member of a racial/ethnic minority group has been associated with better food safety behaviors (FDA/FSIS, 2006; Patil, 2005). Improper home food safety behaviors have been identified in different stages of the life cycle, such as pregnancy (Kwon, 2008; Trepka, 2007), college students (Abbot, 2009; Byrd-Bredbenner, 2007, 2008; Yarrow, 2009), and older adults (Almanza, 2007; Kosa, 2007; Roseman, 2007). Overall, men are more likely than women to practice risky food safety behaviors at home. Thus, all segments of the U.S. population could benefit from improved food safety education based on effective behavioral change theories.

The 2010 DGAC's evidence-based review of behaviors that are likely to prevent food safety problems and U.S. consumers' actions in this regard has led it to one overarching conclusion, which has implications for current and future consumer education efforts. The sections that follow present specific conclusions and evidence reviews for each of the four Fight BAC!® constructs (i.e., clean, separate, cook and chill), plus the "avoiding risky foods" construct.

Overarching Conclusion

Evidence shows that proper hand sanitation techniques, proper washing of vegetables and fruit, prevention of cross-contamination, and appropriate cooking and storage of foods in the home kitchen are most likely to prevent food safety problems. Food safety behaviors least practiced by consumers are hand sanitation, cross-contamination prevention, and use of cooking, refrigerator, and freezer thermometers. Food safety knowledge of U.S. consumers is not being translated into improved food safety practices at home.

Implications

All segments of the U.S. population could benefit from improved food safety education based on effective behavioral change theories. Food safety education is needed to not only improve consumers' knowledge, but also their attitudes and intentions toward reducing home-based food safety risks. In particular, consumers need to take more responsibility regarding food safety. Together, with sound government policies and responsible food industry practices, foodborne illness can be prevented.

Food safety behaviors that particularly need additional promotion are hand sanitation, use of cooking and refrigerator/freezer thermometers, and prevention of cross-contamination. Produce washing practices can vary significantly for different vegetables and this behavior needs to be substantially improved. Additional guidance is needed to provide detailed recommendations on the frequency of refrigerator cleaning to decrease pathogen growth and potential for cross-contamination. It is important to educate consumers on appropriate cooking temperatures and the reasons to avoid consuming raw or undercooked animal protein products. The consumption of certain risky foods (e.g., cookie dough containing raw eggs) is likely to occur at home, but the consumption of other foods (e.g., raw seafood) is more likely to occur outside the home. Thus, consumer food safety education in this area needs to address safe food practices in the different environments in which individuals are likely to consume the different products. Education should also address food safety issues that have emerged due to trends toward local- and regional-based food production.

Of subpopulations in the U.S., older adults may be at greater risk because of the age-related reduction in immunity. Pregnant women also have altered immune status which may render the fetus more susceptible to infection. Foodborne illnesses affecting pregnant women can have extremely serious consequences for the fetus as illustrated by the still births resulting from listeriosis. Foodborne illness outbreaks among college students have the potential to rapidly spread within the student body as a result of the group arrangements in which they often live.

Question 1: CLEAN: What Techniques for Hand Sanitation Are Associated With Favorable Food Safety Outcomes and to What Extent Do U.S. Consumers Follow Them?

Conclusion

Strong, clear, and consistent evidence shows that hand washing with plain soap for 20-30 seconds followed by proper hand drying is an effective hand hygiene technique for preventing cross-contamination during food preparation. Strong, clear, and consistent evidence shows that alcohol–based, rinse-free hand sanitizers are an adequate alternative when proper hand washing with plain soap is not possible. Moderate, consistent evidence shows that U.S. consumers do not follow recommended hand sanitation behaviors.

Review of the Evidence

The conclusion on recommended techniques for hand sanitation is derived from 17 studies, including four meta-analyses or literature reviews (Aiello, 2007, 2008; Haas, 2005; Meadows, 2004), six randomized controlled trials (Aiello, 2004; Fischler, 2007; Larson, 2004; Sandora, 2005, 2008; Vessey, 2007), five quasi-experimental studies (Brown, 2007; Schaffner, 2007; Thorrold, 2007; Tousman, 2007; White, 2005), and two observational prospective studies (Dharod, 2009; Lee, 2005). Studies were conducted in schools and other community settings as well as in homes and under laboratory simulation conditions.

Soaps with antimicrobial additives are not needed for proper hand hygiene at home and should be avoided due to possible microbial resistance to antibacterials associated with their long-term use (Aiello, 2004, 2007; Thorrold, 2007). Under some circumstances involving the presence of highly vulnerable individuals at home, alcohol-based hand sanitizers after hand washing with soap may provide additional protection. It is essential that consumers not only practice adequate hand hygiene techniques at home and in the community, but that they also do it at the right times. Thus, hand hygiene education and promotion should seek to improve the consumers' understanding of the chain of transmission of pathogens from food sources and the risk situations (i.e., critical control points) before, during, and after food preparation and other human activities requiring proper hygiene, including toilet use and contact with pets. Hand washing procedures for consumers adapted from information from the CDC can be seen in Table D8.2.

The conclusion regarding consumers' adherence to recommended hand sanitation is derived from five cross-sectional studies (Abbot, 2008; Anderson, 2008; Comer, 2009; Dharod, 2007a; Thumma, 2009). The FDA/FSIS Food Safety Survey (2006) provided additional evidence. In the Food Safety Survey (FDA/FSIS, 2006) three-quarters of respondents indicated that they always washed their hands before starting food preparation. Gender did not influence the hand washing report, but this behavior was more likely to be reported by those with lower levels of education and by those who identified themselves as White. Close to 88 percent reported washing the cutting board after placing raw meat on it. This behavior was more common among those with lower levels of education, females, and non-Hispanics than among those in other population groups. Studies have consistently shown that proper hand washing associated with food preparation (Abbot, 2008; Dharod, 2007a; Thumma, 2009) and bathroom use (Anderson, 2008; Thumma, 2009) is far less than optimal and needs to be better promoted (Comer, 2009). Two studies involving direct observation of hand washing behaviors during food preparation among college students (Abbot, 2008) and Puerto Rican home meal preparers (Dharod, 2007a) found a high degree of overreporting of desirable hand washing behaviors during food preparation. This finding may be explained by a social desirability bias and indicates that results derived from self-reported hand hygiene behaviors should be interpreted with caution.

Question 2: CLEAN: What Techniques for Washing Fresh Produce Are Associated With Favorable Food Safety Outcomes and to What Extent Do U.S. Consumers Follow Them?

Conclusion

A limited body of evidence has shown that washing vegetables and fruit by running water over them at home or under laboratory simulation conditions is associated with reduced produce microbial loads. Moderate, consistent evidence shows that U.S. consumers are not following recommended produce washing techniques at home.

Review of the Evidence

The conclusion regarding techniques for washing fresh produce is derived from three studies, including two non-randomized trials (Kilonzo-Nthenge, 2006; Parnell, 2005), and one cross-sectional study (Dharod, 2007b). Washing fresh produce at home is the last opportunity that consumers have to reduce potential pathogen loads in these products before consuming them and is likely to help reduce food safety risks (Dharod, 2007b; Kilonzo-Nthenge, 2006; Parnell, 2005). One of the few studies that examined this issue among free-living individuals while preparing a family meal at home provides relevant insights. Dharod et al. (2007b) demonstrated a significant reduction in total microbial and coliform counts associated with washing lettuce and tomato under running water in Puerto Rican households' home kitchens during preparation of a "chicken and salad" meal. Guidance for consumers for washing produce, adapted from information available from the FDA, can be seen in Table D8.3.

The conclusion regarding consumer behaviors related to washing fresh produce is derived from two cross-sectional studies (Dharod, 2007a; Anderson, 2004) and an analysis of responses from the FDA/FSIS Food Safety Survey (2006). Dharod et al. (2007a) found that among Puerto Rican home meal preparers, 87 percent washed the lettuce and 85 percent washed the tomatoes under running water while preparing salad. In their direct observation study among 99 U.S. college students, Anderson et al. (2004) found that six did not clean any of the vegetables used to prepare a salad, 70 rinsed the lettuce, 93 rinsed the tomato, 47 rinsed the carrots, and 55 rinsed the cucumber with water. This study also documented that average washing time ranged from 4.8 to 12.4 seconds, substantially shorter than the 60 seconds recommended by the author. These findings indicate that washing practices can vary significantly for different vegetables and that these behaviors need to be substantially improved.

The FDA/FSIS Food Safety Survey (2006) asked consumers about their behaviors for washing tomatoes, cantaloupe, and strawberries. Among participants who responded that they ever buy the product, a smaller proportion (57%, n=1806) reported usually washing cantaloupe compared to much higher proportions that usually washed tomatoes (97%, n=2029) or strawberries (98%, n=2001). Among participants who reported washing tomatoes, cantaloupe, or strawberries, the method reported for washing was analyzed. Washing produce by rubbing it under running water with a brush, cloth, or hands was considered a favorable behavior. Also reported was use of any type of cleaner to wash produce. Although this is not an encouraged behavior, it is also not necessarily undesirable if a cleaner intended for produce is used. Respondents of lower incomes consistently reported more favorable behaviors than their higher income counterparts for washing tomatoes, cantaloupe, and/or strawberries. Adults ages 18 to 59 years were significantly more likely to practice the desirable behavior of rubbing tomatoes (76%) and strawberries (49%) under running water compared to adults ages 60 years and older (71% and 36%, respectively) ($p < 0.05$). Respondents with children younger than age 5 years were more likely to rub cantaloupe (79%) and strawberries (61%) under running water compared to those without children younger than age 5 years (69% and 40%, respectively) ($p< 0.05$). Women were significantly more likely to use a cleaner to wash tomatoes, cantaloupe, and strawberries (8%, 10%, and 5%, respectively) compared to males (6%, 4%, and 3%, respectively) ($p< 0.05$).

Question 3: CLEAN: To What Extent Do U.S. Consumers Clean Their Refrigerators?

Conclusion

Moderate, consistent evidence shows that U.S. consumers do not clean their refrigerators following available guidance.

Review of the Evidence

This conclusion is derived from four cross-sectional studies (Bryd-Bredbenner, 2007; Godwin, 2006; Kilonzo-Nthenge, 2008; Kosa, 2007). The DGAC also reviewed a case-control study from the United Kingdom (Parry, 2005) to obtain additional contextual information on this question.

The four cross-sectional studies all reported cleanliness and sanitation of refrigerators as a problem. Bryd-Bredbenner et al. (2007) found that young adults scored less than 60 percent on the appliance cleanliness and cold food storage scales. Kosa et al. (2007) found that among a large adult sample, 53 percent of participants had not cleaned their refrigerator for at least 1 month before the survey. Kilonzo-Nthenge et al. (2008) identified 19 different bacterial isolates including *Listeria innocua* in 4.4 percent of domestic refrigerators in a study in Tennessee. They also identified *Klebsiella pneumoniae* and *Enterobacter cloacae* in 23.4 percent and 20.5 percent of the refrigerators, respectively, and identified multidrug antibiotic resistance in *Klebsiella* and *Enterobacter spp*. Although most of the bacteria identified are nonpathogenic to healthy adults, they do serve as sanitation markers. Thus, findings indicate that proper food and refrigerator sanitation practices were not being followed in a significant proportion of households. Godwin et al. (2006) found in Florida and Tennessee households that 72 percent of swabs contained viable microbial populations, as assessed by way of adenosine triphosphate bioluminescence. The highest microbial loads were detected in the vegetable compartment and the meat sections. The microbial load in the vegetable compartment correlated significantly with the cleanliness score for that compartment. Only 5 percent of the respondents reported emptying and cleaning the entire refrigerator often or very often, with 78 percent reporting doing so occasionally or rarely. The UK case-control study (Parry, 2005) did not find an association between the presence of *Salmonella* in dishcloths and refrigerators and risk of salmonellosis.

Findings are difficult to interpret, as 65 percent of individuals who developed salmonellosis had eaten meals prepared outside the home kitchen 72 hours before the onset of symptoms. Godwin et al. (2006) documented that consumers' self-reports of vegetable compartment cleaning frequency did not correlate with microbial loads found in domestic refrigerators. Thus, proper refrigerator hygiene techniques may not be followed even when the behavior is practiced. Table D8.4 provides general guidance for consumers on refrigerator cleaning adapted from information available from FSIS.

Question 4: SEPARATE: What Techniques for Preventing Cross-contamination Are Associated with Favorable Food Safety Outcomes?

Conclusion

Moderate, consistent evidence indicates that preventing cross-contamination in the home kitchen may reduce exposure to foodborne pathogens among U.S. consumers. Techniques associated with favorable food safety outcomes for preventing cross-contamination include proper cleaning of food preparation surfaces and/or cooking utensils, particularly cutting boards and cutlery, accompanied by hand washing.

Review of the Evidence

This conclusion is based on 12 studies, including five comprehensive risk analyses (Kusumaningrum, 2004; Luber, 2009; Mylius, 2007; van Asselt, 2008; Yang, 2006), two laboratory simulation studies (de Jong, 2008; Sharma, 2009), two home kitchen videotaped studies (Redmond, 2004; van Asselt, 2009), one systematic review (Stenberg, 2008), one randomized trial (Larson, 2004), and one case-control study (Parry, 2005).

Four quantitative risk assessments concluded that lack of proper cleaning of food preparation surfaces and/or cooking utensils used in the home kitchen is likely to increase enteropathogenic cross-contamination from poultry meats or eggs to ready-to-eat vegetables or salads (Kusumaningrum, 2004; Luber, 2009; Mylius, 2007; van Asselt, 2008). Laboratory simulation (de Jong, 2008, Redmond, 2004) and home-based inoculation (van Asselt, 2009) studies provide strong support for a link between cutting board and cutlery sanitation and the prevention of microbial cross-contamination during food preparation. Mylius et al. (2007) conducted a risk assessment analysis that illustrated the importance of properly washing food preparation surfaces to prevent cross-contamination from chicken to salad with *Campylobacter*. The key parameters of this simulation study were the transfer probabilities of *Campylobacter* colony forming units (CFU) between kitchen/food objects and the probability for different behaviors to be followed during food preparation. These probabilities were obtained from previously published studies or assigned when no data were available. Simulation results showed that the single most effective action for reducing risk of cross-contamination and corresponding infection risk was cutting-board washing followed by hand washing and salad rinsing. In spite of this consistent evidence, some studies have not been able to empirically document a link between good environmental kitchen hygiene and decreased risk of gastrointestinal infections (Larson, 2004; Stenberg, 2008). Sharma et al. (2009) found that microwaving and dishwashing treatments significantly lowered aerobic bacterial counts (<0.4 log and 1.6 log CFU/sponge, respectively) more than any chemical treatment or control (7.5 CFU/sponge) ($p< 0.05$). This study suggests that microwaving or dishwashing treatments of kitchen sponges may be effective methods to kill foodborne pathogens in sponges to lessen chances of cross-contamination from sponge to other home kitchen surfaces where food is placed (Sharma, 2009).

Two studies had findings that were not consistent with the majority of the studies that led to the conclusion on cross-contamination. In a study by Yang et al. (2006), cross-contamination via refrigerators and hands did not substantially increase the mean level or prevalence of *L. monocytogenes* contamination in deli meats handled in the study. The UK case-control study (Parry, 2005) did not find an association between the presence of Salmonella in dishcloths and refrigerators and risk of salmonellosis. Findings are difficult to interpret, as 65 percent of individuals who developed salmonellosis had eaten meals prepared outside the home kitchen 72 hours before the onset of symptoms.

Recommended techniques for consumers for preventing cross-contamination adapted from information available from FSIS can be found in Table D8.5.

Question 5: COOK AND CHILL: To What Extent Do U.S. Consumers Follow Adequate Temperature Control During Food Preparation and Storage at Home?

Conclusion

Strong, consistent evidence shows that the great majority of U.S. consumers do not use food thermometers to properly assess the internal cooking temperature of meat and poultry while cooking. Moderate, consistent evidence shows that U.S. consumers lack refrigerator and freezer thermometers in their homes.

Review of the Evidence

The conclusion regarding food thermometers is derived from eight studies, including one systematic review (Redmond, 2003), one laboratory simulation study with a cross-sectional study component (Bergsma, 2007), and six cross-sectional studies (Abbot, 2009; Byrd-Bredbenner, 2007; Dharod, 2004, 2007a; Kwon, 2008; Trepka, 2007). The FDA/FSIS Food Safety Survey (2006) provided additional evidence for this conclusion. Table D8.6 shows the safe minimum internal cooking temperatures for meat, poultry, and seafood recommended for consumers by FSIS and FDA. Inadequate cooking represents a food safety hazard that can easily be avoided with the use of food thermometers widely available to consumers and effective dissemination of recommended internal cooking temperatures for different food products. In the FDA/FSIS Food Safety Survey (2006), 34 percent of respondents who reported preparing chicken indicated that they ever use a meat thermometer when cooking chicken. Those with lower levels of education, males, and White and Asian respondents were more likely to report using a meat thermometer when cooking chicken. Seven studies (Abbot, 2009; Byrd-Bredbenner, 2007; Dharod, 2004, 2007a; Kwon, 2008; Redmond, 2003; Trepka, 2007) found that few households reported owning and/or using a food thermometer to check for the doneness of meats. Dharod et al. (2004) found that, among Latino parents, the use of meat thermometers was very rare both before and after exposure to the Fight BAC!® campaign. Redmond and Griffith (2003) found that only 12 percent to 24 percent of consumers regularly used meat thermometers. Using a cross-sectional survey, Bergsma et al. (2007) found that while thorough heating of chicken was considered very important by the study participants, generally those participants only visibly checked chicken meat for doneness and did not use meat thermometers. In the laboratory simulation component of that study, the authors suggested that cooking chicken for recommended periods of time and visually inspecting it for doneness could result in chicken which may not be sufficiently cooked to reduce levels of harmful bacteria (Bergsma, 2007). It is notable that, although just as important as for meat and poultry, no evidence was identified on consumer use of thermometers for ensuring the adequacy of cooking for seafood. Table D8.7 provides information on recommended techniques for consumers for thermometer use adapted from information available from the FSIS and FDA.

The conclusion regarding refrigerator and freezer thermometers is derived from two cross-sectional studies (Kosa, 2007; Towns, 2006). Additional evidence was gathered from the FDA/FSIS Food Safety Survey (2006). The two cross-sectional studies found that subjects reported a lack of thermometers in refrigerators and/or freezers in their homes (Kosa, 2007; Towns, 2006). Towns et al. (2006) concluded that their well educated survey participants failed to follow proper refrigeration and freezer storage practices, in spite of being aware of the importance of doing so to prevent foodborne illness. These findings are supported by findings from the FDA/FSIS Food Safety Survey (2006). Techniques for consumers for using refrigerator and freezer thermometers adapted from information available from the FSIS can be found in Table D8.8.

Question 6: RISKY FOODS: To What Extent Do U.S. Consumers Eat Raw or Undercooked Animal Foods?

Conclusion

Moderate, clear, and consistent evidence shows that the consumption of raw or undercooked animal-source food products is relatively common in the U.S., especially for eggs and egg-containing products, and ground beef products.

Review of the Evidence

This conclusion is derived from eight studies, including one meta-analysis (Patil, 2005) and one systematic review (Redmond, 2003), and six cross-sectional studies (Anderson, 2004; Byrd-Bredbenner, 2008; Dharod, 2007b; Kaylegian, 2008; Lopez Osornio, 2008;

Trepka, 2007). Additional evidence was gathered from the FDA/FSIS Food Safety Survey (2006). In their direct observation study of U.S. household meal preparers, Anderson et al. (2004) found that 61 percent of those who prepared a chicken entrée undercooked the chicken. In this study 46 percent of those who chose to prepare meatloaf undercooked the ground beef. A direct observation study involving videotaping of a small sample of home meal preparers in the Netherlands found that one-third of the participants undercooked the chicken (van Asselt, 2009). Undercooking was estimated based on an eight minute chicken boiling time cutoff. These findings are in contrast with those of Dharod et al. (2007b) who documented that almost none (7%) of the Puerto Rican household meal preparers included in their study undercooked the chicken. In the FDA/FSIS Food Safety Survey (2006), about 38 percent reported eating foods containing raw eggs, with this behavior being less common among those with lower levels of education, Blacks, and Asians. Studies have found that among diverse U.S. study populations, raw or undercooked animal-derived products are widely consumed (Bryd-Bredbenner, 2008; Patil, 2005; Trepka, 2007; FDA/FSIS, 2006). Bryd-Bredbenner et al. (2008) reported that among a large sample of college students, a substantial number reported consuming a variety of risky foods, such as cookie dough containing raw eggs (53%), fried eggs with runny or soft yolks (33%), sushi (29%), raw sprouts (29%), raw oysters, mussels, or clams (11%), and rare hamburgers (7%). Trepka et al. (2007) found that among female African-American WIC clients, 24.7 percent reported usually eating undercooked eggs, 51.6 percent of pregnant women reported "sometimes," or "frequently," eating hot dogs or deli meats since becoming pregnant without first reheating them, and 35.5 percent reported eating soft cheeses and blue-veined cheeses sometimes or more frequently since becoming pregnant. In addition, almost 12 percent reported consuming hamburgers with pink/red color inside, and only 62 percent reported always using boiling water before preparing infant formula. The prevalent consumption of undercooked eggs detected in localized studies is confirmed by a systematic review (Redmond, 2003) and the meta-analysis by Patil et al. (2005). Based on U.S. surveys conducted between 1977 and 2000, Redmond and Griffith (2003) report that the prevalence for this practice has ranged from 5 percent to 56 percent, with the most recent surveys suggesting that as many as half of the U.S. population may consume undercooked or raw eggs. Lopez Osornio et al. (2008) found that the U.S. consumers were more likely than Argentinean and Spanish consumers to prefer beef steaks to be cooked rare. However, Trepka et al. (2007) found in their study that only 3.5 percent of WIC participants liked their meat cooked medium-rare or rare.

Raw milk consumption has been associated with serious foodborne outbreaks in the U.S. Kaylegian et al. (2008) examined raw milk consumption practices in a sample formed predominantly of dairy farmers from upstate New York. As many as 45.3 percent reported having consumed raw milk during the previous year. The main reasons for consuming raw milk were taste, convenience, and cost. Concerns related to health hazards associated with raw milk consumption were expressed by 38.2 percent of the raw milk and 73.2 percent of the pasteurized milk consumers.

Related Contextual Issues

Raw or Undercooked Eggs and Public Health Risks

Historically, in the U.S., guidelines for handling and preparing eggs for human consumption have been issued by the Federal government, and food industry and dietetic associations. Those guidelines have been developed because salmonellosis, an egg-associated foodborne illness, is an important public health problem (Braden, 2006; CDC, 2005). A bacterium, *Salmonella enteritidis*, can be inside perfectly normal-appearing eggs, and if the eggs are eaten raw or undercooked, the bacterium can cause illness (CDC, 2005). A person infected with the *Salmonella enteritidis* bacterium usually has fever, abdominal cramps, and diarrhea beginning 12 to 72 hours after consuming the contaminated food, and the illness usually lasts 4 to 7 days without necessarily requiring antibiotics (CDC, 2005). However, the diarrhea can be severe, and the person may be ill enough to require hospitalization (CDC, 2005). The elderly, infants, and those with impaired immune systems may have a more severe illness in which the infection may spread from the intestines to the bloodstream, and then to other body sites and can cause death unless the person is treated promptly with antibiotics (CDC, 2005).

Therefore, fresh eggs and egg products should be handled, refrigerated, prepared, and stored properly, including the use of sell by dates, to reduce the risk that foodborne pathogens that may be present in those foods will cause foodborne illness in those eating the food. Research shows that shell eggs are a major vehicle for *Salmonella enteric* serotype Enteritidis (SE) infection in humans because eggs can be internally contaminated by transovarian transmission of SE in the laying hen (Braden, 2006). It has been estimated that of the 47 billion eggs consumed annually as shell eggs, 2.3 million are SE-positive, exposing a large number of people to the risk of illness (Potter, 1999). Through proper handling in the home (i.e., refrigeration, avoiding cross-contamination, and thorough cooking to kill pathogens that might exist in eggs and egg products), foodborne illness from eggs can be reduced. Adequate refrigeration prevents any *Salmonella* present in eggs from growing to high numbers (CDC, 2005). Although cooking reduces the number of bacteria present in an egg, an egg with a runny yolk still poses a greater risk than a completely cooked egg (CDC, 2005). Recommendations on in-home handling of eggs from the Federal government range from how to safely transport, handle, store, and sufficiently cook simple egg dishes to how to improve the safety of egg recipes involving food mixtures that include raw egg ingredients (such as homemade ice cream, eggnog, meringue shells, divinity candy, 7-minute frosting, meringue-topped pies, Hollandaise sauce, Caesar salad dressing, and other desserts) (HHS, 2010).

Raw or Undercooked Ground Beef and Public Health Risks

Raw and undercooked meats, such as hamburger meat, are potential sources of pathogenic bacteria that can result in foodborne illness which can have serious health consequences, including death. Since the 1980s, outbreaks of illness in the U.S. have been reported as a result of consuming undercooked hamburgers from some fast food restaurants, in communities, and different facilities (Doyle, 1991; CDC, 1993). Over that period, manufacturers have conducted a series of national recalls by manufacturers of ground beef contaminated with harmful bacteria. Ground beef and hamburger meat can become contaminated with pathogenic bacteria, such as *Salmonella*, *Escherichia coli O157:H7*, *Campylobacter jejuni, Listeria monocytogenes*, and *Staphylococcus aureus*, at different points from the farm to the table (FSIS, 2009). Efforts have been made by the food industry and Federal government to reduce contamination of ground beef from beef production through consumption, but outbreaks still occur. For example, although FSIS has documented a decrease in *Salmonella spp.* in ground beef, from a baseline prevalence of 7.5 percent in 1996 to 1.6 percent of 30,984 regulatory samples collected in 2004 (CDC, 2006; USDA, 1996, 2006), outbreaks of human *Salmonella* infections associated with ground beef continue to occur (CDC, 2006).

One of the bacteria of special concern that could contaminate muscle meat at slaughter is *E. coli O157:H7,* a bacterial pathogen that has a reservoir in cattle and other similar animals (FSIS, 2009). *E. coli O157:H7* produces large quantities of a potent toxin that forms in the intestine and causes severe damage to the lining of the intestine (FSIS, 2009). Consumption of food contaminated with *O157:H7* can cause a severe and bloody diarrhea and painful abdominal cramps and, in 3 percent to 5 percent of cases, a complication called hemolytic uremic syndrome that can result in the development of temporary anemia, profuse bleeding, and kidney failure (FSIS, 2009). *E. coli O157:H7* bacteria survive refrigerator and freezer temperatures and once they get in food, they can multiply very slowly at temperatures as low as 44°F (FSIS, 2009). The actual infectious dose is unknown, but most scientists believe it takes only a small number of this strain of *E. coli* to cause serious illness and even death, especially in children (FSIS, 2009). The bacteria are killed by adequate and proper cooking.

Because consumers cannot see or smell pathogenic bacteria that may be in ground beef, it is impossible for consumers to know if meat obtained from a food store is contaminated with such bacteria. Therefore, it is very important that consumers understand how to properly handle, transport, store, and prepare any raw meat that will be used in the home. The Federal government has issued recommendations on how to reduce risks of contracting foodborne illness from ground meat, including guidance on not eating any raw or undercooked ground beef, not tasting raw or undercooked ground beef during food preparation, avoiding cross-contamination from raw meat to ready-to-eat foods when transporting meat from the store and in the home, cooking food containing ground beef to ensure that any pathogenic bacteria are killed, proper storage in the refrigerator or freezer, and the importance of hand washing after handling raw ground beef (USDA, 1996).

Raw Milk and Milk Products and Public Health Risks

Milk and milk products from cows, sheep, or goats contain a wide variety of important nutrients. However, raw milk and raw milk products (such as cheese and yogurt made from raw milk) have not been pasteurized to kill harmful bacteria (FDA, 2009). These products may contain harmful microorganisms that can cause serious foodborne illnesses, hospitalization or death. Pasteurization is a process that kills harmful bacteria by heating raw milk to a specific temperature for a set period of time (FDA, 2009). These harmful bacteria, which include *Brucella*, *Campylobacter*, *Listeria*, *Mycobacterium bovi*, *Salmonella*, Shiga toxin-producing *E. coli*, *Streptococcus pyogenes*, and *Yersinia enterocolitica* (CDC, 2009), can cause diseases such as listeriosis, typhoid fever, tuberculosis, diphtheria, and brucellosis. Pasteurization of milk became widespread in the U.S. by 1950 and is recommended for all milk consumed by humans by the CDC, the FDA, and many other medical and scientific organizations (CDC, 2009).

From 1993 to 2006, 69 outbreaks of human infections resulting from consumption of raw milk were reported to CDC and these outbreaks included a total of 1,505 reported illnesses, 185 hospitalizations, and 2 deaths (CDC, 2009). Symptoms of foodborne illness that could develop after consuming raw milk include vomiting, diarrhea, and abdominal pain, and flulike symptoms such as fever, headache, and body ache (FDA, 2009). Although most healthy people will recover from an illness caused by harmful bacteria in raw milk, or foods containing raw milk, within a short period of time, some can develop symptoms that are chronic, severe, or even life-threatening (FDA, 2009). Pregnant women who consume raw milk or raw milk cheeses that may be contaminated with the bacteria *Listeria* run a serious risk of developing listeriosis which can cause miscarriage, fetal death, or the illness or death of a newborn (FDA, 2009). Table D8.9 provides guidance for consumers for ensuring milk and milk product choices are safe adapted from information available from the FDA.

As with any animal food product, it is important to handle and store pasteurized milk and milk products properly to prevent the growth of possibly harmful bacteria that can multiply at room temperature. Thus, pasteurized milk and milk products should be stored in a refrigerator (preferably at the back of the refrigerator where it is cooler) kept at 40°F (4°C) or below, refrigerated promptly if used, and not left out at room temperature. Also, to reduce the possibility of contaminating milk with bacteria, unused milk poured out of its container should never be returned to its original container. Just because milk is pasteurized does not mean that it is safe to leave it at room temperature for an extended time.

Raw and Undercooked Seafood and Public Health Risks

Raw and undercooked seafood can be a cause of foodborne illnesses due to contamination by harmful bacteria, viruses, and parasites. Molluscan shellfish (oysters, clams, and mussels) and raw fish and crustaceans can be contaminated with pathogenic strains of the bacterium *Vibrio* (Butt, 2004; IOM, 2007). Some oysters are treated for safety after they are harvested but that information may or may not be disclosed (FDA, 2009a). However, post-harvest treatment of oysters does not necessarily remove all pathogens that can cause illness (FDA, 2009a). Therefore, oysters should not be eaten raw or undercooked by people at risk of foodborne illness, including pregnant women, young children, older adults, and persons with compromised immune systems or who have decreased stomach acidity (FDA, 2009a). Raw oysters contaminated with certain bacteria viruses can be life threatening, even fatal when eaten by someone with liver disease, diabetes, or a weakened immune system (FDA, 2009b).

Eating raw and undercooked oysters is an especially risky practice because the *Vibrio* bacteria in the food is not visible and may not be picked up by an off smell or unusual taste. The seriousness of symptoms that could develop after eating contaminated shellfish depends on many factors, including how much bacteria is ingested and the person's underlying health conditions (FDA, 2009b). In addition to *Vibrios*, a variety of potentially pathogenic bacteria (including *Salmonella spp*. and *Listeria monocytogenes*) have been associated with seafood safety risks, although actual occurrence is very rare or not reported due to lack of severity of symptoms (IOM, 1991, 2007).

Regarding viruses, contamination of water with human fecal matter on or near oyster beds has resulted in shellfish-borne "Norwalk-like" viruses and hepatitis A infections in consumers of raw oysters harvested from contaminated water (IOM, 2007; Kohn, 1995). Regarding parasites, consumption of raw or undercooked seafood products that have not been previously frozen has been implicated in certain parasitic infections, but incidence of those infections is more common in regions of the world where raw consumption is more common (IOM, 2007). Parasites that have been found in consumable seafood and have infected human beings include nematodes, trematodes, cestodes, and protozoa (Butt, 2004).

Adequate cooking of raw seafood is the safest method of preventing infections from harmful microorganisms that may be found in oysters, clams, mussels, other shellfish, or finfish. According to the FDA, consumers who choose to eat raw seafood despite the risks, should choose seafood that has been previously frozen (FDA, 2009a). However, although freezing will kill any parasites that may be present in certain seafood, freezing does not kill all harmful microorganisms and does not decrease the potency of some toxins that some bacteria may produce. Therefore, proper cooking of seafood to recommended temperatures is the best way to reduce the risk of foodborne illness.

Recommendations on proper handling of raw seafood from the Federal government range from how to safely transport, handle, store, and sufficiently cook, and serve all types of fish, shellfish, and mollusks to ways to determine whether seafood is cooked to a sufficient temperature to kill harmful contaminants that may be in the food (FDA, 2009a).

Additional guidelines have been issued for pregnant women, older adults, and people with weakened immune systems to reduce their risk of contracting listeriosis from seafood. Those guidelines specify to avoid refrigerated types of smoked seafood except in a cooked recipe. The types to be avoided include refrigerated smoked salmon, trout, whitefish, cod, tuna, and mackerel. They are usually labeled as “nova-style,” “lox,” “kippered,” “smoked,” or “jerky” fish and can be found in the refrigerated section of grocery stores and delicatessens (FDA, 2009a).

Question 7: To What Extent Do Specific Subpopulations Practice Unsafe Food Safety Behaviors?

Conclusion

Moderate available evidence, which focused on pregnant women, college students, and older adults, shows that these populations commonly practice unsafe food handling and consumption behaviors.

Review of the Evidence

This conclusion is derived from nine studies, including eight cross-sectional studies (Abbot, 2009; Almanza, 2007; Byrd-Bredbenner, 2007, 2008; Kosa, 2007; Kwon, 2008; Roseman, 2007; Trepka, 2007) and one non-randomized trial (Yarrow, 2009).

Pregnant Women

As reported previously as evidence on the consumption of “risky foods,” Trepka et al. (2007) conducted a study in a sample consisting predominantly of African-American WIC participants. Pregnant women reported practicing risky food handling and consumption behaviors that could put them at greater risk for acquiring listeriosis. For example, pregnant women reported eating hot dogs or deli meats without first reheating and reported eating soft cheeses and blue-veined cheeses. Using a cooking thermometer, refrigerating foods within 2 hours, and thawing frozen foods safely were the least frequently reported recommended food safety behaviors. Primiparous women had lower food safety scores than their multiparous counterparts. Kwon et al. (2008) applied a food safety survey in 87 WIC offices in 31 states. The need for a meat thermometer to check doneness while cooking ground beef patties was acknowledged by 23.7 percent of respondents, but only 7.7 percent reported actually using it when cooking ground beef patties. Hispanic women were the least likely to have ever used a meat thermometer (25.4%), followed by non-Hispanic Black women (36.2%) and non-Hispanic White women (46.1%). More than 40 percent of respondents did not use adequate methods to thaw frozen foods, with the likelihood of this happening being much higher among Hispanic and non-Hispanic Black individuals than among their White counterparts. The overall food safety knowledge score was significantly higher among those with higher levels of education, and White (vs. Hispanic) women. However, the food safety behavior score was not significantly different when comparing White women with their Hispanic counterparts. Black women had the lowest food safety behavior score.

College Students

Four studies agree that U.S. college students do not engage in many recommended safe food-handling practices (Abbot, 2009; Byrd-Bredbenner, 2007, 2008; Yarrow, 2009). Participants in the study by Abbot et al. (2009) self-reported engaging in less than half of the recommended safe food-handling practices evaluated (i.e., cross-contamination, hygiene, cooking temperatures, food storage, risky food consumption). This was confirmed through direct observation of their food preparation behaviors in a laboratory kitchen. For example, only half of them practiced adequate hand and kitchen sanitation; one-third did not follow adequate procedures to prevent cross-contamination between raw chicken and ready-to-eat produce; and more than 70 percent did not follow recommended procedures for safe chicken cooking. Byrd-Bredbenner et al. (2007), audited the home kitchens of the same college students studied by Abbot et al. (2009), and found that their scores were lower than 60 percent on the kitchen appliance cleanliness (i.e., microwave oven, can opener, dishwasher) and cold food storage scales, and that only 7 percent of kitchens had a food thermometer. Mean refrigerator temperature was 6.1°C (range: 0-16°C) which is higher than recommended (i.e., 4.4°C/40°F or below). Byrd-Bredbenner et al. (2008) found in an online survey among college students across the U.S. that they reported consuming some "risky foods" including homemade cookie dough containing raw eggs (53%); fried eggs with runny or soft yolks (33%); sushi (29%); raw sprouts (29%), raw oysters, clams, or mussels (11%); and hamburgers cooked rare (7%). Male students ate significantly more "risky foods" than women ($p<0.0001$). While consumption of raw/undercooked animal source foods may be culturally or socially acceptable and/or desirable, consumers should be aware of the health risks associated with the consumption of these foods. Yarrow et al. (2009) found that non-health majors whose food safety beliefs and knowledge improved after exposure to a food safety educational intervention, showed no improvements in the practice of risky behaviors, including not using thermometers and eating "risky foods," as a result.

Older Adults

Three studies (Almanza, 2007; Kosa, 2007; Roseman, 2007) agree that older adults report partaking in risky food-handling behaviors. A study of Elderly Nutrition Program clients (Roseman, 2007) found that 22 percent reported not throwing away casseroles or other food dishes that had been left on the counter for 2 or more hours (41% of men vs. 18% of women, $p=0.004$). Fifty percent of the oldest group ($\geq$ 91 years) and 36 percent of the ages 60 to 70 years group, kept all or part of their unconsumed meal on the counter instead of the refrigerator, and 16 percent were somewhat or not likely to wash hands before eating their meals. Whereas 93 percent of White respondents indicated that they would throw away a meal that was left on counter overnight, this was true for only 77 percent of their non-White counterparts. The risk of practicing this behavior was also lower among the less educated and those in younger age brackets. Almanza et al. (2007) report from a multi-state study that of the 35 percent of seniors who kept leftovers from a home-delivered meal program, only 15 percent ate the non-refrigerated leftovers within 2 hours. Also, 38 percent of participants who were delivered hot food and did not consume it right away left it on a counter or table. Kosa et al. (2007) found that only 16 percent of older adults participating in a nationally representative web-based survey had a refrigerator thermometer at home. Older adults who were not married and who lived alone were less likely to have refrigerator thermometers or have their refrigerators at a recommended temperature ($p< 0.05$).

Related Contextual Issues

Listeriosis

Listeriosis is an infection caused by *Listeria monocytogenes*, a pathogen that can grow at low temperatures. It is estimated that 2,500 cases of listeriosis occur annually in the U.S. and that 500 people die of this disease each year. Individuals with compromised immune systems, including pregnant women and their unborn child, as well as older adults are at higher risk of listeriosis. Cates et al. (2006) conducted a nationwide representative web-based survey of food safety knowledge and practices among U.S. adults (response rate=71%). Awareness was much lower for *Listeria* (43.8%) than for *E. coli* (94.2%) and *Salmonella* (93.9%). Slightly more than two-thirds of respondents indicated that they did not know which foods could transmit *Listeria* and less than 5 percent correctly identified likely sources. Indeed, only 3.2 percent identified deli meats and frankfurters as potential *Listeria* vehicles. The great majority followed recommended guidelines for frankfurter's cold storage time and temperature. However, they were less likely to do the same with deli meats. *Listeria* awareness was lower among those with lower socio-economic status but improper frankfurter cold storage was significantly more common among those with higher levels of education. Men were significantly more likely than women to store frankfurters and deli meats outside the recommended storage guidelines. Likewise, those ages 18 to 29 years and 60 years and older were more likely to mishandle deli meats compared with their counterparts in the intermediate age groups.

FOOD SAFETY TECHNOLOGIES

Question 8: To What Extent Are Recently Developed Technological Materials That Are Designed to Improve Food Safety Effective in Reducing Exposure to Pathogens and Decreasing the Risk of Foodborne Illnesses in the Home?

Conclusion

A limited body of inconsistent evidence describes and evaluates contributions to or advances of food safety modalities or practices in the home. These small studies indicate the correct usage of these kinds of products is critical for assessing proper cooking temperature and ensuring adequate reduction of microbial burden on food contact surfaces. Not all thermometers tested, wipes assessed, and sanitizers evaluated were accurate or effective in providing correct cook temperatures or assuring consistent safety against typical foodborne organisms.

Implications

New and emerging technologies over the past 5 years can assist consumers in preserving and protecting foods while encouraging safe food handling practices in the home; however, appropriate techniques for using products is essential in the efficacy of decreasing the risk for foodborne illness. The evidence supporting emerging food safety technologies in the home is limited, despite the emergence of commercial tools and appliances intended to improve safe food handling and management practices in the home. Consumers should adhere to food safety fundamentals in the home, which will remain foundational, even with future introductions of food safety technologies.

Review of the Evidence

This conclusion is based on eight studies, including five randomized block trials (LeBlanc, 2005; Liu, 2009a, 2009b; McCurdy, 2004; McKee, 2005); two non-randomized trials (DeVere, 2007; Yucel Sengun, 2005); and one case-control study (Kounosu, 2007). These studies evaluated the accuracy and reliability of several types of home thermometers and the effectiveness of antibacterial products, including wipes, food contact surfaces, and sanitizers.

Thermometers

Four randomized block design studies evaluated the accuracy and reliability of several types of cooking thermometers available to the general consumer (LeBlanc, 2005; Liu, 2009a, 2009b; McCurdy, 2004).

In two randomized, block designed studies by Liu et al. (2009a, 2009b), the accuracy and reliability of commercially available instant-read consumer thermometers (forks, remotes, digital probes, and disposable color change indicators) were assessed in several grades of beef patties and cuts of chicken. Three models of each thermometer were evaluated under three different cooking methods. These studies indicated that all models of thermometers tested were poor indicators of accurate temperatures in that they did not match the calibrated controls over a broad range of acceptance standards (0% to 92% acceptance). The results suggest that using these thermometers could either undercook or overcook these foods, thereby compromising food safety and food quality, and that these thermometers required more than the recommended time to register products as cooked (Liu, 2009a, 2009b).

LeBlanc et al. (2005) assessed the attributes of six models of analog fork thermometers and six types of digital instant read-probe thermometers. These products were evaluated while cooking pre-formed beef patties and roasts. When applied to these foods, fork thermometers and digital read thermometers underestimated the temperature of the cooked foods by 1°C to 11°C (1.8-19.8°F). However, when the thermometers were correctly used according to manufacturers’ instructions, such as proper placement in the food for a specified time (at least 30 seconds), the analog and digital thermometers provided reliable information on cook temperatures.

In a similar study, McCurdy et al. (2004) evaluated 21 models of instant-read pocket food thermometers (8 dial models and 13 digital models) available from local grocery, department, and hardware stores, by catalog/internet order, or free from the Idaho Beef Commission. Accuracy and response time were assessed using standardized protocols. Importantly, the accuracy of dial and digital thermometers was good (within 2°F) for 98 percent of those tested. On the other hand, response time in small meat items was quite variable (10-31 seconds).

Antibacterial Products for Cleaning Food Contact Surfaces

A single nonrandomized study (DeVere, 2007) investigated the effectiveness of domestic antibacterial wipes and sprays in decontaminating food contact surfaces. Four commercially available antibacterial products were evaluated under controlled laboratory conditions. Using *E. coli* and *S. aureus* as Gram negative and Gram positive indicators of food contact surface contaminants, the antibacterial wipes were applied and used as stipulated by the manufacturers. Food contact surfaces included plastic, glass, wood and antimicrobial treated materials. Microbial survival was the indicator of antimicrobial effectiveness. This small study indicated that the effectiveness of these products was dependent upon the type of surface (lower microbial reduction with plastic surfaces) and type of antimicrobial product (wipes were least effective) (DeVere, 2007). The active ingredients in wipes were butoxypropanol and ethanol or Microban® (a broad-spectrum antimicrobial containing triclosan). The sprays contained isopropanol and surfactants or Microban® as antimicrobial agents. The effectiveness of the wipes was dependent upon the applier who controlled the amount of surface and degree of pressure applied (DeVere, 2007).

Unless food contact surfaces, such as counter tops, cutting boards, and refrigerator shelves, are cleaned and sanitized on a regular basis, the risk of microbial contamination and subsequent foodborne illnesses increases. In addition to following recommended cleaning practices that include washing in hot water (sanitizing temperature ≥155°F) with appropriate detergents, consumers can use numerous antimicrobial products in the form of sprays, wipes, and sponges. These products are intended to reduce the presence of and contamination with food pathogens (DeVere, 2007). The effectiveness of these products varies with the kind and concentration of bacteria, the type of surface (e.g., glass, plastic, stone, wood), and the apparent active ingredient. The most common active ingredients are quaternary ammonium compounds, such as the sanitizing agents used in commercial environments and hospital settings. One important aspect for the effective application of products is residence time, namely the time the surface is exposed to the sanitizing agent. Thus, many manufacturers of these kinds of products recommend their application after cleaning the contact surface, and allowing the surface to air dry without any rinsing. This air dry approach is critical to ensure adequate surface cleaning. Consumers also must remember that another key concern is potential contamination if the rinse water or solution and applicator, if used, are not clean. For simplicity and to reduce costs, according to the CDC (2008), it may be easiest for most consumers to use approximately 3 tablespoons of ordinary, unscented bleach per 1 gallon of clean water. This solution may be easily applied as a spray, wipe or dip. The contact surfaces should not be dried or rinsed for at least 10 minutes. This is an excellent approach of decontamination for most microbes and food surfaces, as well as other common contact points found in the home kitchen.

Antibacterial Cutting Boards

Antimicrobial cutting boards, often color-coded to minimize cross-contamination, are readily available. The antimicrobial property of these cutting boards is based on the natural characteristics of silver-ions to fight off an array of bacteria, fungi, mold and some viruses commonly found in the home kitchen (Kounosu, 2007).

A single case-control study (Kounosu, 2007) evaluated the antibacterial properties of cutting boards treated with antimicrobial materials. This small (n=10 households) study, using *E. coli* and *S. aureus* as Gram negative and Gram positive indicators of antimicrobial effectiveness, also monitored other environmental microbes common in kitchens and food preparation areas. The effectiveness of cutting boards in reducing the microbial burden depended upon the antibacterial rating of the cutting boards (Kounosu, 2007). Another indicator for home food safety indicated that the use of these antimicrobial cutting boards tended to reduce the concentration of common organisms, such as *Pseudomonas, Flavobacerium, Micrococcus,* and *Bacillus* better than untreated cutting boards (Kounosu, 2007).

Consumable Sanitizers for Foods

One small randomized block designed study (McKee, 2005) and one non-randomized trial (Yucel Sengun, 2005) evaluated the effectiveness of consumable sanitizers intended to decontaminate foods. McKee et al. (2005) evaluated household juices, baking soda, sodium chloride (table salt solution), wine, soy sauce (low pH, high sodium), and vinegar (lower pH) on several cuts of raw chicken. The microbial load of cranberry juice and vinegar-rinsed chicken cuts was typically lower than the other solutions except for 10 percent sodium chloride and 10 percent sodium bicarbonate solutions (McKee, 2005). However, all of the tested in-home products that lowered the pH, particularly white vinegar and salt solution (10% brine), produced a lower microbial burden (McKee, 2005).

In a laboratory study, Yucel Sengun and Karapinar (2005) noted that a solution of equal volumes of vinegar (source of acetic acid) and lemon juice (source of citric acid) can be effective in reducing potential *Salmonella* burden on lettuce surfaces following a 15-minute no-rinse period. Chicken meat marinades often consist of this kind of mixture which, in turn, may reduce the risk of other kinds of microbial contaminants, such as *Campylobacter jejuni* (Birk, 2010). However, the impact of organic acids on food safety is generally considered not as effective or efficient as commercial agents.

Many foods, such as olives and some poultry and fish, are traditionally “preserved” in brines. Brining or salting is one of the oldest forms of food preservation for reducing food spoilage, and some U.S. food regulations that set food standards require this approach in the production of commercial foods to ensure food safety (Title 21, U.S. Code of Federal Regulations, Parts 130-169; Title 9, U.S. Code of Federal Regulations, Parts 319 and 381).

SEAFOOD

Question 9: What Are the Benefits in Relationship to the Risks for Seafood Consumption?

Conclusion

Moderate, consistent evidence shows that health benefits derived from the consumption of a variety of cooked seafood in the U.S. in amounts recommended by the Committee outweigh the risks associated with methyl mercury (MeHg) and persistent organic pollutants (POPs) exposure, even among women who may become or who are pregnant, nursing mothers, and children ages 12 and younger. Overall, consumers can safely eat at least 12 ounces of a variety of cooked seafood per week provided they pay attention to local seafood advisories and limit their intake of large, predatory fish. Women who may become or who are pregnant, nursing mothers, and children ages 12 and younger can safely consume a variety of cooked seafood in amounts recommended by this Committee while following Federal and local advisories.

Implications

Seafood is a healthy food choice that can be safely promoted provided that the types and sources of seafood to be limited or avoided by some consumers are clearly communicated to consumers. Consumers may be able to eat safely more than 12 ounces per week of seafood if they chose to do so provided they choose the right mix of seafood that emphasizes the consumption of seafood species with relatively low concentrations of contaminants such as MeHg and POPs. Encouraging consumption of seafood in the U.S. is justified, as consumption continues to be far below amounts recommended for health by the IOM and by this Committee (see *Part D. Section 3: Fatty Acids and Cholesterol*).

Current Federal advisories on consumption of seafood species with high MeHg levels that vulnerable groups need to avoid are well justified by the scientific evidence. Regarding women who may become or who are pregnant, nursing mothers, and young children, there is emerging evidence that consumption beyond 12 ounces per week may be safe. However, additional benefit/risk modeling is needed taking into account the simultaneous presence of multiple contaminants in a shifting seafood supply. State and local agencies should continue to reach out to vulnerable groups and the population at large with advisories about the presence of diverse environmental contaminants in different water bodies. This is particularly relevant for seafood caught by consumers. The public also needs to be advised that eating a variety of seafood, as opposed to just a few choices, is likely to reduce their exposure to ‘single source’ contaminants. Clear, consistent evidence indicates that consumers will need access to publicly available user-friendly benefit/risk information to make informed seafood choices that maximize their health taking into account their seafood preferences.

Review of the Evidence

Background

Mercury in water is derived from human activities involving the combustion of fossil carbon fuels and from natural sources, including volcanic emissions. MeHg is formed through the normal biological processing of mercury by aquatic microorganisms, and it bioaccumulates up the trophic food chain in the muscle tissue of aquatic animals (IOM, 2007). As a result, large, predatory fish such as shark, swordfish, tilefish, and king mackerel have the highest MeHg concentrations.

On the one hand, seafood consumption has been associated with health risks for infants, children, and adults. MeHg exposure has been found to impair the neurological development of the fetus and young child (IOM, 2007). In addition, it has been proposed that MeHg is a risk factor for CVD perhaps as a result of pro-oxidant mechanisms involving the activation of free radical formation and the inhibition of cellular antioxidant systems (Guallar, 2002). However, the evidence for this risk is inconsistent (IOM, 2007; Stern, 2007) with a recent meta-analysis of five prospective studies and one retrospective study suggesting no overall significant association between coronary heart disease (CHD) risk and high MeHg exposure (i.e., top quartile) in European and U.S. populations (Mozaffarian, 2009). However, a Finnish prospective study (Rissanen, 2000) did identify an interaction between serum *n*-3 polyunsaturated fatty acids (PUFA) and hair MeHg on CHD risk. Consuming seafood was protective against CHD for those with higher (upper tertile) and lower (two lower tertiles) MeHg exposures, but the benefit was greater for those in the lower MeHg exposure group.

On the other hand, seafood consumption also offers CVD and neurological development benefits associated with EPA and DHA consumption (see *Part B. Section 2. The Total Diet: Combining Nutrients, Consuming Food*; *Part D. Section 2. Nutrient Adequacy*; and *Part D. Section 3: Fatty Acids and Cholesterol*). In March 2004, the EPA and the FDA issued a seafood advisory based on seafood benefit/risk considerations, entitled, *What You Need to Know about Mercury in Fish and Shellfish* (EPA/FDA, 2004). It specifically targeted pregnant and nursing women, young children, and non-pregnant women of childbearing age because of their potential vulnerability to the effects of MeHg. The advisory recommended that, in order for women to receive the benefits of eating seafood and be confident that they have reduced their exposure to the harmful effects of mercury, they could safely consume up to 12 ounces (2 average meals) per week of a variety of cooked seafood, but to not exceed white (albacore) tuna consumption beyond 6 ounces per week. The same advice was given for young children except that they would be fed smaller portions. These target groups were advised to avoid consuming species high in MeHg, including shark, swordfish, king mackerel, and tilefish. This Federal advisory, which is still in effect, also recognized the importance of state seafood advisories for informing consumers about the safety of consuming locally caught and harvested seafood. These recommendations are consistent with those issued by other national scientific groups (IOM, 2007) and other countries, including Canada (Health Canada, 2009).

The 2005 DGAC Report concluded that it is possible for vulnerable groups to obtain the benefits of seafood consumption without exceeding tolerable levels of MeHg intakes. Re-addressing this question is relevant because new evidence has become available and consumers are still receiving conflicting seafood consumption messages, some of which are inconsistent with Federal advice (Ginsberg, 2009).

Review of the Evidence

This conclusion is derived from nine studies, including three quantitative risk/benefit assessment studies (Ginsberg, 2009; Guevel, 2008; Sioen, 2008); four cross-sectional studies (Dewailly, 2007; Huang, 2006; Rawn, 2006; Verger, 2008) which also included a risk/benefit analysis; one meta-analysis (Gochfeld, 2005); and one systematic review (Mozaffarian, 2006). A report from the IOM, *Seafood Choices* (2007), was used as evidence before 2006 to develop the conclusion.

Since the publication of the 2005 DGAC Report, five quantitative (Ginsberg, 2009; Guevel, 2008; Gochfeld, 2005; Sioen, 2008; Verger, 2008) and two qualitative (IOM, 2007; Mozaffarian, 2006) risk/benefit assessments have been published. These studies targeted the U.S. (Ginsberg, 2009; Gochfeld, 2005; Mozaffarian, 2006), French (Guevel, 2008; Verger, 2008), and Belgian (Sioen, 2008) populations. The two U.S. quantitative benefit/risk analyses modeled neurodevelopmental and CVD benefits and risks associated with DHA and MeHg in seafood (mostly fish), respectively (Ginsberg, 2009; Gochfeld, 2005). The French study based on the Quality-Adjusted Life Year (QALY) approach modeled neurodevelopmental benefits and risks associated with DHA and MeHg but did not include the function describing the potential harm of MeHg on cardiovascular health (Guevel, 2008). The Belgian study examined different levels of seafood intake in relationship to the tolerable weekly intake levels of MeHg and dioxin-like compounds (Sioen, 2008). The other French study examined seafood intake thresholds based on omega-3 PUFA recommendation and the upper tolerable intake limits for dioxins and polychlorinated biphenyls (PCBs), a type of POP (Verger, 2008). The two qualitative analyses addressed benefit and risks on neurodevelopment and cardiovascular health attributed to DHA and MeHg. In addition, Mozaffarian and Rimm (2006) estimate the benefit/risk ratios based on omega-3 PUFA benefits and POPs exposure risks.

A comprehensive assessment of the evidence by the DGAC indicates that neurodevelopmental and/or cardiovascular benefits of seafood consumption outweigh the MeHg risks associated with the same outcomes provided that consumers stay within amounts recommended for safety, according to the MeHg and POPs content of the mix of seafood species being consumed. Furthermore, the benefit threshold for neurodevelopmental and CVD outcomes appears to be at seafood intakes below the harm threshold associated with MeHg consumption (Gochfeld, 2005).

With regard to the risk of POPs exposure, evidence suggests that POPs levels at current and recommended (EPA/FDA, 2004) levels of seafood consumption in North America from commercially caught or farmed seafood are safe (Dewailly, 2007; Mozaffarian, 2006; Rawn, 2006; Santerre, 2004; Tittlemier, 2004). However, concerns continue to be raised about the higher levels of POPs found in farmed versus wild seafood, including salmon (Huang, 2006). Regarding this concern, Mozaffarian and Rimm (2006) documented strong benefit/risk ratios (range: 100 to 1000-fold) associated with the consumption of wild or farmed salmon taking into account cardiovascular benefits associated with DHA consumption and excessive cancer rates attributed to potential exposure to POPs. Consistent with this finding, Verger et al. (2008) found that recommended intakes of omega-3 PUFA can be met and even exceeded through eating seafood without going beyond POP's upper tolerable intake limits.

In summary, benefit/risk modeling studies indicate that if appropriate seafood choices are made, namely emphasizing consumption of seafood low in MeHg and POPs, consumers may be able to eat 12 ounces or more of a variety of seafood per week safely, although additional CVD benefits may not be obtained beyond 12 ounces (Mozaffarian, 2006). Indeed, this is the only quantitative study that conducted benefit/risk assessments by seafood species consumed in the U.S. (based on MeHg risk only). Ginsberg and Toal (2009) concluded that individuals can consume safely one 6-ounce meal per day for seven out of the 16 seafood species modeled taking into account infant neurodevelopment, and for nine of these species when modeling cardiovascular health.

Related Contextual Issues

Implications of Dietary Selenium and the Potential Health Risks of Methyl Mercury Exposure From Seafood

In reviewing the literature on the benefits and risks related to seafood consumption, the Committee was interested in the role selenium may play in mitigating harmful effects of MeHg and POPs. However, no studies were identified that met the inclusion criteria for this question for the topic of selenium. Therefore, a summation of current evidence is provided here for context.

Several investigators have hypothesized that dietary selenium from seafood may play a possible role in protecting against environmental exposure to MeHg and PCBs (Berry, 2008; Kaneko, 2007; Ralston, 2008; Ravoori, 2009). On the other hand, high exposure levels to MeHg can inhibit vital functions of selenium. The mercury-selenium ratio in seafood may, in part, explain some of the health benefits and adverse effects of some species of seafood consumed as observed in several prospective studies, such as those in the Seychelles Islands versus Northern Europe (Kaneko, 2007; Myers, 2009; Rice, 2008). However, a recent study of flatfish harvested from the New Jersey coast did not indicate a strong correlation of mercury-selenium ratio, regardless of season or geographic location (Burger, 2009). Thus, although the review of several recent studies on the potential benefit-risk relationship of seafood consumption and selenium show an interesting possible protective effect of selenium, the data are insufficient to affect the immediate and consistent public health recommendation regarding the consumption of seafood previously reported in this chapter.

Implications of Aquacultural Practices for a Safe, Nutritious Food Supply

The recommendations of the Committee related to seafood consumption led to discussions of the role of aquaculture in providing a safe and nutritious food supply. Aquaculture refers to the breeding, rearing, and harvesting of plants and animals in all types of water environments, including ponds, rivers, lakes, and the ocean (National Oceanic and Atmospheric Administration [NOAA], 2010). Similar to agriculture, aquaculture can take place in the natural environment or in a manmade environment. Using aquaculture techniques and technologies, researchers and the aquaculture industry are “growing,” “producing,” “culturing,” and “farming” all types of marine and freshwater species. About 20 percent of U.S. aquaculture production is marine species; the rest is freshwater species. Aquaculture techniques also can be applied to some plants, including vegetables (Cahu, 2004). Aquaculture is the most rapidly growing form of food production on a global basis. Globally, nearly 50 percent of the fish consumed comes from aquaculture farms (Naylor, 2009; FAO, 2010). In response to the rapid growth of and need for aquaculture, the Committee has included research recommendations on this topic.

Chapter Summary

Consumers need to take more responsibility regarding food safety. In doing so, along with sound government policies and responsible food industry practices, consumers can help prevent foodborne illness. Consumers should better understand their role in ensuring that the foods they prepare at home or order at food service outlets are handled safely and contain ingredients known to them. Americans could benefit from improved food safety education on hand sanitation, use of food/appliance thermometers, prevention of cross-contamination, and consumption of certain risky foods in the home (e.g., cookie dough containing raw eggs), as well as outside the home (e.g., raw fish and shellfish). Even with current and future introductions of food safety technologies, food safety fundamentals in the home remain foundational. Seafood is a healthy food choice that can be safely promoted provided that the types and sources of seafood to be avoided are clearly communicated to consumers. Consumption of at least 12 ounces per week of seafood can be safe for the general population provided consumers choose the right mix of seafood, emphasizing species low in contaminants (e.g., MeHg and POPs). The Committee supports the recommendations of the 2004 FDA/EPA seafood advisory that states women who may become or who are pregnant, nursing mothers, and young children can safely eat up to 12 ounces of seafood, should limit white (albacore) tuna to 6 ounces per week, and should not eat large, predatory fish. Among these vulnerable groups, there is emerging evidence that consumption beyond 12 ounces per week may be safe; however, additional benefit/risk modeling is needed taking into account the simultaneous presence of multiple contaminants in a shifting seafood supply. Consumers need improved access to publicly available user-friendly benefit/risk information to make informed seafood choices.

Research Recommendations

Food Safety in the Home

1. Improve the validity of self-reported food safety behaviors.

   Rationale: The great majority of the published descriptive epidemiology on U.S. food safety consumer behaviors is based on self-report. Food safety self-reported behaviors are subject to "social desirability" biases. This is particularly evident among hygiene/cleaning behaviors.

2. Understand how to improve consumers' food safety knowledge, attitudes, self-efficacy, internal locus of control and ultimately behaviors.

   Rationale: Studies have consistently documented the need to develop cost–effective consumer food safety behavior change interventions. This research needs to take into account the socio-ecological framework that acknowledges the constant interaction between environmental forces and individuals' choices on health behaviors (Levy, 2008; Story, 2008). Whenever possible, these studies should include objective microbiological food safety indicators to assess the effectiveness of the interventions.

3. Understand whether and how home kitchen microbial cross-contamination during food preparation translates into actual risk for foodborne illness.

   Rationale: There is indisputable laboratory evidence demonstrating that potentially harmful bacteria (mostly *Campylobacter*) present in raw poultry can be transferred to ready-to-eat foods through cross-contamination in the home kitchen. Cross-contamination risk studies have heavily concentrated on the transmission of *Campylobacter* through poultry, and the great majority have been conducted in Europe, leaving a knowledge gap for the U.S. Studies are also needed in the U.S. that concentrate on pathogens and food vehicles other than *Campylobacter* and poultry.

4. Improve monitoring and surveillance to better understand the epidemiology of home-based foodborne illness outbreaks.

   Rationale: The proportion of foodborne outbreaks that can be attributed to improper food safety practices in the home kitchen remains largely undetermined. Translating unsafe food safety behaviors into actual food safety risk will require prospective studies that collect microbial as well as associated morbidity data, in addition to observed food safety behaviors.

Technologies Related to Food Safety

5. Validate and apply food safety sensors for home appliances and cooking utensils.

   Rationale: The development of sensors that monitor commercial food processing standards has improved the quality assurance and safety of those food products. Applications of this technology should be incorporated into and validated in home refrigerators, stoves, ovens, and cooking utensils.

6. Develop, test, and apply environmentally friendly food safety packaging technologies to improve nutritional quality and safety of foods.

   Rationale: Future packaging materials and in-home containers, in addition to being biodegradable and environmentally friendly, will function beyond protecting the product from contamination and maintaining physical properties to nutritional qualities of foods. Some common food ingredients, such as several kinds of dietary fiber and food flavors, when incorporated into food packing materials, can inhibit the growth of potential pathogens. In addition, some foods, like meats, poultry, and seafood, may be packaged in an environment with different kinds of gases, such as nitrogen and carbon dioxide. Applications of these gases at the levels necessary to inhibit microbial growth in the food supply are considered safe by the FDA. (Title 21, U.S. Code of Federal Regulations, Part 184). These kinds of environments, in conjunction with good sanitation practices, can effectively reduce the risk of microbial growth and subsequent contamination, and extend the quality and shelf life of frozen and refrigerated food products.

7. Further develop and promote contemporary educational resources for encouraging food safety behaviors in the home.

   Rationale: The USDA has numerous food safety education sources in contemporary electronic game formats. It is expected that the further development and acceptance of these kinds of educational sources linked to in-home food safety practices and monitoring of in-home environments will reduce the risk of food-related illnesses in the home.

Seafood Safety

8. Conduct consumer risk communication research to determine how best to translate seafood benefit/risk findings to the public.

   Rationale: An unfortunate outcome for the 2004 EPA/FDA Federal seafood consumption advisory was an unintended decrease in fish consumption among pregnant women (Oken, 2008). This may have been the result of a lack of proper coordination and formative evaluation in benefit/risk communications targeting diverse audiences. Since then, researchers have developed user-friendly computer-based educational systems (Domingo, 2007a; Santerre, 2009). However, much more research is needed in this area to effectively reach out to the socioeconomically and culturally diverse U.S. population with the tools needed to maximize the health benefit of their individual seafood choices (Ginsberg, 2009; Verger, 2008).

9. Further refine seafood intake recommendations for U.S. consumers (IOM 2007).

   Rationale: Improving seafood intake recommendations will require a better understanding of benefit(s) and risk(s) response functions that take into account the simultaneous presence of multiple beneficial and detrimental bioactive substances in a variety of seafood (Domingo, 2007b; Ginsberg, 2009; Gochfeld, 2005; Mozaffarian, 2006; Sioen, 2008; Verger, 2008). Similar information also will be needed for other key protein sources (e.g., dairy, meat, plant-based), as consumption changes in one protein source lead to concomitant changes in consumption of other protein sources.

10. Improve and optimize current seafood contaminants surveillance and monitoring.

    Rationale: Monitoring of POPs and other contaminants should be a priority, especially because of the increasing reliance in aquaculture and the multiple origins of seafood being consumed in the U.S. In particular, systems should become more proactive and less reactive in nature (IOM, 2006).

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Part D. Section 8: Food Safety—Tables

Table D8.1. Original and final research questions for food safety techniques and consumer behaviors in the home

Original Questions	Final Questions
To what extent do consumers follow proper techniques/behaviors and procedures for food storage and food preparation and handling?	Question 4. SEPARATE: What techniques for preventing cross-contamination are associated with favorable food safety outcomes? Question 5. COOK AND CHILL: To what extent do U.S. consumers follow adequate temperature control during food preparation and storage at home?
What in-home techniques for food storage and food preparation and handling are associated with favorable food safety outcomes, such as reduced pathogen loads and subsequent risk of home-based foodborne illnesses?	See Questions 4 and 5.
To what extent do consumers follow proper techniques/behaviors and procedures for hand washing?	Question 1. CLEAN: What techniques for hand sanitation are associated with favorable food safety outcomes and to what extent do U.S. consumers follow them?
What in-home techniques for hand washing are associated with favorable food safety outcomes, such as reduced pathogen loads and subsequent risk of home-based foodborne illnesses?	See Question 1.
To what extent do consumers follow proper techniques/behaviors and procedures for washing/cleaning utensils, equipment, and surfaces used in food preparation, serving, cooking, and eating?	Question 3. CLEAN: To what extent do U.S. consumers clean their refrigerators? See Question 4.
What in-home techniques, for washing/cleaning utensils, equipment, and surfaces used in food preparation, serving, cooking, eating, are associated with favorable food safety outcomes, such as reduced pathogen loads and subsequent risk of home-based foodborne illnesses?	See Questions 3 and 4.
To what extent do consumers follow proper techniques/behaviors and procedures for washing/cleaning foods (such as fruits, vegetables, meat, poultry, seafood, eggs) at home? Which food washing/cleaning technique(s) are most commonly used by consumers?	Question 2. CLEAN: What techniques for washing fresh produce are associated with favorable food safety outcomes and to what extent do U.S. consumers follow them? See Question 4.
What in-home techniques for washing/cleaning foods such as fruits, vegetables, meat, poultry, seafood, eggs are associated with favorable food safety outcomes, such as reduced pathogen loads (and reduced chemical contaminant load related to fruits and vegetables) and subsequent risk of home-based foodborne illnesses?	See Questions 2 and 4.

Table D8.1 (continued). Original and final research questions for food safety techniques and consumer behaviors in the home

Original Questions	Final Questions
To what extent do consumers follow proper techniques/behaviors and procedures for consumption of undercooked or raw foods?	Question 6. AVOID RISKY FOODS: To what extent do U.S. consumers eat raw or undercooked animal foods?
	Question 7. To what extent do specific subpopulations practice unsafe food safety behaviors? (Question 7 was within the criteria for all questions, and was made into a question of its own.)

Table D8.2. Recommended procedures for hand sanitation

When washing hands with soap and water:

- Wet your hands with clean running water and apply soap. Use warm water if it is available.
- Rub hands together to make a lather and scrub all surfaces.
- Continue rubbing hands for 20 seconds. Need a timer?
- Rinse hands well under running water.
- Dry your hands using a paper towel or air dryer. If possible, use your paper towel to turn off the faucet.

If soap and water are not available, use alcohol-based gel to clean hands. When using an alcohol-based hand sanitizer:

- Apply product to the palm of one hand.
- Rub hands together.
- Rub the product over all surfaces of hands and fingers until hands are dry.

Source: Adapted from http://www.cdc.gov/cleanhands/. Accessed April 19, 2010.

Table D8.3. Recommended techniques for washing produce

When preparing any fresh produce, begin with clean hands. Wash your hands for 20 seconds with warm water and soap before and after preparation.
Cut away any damaged or bruised areas on fresh fruits and vegetables before preparing and/or eating. Produce that looks rotten should be discarded.
All produce should be **thoroughly washed before eating**. This includes produce grown conventionally or organically at home, or produce that is purchased from a grocery store or farmer's market. Wash fruits and vegetables under potable running water just before eating, cutting, or cooking.
Even if you plan to peel the produce before eating, it is still important to wash it first.
Washing fruits and vegetables with soap or detergent or using commercial produce washes is not recommended.
Scrub firm produce, such as melons and cucumbers, with a clean produce brush.
Drying produce with a clean cloth towel or paper towel may further reduce bacteria that may be present.
Many precut, bagged, or packaged produce items like lettuce are pre-washed and ready to eat. If the package indicates that the contents have been pre-washed and ready to eat, you can use the product without further washing.
If you do choose to wash a product marked "pre-washed" and "ready-to-eat," be sure to use safe handling practices to avoid any cross-contamination. Wash your hands for 20 seconds with warm water and soap before and after handling the product and wash the produce under running water just before preparing or eating.

Source: Adapted from http://www.fda.gov/downloads/Food/ResourcesForYou/Consumers/UCM174142.pdf. Accessed April 19, 2010.

Table D8.4. Recommended techniques for keeping the refrigerator clean

Wipe up spills immediately—clean surfaces thoroughly with hot, soapy water; then rinse.
Once a week, throw out perishable foods that should no longer be eaten. A general rule of thumb for refrigerator storage for cooked leftovers is 4 days; raw poultry and ground meats, 1 to 2 days.
The exterior of the refrigerator may be cleaned with a soft cloth and mild liquid dishwashing detergent as well as cleansers and polishes that are made for appliance use.

Source: Adapted from http://www.fsis.usda.gov/Fact_Sheets/Refrigeration_&_Food_Safety/index.asp#11. Accessed April 19, 2010.

Table D8.5. Recommended techniques for preventing cross-contamination

When Shopping:
Separate raw meat, poultry, and seafood from other foods in your grocery shopping cart. Place these foods in plastic bags to prevent their juices from dripping onto other foods. Raw juices often contain harmful bacteria. It is also best to separate these foods from other foods at checkout and in your grocery bags.
When Refrigerating Food:
Place raw meat, poultry, and seafood in containers or sealed plastic bags to prevent their juices from dripping onto other foods. When not possible, store raw animal foods below ready-to-eat foods and separate different types of raw animal foods, such as meat, poultry, and seafood from each other so that they do not cross-contaminate each other.
Store eggs in their original carton and refrigerate as soon as possible.
When Preparing Food:
Washing raw poultry, beef, pork, lamb, or veal before cooking it is not recommended. Bacteria in raw meat and poultry juices can be spread to other foods, utensils, and surfaces.
Wash hands and surfaces often. Harmful bacteria can spread throughout the kitchen and get onto cutting boards, utensils, and countertops. To prevent this: • Wash hands with soap and warm water for 20 seconds before and after handling food, and after using the bathroom, changing diapers, handling pets, or anytime hands become contaminated. • Use hot, soapy water and paper towels or clean cloths to wipe up kitchen surfaces or spills. Wash cloths often in the hot cycle of your washing machine. • Wash cutting boards, dishes, and countertops with hot, soapy water after preparing each food item and before you go on to the next item. • A solution of 1 tablespoon of unscented, liquid chlorine bleach per gallon of water may be used to sanitize surfaces and utensils.
Cutting Boards:
Always use a clean cutting board.
If possible, use one cutting board for fresh produce and a separate one for raw meat, poultry, and seafood.
Once cutting boards become excessively worn or develop hard-to-clean grooves, you should replace them.
Marinating Food:
Always marinate food in the refrigerator, not on the counter.
Sauce that is used to marinate raw meat, poultry, or seafood should not be used on cooked foods, unless it is boiled just before using.
When Serving Food:
Always use a clean plate.
Never place cooked food back on the same plate or cutting board that previously held raw food.

Source: Adapted from http://origin-www.fsis.usda.gov/Fact_Sheets/Does_Washing_Food_Promote_Food_Safety/index.asp and http://origin-www.fsis.usda.gov/Fact_Sheets/Be_Smart_Keep_Foods_Apart/index.asp. Accessed April 19, 2010.

Table D8.6. Recommended safe minimal internal temperatures

Food	Degrees Fahrenheit
Ground Meat and Meat Mixtures[a]	
Beef, Pork, Veal, Lamb	160
Turkey, Chicken	165
Fresh Beef, Veal, Lamb[a]	
Steaks, roasts, chops[a]	145
Poultry[a]	
Chicken and Turkey, whole	165
Poultry breasts, roasts	165
Poultry thighs, wings	165
Duck and Goose	165
Stuffing (cooked alone or in bird)	165
Fresh Pork[a]	160
Ham[a]	
Fresh (raw)	160
Pre-cooked (to reheat)	140
Eggs and Egg Dishes[a]	
Eggs	Cook until yolk and white are firm.
Egg dishes	160
Fresh Seafood [b]	
Finfish	145
	Cook fish until it is opaque (milky white) and flakes with a fork.
Shellfish	Cook shrimp, lobster, and scallops until they reach their appropriate color. The flesh of shrimp and lobster should be an opaque (milky white) color. Scallops should be opaque (milky white) and firm.
	Cook clams, mussels, and oysters until their shells open. This means that they are done. Throw away any that were already open before cooking as well as ones that didn't open after cooking.
Leftovers and Casseroles[a]	165

Source: [a]http://origin-www.fsis.usda.gov/PDF/Kitchen_Companion.pdf. Accessed May 6, 2010.
[b] http://www.fda.gov/Food/ResourcesForYou/HealthEducators/ucm082294.htm. Accessed April 26, 2010.

Table D8.7. Recommended techniques for food thermometers

To be safe, meat, poultry, and egg[a] and seafood[b] products must be cooked to a safe minimum internal temperature to destroy any harmful microorganisms that may be in the food.
A food thermometer should also be used to ensure that cooked food is held at safe temperatures until served. Cold foods should be held at 40°F or below. Hot foods should be kept hot at 140°F or above.[a]
Most available food thermometers will give an accurate reading within 2 to 4°F. The reading will only be correct, however, if the thermometer is placed in the proper location in the food.[a]
In general, the food thermometer should be placed in the thickest part of the food, away from bone, fat, or gristle.[a]
When the food being cooked is irregularly shaped, such as with a beef roast, check the temperature in several places. Egg dishes and dishes containing ground meat and poultry should be checked in several places.[a]
When measuring the temperature of a thin food, such as a hamburger patty, pork chop, or chicken breast, a thermistor or thermocouple food thermometer should be used, if possible.[a]
However, if using an “instant-read” dial bimetallic-coil food thermometer, the probe must be inserted in the side of the food so the entire sensing area (usually 2 to 3 inches) is positioned through the center of the food.[a]
To avoid burning fingers, it may be helpful to remove the food from the heat source (if cooking on a grill or in a frying pan) and insert the food thermometer sideways after placing the item on a clean spatula or plate.[a]
Food thermometers should be washed with hot soapy water. Most thermometers should not be immersed in water.[a]

Adapted from [a] http://origin-www.fsis.usda.gov/Fact_Sheets/Kitchen_Thermometers/index.asp. Accessed April 19, 2010.
[b] http://www.fda.gov/Food/ResourcesForYou/HealthEducators/ucm082294.htm. Accessed April 26, 2010.

Table D8.8. Recommended techniques for using refrigerator/freezer thermometers

For safety, it is important to verify the temperature of refrigerators and freezers.
Refrigerators should maintain a temperature no higher than 40°F.
Frozen food will hold its top quality for the longest possible time when the freezer maintains 0°F.
To measure the temperature in the refrigerator:
Put the thermometer in a glass of water and place in the middle of the refrigerator. Wait 5 to 8 hours. If the temperature is not 38 to 40°F, adjust the refrigerator temperature control. Check again after 5 to 8 hours.
To measure the temperature in the freezer:
Place the thermometer between frozen food packages. Wait 5 to 8 hours. If the temperature is not 0 to 2°F, adjust the freezer temperature control. Check again after 5 to 8 hours. An appliance thermometer can be kept in the refrigerator and freezer to monitor the ambient temperature at all times. This can be critical in the event of a power outage. When the power goes back on, if the refrigerator is still 40°F and the freezer is 0°F or below, the food is safe.

Adapted from http://origin-www.fsis.usda.gov/PDF/Appliance_Thermometers.pdf. Accessed April 19, 2010.

Table D8.9. Guidance for choosing pasteurized milk and milk products

Read food labels to make sure that the word “pasteurized” is on the label of milk or milk products and, if unsure, ask a grocery store employee whether a milk or milk product contains pasteurized milk. Such foods made from unpasteurized milk could contain harmful bacteria.

Choose versions of these types of food made only with pasteurized milk:
Milk
Cream
Yogurt
Pudding
Ice cream and frozen yogurt
Cottage, cream, and ricotta cheeses
Processed cheeses
Soft cheeses such as Brie, Camembert, blue-veined cheeses, and Mexican-style soft cheeses such as Queso Fresco, Panela, Asadero, and Queso Blanco

Source**:** Adapted from http://www.fda.gov/Food/ResourcesForYou/Consumers/ucm079516.htm. Accessed April 20, 2010.

Part E. Appendices
Appendix E-1: Major Conclusions

SECTION 1: ENERGY BALANCE AND WEIGHT MANAGEMENT

Question 1: What Effects Do the Food Environment and Dietary Behaviors Have on Body Weight?

Conclusion

An emerging body of evidence has documented the impact of the food environment and select behaviors on body weight in both children and adults. Moderately strong evidence now indicates that the food environment is associated with dietary intake, especially less consumption of vegetables and fruits and higher body weight. The presence of supermarkets in local neighborhoods and other sources of vegetables and fruits are associated with lower body mass index, especially for low-income Americans, while lack of supermarkets and long distances to supermarkets are associated with higher body mass index. Finally, limited but consistent evidence suggests that increased geographic density of fast food restaurants and convenience stores is also related to increased body mass index.

Strong and consistent evidence indicates that children and adults who eat fast food are at increased risk of weight gain, overweight, and obesity. The strongest documented relationship between fast food and obesity is when one or more fast food meals are consumed per week. There is not enough evidence at this time to similarly evaluate eating out at other types of restaurants and risk of weight gain, overweight, and obesity. Strong evidence documents a positive relationship between portion size and body weight. Strong and consistent evidence in both children and adults shows that screen time is directly associated with increased overweight and obesity. The strongest association is with television screen time. Strong evidence shows that for adults who need or desire to lose weight, or who are maintaining body weight following weight loss, self-monitoring of food intake improves outcomes. Moderate evidence suggests that children who do not eat breakfast are at increased risk of overweight and obesity. The evidence is stronger for adolescents. There is inconsistent evidence that adults who skip breakfast are at increased risk for overweight and obesity. Limited and inconsistent evidence suggests that snacking is associated with increased body weight. Evidence is insufficient to determine whether frequency of eating has an effect on overweight and obesity in children and adults.

Implications

In order to reduce the obesity epidemic, actions must be taken to improve the food environment. Policy (local, state, and national) and private-sector efforts must be made to increase the availability of nutrient-dense foods for all Americans, especially for low-income Americans, through greater access to grocery stores, produce trucks, and farmers' markets, and greater financial incentives to purchase and prepare healthy foods. The restaurant and food industries are encouraged to offer foods in appropriate portion sizes that are low in calories, added sugars, and solid fat. Local zoning policies should be considered to reduce fast food restaurant placement near schools.

In addition, individuals can adopt a series of dietary behaviors:

- Individuals are encouraged to prepare, serve, and consume smaller portions at home and choose smaller portions of food while eating foods away from home.
- Children and adults are also encouraged to eat a healthy breakfast and to choose nutrient-dense, minimally processed foods whenever they snack.
- Children and adults should limit screen time, especially television viewing, and not eat food while watching television. The American Academy of Pediatrics (AAP) recommends no more than 1 to 2 hours per day of total media time for children and adolescents and discourages television viewing for children younger than age 2 years (AAP, 2001). A Healthy People 2010 objective is to increase the

proportion of adolescents who view television 2 or fewer hours on a school day (HHS, 2000).

- Adults are encouraged to self-monitor body weight, food intake, and physical activity to improve outcomes when actively losing weight or maintaining body weight following weight loss. There is also evidence that self-monitoring of body weight and physical activity also improves outcomes when actively losing weight or maintaining bodyweight following weight loss (Butryn, 2007; Wing, 2006). In order to facilitate better self-monitoring of food intake, there needs to be increased availability of nutrition information at the point of purchase.
- Children and adults are encouraged to follow a frequency of eating that provides nutrient-dense foods within daily caloric requirements periodically through the day. Caution must be taken such that the frequency of eating does not lead to excess calorie intake but does meet nutrient needs.

Question 2: What Is the Relationship Between Maternal Weight Gain During Pregnancy and Maternal-Child Health?

Conclusion

Maternal weight gain during pregnancy outside the recommended ranges is associated with suboptimal maternal and child health. Women who gain weight excessively during pregnancy retain more weight after delivery, are more likely to undergo a cesarean section and to deliver large-for-gestational age newborns, and their offspring may be at increased risk of becoming obese later on in life. Women who gain weight below recommendations are more likely to deliver small-for-gestational age newborns.

Implications

Women are encouraged to maintain a healthy weight before conception. Additionally, women are encouraged to practice sound dietary and physical activity practices to help them attain gestational weight gain within the guidelines outlined by the Institute of Medicine (IOM).

Question 3: What Is the Relationship Between Breastfeeding and Maternal Postpartum Weight Change?

Conclusion

A moderate body of consistent evidence shows that breastfeeding may be associated with maternal postpartum weight loss. However, this weight loss is small, transient, and depends on breastfeeding intensity and duration.

Implications

Transient weight loss has been associated with intensive breastfeeding. However, it is unlikely that breastfeeding currently plays a significant role in promoting more rapid postpartum maternal weight loss in the U.S. given the small size of the effect, large inter-individual variability in maternal postpartum weight changes, and the fact that in the U.S., only one-third of women breastfeed exclusively at 3 months postpartum. Thus, breastfeeding should not be promoted as an effective maternal postpartum weight loss method.

Question 4: How Is Dietary Intake Associated With Childhood Adiposity?

Conclusion

Evidence suggests that certain aspects of dietary intake are associated with greater or lesser adiposity in children. Moderately strong evidence from recent prospective cohort studies that identified plausible reports of energy intake support a positive association between total energy (caloric) intake and adiposity in children. Moderately strong evidence from methodologically rigorous longitudinal cohort studies of children and adolescents suggests that there is a positive association between dietary energy density and increased adiposity in children. Moderate evidence from prospective cohort studies suggests that increased intake of dietary fat is associated with greater adiposity in children; however, no studies were conducted under isocaloric conditions. Strong evidence supports the conclusion that greater intake of sugar-sweetened beverages is associated with increased adiposity in children. Moderate evidence suggests that there is not a relationship between intake of calcium and/or dairy (milk and milk products) and adiposity in children and adolescents. A limited body of evidence from longitudinal studies suggests that greater intake of fruits and/or vegetables may protect against increased adiposity in children and adolescents. Limited and inconsistent evidence suggests that for most children, intake of 100 percent fruit juice is not associated with increased adiposity, when consumed in amounts that are appropriate for age and energy needs of the child. However, intake of 100 percent juice has been prospectively associated with increased adiposity in children who are overweight or obese. There is insufficient evidence that dietary fiber is associated with adiposity in children.

Implications

Strategies to prevent childhood obesity should include efforts to reduce surplus energy intake, especially energy from foods and beverages that provide empty calories from added sugars and solid fats. Total fat intake should not exceed the IOM acceptable ranges, and should consist primarily of mono-and polyunsaturated fats that promote heart health and provide essential fatty acids for growth and development. Increasing consumption of vegetables and fruits in childhood is an important public health goal, not only from the perspective of increasing intake of "shortfall" nutrients, but also because diets high in a variety of vegetables and fruits tend to be lower in energy density, and therefore likely to improve energy balance and prevent obesity. When consumed in moderation as part of a nutrient rich, energy-balanced diet, 100 percent juice can be a healthy part of a child's diet. Children should be encouraged to consume recommended servings of low-fat dairy products daily in order to meet recommended dietary intake levels for key nutrients, such as calcium. Children should also be encouraged to consume greater amounts and varieties of high-fiber foods in order to increase nutrient density and to promote healthy lipid profiles, glucose tolerance, and normal gastrointestinal function. Consumption of sugar-sweetened beverages in childhood should be discouraged (1) because of the positive association with increased adiposity; and (2) because of the need to replace empty calories with nutrient-rich energy for optimal growth and development.

Question 5: What Is the Relationship Between Macronutrient Proportion and Body Weight in Adults?

Conclusion

There is strong and consistent evidence that when calorie intake is controlled, macronutrient proportion of the diet is not related to losing weight. A moderate body of evidence provides no data to suggest that any one macronutrient is more effective than any other for avoiding weight regain in weight reduced persons. A moderate body of evidence demonstrates that diets with less than 45 percent of calories as carbohydrates are not more successful for long-term weight loss (12 months). There is also some evidence that they may be less safe. In shorter-term studies, low calorie, high protein diets may result in greater weight loss, but these differences are not sustained over time. A moderate amount of evidence demonstrates that intake of dietary patterns with less than 45 percent calories from carbohydrates or more than 35 percent calories from protein are not more effective than other diets for weight loss or weight maintenance, are difficult to maintain over the long term, and may be less safe.

Implications

No optimal macronutrient proportion was identified for enhancing weight loss or weight maintenance. However, decreasing caloric intake led to increased weight loss and improved weight maintenance. Therefore, diets that are reduced in calories and have macronutrient proportions that are within the ranges recommended in the Dietary References Intakes (IOM, 2002/2005) (protein: 10%-35%; carbohydrate: 45%-65%; fat: 20%-35%) are appropriate for individuals who desire to lose weight or maintain weight loss. Diets that are less than 45 percent carbohydrate or more than 35 percent protein are difficult to adhere to, are not more effective than other calorie-controlled diets for weight loss and weight maintenance, and may pose health risk, and are therefore not recommended for weight loss or maintenance.

Question 6: Is Dietary Energy Density Associated With Weight Loss, Weight Maintenance, and Type 2 Diabetes Among Adults?

Conclusion

Strong and consistent evidence indicates that dietary patterns that are relatively low in energy density improve weight loss and weight maintenance among adults. Consistent but limited evidence suggests that lower energy density diets may be associated with lower risk of type 2 diabetes among adults.

Implications

Dietary patterns relatively low in energy density that have been associated with beneficial body weight outcomes also may be associated with lower risk of type 2 diabetes (T2D). They are characterized by a relatively high intake of vegetables, fruit, and total fiber and a relatively low intake of total fat, saturated fat, and added sugars (Kant and Graubard, 2005; Ledikwe, 2006a, 2006b; Lindstrom, 2006; Murakami, 2007; Savage, 2008b; Wang, 2008). Additionally, lower dietary energy density may be associated with a dietary intake pattern characterized by lower consumption of meat and processed meats and energy-containing beverages (Wang, 2008). The Committee's conclusion applies to the whole dietary pattern, not to individual foods, and recognizes that a beneficial low-energy density dietary pattern can include consumption of some energy-dense foods (e.g., olive oil and nuts) that have been associated with improved health outcomes (see *Part D. Section 3: Fatty Acids and Cholesterol*).

Question 7: For Older Adults, What Is the Effect of Weight Loss Versus Weight Maintenance on Selected Health Outcomes?

Conclusion

Weight loss in older adults has been associated with an increased risk of mortality, but because most studies have not differentiated between intentional versus unintentional weight loss, recommending intentional weight loss has not been possible. Recently, however, moderate evidence of a reduced risk of mortality with intentional weight loss in older persons has been published. Intentional weight loss among overweight and obese older adults, therefore, is recommended. In addition, with regard to morbidity, moderate evidence suggests that intentional weight loss in older adults has been associated with reduced development of T2D and improved cardiovascular risk factors. There are insufficient data on cancer to come to a conclusion. Weight gain produces increased risk for several health outcomes.

Implications

Observational studies of weight loss, especially when intentionality cannot be rigorously established, may be misleading with respect to the effect of weight on mortality. Loss of weight is appropriate advice for elderly overweight/obese persons. Weight gain should be avoided.

Question 8: What Is the Relationship Between Physical Activity, Body Weight, and Other Health Outcomes?

Conclusion

Strong, consistent evidence indicates that physically active people are at reduced risk of becoming overweight or obese. Furthermore, there is strong evidence that physically active adults who are overweight or obese experience a variety of health benefits that are generally similar to those observed in people of ideal body weight. Because of the health benefits of physical activity that are independent of body weight classification, people of all body weight classifications gain health and fitness benefits by being habitually physically active.

In addition, strong and consistent evidence based on a wide range of well-conducted studies indicates that physically active people have higher levels of health-related fitness, lower risk of developing most chronic disabling medical conditions, and lower rates of various chronic diseases than do people who are inactive. The health benefits of being habitually active appear to apply to all people regardless of age, sex, race/ethnicity, socioeconomic status, and to people with physical or cognitive disabilities.

Implications

Americans are encouraged to meet the 2008 *Physical Activity Guidelines for Americans*. Children and adults should avoid inactivity. Some physical activity is better than none, and more is better. Achieving energy balance and a healthy weight depends on both energy intake and expenditure.

SECTION 2: NUTRIENT ADEQUACY

Question 1: What Nutrients and Dietary Components Are Overconsumed by the General Public?

Conclusion

Estimated intakes of the following nutrients and dietary components are high enough to be of concern:

- For adults: total energy intake, particularly energy intake from solid fats and added sugars; sodium; percentage of total energy from saturated fats; total cholesterol (in men); and refined grains.
- For children: energy intake from solid fats and added sugars; sodium; percentage of total energy from saturated fats; total cholesterol (only in boys, aged 12 to 19 years); and refined grains.

Implications

To lower overall energy intakes (see *Part D. Section 1: Energy Balance and Weight Management*) without compromising nutrient intakes, Americans should reduce consumption of calories from solid fats and added sugars (SoFAS). SoFAS generally provide few, if any, micronutrients. Intakes of SoFAS should be kept as low as possible across all age-sex groups, to less than the maximum limits calculated for the USDA Food Patterns. Concentrated efforts are needed to lower total sodium intakes by all Americans (see *Part D. Section 6: Sodium, Potassium, and Water*). Likewise, deliberate public health efforts are warranted to reduce intakes of saturated fats to meet dietary guidelines for optimal health. Males older than age 12 years also are encouraged to consume less total dietary cholesterol (see *Part D. Section 3: Fatty Acids and Cholesterol*). Intakes of refined grain are too high and at least half of all refined grains should be replaced with high-fiber whole grains (see *Part D. Section 5: Carbohydrates*).

Question 2: What Food Groups and Selected Dietary Components Are Underconsumed by the General Public?

Conclusion

Currently reported dietary intakes of the following food groups and selected dietary components are low enough to be of concern:

- For both adults and children: vegetables, fruits, whole grains, fluid milk and milk products, and oils.

Implications

Despite the evidence that health-promoting dietary patterns are those that include a variety of foods and combinations of foods from each of the basic food groups, many Americans make food choices that do not meet the characteristics of healthy dietary patterns (Bachman, 2008). A fundamental premise of the DGAC is that nutrients should come from foods. Often, nutrient intake shortfalls are an indicator of low intakes of certain food groups that provide specific nutrients. Hence, efforts are warranted to promote increased intakes of vegetables (especially dark-green vegetables, red-orange vegetables, and cooked dry beans and peas), fruits, whole grains, and fat-free or low-fat fluid milk and milk products (including calcium and vitamin D fortified soymilk) among all ages; substitution of oils for solid fats, regardless of age; and increased intakes of lean, heme-iron-rich meat, poultry, and fish by adult women and adolescent girls. Intake of nutrient-dense foods—that is, foods in their leanest or lowest fat forms and without added fats, sugars, starches, or sodium—should replace foods in the current American diet that contribute to high intakes of SoFAS and refined grains (see Question 1 on Nutrients and Dietary Components Overconsumed). Oils should only be substituted for solid fats rather than added to the diet. Substitutions and selection of nutrient-dense forms of vegetables, fruits, whole grains, and fluid milk and milk products to replace non-nutrient-dense forms of foods should be done in a manner such that total caloric intake falls within or below daily energy needs.

Question 3: What Nutrients Are Underconsumed by the General Public and Present a Substantial Public Health Concern?

Conclusion

Reported dietary intakes and associated indices of nutrient status for the following nutrients are of public health concern:

- For both adults and children: vitamin D, calcium, potassium, and dietary fiber.

Implications

Efforts are warranted to promote increased dietary intakes of foods higher in vitamin D, calcium, potassium, and dietary fiber for all Americans regardless of age. Recommended intakes of these nutrients of concern, in particular, and of all essential nutrients, in general, should be achieved within the context of flexible dietary intake patterns that balance energy intake with energy expenditure.

Question 4: What Is the Relationship Between Folate Intake and Health Outcomes in the U.S. and Canada Following Mandatory Folic Acid Fortification?

Conclusion

Strong and consistent evidence demonstrates a large reduction in the incidence of neural tube defects (NTDs) in the U.S. and Canada following mandatory folic acid fortification. A limited body of evidence suggests stroke mortality has declined in the U.S. and Canadian populations following mandatory folic acid fortification. A limited body of evidence suggests that mandatory folic acid fortification has increased the incidence of colorectal cancer (CRC) in the U.S. and Canada.

Implications

Folic acid fortification in the U.S. and Canada appears to be successful in the primary health objective of reducing the incidence of NTDs. Although some negative consequences appear to have occurred (i.e., possible increase in CRC), the evidence supports the continuation of folic acid fortification of flour and uncooked cereals at current levels (140 µg/100 g). Despite the increases in folic acid through fortification, about 22 percent of women of reproductive capacity still do not meet the Estimated Average Requirements. Women of reproductive capacity should continue to be counseled to select foods high in folate, and when necessary, take a folic acid supplement to meet their folate requirements. As a result of the increase in folic acid in food from fortification and because many adults take a supplement containing folic acid, approximately 5 percent of adults older than age 50 years now exceed the UL (1000 µg/day) for folic acid intake. To avoid exceeding the UL, adults over age 50 years should not supplement with folic acid in excess of 400 µg per day. Because whole grain foods are not always fortified with folic acid, individuals who consume mainly whole grains in their dietary patterns should ensure that some of these whole grains are fortified to achieve dietary folate recommendations.

Question 5: Is Iron a Nutrient of Special Concern for Women of Reproductive Capacity?

Conclusion

Substantial numbers of adolescent girls and women of reproductive capacity have laboratory evidence of iron deficiency.

Implications

Efforts are warranted to increase dietary intake of heme-iron-rich foods and of enhancers of iron absorption by these special populations.

Question 6: Are Older Adults Consuming Sufficient Vitamin B_{12}?

Conclusion

Recent evaluation of NHANES data shows that individuals older than age 50 years are consuming adequate intakes of vitamin B_{12}, including B_{12} found naturally in foods and crystalline B_{12} consumed in fortified foods. Nonetheless, a substantial proportion of individuals older than age 50 years may have reduced ability to absorb naturally occurring vitamin B_{12} but not the crystalline form.

Implications

Although individuals older than age 50 years appear to be meeting their need for vitamin B_{12}, they should be encouraged to consume foods fortified with B_{12}, such as fortified cereals, or the crystalline form of B_{12} supplements, when necessary. Practitioners should assess vitamin B_{12} status in those older than age 65 years, using a low serum vitamin B_{12} value of less than 300 pg/mL, high serum methylmalonic acid value of greater than 0.4 µmol/L, and serum total homocysteine level of greater than 15.0 µmol/L as evidence of vitamin B_{12} deficiency.

Question 7: Can a Daily Multivitamin/Mineral Supplement Prevent Chronic Disease?

Conclusion

For the general, healthy population, there is no evidence to support a recommendation for the use of multivitamin/mineral supplements in the primary prevention of chronic disease. Limited evidence suggests that supplements containing combinations of certain nutrients are beneficial in reversing chronic disease when used by special populations; in contrast, certain nutrient supplements appear to be harmful in other subgroups.

Implications

Although intake of a variety of multivitamin/mineral supplements increases blood levels of many nutrients, notably in individuals with suboptimal nutrient status before supplementation (Maraini, 2009), long-term effects on primary prevention of several chronic diseases has not been demonstrated. In this context, obtaining essential micronutrients from foods when possible is the optimal approach and reliance on multivitamin/mineral supplements is discouraged. At present, Americans are encouraged to meet overall nutrient requirements within energy levels that balance daily energy intake with expenditure. This can be accomplished through a variety of food intake patterns that include nutrient-dense forms of foods.

Question 8: What Is the Relationship Between Nutrient Intake and Breakfast Consumption, Snacking, and Eating Frequency?

Conclusion

Moderate evidence supports a positive relationship between breakfast consumption and intakes of certain nutrients in children, adolescents, and adults. A limited body of evidence supports a positive relationship between snacking and increased nutrient intake in children, adolescents, adults, and older adults, and inadequate evidence is available to evaluate the relationship between eating frequency and nutrient intakes.

Implications

Americans are encouraged to eat nutrient-dense forms of foods for breakfast while staying within energy needs to facilitate achieving nutrient recommendations. Likewise nutrient-dense forms of foods are suggested for any snacks, if energy allowance permits this behavior without incurring weight gain.

SECTION 3: FATTY ACIDS AND CHOLESTEROL

Question 1: What Is the Effect of Saturated Fat Intake on Increased Risk of Cardiovascular Disease or Type 2 Diabetes, Including Effects on Intermediate Markers Such as Serum Lipid and Lipoprotein Levels?

Conclusion

Strong evidence indicates that intake of dietary saturated fatty acids (SFA) is positively associated with intermediate markers and end point health outcomes for two distinct metabolic pathways: (1) increased serum total and low-density lipoprotein (LDL) cholesterol and increased risk of cardiovascular disease (CVD) and (2) increased markers of insulin resistance and increased risk of T2D. Conversely, decreased SFA intake improves measures of both CVD and T2D risk. The evidence shows that 5 percent energy decrease in SFA, replaced by monounsaturated fatty acids (MUFA) or polyunsaturated fatty acids (PUFA), decreases risk of

CVD and T2D in healthy adults and improves insulin responsiveness in insulin resistant and T2D individuals.

Implications

As the evidence indicates that a 5 percent energy decrease in SFA, replaced by MUFA or PUFA, results in meaningful reduction of risk of CVD or T2D, and given that in the U.S. population 11 to 12 percent of energy from SFA intake has remained unchanged for over 15 years, a reduction of this amount resulting in the goal of less than 7 percent energy from SFA should, if attained, have a significant public health impact. As an interim step toward this less than 7 percent goal, all individuals should immediately consume less than 10 percent of energy as saturated fats. This impact would not only be limited to a reduction in heart disease and stroke, but also in T2D, a disease currently rising in incidence and prevalence. This substitution of MUFA and PUFA for SFA assumes no change in energy intake. The age of onset of T2D is substantially younger than that of CVD and increasingly frequent in adolescence. Reduction in SFA in children and young adults may provide benefits decades earlier than currently appreciated. The growing data to support a risk of T2D from SFA consumption supports the need for fat-modified diets in persons with pre-diabetes, including those with metabolic syndrome, and those with established diabetes. Early signs of atherosclerotic CVD are also seen in children and a number of studies indicate that the atherosclerotic process begins in childhood and is affected by high blood cholesterol levels. Therefore, reduction in SFA in children and young adults may provide benefits decades earlier than currently appreciated relative to both CVD and T2D incidence.

Question 2: What Is the Effect of Dietary Cholesterol Intake on Risk of Cardiovascular Disease, Including Effects on Intermediate Markers Such as Serum Lipid and Lipoprotein Levels and Inflammation?

Conclusion

Moderate evidence from epidemiologic studies relates dietary cholesterol intake to clinical CVD endpoints. Many randomized clinical trials on dietary cholesterol use eggs as the dietary source. Independent of other dietary factors, evidence suggests that consumption of one egg per day is not associated with risk of coronary heart disease (CHD) or stroke in healthy adults, although consumption of more than seven eggs per week has been associated with increased risk. An important distinction is that among individuals with T2D, increased dietary cholesterol intake is associated with CVD risk.

Implications

Overall, the evidence shows that consumption of dietary cholesterol in the amount of one egg per day is not harmful and does not result in negative changes in serum lipoprotein cholesterol and triglyceride levels. Neither does consumption of eggs at this level increase risk of CVD in healthy individuals. Eggs also are a good source of high quality protein and numerous micronutrients. However, in individuals with T2D, egg consumption (at one egg/day) does have negative effects on serum lipids and lipoprotein cholesterol levels and does increase risk of CVD. Furthermore, consumption of more than seven eggs per week is not recommended for the general public. Overall, limiting dietary cholesterol to less than 300 milligrams per day, with further reductions of dietary cholesterol to less than 200 milligrams per day for persons with or at high risk for CVD and T2D, is recommended.

Question 3: What Is the Effect of Dietary Intake of MUFA When Substituted for SFA on Increased Risk of Cardiovascular Disease and Type 2 Diabetes, Including Intermediate Markers Such as Lipid and Lipoprotein Levels and Inflammation? And What Is the Effect of Replacing a High Carbohydrate Diet With a High MUFA Diet in Persons With Type 2 Diabetes?

Conclusion

Strong evidence indicates that dietary MUFA are associated with improved blood lipids related to both CVD and T2D when MUFA is a replacement for dietary SFA. The evidence shows that 5 percent energy replacement of SFA with MUFA decreases intermediate markers and the risk of CVD and T2D in healthy adults and improves insulin responsiveness in insulin resistant and T2D subjects.

Moderate evidence indicates that increased MUFA intake, rather than high carbohydrate intake, may be beneficial for persons with T2D. High MUFA intake, when replacing a high carbohydrate intake, results in improved biomarkers of glucose tolerance and diabetic control.

Implications

At the current level of 11 to 12 percent of energy from SFA, healthy American adults would benefit substantially by replacing 5 percent of that total energy with MUFA (e.g., 12% SFA reduced to 7% SFA, 12% MUFA increased to 17% MUFA). Beneficial outcomes would include reduced rates of CVD and T2D as well as improved lipids and lipoproteins, inflammatory markers, and measures in insulin resistance. Persons with a predisposition to T2D or established T2D may especially benefit from a high MUFA diet, both as a substitute for SFA and as a substitute for carbohydrates. Given the high prevalence of T2D and the metabolic syndrome in the U.S., such benefits would have a large public health impact.

Question 4: What Is the Effect of Dietary Intake of *n*-6 Polyunsaturated Fatty Acids on Risk of Cardiovascular Disease and Type 2 Diabetes, Including Intermediate Markers Such as Lipid and Lipoprotein Levels and Inflammation?

Conclusion

Strong and consistent evidence indicates that dietary PUFA are associated with improved blood lipids related to CVD, in particular when PUFA is a replacement for dietary SFA or *trans* fatty acids. Evidence shows that energy replacement of SFA with PUFA decreases total cholesterol, LDL cholesterol and triglycerides, as well as numerous markers of inflammation. PUFA intake significantly decreases risk of CVD and has also been shown to decrease risk of T2D.

Implications

All recommendations assume an isocaloric replacement of SFA or *trans* fatty acids with PUFA. In this setting, both CVD and, potentially T2D, may be reduced with PUFA replacement. The mechanisms of CVD reduction, including improvement in serum lipid levels and reduced markers of inflammation, may have additional health benefits. PUFA consumption in the U.S. is lower than that of SFA or MUFA, although the only essential fatty acids are PUFA, so a reduction of SFA from 12 percent to 7 percent of energy through an increase in PUFA alone would increase PUFA from 7 percent to 12 percent of energy. This, or replacing SFA with some combination of PUFA and MUFA, should yield significant public health benefits.

Question 5: What Are the Effects of Dietary Stearic Acid on Low-density Lipoprotein Cholesterol?

Conclusion

Moderate evidence from a systematic review indicates that when stearic acid is substituted for other SFA or *trans* fatty acids[1], plasma LDL cholesterol levels are decreased; when substituted for carbohydrates, LDL cholesterol levels are unchanged; and when substituted for MUFA or PUFA, LDL cholesterol levels are increased. Therefore, the impact of stearic acid replacement of other energy sources is variable regarding LDL cholesterol, and the potential impact of changes in stearic acid intake on cardiovascular disease risk remains unclear.

Implications

Since stearic acid is not known to raise LDL cholesterol, the DGAC is recommending that stearic acid not be categorized with known “cholesterol-raising fats,” which include C12, C14, C16 SFA and *trans* fatty acids. Foods that are high in stearic acid, such as dark chocolate and shea nut oil, need not be considered as problematic as foods high in other SFA or *trans* fatty acids. In addition, setting the recommended percent of energy from these cholesterol-raising fats to a less than 5 to 7 percent will help to maintain blood cholesterol at desirable concentrations.

Question 6: What Effect Does Consuming Natural (Ruminant) Versus Synthetic (Industrially Hydrogenated) *Trans* Fatty Acids Have on LDL-, HDL- and Non HDL Cholesterol Levels?

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[1] *Trans* fatty acids as used in this Report is a term consistent with that defined by the U.S. Food and Drug Administration for use in food labeling. See *Part D. Section 3: Fatty Acids and Cholesterol*.

Conclusion

Limited evidence is available to support a substantial biological difference in the detrimental effects of industrial *trans* fatty acids (iTFA) and ruminant *trans* fatty acids (rTFA) on health when rTFA is consumed at 7 to 10 times the normal level of consumption.

Implications

The level of daily intake of rTFA is quite small with the U.S. adult population's average daily intake approximating 1.2 grams (1.5 g for men and 0.9 g for women). This represents less than 0.5 percent of total daily energy intake. This is a relatively minor exposure in the diet regardless of its metabolic effect.

The very limited data available provide insufficient evidence to suggest rTFA and iTFA be considered differently in their metabolic effects. Total *trans* fatty acid intake should be considered the target for dietary change. Total elimination of rTFA would require elimination of red meat and dairy products from the diet. Although total elimination of iTFA may be desirable, the elimination of rTFA would have wider implications for dietary adequacy and is not recommended. It is best to avoid iTFA while leaving small amounts of rTFA in the diet. Overall, *trans* fatty acid levels in the U.S. food supply have decreased dramatically following mandatory *trans* fatty acids labeling regulations, which went into effect in 2006. Continued reductions in iTFA are to be encouraged.

Question 7: What Is the Relationship Between Consumption of Seafood *n*-3 Fatty Acids and Risk of CVD?

Conclusion

Moderate evidence shows that consumption of two servings of seafood per week (4 oz per serving), which provide an average of 250 milligrams per day of long-chain *n*-3 fatty acids, is associated with reduced cardiac mortality from CHD or sudden death in persons with and without CVD.

Implications

An increase in seafood intake to two servings per week at 4 ounces per serving, is advised for high-risk (those with CVD) and average-risk persons, especially as the first presentation of CVD (myocardial infarction, stroke) is frequently fatal or disabling. The quantity and frequency of seafood consumption is important, but the type of seafood (those providing at least 250 mg of long-chain *n*-3 fatty acids per day) also is critical. Increased consumption of seafood will require efficient and ecologically friendly strategies be developed to allow for greater consumption of seafood that is high in EPA and DHA, and low in environmental pollutants such as methyl mercury (see *Part D.8: Food Safety and Technology* for a detailed discussion of the risks and benefits of seafood consumption).

Question 8: What Is the Relationship Between Consumption of Plant *n*-3 Fatty Acids and Risk of CVD?

Conclusion

Alpha-linolenic acid (ALA) intake of 0.6 to 1.2 percent of total calories will meet current recommendations and may lower CVD risk, but new evidence is insufficient to warrant greater intake beyond this level. Limited but supportive evidence suggests that higher intake of *n*-3 fatty acids from plant sources may reduce mortality among persons with existing CVD.

Implications

Evidence is currently insufficient to make a formal guideline to increase *n*-3 intake from plant sources without additional evidence from randomized clinical trials and prospective observational studies among participants with a broad range of *n*-3 intake. As relatively little ALA converts to EPA and DHA, evidence is lacking that plant-derived *n*-3 fatty acids alone will provide the same cardioprotective effects as EPA and DHA consumed at the recommended level discussed above. This increases the need for efficient and ecologically friendly strategies to allow for greater consumption of seafood *n*-3 fatty acids, unless plant-derived sources of EPA or DHA can be developed.

Question 9: What Are the Effects of Maternal Dietary Intake of *n*-3 Fatty Acids From Seafood on Breast Milk Composition and Health Outcomes in Infants?

Conclusion

Moderate evidence indicates that increased maternal dietary intake of long chain *n*-3 PUFA (in particular docosahexaenoic acid [DHA]) from at least two servings of seafood per week during pregnancy and lactation is associated with increased DHA levels in breast milk and improved infant health outcomes, such as visual acuity and cognitive development.

Implications

There has been controversy and concern over the consumption of fish during pregnancy and lactation with regard to exposure of the fetus and infant to heavy metals during the most sensitive period of neurodevelopment. The current evidence, however, favors consumption of fish for pregnant and lactating women, particularly in the context of women making educated choices to consume seafood that is high in *n*-3 fatty acids and low in environmental pollutants. The benefits of fish consumption are maximized with fatty fish high in EPA and DHA but low in methyl mercury. These conclusions are consistent with those found in the discussion of seafood benefits and risks in *Part D.8: Food Safety and Technology*. The previously described modeling analysis of seafood identified scenarios of type and quantity of fish that provide 250 milligrams per day of EPA + DHA.

Question 10: What Are the Health Effects Related to Consumption of Nuts?

Conclusion

There is moderate evidence that consumption of unsalted peanuts and tree nuts, specifically walnuts, almonds, and pistachios, in the context of a nutritionally adequate diet and when total calorie intake is held constant, has a favorable impact on cardiovascular disease risk factors, particularly serum lipid levels.

Implications

Most nut consumption is in the form of peanuts, though tree nuts (walnuts, almonds, pecans, pistachios) are frequently used in cooking and as snack foods. Peanuts are also an important source of vegetable protein. Many nuts (e.g., peanuts, almonds, cashews) are sold with added salt as snack foods; thus, the recommendations for consumption are limited to unsalted nuts as a means to reduce sodium intake. It also is important to note that nuts should be consumed in small portions, as they are high in calories and can contribute to weight gain.

Question 11: What Are the Health Effects Related to Consumption of Chocolate?

Conclusion

Moderate evidence suggests that modest consumption of dark chocolate or cocoa is associated with health benefits in the form of reduced CVD risk. Potential health benefits need to be balanced with caloric intake.

Implications

Chocolate as currently consumed is a small component of the total diet, and benefits or risks will likely be minimal. Potential health effects need to be balanced with caloric intake, as chocolate is a calorie dense product. The predominant fat in chocolate is stearic acid, which has been shown to not raise blood cholesterol. Different formulations of chocolate vary in their content of dairy fat, with darker chocolate containing less dairy fat. Beneficial effects of chocolate have been attributed to polyphenolic compounds, in particular flavonoids. Many plant-based foods contain polyphenolic compounds and chocolate is a minor source. Formulations of chocolate are known to have different polyphenolic profiles, and, if this is the mechanism of chocolate's beneficial actions, different forms of chocolate may confer different benefits.

SECTION 4: PROTEIN

Question 1: What Is the Relationship Between the Intake of Animal Protein Products and Selected Health Outcomes?

Conclusion

Limited evidence from prospective cohort studies show inconsistent relationships between intake of animal protein products and CVD with somewhat more positive evidence for processed meats and CHD. Moderate evidence found no clear association between intake of animal protein products and blood pressure in prospective cohort studies. Limited inconsistent evidence from prospective cohort studies suggests that intake of animal protein products, mainly processed meat, may have a link to T2D. Insufficient evidence is available to link animal protein intake and body weight. Moderate evidence reports inconsistent positive associations between colorectal cancer and the intake of certain animal protein products, mainly red and processed meat. Limited evidence shows that intake of animal protein products are associated with prostate cancer incidence. Limited evidence from cohort studies shows there is no association between the intake of animal protein products and overall breast cancer risk. However in subgroups of breast cancer patients, limited evidence suggested a relationship between the intake of animal protein products and risk of developing breast cancer.

Implications

Americans may choose animal products as part of their diet based on the body of evidence showing a general lack of relationship between animal protein consumption and selected health outcomes. However, attention should be given to quantity and preparation, as some forms of meat (well done and processed) may be linked to specific cancers. In addition, animal protein products contain saturated fat and proportionately, a high calorie load, so serving sizes should be appropriate.

Question 2: What Is the Relationship Between Vegetable Protein and/or Soy Protein and Selected Health Outcomes?

Conclusion

Few studies are available, and the limited body of evidence suggests that vegetable protein intake does not offer special protection against T2D, coronary heart disease, and selected cancers. Moderate evidence from both cohort and cross-sectional studies show that intake of vegetable protein is generally linked to lower blood pressure. Moderate evidence suggests soy protein intake may have small effects on total and low density lipoprotein cholesterol in adults with normal or elevated blood lipids, although results from systematic reviews are inconsistent. A moderate body of consistent evidence finds no unique benefit of soy protein intake on body weight. A limited and inconsistent body of evidence shows that soy protein intake does not provide any unique benefits in blood pressure control.

Implications

Our review indicated that intake of vegetable protein is generally linked to lower blood pressure, but this could be due to other components in plant foods, such as fiber, or other nutrients. Individual sources of vegetable protein have no unique health benefits so choice of plant protein sources can come from a wide range of plant-based foods. Consumption of plant proteins of lower quality is generally fine as long as calorie needs are met and effort is made to complement the incomplete vegetable proteins. Consumption of lower-quality or incomplete protein is of greater concern when protein needs are high. Thus, consumption of lower-quality vegetable protein must be carefully considered during pregnancy, lactation, and childhood. Additionally, recommendations to lower calorie intake to combat obesity by increasing plant-based food intake must be linked to cautionary messages to maintain protein total intake of sufficient quality at recommended levels.

Question 3: How Do the Health Outcomes of a Vegetarian Diet Compare to That of a Diet Which Customarily Includes Animal Products?

Conclusion

Limited evidence is available documenting that vegetarian diets protect against cancer. However, it suggests that vegetarian diets, including vegan, are associated with lower BMI and blood pressure. Vegan diets may increase risk of osteoporotic fractures. The effect of vegetarian diets on cardiovascular disease, stroke, and mortality is discussed further in *Part B. Section 2: The Total Diet: Combining Nutrients, Consuming Food.*

Implications

Most people consume diets containing both animal and plant foods. Few studies exist on the nutritional or health status of vegetarians and/or vegans. Individuals who restrict their diet to plant foods may be at risk of not getting adequate amounts of certain indispensable amino acids because the concentration of lysine, sulfur amino acids, and threonine are sometimes lower in plant than in animal food proteins. Nutrients of concern on vegan diets include calcium, iron, B_{12}, zinc, and long-chain *n*-3 fatty acids. Vegetarian diets that include complementary mixtures of plant proteins can provide the same quality of protein as that from animal protein. Education is needed for those designing diets containing complementary proteins for consumers switching to a more plant-based diet. Additionally, individuals consuming vegetarian, particularly vegan, diets should ensure adequate intake of all nutrients.

Question 4: What Is the Relationship Between the Intake of Milk and Milk Products and Selected Health Outcomes?

Conclusion

Strong evidence demonstrates that intake of milk and milk products provide no unique role in weight control. Moderate evidence indicates that the intake of milk and milk products is linked to improved bone health in children. Limited evidence suggests a positive relationship between the intake of milk and milk products and bone health in adults, but results are inconsistent due to variability in outcomes considered. Moderate evidence shows that intake of milk and milk products are inversely associated with cardiovascular disease. A moderate body of evidence suggests an inverse relationship between the intake of milk and milk products and blood pressure. Moderate evidence shows that milk and milk products are associated with a lower incidence of T2D in adults. Limited evidence is available showing intake of milk and milk products are associated with reduced risk of metabolic syndrome. Insufficient evidence is available to assess the relationship between intake of milk and milk products and serum cholesterol levels.

Implications

Currently, many children and adults are not consuming adequate amounts of milk and milk products. NHANES 2005-2006 reported that the mean consumption of calcium does not meet the recommended Dietary Reference Intakes for any age group older than age 12. Research since 2004 shows that the underconsumption of milk and milk products may lead to an increase in cardiovascular disease and T2D, as well as an increased risk for poor bone health and related diseases. Consumption of the recommended daily amounts of low-fat or fat-free milk and milk products (2 cups for children ages 2 to 8 years, 3 cups for those ages 9 years and older) should be promoted. It is especially important to establish milk drinking in young children, as those who consume milk as children are more likely to do so as adults. Those who choose not to consume milk and milk products should include other foods in the diet that contain the nutrients provided by the milk and milk products group, protein, calcium, potassium, magnesium, vitamin D, and vitamin A.

Question 5: What Is the Relationship Between the Intake of Cooked Dry Beans and Peas and Selected Health Outcomes?

Conclusion

Limited evidence exists to establish a clear relationship between intake of cooked dry beans and peas and body weight. There is limited evidence that intake of cooked dry beans and peas lowers serum lipids. Limited evidence is available to determine a relationship between the intake of cooked dry beans and peas and T2D.

Implications

Legumes and soybeans, including dried beans and peas, are typically recommended foods because of their content of dietary fiber, protein, vitamins, and minerals (Mesina, 1999). Because soybeans are particularly high in isoflavones, a phytoestrogen, they have been more extensively studied than other legumes. Legumes are also promoted as a complementary protein source to grains since legumes are low in methionine and grains are low in lysine. Thus, legumes play an important role in vegan diets for enhancing protein quality. They may also provide a beneficial contribution to the general population in part to increase total vegetable consumption and dietary fiber intake.

SECTION 5: CARBOHYDRATES

Question 1: What Are the Health Benefits of Dietary Fiber?

Conclusion

A moderate body of evidence suggests that dietary fiber from whole foods protects against cardiovascular disease, obesity, and T2D and is essential for optimal digestive health.

Implications

Dietary fiber is underconsumed across all segments of the American population. The development of many risk factors that are associated with incidence of several highly prevalent chronic diseases could be reduced by increasing consumption of naturally-occurring plant-based foods that are high in dietary fiber, including whole grain foods, cooked dry beans and peas, vegetables, fruits, and nuts.

Question 2: What Is the Relationship Between Whole Grain Intake and Selected Health Outcomes?

Conclusion

A moderate body of evidence from large prospective cohort studies shows that whole grain intake, which includes cereal fiber, protects against cardiovascular disease. Limited evidence shows that consumption of whole grains is associated with a reduced incidence of T2D in large prospective cohort studies. Moderate evidence shows that intake of whole grains and grain fiber is associated with lower body weight.

Implications

Currently most Americans are not consuming adequate amounts of whole grains, which are an important source of dietary fiber and other nutrients. Enriched and fortified grains provide important nutrients; hence, individuals are encouraged to consume grains as both fiber-rich whole grains and enriched grains. To ensure nutrient adequacy, especially for folate, individuals who consume all of their grains as whole grains should include some that have been fortified with folic acid. Total grains servings are typically overconsumed in the U.S., so recommendations to consume more grains are not supported by this review. Advice should be to make more grain choices as fiber-rich whole grains, rather than eat more grains. The lack of standards for whole grain foods and measuring whole grain content of foods also make any recommendations difficult to implement.

Question 3: What Is the Relationship Between the Intake of Vegetables and Fruits, Not Including Juice, and Selected Health Outcomes?

Conclusion

Consistent evidence suggests at least a moderate inverse relationship between vegetable and fruit consumption with myocardial infarction and stroke, with significantly larger, positive effects noted above five servings of vegetables and fruits per day. Notwithstanding prior work on dietary patterns that emphasize vegetables and fruits, insufficient evidence published since 2004 is available to assess the independent relationship between vegetable and fruit intake and blood pressure or serum cholesterol. The evidence for an association between increased fruit and vegetable intake and lower body weight is modest with a trend towards decreased weight gain over 5+ years in middle adulthood. No conclusions can be drawn from the evidence on the efficacy of increased fruit and vegetable consumption in weight loss diets. Limited and inconsistent evidence suggests an inverse association between total vegetable and fruit consumption and the development of T2D. Evidence also indicates that some types of vegetables and fruits are probably protective against some cancers.

Implications

Vegetables and fruits are nutrient-dense and relatively low in calories. In order to meet the recommended intakes, Americans should emphasize vegetables and fruits in their daily food choices, without added solid fats, sugars, starches, or sodium to maximize health benefits. Significant favorable associations between vegetable and fruit consumption and health outcomes appear to be linked to a minimum of five servings per day and positive linear effects may be noted at even higher consumption levels. While the impact of increased vegetable and fruit consumption per se is unclear for some chronic diseases and markers (blood lipids, glucose control, T2D, and weight loss), improvements in preventing cardiovascular disease and certain cancers, especially cancers of the alimentary tract, may occur with increased consumption of these foods. Additionally, there is evidence that vegetables and fruits, when considered as part of a dietary pattern, are associated with improved weight and health outcomes (see *Part D. Section 2: The Total Diet: Combining Nutrients, Consuming Food* for a discussion of dietary patterns and *Part D. Section 1: Energy Balance and Weight Management* for a discussion of energy density).

Question 4: What Is the Relationship Between Glycemic Index or Glycemic Load and Body Weight, Type 2 Diabetes, Cardiovascular Disease, and Cancer?

Conclusion

Strong and consistent evidence shows that glycemic index and/or glycemic load are not associated with body weight and do not lead to greater weight loss or better weight maintenance. Abundant, strong epidemiological evidence demonstrates that there is no association between glycemic index or load and cancer. A moderate body of inconsistent evidence supports a relationship between high glycemic index and T2D. Strong, convincing evidence shows little association between glycemic load and T2D. Due to limited evidence, no conclusion can be drawn to assess the relationship between either glycemic index or load and cardiovascular disease.

Implications

When selecting carbohydrate foods, there is no need for concern with their glycemic index or glycemic load. What is important to heed is their calories, caloric density, and fiber content.

Question 5: In Adults, What Are the Associations Between Intake of Sugar-sweetened Beverages and Energy Intake and Body Weight?

Conclusions

Limited evidence shows that intake of sugar-sweetened beverages is linked to higher energy intake in adults. A moderate body of epidemiologic evidence suggests that greater consumption of sugar-sweetened beverages is associated with increased body weight in adults. A moderate body of evidence suggests that under isocaloric controlled conditions, added sugars, including sugar-sweetened beverages (SSB), are no more likely to cause weight gain than any other source of energy.

Implications

Added sugars, as found in SSB, are not different than other extra calories in the diet for energy intake and body weight. Thus, reducing intake of all added sugars, including sucrose, corn sweetener, fructose, high fructose corn syrup, and other forms of added sugars, is a recommended strategy to reduce calorie intake in Americans. Intake of caloric beverages, including SSB, sweetened coffee and tea, energy drinks, and other drinks high in calories and low in nutrients should be reduced in consumers needing to lower body weight. While still moderate, recent evidence is stronger than prior evidence available to assess the relationship between SSB and increased body weight.

Question 6: How Are Non-caloric Sweeteners Related to Energy Intake and Body Weight?

Conclusion

Moderate evidence shows that using non-caloric sweeteners will affect energy intake only if they are substituted for higher calorie foods and beverages. A few observational studies reported that individuals who use non-caloric sweeteners are more likely to gain weight or be heavier. This does not mean that non-caloric sweeteners cause weight gain, but rather that they are more likely to be consumed by overweight and obese individuals.

Implications

The replacement of sugar-sweetened foods and beverages with sugar-free products should theoretically reduce body weight. Yet many questions remain, as epidemiologic studies show a positive link with use of nonnutritive sweeteners and BMI. Additionally, whether use of low calorie sweeteners is linked to higher intake of other calories in the diet remains a debated question.

Question 7: What Is the Impact of Liquid Versus Solid Foods on Energy Intake and Body Weight?

Conclusion

A limited body of evidence shows conflicting results about whether liquid and solid foods differ in their effects on energy intake and body weight except that liquids in the form of soup may lead to decreased energy intake and body weight.

Implications

In general, if total calorie content is held constant, there is little support for any effects on energy intake and body weight due to the calories consumed either as liquid or solid. Some studies suggest that whole foods may be more satiating than liquid foods. Food structure, specifically a whole food (apple, carrots), plays a role in satiety and decreasing food intake at subsequent meals, yet fiber added to a drink is not effective in reducing food intake at subsequent meals. Soup as a preload decreases food intake at a subsequent meal. Thus, Americans are advised to pay attention to the calorie content of the food or beverage consumed, regardless of whether it is a liquid or solid. Calories are the issue in either case.

Question 8: What Is the Role of Carbohydrate, Fiber, Protein, Fat, and Food Form on Satiety?

Conclusion

Many factors affect satiety and most studies are conducted in laboratory settings to control for variables. Thus results may not be generalized to the more complicated eating environment of the outside world. Foods high in dietary fiber generally are more satiating than low fiber foods, although some fibers added to drinks have little impact on satiety. Overall, small changes in the macronutrient content of the diet do not significantly alter satiety.

Implications

Intakes of caloric preloads, whether carbohydrate, protein, or fat, typically increase satiety. Protein and carbohydrate may be more satiating than fat, although studies are not consistent. Dietary fiber, especially from whole foods, appears to enhance satiety in studies. Not all fibers added to beverages or foods are equally satiating. In fact, some functional fibers show no effect on satiety.

Question 9: What Is the Role of Prebiotics and Probiotics in Health?

Conclusion

Gut microflora play a role in health, although the research in this area is still developing. Foods high in prebiotics (wheat, onions, garlic) may be consumed, as well as food concentrated in probiotics (yogurt), within accepted dietary patterns.

Implications

The lack of epidemiologic studies that support a role for changes in gut microflora and health outcomes limits any specific dietary recommendations in this area. Foods high in prebiotics and probiotics are linked to health benefits. For example, fiber is a prebiotic linked to health benefits. Many probiotic-containing foods, such as dairy foods, also are linked to health benefits and are recommended for inclusion in the diet.

SECTION 6: SODIUM, POTASSIUM, AND WATER

Question 1: What Is the Effect of Sodium Intake on Blood Pressure in Children and in Adults?

Conclusion

A strong body of evidence has documented that in adults, as sodium intake decreases, so does blood pressure. A moderate body of evidence has documented that as sodium intake decreases, so does blood pressure in children, birth to 18 years of age.

Implications

The projected health benefits of a reduced sodium intake are substantial and include fewer strokes, cardiovascular disease events, and deaths, as well as substantially reduced health care costs. In view of these potential benefits and the current very high intake of sodium in the general population, children and adults should lower their sodium intake as much as possible by consuming fewer processed foods that are high in sodium, and by using little or no salt when preparing or eating foods.

The current food supply is replete with excess sodium. Many foods contribute to the high intake of sodium. While some foods are extremely high in sodium, the problem of excess sodium reflects frequent consumption of foods that are only moderately high in sodium. The major sources of sodium intake among the U.S. population are yeast breads; chicken and chicken mixed dishes; pizza; pasta and pasta dishes; cold cuts; condiments; Mexican mixed dishes; sausage, franks, bacon, and ribs; regular cheese; grain-based desserts; soups; and beef and beef mixed dishes (National Cancer Institute [NCI], 2010). Collectively, this group of foods contributes about 56 percent of the dietary sodium, or nearly 2000 milligrams per person per day.

A major new concern is the excessive sodium added to products such as poultry, pork, and fish through injections or marination; efforts to quantify the amount of sodium from this type of processing are warranted. Finally, an important determinant of sodium intake is calorie intake. Hence, efforts to reduce calorie intake should also lower sodium intake.

In 2005, the DGAC recommended a daily sodium intake of less than 2300 milligrams for the general adult population and stated that hypertensive individuals, Blacks, and middle-aged and older adults would benefit from reducing their sodium intake even further. Because these latter groups together now comprise nearly 70 percent of U.S. adults, the goal should be 1500 milligrams per day for the general population. Given the current U.S. marketplace and the resulting excessively high sodium intake, it will be challenging to achieve the lower level. In addition, time is required to adjust taste perception in the general population. Thus, the reduction from 2300 milligrams to 1500 milligrams per day should occur gradually over time. A recent Institute of Medicine (IOM) report has provided a roadmap to achieve gradual reductions in sodium intake. Because early stages of blood pressure-related atherosclerotic disease begin during childhood, both children and adults should reduce their sodium intake. Individuals should also increase their consumption of dietary potassium because increased potassium intakes helps to attenuate the effects of sodium on blood pressure.

Question 2: What Is the Effect of Potassium Intake on Blood Pressure in Adults?

Conclusion

A moderate body of evidence has demonstrated that a higher intake of potassium is associated with lower blood pressure in adults.

Implications

Increasing dietary potassium intake can lower blood pressure. A higher intake of potassium also attenuates the adverse effects of sodium on blood pressure. Other possible benefits include a reduced risk of developing kidney stones and decreased bone loss. In view of the health benefits of adequate potassium intake and its relatively low current intake by the general population, increased intake of dietary potassium is warranted. The IOM set the Adequate Intakes (AI) for potassium for adults at 4700 milligrams per day. Available evidence suggests that Blacks and hypertensive individuals especially benefit from an increased intake of potassium.

Question 3: What Amount of Water Is Recommended for Health?

Conclusion

Based on an extensive review of evidence, an IOM panel in 2004 concluded that the combination of thirst and usual drinking behavior, especially the consumption of fluids with meals, is sufficient to maintain normal hydration. However, because water needs vary considerably and because there is no evidence of chronic dehydration in the general population, a minimum intake of water cannot be set.

Implications

In order to prevent dehydration, water must be consumed daily. Healthy individuals who have routine access to fluids and who are not exposed to heat stress consume adequate water to meet their needs. Purposeful drinking is warranted for individuals who are exposed to heat stress or who perform sustained vigorous physical activity. Although uncommon, heat waves are one setting of extreme heat stress that increases the risk of morbidity and mortality from dehydration, especially in older-aged persons. In view of the ongoing obesity epidemic, individuals are encouraged to drink water and other fluids with few or no calories.

SECTION 7: ALCOHOL

Question 1: What Is the Relationship Between Alcohol Intake and Weight Gain?

Conclusion

Moderate evidence suggests that among free-living populations, moderate drinking is not associated with weight gain. However, heavier consumption over time is associated with weight gain.

Implications

In general, all alcoholic beverages contain calories that are not a good source of nutrients and when consumed beyond an average of two drinks a day may lead to weight gain. Below this level of consumption, the results from most well designed large prospective studies suggest that individuals who drink in moderation do not gain weight at a faster rate than non-drinkers.

Question 2: What Is the Relationship Between Alcohol Intake and Cognitive Decline With Age?

Conclusion

Moderate evidence suggests that compared to non-drinkers, individuals who drink moderately have a slower cognitive decline with age. Although limited, evidence suggests that heavy or binge drinking is detrimental to age-related cognitive decline.

Implications

Alcohol, when consumed in moderation, did not quicken the pace of age-related loss of cognitive function. In most studies, it was just the opposite—moderate alcohol consumption, when part of a healthy diet and physical activity program, appeared to help to keep cognitive function intact with age. Despite the potential benefit at moderate consumption levels, heavy drinking and episodes of binge drinking impairs short- and long-term cognitive function and should be avoided.

Question 3: What Is the Relationship Between Alcohol Intake and Coronary Heart Disease?

Conclusion

Strong evidence consistently demonstrates that compared to non-drinkers, individuals who drink moderately have lower risk of CHD. Insufficient evidence was available to determine if any one single drinking pattern was predictive of lower or higher risk of coronary heart disease, although there was moderate evidence to suggest that heavy or binge drinking is detrimental.

Implications

An average daily intake of one to two alcoholic beverages is associated with a low risk of CHD among middle-aged and older adults. Binge or heavy irregular drinking should be avoided.

Question 4: What Is the Relationship Between Alcohol Intake and Bone Health?

Conclusion

Moderate evidence suggests a J-shaped association between alcohol consumption and incidence of hip fracture; there was a suggestion that heavy or binge drinking was detrimental to bone health.

Implications

There is insufficient evidence from epidemiological data to make a strong conclusion related to patterns of alcohol intake and bone health. However, it is very likely that the increased risk of fracture among individuals who drink more than one to two drinks per day on average is due to injuries that follow heavier consumption. What further complicates the interpretation of the existing studies is that moderate and heavy drinkers frequently were combined in the same category, making it impossible to disentangle potential benefits and risks. In addition, many studies failed to control adequately for physical activity, an important lifestyle characteristic beneficially related to bone density.

Question 5: What Is the Relationship Between Alcohol Intake and Unintentional Injury?

Conclusion

Strong evidence demonstrates that drinking in excess of current guidelines increases the risk of unintentional falls, motor vehicle crashes, and drowning. When alcohol is consumed in moderation, the evidence for risk of unintentional injury is less well established for activities such as driving, swimming, and athletic participation, but abstention from alcohol is the safest.

Implications

Adverse effects, in terms of unintentional injury, can occur even at levels of moderate alcohol consumption.

Question 6: Does Alcohol Consumption During Lactation Have Adverse Health Effects? What Is the Relationship Between Alcohol Consumption and the Quality and Quantity of Breast Milk Available for the Offspring? What Is the Relationship Between Alcohol Consumption and Postnatal Growth Patterns, Sleep Patterns, and/or Psychomotor Patterns of the Offspring?

Conclusion

Moderate, consistent evidence shows that when a lactating mother consumes alcohol, alcohol enters the breast milk, and the quantity of milk produced is reduced, leading to reduced milk consumption by the infant. Although limited, evidence suggests that alcohol consumption during lactation was associated with altered post-natal growth, sleep patterns, and/or psychomotor patterns of the offspring.

Implications

The benefits of breastfeeding to the infant are well established. A woman who chooses to breast feed, however, need not completely abstain from alcohol. Because the level of alcohol in breast milk mirrors the mother's blood alcohol content, after latch-on has been perfected and a pattern of consistent breastfeeding has been established (i.e., around age 2 to 3 months), a mother could wait 3 to 4 hours after a single drink (the time it would take to metabolize the ethanol) before breastfeeding and the infant exposure to alcohol would likely be negligible. It is not sufficient for a woman to express breast milk after alcohol consumption to prevent exposure to the infant because the concentration of alcohol in breast milk will remain at levels in the blood until all the alcohol is metabolized. Contrary to medical and cultural folklore, alcohol consumption does not enhance lactational performance and instead reduces milk production and decreases infant milk consumption in the 3 to 4 hours after alcohol is consumed. Finally, there is still insufficient evidence to conclude definitively that alcohol exposure to an infant during lactation affects the postnatal growth of the child, but nonetheless alcohol exposure to the breastfeeding infant by breastfeeding too soon after consuming a single drink should be avoided.

SECTION 8: FOOD SAFETY AND TECHNOLOGY

BEHAVIORS MOST LIKELY TO PREVENT FOOD SAFETY PROBLEMS AND THE EXTENT TO WHICH U.S. CONSUMERS FOLLOW THESE BEHAVIORS

Overarching Conclusion

Evidence shows that proper hand sanitation techniques, proper washing of vegetables and fruit, prevention of cross-contamination, and appropriate cooking and storage of foods in the home kitchen are most likely to prevent food safety problems. Food safety behaviors least practiced by consumers are hand sanitation, cross-contamination prevention, and use of cooking, refrigerator, and freezer thermometers. Food safety knowledge of U.S. consumers is not being translated into improved food safety practices at home.

Implications

All segments of the U.S. population could benefit from improved food safety education based on effective behavioral change theories. Food safety education is needed to not only improve consumers' knowledge, but also their attitudes and intentions toward reducing home-based food safety risks. In particular, consumers need to take more responsibility regarding food safety. Together, with sound government policies and responsible food industry practices, foodborne illness can be prevented.

Food safety behaviors that particularly need additional promotion are hand sanitation, use of cooking and refrigerator/freezer thermometers, and prevention of cross-contamination. Produce washing practices can vary significantly for different vegetables and this behavior needs to be substantially improved. Additional guidance is needed to provide detailed recommendations on the frequency of refrigerator cleaning to decrease pathogen growth and potential for cross-contamination. It is important to educate consumers on appropriate cooking temperatures and the reasons to avoid consuming raw or undercooked animal protein products. The consumption of certain risky foods (e.g., cookie dough containing raw eggs) is likely to occur at home, but the consumption of other foods (e.g., raw seafood) is more likely to occur outside the home. Thus, consumer food safety education in this area needs to address safe food practices in the different environments in which individuals are likely to consume the different products. Education should also address food safety issues that have emerged due to trends toward local- and regional-based food production.

Of subpopulations in the U.S., older adults may be at greater risk because of the age-related reduction in immunity. Pregnant women also have altered immune status which may render the fetus more susceptible to infection. Foodborne illnesses affecting pregnant women can have extremely serious consequences for the fetus as illustrated by the stillbirths resulting from listeriosis. Foodborne illness outbreaks among college students have the potential to rapidly spread within the student body as a result of the group arrangements in which they often live.

Question 1: CLEAN: What Techniques for Hand Sanitation Are Associated With Favorable Food Safety Outcomes and to What Extent Do U.S. Consumers Follow Them?

Conclusion

Strong, clear, and consistent evidence shows that hand washing with plain soap for 20-30 seconds followed by proper hand drying is an effective hand hygiene technique for preventing cross-contamination during food preparation. Strong, clear, and consistent evidence shows that alcohol–based, rinse-free hand sanitizers are an adequate alternative when proper hand washing with plain soap is not possible. Moderate, consistent evidence shows that U.S. consumers do not follow recommended hand sanitation behaviors.

Question 2: CLEAN: What Techniques for Washing Fresh Produce Are Associated With Favorable Food Safety Outcomes and to What Extent Do U.S. Consumers Follow Them?

Conclusion

A limited body of evidence has shown that washing vegetables and fruit by running water over them at home or under laboratory simulation conditions is associated with reduced produce microbial loads. Moderate, consistent evidence shows that U.S. consumers are not following recommended produce washing techniques at home.

Question 3: CLEAN: To What Extent Do U.S. Consumers Clean Their Refrigerators?

Conclusion

Moderate, consistent evidence shows that U.S. consumers do not clean their refrigerators following available guidance.

Question 4: SEPARATE: What Techniques for Preventing Cross-contamination Are Associated With Favorable Food Safety Outcomes?

Conclusion

Moderate, consistent evidence indicates that preventing cross-contamination in the home kitchen may reduce exposure to foodborne pathogens among U.S. consumers. Techniques associated with favorable food safety outcomes for preventing cross-contamination include proper cleaning of food preparation surfaces and/or cooking utensils, particularly cutting boards and cutlery, accompanied by hand washing.

Question 5: COOK AND CHILL: To What Extent Do U.S. Consumers Follow Adequate Temperature Control During Food Preparation and Storage at Home?

Conclusion

Strong, consistent evidence shows that the great majority of U.S. consumers do not use food thermometers to properly assess the internal cooking temperature of meat and poultry while cooking. Moderate, consistent evidence shows that U.S. consumers lack refrigerator and freezer thermometers in their homes.

Question 6: RISKY FOODS: To What Extent Do U.S. Consumers Eat Raw or Undercooked Animal Foods?

Conclusion

Moderate, clear, and consistent evidence shows that the consumption of raw or undercooked animal-source food products is relatively common in the U.S., especially for eggs and egg-containing products, and ground beef products.

Question 7: To What Extent Do Specific Subpopulations Practice Unsafe Food Safety Behaviors?

Conclusion

Moderate available evidence, which focused on pregnant women, college students, and older adults, shows that these populations commonly practice unsafe food handling and consumption behaviors.

FOOD SAFETY TECHNOLOGIES

Question 8: To What Extent Are Recently Developed Technological Materials That Are Designed to Improve Food Safety Effective in Reducing Exposure to Pathogens and Decreasing the Risk of Foodborne Illnesses in the Home?

Conclusion

A limited body of inconsistent evidence describes and evaluates contributions to or advances of food safety modalities or practices in the home. These small studies indicate the correct usage of these kinds of products is critical for assessing proper cooking temperature and ensuring adequate reduction of microbial burden on food contact surfaces. Not all thermometers tested, wipes assessed, and sanitizers evaluated were accurate or effective in providing correct cook temperatures or assuring consistent safety against typical foodborne organisms.

Implications

New and emerging technologies over the past 5 years can assist consumers in preserving and protecting foods while encouraging safe food handling practices in the home; however, appropriate techniques for using products is essential in the efficacy of decreasing the risk for foodborne illness. The evidence supporting emerging food safety technologies in the home is limited, despite the emergence of commercial tools and appliances intended to improve safe home food handling and management practices. Consumers should adhere to food safety fundamentals in the home even with future introductions of food safety technologies.

SEAFOOD

Question 9: What Are the Benefits in Relationship to the Risks for Seafood Consumption?

Conclusion

Moderate, consistent evidence shows that health benefits derived from the consumption of a variety of cooked seafood in the U.S. in amounts recommended by the Committee outweigh the risks associated with methyl mercury (MeHg) and persistent organic pollutants (POPs) exposure, even among women who may become or who are pregnant, nursing mothers, and children ages 12 and younger. Overall, consumers can safely eat at least 12 ounces of a variety of cooked seafood per week provided they pay attention to local seafood advisories and limit their intake of large, predatory fish. Women who may become or who are pregnant, nursing mothers, and children ages 12 and younger can safely consume a variety of cooked seafood in amounts recommended by this Committee while following Federal and local advisories.

Implications

Seafood is a healthy food choice that can be safely promoted provided that the types and sources of seafood to be limited or avoided by some consumers are clearly communicated to consumers. Consumers may be able to eat safely more than 12 ounces per week of seafood if they chose to do so provided they choose the right mix of seafood that emphasizes the consumption of seafood species with relatively low concentrations of contaminants such as MeHg and POPs. Encouraging consumption of seafood in the U.S. is justified, as consumption continues to be far below amounts recommended for health by the IOM and by this Committee (see *Part D. Section 3: Fatty Acids and Cholesterol*).

Current Federal advisories on consumption of seafood species with high MeHg levels that vulnerable groups need to avoid are well justified by the scientific evidence. Regarding women who may become or who are pregnant, nursing mothers, and young children, there is emerging evidence that consumption beyond 12 ounces per week may be safe. However, additional benefit/risk modeling is needed that takes into account the simultaneous presence of multiple contaminants in a shifting seafood supply. State and local agencies should continue to reach out to vulnerable groups and the population at large with advisories about the presence of diverse environmental contaminants in different water bodies. This is particularly relevant for seafood caught by consumers. The public also needs to be advised that eating a variety of seafood, as opposed to just a few choices, is likely to reduce their exposure to 'single source' contaminants. Clear, consistent evidence indicates that consumers will need access to publicly available user-friendly benefit/risk information to make informed seafood choices that maximize their health and that take their seafood preferences into account.

Appendix E-2: Glossary of Terms

The terms in this Glossary appear in multiple sections of the Report and are essential to understanding the major themes and concepts discussed throughout. Terms specific to individual sections are defined there. Definitions are taken from a variety of sources, including 2010 DGAC chapters, the 2005 DGAC Report, 2005 *Dietary Guidelines for Americans*, Institute of Medicine reports, USDA and HHS regulatory definitions, and published sources in the scientific literature.

Added sugars—Sugars, syrups, and other caloric sweeteners that are added to foods during processing, preparation, or consumed separately. Added sugars do not include naturally occurring sugars such as those in milk or fruits. Names for added sugars include: brown sugar, corn sweetener, corn syrup, dextrose, fructose, fruit juice concentrates, glucose, high-fructose corn syrup, honey, invert sugar, lactose, maltose, malt syrup, molasses, raw sugar, turbinado sugar, trebalose, and sucrose.

Body mass index (BMI)—A measure of weight in kilograms (kg) relative to height in meters (m) squared. BMI is considered a reasonably reliable indicator of total body fat, which is related to the risk of disease and death. BMI status categories include underweight, healthy weight, overweight, and obese. Overweight and obese describe ranges of weight that are greater than what is considered healthy for a given height, while underweight describes a weight that is lower than what is considered healthy. Because children and adolescents are growing, their BMI is plotted on growth charts for sex and age. The percentile indicates the relative position of the child's BMI among children of the same sex and age.

Calorie—Unit of energy that is required to sustain the body's various functions, including metabolic processes and physical activity. Carbohydrate, fat, protein, and alcohol provide all of the energy supplied by foods and beverages. Calories referred to in terms of dietary intake and expenditure are kilocalories, but are referred to as calories in this Report.

Carbohydrates—One of the three classes of macronutrients that include sugars, starches, and fibers:

- **Sugars—**A simple carbohydrate composed of one unit (a monosaccharide, such as glucose and fructose) or two joined units (a disaccharide, such as lactose and sucrose). Sugars include white and brown sugar, fruit sugar, corn syrup, molasses, and honey.
- **Starches—**Many glucose units linked together. Examples of foods containing starch include vegetables, dry beans and peas, and grains (e.g., brown rice, oats, wheat, barley, corn).
- **Fiber—**Nondigestible carbohydrates and lignin that are intrinsic and intact in plants. Fiber consists of dietary fiber, the fiber naturally occurring in foods, and functional fiber— isolated, nondigestible carbohydrates that have beneficial physiological effects in humans.

Body Weight Category	Children and Adolescents (BMI-for-Age Percentile Range)	Adults (BMI)
Underweight	Less than the 5th percentile	Less than 18.5 kg/m^2
Healthy weight	5th percentile to less than the 85th percentile	18.5 to 24.9 kg/m^2
Overweight	85th to less than the 95th percentile	25.0 to 29.9 kg/m^2
Obese	Equal to or greater than the 95th percentile	30 kg/m^2 or greater

Cardiovascular disease—Diseases of the heart and diseases of the blood vessel system (arteries, capillaries, veins) within a person's entire body, including the brain, muscle, lungs, adipose tissue (or fat), or kidneys.

Cholesterol—A natural sterol present in all animal tissues. Free cholesterol is a component of cell membranes and serves as a precursor for steroid hormones (estrogen, testosterone, aldosterone), and for bile acids. Humans are able to synthesize sufficient cholesterol to meet biologic requirements, and there is no evidence for a dietary requirement for cholesterol.

- **Dietary cholesterol—**Cholesterol is found in foods of animal origin, including meat, fish, poultry, eggs, and dairy products. Biologically, a liver is required to produce cholesterol, thus plant foods, such as grains, vegetables and fruits, and oils contain no dietary cholesterol.
- **Serum cholesterol—**Cholesterol that travels in the blood as part of distinct particles containing both lipids and proteins (lipoproteins). Three major classes of lipoproteins are found in the serum of a fasting individual: low-density lipoprotein (LDL), high-density lipoprotein (HDL), and very-low-density lipoprotein (VLDL). Another lipoprotein class, intermediate-density lipoprotein (IDL), resides between VLDL and LDL; in clinical practice, IDL is included in the LDL measurement

Cross-contamination—The spread of bacteria, viruses, or other harmful agents from one surface to another.

Cup equivalent (cup eq)—The amount of a food product that is considered equal to 1 cup from the vegetable, fruit, or milk food group. A cup eq for some foods may be less than a measured cup, because the food has been concentrated (such as raisins or tomato paste), more than a cup for some foods that are airy in their raw form and do not compress well into a cup (such as salad greens), or measured in a different form (such as cheese).

Dietary Approaches to Stop Hypertension (DASH)—A dietary pattern that emphasizes potassium-rich vegetables and fruits and low-fat dairy products; includes whole grains, poultry, fish, and nuts; and is reduced in red meat, sweets, and sugar-containing beverages. As a result, it is rich in potassium, magnesium, calcium and fiber, and reduced in total fat, saturated fat, and cholesterol. It also is slightly increased in protein. This nutrient-rich diet has been shown to lower blood pressure and LDL-cholesterol and it meets each of the major nutrient recommendations set by the Institute of Medicine Dietary Reference Intake Committees.

Dietary pattern—A description of the types and amounts of foods and beverages consumed on average, over time. This may be a description of a customary way of eating, or a description of a combination of foods recommended for consumption. Specific examples include Dietary Approaches to Stop Hypertension (DASH), Mediterranean, and USDA patterns. Dietary patterns fall into several broad categories:

- **Omnivorous—**A pattern that includes both animal and plant products.
- **Plant-based—**A pattern in which the majority of protein sources come from plant products, though some animal products can be included.
- **Vegetarian—**A pattern that is exclusively or almost exclusively composed of plant foods. Some vegetarians may consume specified animal products, such as eggs, milk, and milk products (lacto-ovo vegetarians), and processed foods containing small amounts of animal products.
- **Vegan—**A pattern that is exclusively composed of plant foods, containing no animal products.

Dietary Reference Intakes (DRIs)—A set of nutrient-based reference values that expand upon and replace the former Recommended Dietary Allowances (RDAs) in the United States and the Recommended Nutrient Intakes (RNIs) in Canada. They include:

- **Acceptable Macronutrient Distribution Ranges (AMDR)—**Range of intake for a particular energy source that is associated with reduced risk of chronic disease while providing intakes of essential nutrients. If an individual's intake is outside of the AMDR, there is a potential of increasing the risk of chronic diseases and/or insufficient intakes of essential nutrients.
- **Adequate Intakes (AI)—**A recommended average daily nutrient intake level based on observed or experimentally determined approximations or estimates of mean nutrient intake by a group (or groups) of apparently healthy people. This is used when the Recommended Dietary Allowance cannot be determined.
- **Estimated Average Requirements (EAR)—**The average daily nutrient intake level estimated to meet

the requirement of half the healthy individuals in a particular life stage and sex group.

- **Recommended Dietary Allowance (RDA)—**The average dietary intake level that is sufficient to meet the nutrient requirement of nearly all (97 to 98 percent) healthy individuals in a particular life stage and sex group.
- **Tolerable Upper Intake Level (UL)—**The highest average daily nutrient intake level likely to pose no risk of adverse health effects for nearly all individuals in a particular life stage and gender group. As intake increases above the UL, the potential risk of adverse health effects increases.

Energy density—The amount of energy per unit of weight, usually expressed as calories per 100 grams.

Energy balance—The balance between calories consumed through eating and drinking and those expended through physical activity and metabolic processes. Energy consumed must equal energy expended for a person to remain at the same body weight. Weight gain will result from excess calorie intake and/or inadequate physical activity. Weight loss will occur when a calorie deficit exists, which can be achieved by eating less, being more physically active, or a combination of the two.

Enrichment—The addition of specific nutrients (iron, thiamin, riboflavin, and niacin) to refined grain products in order to replace losses of the nutrients that occur during processing.

Fast food—Foods designed for ready availability, use or consumption and sold at eating establishments for quick availability or take-out. Fast food restaurants are also known as quick-service restaurants.

Fats—One of the three classes of macronutrients. (See Solid Fats and Oils.)

- **Monounsaturated fatty acids—**Monounsaturated fatty acids (MUFAs) have one double bond. Plant sources that are rich in MUFAs include nuts and vegetable oils that are liquid at room temperature (e.g., canola oil, olive oil, high oleic safflower and sunflower oils).
- **Polyunsaturated fatty acids—**Polyunsaturated fatty acids (PUFAs) have two or more double bonds and may be of two types, based on the position of the first double bond.
- ***n*-6 PUFAs—**Linoleic acid, one of the *n*-6 fatty acids, is required but cannot be synthesized by humans and, therefore, is considered essential in the diet. Primary sources are liquid vegetable oils, including soybean oil, corn oil, and safflower oil. Also called omega-6 fatty acids.
- ***n*-3 PUFAs—**α-linolenic acid is an *n*-3 fatty acid that is required because it is not synthesized by humans and, therefore, is considered essential in the diet. It is obtained from plant sources, including soybean oil, canola oil, walnuts, and flaxseed. Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are long chain *n*-3 fatty acids that are contained in fish and shellfish. Also called omega-3 fatty acids.
- **Saturated fatty acids—**Saturated fatty acids have no double bonds. Examples include animal products such as meat and dairy products, hydrogenated shortening, and coconut or palm oils. In general, saturated fats are solid at room temperature.
- ***Trans* fatty acids—** As used in this Report, *trans* fatty acids is a term consistent with that defined by the U.S. Food and Drug Administration for use in food labeling. In this definition, *trans* fatty acids are unsaturated fatty acids that contain one or more isolated (i.e., nonconjugated) double bonds in a *trans* configuration. Sources of industrial *trans* fatty acids include hydrogenated/partially hydrogenated vegetable oils that are used to make shortening and commercially prepared baked goods, snack foods, fried foods, and margarine. *Trans* fatty acids also are present in foods that come from ruminant animals (e.g., cattle and sheep) and are called “natural” or rTFA. Such foods include dairy products, beef, and lamb.

Food environment—The collective group of settings from which a person can access food, including the home, food retail establishments, restaurants, schools, worksites, as well as the overall food supply.

Food pattern modeling—The process of developing and adjusting daily intake amounts from food categories or groups to meet specific criteria, such as meeting nutrient intake goals, limiting nutrients or other food components, or varying proportions or amounts of specific food categories or groups.

Food security—Access by all people at all times to enough food for an active, healthy life. Food security includes, at a minimum: (a) the ready availability of nutritionally adequate and safe foods and (b) an assured ability to acquire acceptable foods in socially acceptable ways (e.g., without resorting to emergency food supplies, scavenging, stealing, or other coping strategies).

Food insecurity—The limited or uncertain availability of nutritionally adequate and safe foods or uncertain ability to acquire acceptable foods in socially acceptable ways. Hunger is defined as the uneasy or painful sensation caused by a lack of food; the recurrent and involuntary lack of access to food.

Foodborne disease—Disease caused by consuming foods or beverages contaminated with disease-causing bacteria or viruses. Many different disease-causing microbes, or pathogens, can contaminate foods, so there are many different foodborne infections. In addition, poisonous chemicals, or other harmful substances, can cause foodborne diseases if they are present in food. The most commonly recognized foodborne infections are those caused by the bacteria *Campylobacter*, *Salmonella,* and *E. coli O157:H7*, and by a group of viruses called calicivirus, also known as the Norwalk and Norwalk-like viruses.

Foodborne disease outbreak—Illness that occurs when a group of people consume the same contaminated food and two or more of them come down with the same illness. It may be a group that ate a meal together somewhere, or it may be a group of people who do not know each other at all, but who all happened to buy and eat the same contaminated item from a grocery store or restaurant.

Hypertension—A condition, also known as high blood pressure, in which blood pressure remains elevated over time. Hypertension makes the heart work too hard, and the high force of the blood flow can harm arteries and organs, such as the heart, kidneys, brain, and eyes. If uncontrolled, hypertension can lead to heart attacks, heart failure, kidney disease, stroke, and blindness. In adults, hypertension is defined as systolic blood pressure of 140 mmHg or higher or diastolic blood pressure of 90 mmHg or higher. In children, hypertension is defined as systolic or diastolic blood pressure equal to or greater than the 95th percentile for sex-, age-, and height-specific blood pressure percentiles In adults, prehypertension is defined as systolic blood pressure of 120-139 mmHg or diastolic blood pressure of 80-89 mmHg. In children, prehypertension is defined as systolic or diastolic blood pressure that is equal to or greater than the 90th percentile but less than the 95th percentile for sex-, age-, and height-specific blood pressure percentiles, or blood pressure that is greater than 120/80 but less than the 95th percentile.

Isocaloric—Having the same caloric values. For example, two dietary patterns that vary in macronutrient proportions but have the same calorie content are isocaloric.

Metabolic syndrome—Metabolic syndrome consists of a collection of risk factors for cardiovascular disease manifested in an individual. The syndrome is considered to be present if three of five risk factors are present: glucose intolerance or frank diabetes mellitus, high blood pressure, elevated triglycerides, low HDL cholesterol, and abdominal obesity. Persons with metabolic syndrome often also manifest a prothrombotic and proinflammatory state.

Moderate alcohol consumption—Average daily consumption of up to one drink per day for women and up to two drinks per day for men, with no more than three drinks in any single day for women and no more than four drinks in any single day for men. One drink is defined as 12 fluid ounces of regular beer, 5 fluid ounces of wine, or 1.5 fluid ounces of distilled spirits.

NEL evidence-based systematic review—A protocol-driven, transparent process used to assist the 2010 Dietary Guidelines Advisory Committee, which includes pre-defined criteria for searching and sorting the scientific literature; critical appraisal of methodological rigor of each included study; extracting, summarizing, and synthesizing the evidence; and grading the overall quality and consistency of the body of evidence.

Nutrient-dense foods—Foods that are naturally rich in vitamins, minerals, and phytochemicals, and are lean or low in solid fats and without added solid fats, sugars, starches, or sodium and that retain naturally-occurring components such as fiber. All vegetables, fruits, whole grains, fish, eggs, and nuts prepared without added solid fats or sugars are considered nutrient-dense, as are lean or low-fat forms of fluid milk, meat, and poultry prepared without added solid fats or sugars. Nutrient-dense foods provide substantial amounts of vitamins and minerals (micronutrients) and relatively few calories.

Oils—Fats that are liquid at room temperature. Oils come from many different plants and from fish. Some common oils include canola, corn, olive, peanut, safflower, soybean, and sunflower oils. A number of foods are naturally high in oils, such as nuts, olives, some fish, and avocados. Foods that are mainly oil include mayonnaise, certain salad dressings, and soft (tub or squeeze) margarine with no *trans* fats. Most oils are high in monounsaturated or polyunsaturated fats and low in saturated fats. A few plant oils, including coconut oil and palm kernel oil, are high in saturated fats and for nutritional purposes should be considered solid fats. Hydrogenated oils that contain *trans* fats should also be considered solid fats for nutritional purposes. (See Fats.)

Ounce equivalent (oz eq)—The amount of a food product that is considered equal to one ounce from the grain or meat, poultry, fish, eggs, and nuts food group. An ounce equivalent for some foods may be less than a measured ounce if the food is concentrated or low in water content (nuts, peanut butter, dried meats, flour), more than an ounce if the food contains a large amount of water (tofu, cooked beans, cooked rice, or pasta).

Persistent organic pollutants (POPs)—Toxic chemicals that adversely affect human health and the environment around the world. Because they can be transported by wind and water, most POPs generated in one country can and do affect people and wildlife far from where they are used and released. They persist for long periods of time in the environment and can accumulate and pass from one species to the next through the food chain.

Portion size—The amount of a food served or consumed in one eating occasion. A portion is not a standardized amount, and the amount considered to be a portion is subjective and varies. (See Serving size.)

Processed food—Any food other than a raw agricultural commodity, including any raw agricultural commodity that has been subject to washing, cleaning, milling, cutting, chopping, heating, pasteurizing, blanching, cooking, canning, freezing, drying, dehydrating, mixing, packaging, or other procedures that alter the food from its natural state. Processing also may include the addition of other ingredients to the food, such as preservatives, flavors, nutrients, and other food additives or substances approved for use in food products, such as salt, sugars, and fats. Processing of foods, including the addition of ingredients, may reduce, increase, or leave unaffected the nutritional characteristics of raw agricultural commodities.

- **Minimally-processed food—**Food that is processed but retains most of its inherent physical, chemical, sensory, and nutritional properties. Many minimally processed foods are as nutritious as the food in its unprocessed form.

Protein—One of the three macronutrients classes. Protein is the major functional and structural component of every cell in the body. Proteins are composed of amino acids, nine of which are indispensable, meaning they cannot be synthesized to meet the body's needs and therefore must be obtained from the diet. The quality of a source of dietary protein depends on its ability to provide the nitrogen and amino acid requirements that are necessary for the body's growth, maintenance, and repair. This ability is determined by two factors: digestibility and amino acid composition.

- **Animal protein -** Protein from animal products such as meat, poultry, seafood, eggs, and milk and milk products. Animal proteins tend to have higher protein quality based on their complete amino acid profile relative to human requirements and higher digestibility.
- **Vegetable protein -** Protein from plants such as legumes, dry beans, grains, nuts, seeds, and vegetables. Vegetable proteins tend to have lower protein quality based on their incomplete amino acid profile relative to human requirements and lower digestibility.

Refined grains—Grains and grain products missing the bran, germ, and/or endosperm; any grain product that is not a whole grain. Many refined grains are low in fiber but enriched with thiamin, riboflavin, niacin, and iron, and fortified with folic acid as required by U.S. regulations.

Seafood—All commercially obtained fish, shellfish, and mollusks, both marine and freshwater.

Serving size—A standardized amount of a food, such as a cup or an ounce, used in providing information about the food, such as on the Nutrition Facts label or in dietary guidance, or in making comparisons among similar foods. The portion size consumed may differ from the standard service size. (See Portion size.)

SoFAAS—Solid Fats, Alcohol, and Added Sugars. This term is used in the Healthy Eating Index 2005 and in other publications. The term SoFAS is preferred to SoFAAS when discussing intakes or limits for the total population, because many individuals do not consume calories from alcohol.

SoFAS—Solid Fats and Added Sugars. This term is used when calculating the number of calories that come from these two food components together. Limits for the amount of calories from SoFAS are included in the USDA food patterns.

Solid fats—Fats that are usually not liquid at room temperature. Solid fats are found in most animal foods but also can be made from vegetable oils through hydrogenation. Some common solid fats include: butter, beef fat (tallow, suet), chicken fat, pork fat (lard), stick margarine, and shortening. Foods high in solid fats include: many cheeses, creams, whole milk, ice creams, well-marbled cuts of meats, regular ground beef, bacon, sausages, poultry skin, and many baked goods (such as cookies, crackers, doughnuts, pastries, and croissants). Most solid fats contain saturated fats, cholesterol and/or *trans* fats, and have less or no monounsaturated or polyunsaturated fats. (See Fats.)

Study design—An experimental approach to address a specific question; it includes clinical trials, observational studies, and summary and quantitative analysis of numerous studies.

- **Case-control study—**A study that compares people with a specific disease or outcome of interest (cases) to people from the same population without that disease or outcome (controls), and which seeks to find associations between the outcome and prior exposure to particular risk factors. Case-control studies are usually retrospective, but not always.
- **Cohort study—**An observational study in which a defined group of people (the cohort) is followed over time. The outcomes of people in subsets of this cohort are compared to examine people who were exposed or not exposed (or exposed at different levels) to a particular intervention or other factor of interest. A **prospective** cohort study assembles participants and follows them into the future. A **retrospective** (or historical) cohort study identifies subjects from past records and follows them from the time of those records to the present.
- **Meta-analysis—**A quantitative method of combining the results of independent studies (usually drawn from the published literature) and synthesizing summaries and conclusions which may be used for several purposes, such as evaluating therapeutic effectiveness or planning new studies, with application chiefly in the areas of research and medicine.
- **Randomized controlled trial—**An experiment in which two or more interventions, possibly including a control intervention or no intervention, are compared by being randomly allocated to participants. In most trials, one intervention is assigned to each individual but sometimes assignment is to defined groups of individuals (e.g., households) or interventions are assigned within individuals (e.g., in different orders). Also called a randomized clinical trial.
- **Systematic review—**A review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyze data from the studies that are included in the review. Statistical methods (meta-analysis) may or may not be used to analyze and summarize the results of the included studies.

Sugar-sweetened beverages—Liquids that are sweetened with various forms of sugars that add calories. These beverages include, but are not limited to, soda, fruit ades, and sports drinks. Also called calorically-sweetened beverages.

Whole grains—Grains and grain products made from the entire grain seed, usually called the kernel, which consists of the bran, germ, and endosperm. If the kernel has been cracked, crushed, or flaked, it must retain nearly the same relative proportions of bran, germ, and endosperm as the original grain in order to be called whole grain. Many, but not all, whole grains are also a source of dietary fiber.

Appendix E-3: USDA Food Pattern Modeling Analyses

The 2010 Dietary Guidelines Advisory Committee (DGAC) identified specific questions that they felt could best be addressed through a food pattern modeling approach, using the USDA Food Patterns and the modeling process developed to address similar requests by the 2005 DGAC. Twelve modeling analyses were completed and provided as reports to four DGAC subcommittees. The food pattern modeling analyses conducted for the DGAC are listed below. Full reports for each analysis are available online at www.dietaryguidelines.gov.

E3.1: **Adequacy of the USDA Food Patterns.** How well do the USDA Food Patterns, using updated food intake and nutrient data, meet IOM and potential DG 2010 nutrient recommendations?

E3.2: **Realigning Vegetable Subgroups.** What revisions to the vegetable subgroups may help to highlight vegetables of importance and allow recommendations for intake levels that are achievable, without compromising the nutrient adequacy of the patterns?

E3.3: **Vegetarian Food Patterns.** How well do plant-based or vegetarian food patterns, adapted from the USDA Food Patterns, meet IOM and potential DG 2010 nutrient recommendations?

E3.4: **Starchy Vegetables.** How do the nutrients provided by the starchy vegetable subgroup compare with those provided by grains and those provided by other vegetable subgroups? How would nutrient adequacy of the patterns be affected by considering starchy vegetables as a replacement for some grains rather than as a vegetable subgroup?

E3.5: **"Typical Choices" Food Patterns.** What is the impact on caloric and nutrient intake if the USDA Food Patterns are followed but typical rather than nutrient-dense food choices are made?

E3.6: **Milk Group and Alternatives.** What is the impact on nutrient adequacy (1) if no milk or milk products were consumed, (2) if calcium was obtained from nondairy sources or fortified foods, and (3) if more fluid milk and less cheese were consumed?

E3.7: **Replacing all Non-Whole Grains with Whole Grains.** What is the impact on intake of folate and other nutrients if all recommended grain amounts are selected as whole grains rather than half whole and half nonwhole grains?

E3.8: **Cholesterol.** What is the impact on food choices and overall nutrient adequacy of limiting cholesterol to less than 200 milligrams per day?

E3.9: **Reducing Cholesterol-Raising Fatty Acids.** What is the impact on food choices and overall nutrient adequacy of limiting cholesterol-raising (CR) fatty acids to less than 7 percent of total calories and to less than 5 percent of total calories, with CR fatty acids operationalized as total saturated fatty acids minus stearic acid?

E3.10: **Seafood.** What is the impact on nutrient adequacy of increasing seafood in the USDA Food Patterns to (1) 4 ounces per week of seafood high in *n*-3 fatty acids, (2) 8 ounces per week of seafood in proportions currently consumed, and (3) 12 ounces per week of seafood low in *n*-3 fatty acids?

E3.11: **Sodium.** What would the sodium levels of the USDA Food Patterns be (1) using current patterns, (2) using "typical choices" patterns, and (3) using only low sodium and no-salt-added foods?

E3.12: **Potassium.** What are the potassium levels in the USDA Food Patterns, in comparison to current consumptions and DASH diet levels, in absolute amounts, adjusted for energy intake, and as a ratio of sodium to potassium? How would potassium levels of the USDA Food Pattern change if current levels of coffee and tea intake were included?

Appendix E-4: History of the Dietary Guidelines for Americans

In early 1977, after years of discussion, scientific review, and debate, the U.S. Senate Select Committee on Nutrition and Human Needs, led by Senator George McGovern, recommended Dietary Goals for the American people (U.S. Senate Select Committee, 1977). The Goals consisted of complementary nutrient-based and food-based recommendations. The first Goal focused on energy balance and recommended that, to avoid overweight, Americans should consume only as much energy as they expended. Overweight Americans should consume less energy and expend more energy. For the nutrient-based Goals, the Senate Committee recommended that Americans:

- Increase consumption of complex carbohydrates and "naturally occurring sugars;"and
- Reduce consumption of refined and processed sugars, total fat, saturated fat, cholesterol, and sodium.

For the food-based Goals, the Committee recommended that Americans:

- Increase consumption of fruits, vegetables, and whole grains
- Decrease consumption of:
  - — refined and processed sugars and foods high in such sugars
  - — foods high in total fat and animal fat, and partially replace saturated fats with polyunsaturated fats
  - — eggs, butterfat, and other high-cholesterol foods
  - — salt and foods high in salt
- Choose low-fat and non-fat dairy products instead of high-fat dairy products (except for young children)

The issuance of the Dietary Goals was met with considerable debate and controversy, as industry groups and the scientific community expressed doubt that the science available at the time supported the specificity of the numbers provided in the Dietary Goals. To support the credibility of the science used by the Committee, the U.S. Department of Agriculture and U.S. Department of Health and Human Services (then called the Department of Health, Education, and Welfare) selected scientists from the two Departments and obtained additional expertise from the scientific community throughout the country to address the public's need for authoritative and consistent guidance on diet and health.

In February 1980, the two Departments collaboratively issued *Nutrition and Your Health: Dietary Guidelines for Americans, a* brochure that, in describing seven principles for a healthful diet, provided assistance for healthy people in making daily food choices (USDA/HHS, 1980). These Guidelines were based, in part, on the 1979 *Surgeon General's Report on Health Promotion and Disease Prevention* (DHEW/PHS, 1979) and reflected findings from a study on the relationship between dietary practices and health outcomes (ASCN, 1979). Ideas for incorporating a variety of foods to provide essential nutrients while maintaining recommended body weight were a focus. The brochure also provided guidance on limiting dietary components such as fat, saturated fat, cholesterol, and sodium, which were beginning to be considered risk factors in certain chronic diseases. Both the Dietary Goals and the first *Dietary Guidelines for Americans* were different from previous dietary guidance in that they reflected the emerging scientific evidence and changed the historical focus on nutrient adequacy to also identify the impacts of diet on chronic disease. These documents discussed the concepts of moderation as well as nutrient adequacy.

Even though the recommendations of the 1980 *Dietary Guidelines for Americans* were presented as innocuous and straightforward extrapolations from the science base, they, too, were met with a fair amount of controversy from a variety of industry and scientific groups.

The debate about the 1980 *Dietary Guidelines for Americans* led to Congressional report language that directed the two Departments to convene an advisory committee that would ensure that outside advice, both formal and informal, was captured in developing future editions of the *Dietary Guidelines*. A Dietary Guidelines Advisory Committee composed of scientific experts outside the Federal sector was established shortly after that directive and was very helpful in the development of the *1985 Nutrition and Your Health: Dietary Guidelines for Americans* (USDA/HHS, 1985). The Departments made relatively few changes from the first edition, but this second edition was issued with much less debate from either industry or the scientific community. The 1985 *Dietary Guidelines* were widely accepted and were used as the framework for consumer nutrition education messages. They also were used as a guide for healthy diets by scientific, consumer, and industry groups.

In 1989, USDA and HHS established a second scientific advisory committee to review the 1985 *Dietary Guidelines* and make recommendations for revision. The basic tenets of earlier *Dietary Guidelines* were reaffirmed, and the 1990 *Nutrition and Your Health: Dietary Guidelines for Americans* (USDA/HHS, 1990) promoted enjoyable and healthful eating through variety and moderation, rather than dietary restriction. For the first time, the Guidelines also suggested numerical goals for fat and saturated fat, though they stressed that the goals were to be met through dietary choices made over several days, not through choices about one meal or one food.
The 1980, 1985, and 1990 editions of the *Dietary Guidelines* were issued voluntarily by the two Departments. With the passage of the 1990 National Nutrition Monitoring and Related Research Act (Section 301 of Public Law 101-445, 7 U.S.C. 5341, Title III) (U.S. Congress, 1990), the 1995 edition of *Nutrition and Your Health: Dietary Guidelines for Americans* became the first *Dietary Guidelines* Report mandated by statute. This Act directed the Secretaries of USDA and HHS to jointly issue at least every 5 years a report entitled *Dietary Guidelines for Americans*. A Dietary Guidelines Advisory Committee was established to assist in the preparations of the 1995, 2000, 2005, and now 2010 versions of the *Dietary Guidelines for Americans* (HHS/USDA, 1995a, 1995b, 2000a, 2000b, 2004, 2005a, 2005b).

Since 1980, the *Dietary Guidelines* have been notably consistent in their recommendations on the components of a healthful diet, but they also have changed in some significant ways to reflect emerging science. In keeping with renewed emphasis on data quality, the 2005 Committee used a systematic approach for reviewing the scientific literature in developing its recommendations. This systematic review of the evidence has been further expanded for the 2010 revision cycle. USDA has established the Nutrition Evidence Library, a comprehensive evidence-based review process, to support the 2010 Dietary Guidelines Advisory Committee (see *Part C. Methodology* for additional information about the Nutrition Evidence Library).

Over the past two decades, *Nutrition and Your Health: Dietary Guidelines for Americans* has evolved to become a broadly accepted, evidence-based document that serves as the basis for Federal nutrition policy from which nutrition education materials and activities are developed. The *Dietary Guidelines* have presented advice for healthy Americans, ages 2 years and older, about making food choices that promote health and help prevent disease. As new data emerge about the role of diet in utero and from birth on, it will be important also to consider those ages 2 years and younger. Nutrition and health professionals actively promote the *Dietary Guidelines* as a means of encouraging Americans to focus on eating a healthful diet and being physically active throughout the entire lifespan.

Development of the Dietary Guidelines – A Chronology

1977 *Dietary Goals for the United States* (the McGovern report) was issued by the U.S. Senate Select Committee on Nutrition and Human Needs (U.S. Senate Select Committee, 1977). The *Dietary Goals* reflected a shift in focus, from obtaining adequate nutrients to avoiding excessive intake of food components linked to chronic disease. These goals were controversial among some nutritionists and others concerned with food, nutrition, and health.

1979 The American Society for Clinical Nutrition formed a panel to study the relationship between dietary practices and health outcomes (ASCN, 1979). The findings, presented in 1979, were reflected in *Healthy People: The Surgeon General's Report on Health Promotion and Disease Prevention* (DHEW/PHS, 1979).

1980 Seven principles for a healthful diet were jointly issued by the then U.S. Department of Health, Education, and Welfare (now HHS) and the U.S. Department of Agriculture (USDA) in response to the public's desire for authoritative, consistent guidelines on diet and health. These principles became the first edition of *Nutrition and Your Health: Dietary Guidelines for*

Americans (USDA/HHS, 1980). The 1980 Guidelines were based on the most up-to-date information available at the time and were directed to healthy Americans ages two and older. The Guidelines generated some concern among consumer, commodity, and food industry groups, as well as some nutrition scientists, who questioned the causal relationship between certain guidelines and health.

1980 A U.S. Senate Committee on Appropriations report directed that a committee be established to review scientific evidence and recommend revisions to the *1980 Nutrition and Your Health: Dietary Guidelines for Americans* (U.S. Senate, 1980).

1983 A Federal advisory committee of nine nutrition scientists was convened to review and make recommendations in a report to the Secretaries of USDA and HHS about the first edition of the *Dietary Guidelines* (USDA/HHS, 1985a).

1985 USDA and HHS jointly issued the second edition of *Nutrition and Your Health: Dietary Guidelines for Americans* (USDA/HHS, 1985b). This edition was nearly identical to the first, retaining the seven guidelines from the 1980 edition. Some changes were made for clarity, while others reflected advances in scientific knowledge of the associations between diet and chronic diseases. The second edition received wide acceptance and was used as the basis for dietary guidance for the general public as well as a framework for developing consumer education messages.

1987 Language in the *Conference Report of the House Committee on Appropriations* indicated that USDA, in conjunction with HHS, "shall reestablish a Dietary Guidelines Advisory Group on a periodic basis. This Advisory Group will review the scientific data relevant to nutritional guidance and make recommendations on appropriate changes to the Secretaries of the Departments of Agriculture and Health and Human Services" (U.S. House of Representatives, 1987).

1989 USDA and HHS established a second Federal advisory committee of nine members, which considered whether revisions to the 1985 *Dietary Guidelines* were needed and made recommendations for revision in a report to the Secretaries (USDA/HHS, 1990a). The 1988 *Surgeon General's Report on Nutrition and Health* (HHS/PHS, 1988) and the 1989 National Research Council's report *Diet and Health: Implications for Reducing Chronic Disease Risk* were key resources used by the Committee (NAS/NRC, 1989).

1990 USDA and HHS jointly released the third edition of *Nutrition and Your Health: Dietary Guidelines for Americans* (USDA/HHS, 1990b). The basic tenets of the *1990 Dietary Guidelines* were reaffirmed, with additional refinements made to reflect increased understanding of the science of nutrition and how best to communicate the science to consumers. The language of the new *Dietary Guidelines* was positive, was oriented toward the total diet, and provided specific information regarding food selection. For the first time, numerical recommendations were made for intakes of dietary fat and saturated fat.

1990 The 1990 National Nutrition Monitoring and Related Research Act (Section 301 of Public Law 101-445, 7 U.S.C. 5341, Title III) directed the Secretaries of the USDA and HHS to jointly issue at least every 5 years a report entitled *Dietary Guidelines for Americans* (U.S. Congress, 1990). This legislation also required review by the Secretaries of USDA and HHS of all Federal publications containing dietary advice for the general public.

1993 The HHS Charter established the 1995 Dietary Guidelines Advisory Committee.

1994 An 11-member Dietary Guidelines Advisory Committee was appointed by the Secretaries of HHS and USDA to review the third edition of the *Dietary Guidelines* and determine whether changes were needed. If so, the Committee was to recommend suggestions and the rationale for any revisions.

1995 The report of the Dietary Guidelines Advisory Committee to the Secretaries of HHS and USDA was published (HHS/USDA, 1995a).

1995 Using the 1995 report of the Dietary Guidelines Advisory Committee as the foundation, HHS and USDA jointly released the fourth edition of *Nutrition and Your Health: Dietary Guidelines for Americans* (HHS/USDA, 1995b). This edition continued to support the concepts from earlier editions. New information included the Food Guide Pyramid, Nutrition Facts Label, boxes highlighting good food sources of key nutrients, and a chart illustrating three weight ranges in relation to height.

1997 The USDA Charter established the 2000 Dietary Guidelines Advisory Committee.

1998 An 11-member Dietary Guidelines Advisory Committee was appointed by the Secretaries of USDA and HHS to review the fourth edition of the *Dietary Guidelines* to determine whether changes were needed and, if so, to recommend suggestions for revision.

2000 The Committee submitted its report to the Secretaries of USDA and HHS (USDA/HHS, 2000a). This report contained the proposed text for the fifth edition of *Nutrition and Your Health: Dietary Guidelines for Americans.*

2000 The President of the United States spoke of the *Dietary Guidelines* in his radio address after USDA and HHS jointly issued the fifth edition of *Nutrition and Your Health: Dietary Guidelines for Americans earlier in the day* (USDA/HHS, 2000b). Earlier versions of the Guidelines included seven statements. This version included 10—created by breaking out physical activity from the weight guideline, splitting the grains and fruits/vegetables recommendations for greater emphasis, and adding a new guideline on safe food handling.

2003 The HHS Charter established the 2005 Dietary Guidelines Advisory Committee.

2003 A 13-member Dietary Guidelines Advisory Committee was appointed by the Secretaries of HHS and USDA to review the fifth edition of the *Dietary Guidelines* to determine whether changes were needed and, if so, to recommend suggestions for revision.

2003-2004 In keeping with renewed emphasis on data quality, the Committee used a systematic approach to reviewing the scientific literature to develop its recommendations. Committee members initially posed approximately 40 specific research questions that were put through an extensive evidence-based search and review of the scientific literature. Issues relating diet and physical activity to health promotion and chronic disease prevention also were examined. Other major sources of evidence used were the Dietary Reference Intake (DRI) reports prepared by expert committees convened by the Institute of Medicine (IOM) as well as various Agency for Healthcare Research and Quality (AHRQ) and World Health Organization (WHO) reports. USDA completed numerous food intake pattern modeling analyses and the Committee analyzed various national data sets and sought advice from invited experts.

2004 The Committee submitted its technical report to the Secretaries of HHS and USDA (HHS/USDA, 2004). This 364-page report resulted in a detailed analysis of the science and was accompanied by many pages of evidence-based tables that were made available electronically. After dropping some questions because of incomplete or inconclusive data, the Committee wrote conclusive statements and comprehensive rationales for 34 of the 40 original questions.

2005 Using the Committee's technical report as a basis, HHS and USDA jointly prepared and issued the sixth edition of *Dietary Guidelines for Americans* in January 2005 (HHS/USDA, 2005a). This 80-page policy document was prepared from the DGAC Report. It was the first time the Departments prepared a policy document that was intended primarily for use by policy makers, healthcare providers, nutritionists, and nutrition educators. The content of this document included nine major *Dietary Guidelines* messages that resulted in 41 Key Recommendations, of which 23 were for the general public and 18 for special population groups. The report highlighted the USDA Food Guide and the DASH Eating Plan as two examples of eating patterns that exemplify the *Dietary Guidelines*. This publication continues to serve as the basis for Federal nutrition policy until the next policy document is released in 2010. A companion, 10-page brochure called *Finding Your Way to a Healthier You* (HHS/USDA, 2005b) was released concurrently with the *Dietary Guidelines* to provide advice to consumers about food choices that promote health and decrease the risk of chronic disease. Shortly thereafter, USDA released the MyPyramid Food Guidance System, an update of the Food Guide Pyramid, which included more detailed advice for consumers to follow the *Dietary Guidelines*.

2008 The USDA Charter established the 2010 Dietary Guidelines Advisory Committee.

2008 A 13-member Dietary Guidelines Advisory Committee was appointed by the Secretaries of USDA and HHS to review the sixth edition of *Dietary Guidelines for Americans* to determine whether changes were needed and, if so, to recommend suggestions for revision.

2009 USDA established a Nutrition Evidence Library (NEL) for use in reviewing the scientific literature for answering approximately 130 of the 180 scientific questions posed by the Dietary Guidelines Advisory Committee. This was the most rigorous and comprehensive approach ever used for reviewing the science in order to develop nutrition-related recommendations for the public. When a full systematic review of the evidence was not needed, other methods for answering scientific questions were used. These included brief updates to substantial sources of evidences already completed in the past such as the 2005 DGAC Report and IOM Reports. Food pattern modeling using USDA's MyPyramid Food Guidance System and the review of various data analyses were also used in formulating answers for some of the questions posed. An elaborate public comments database was developed and successfully served to accept comments and attachments from the public in one central location. This database served to encourage public participation and supported a collection of more than 800 public comments related to the DGAC process.

2010 The Committee submitted its report to the Secretaries of USDA and HHS. This report will serve as the basis for preparing the seventh edition of *Dietary Guidelines for Americans*. USDA and HHS will jointly issue the seventh edition of the *Dietary Guidelines for Americans.* This publication will continue to serve as the basis of Federal nutrition policy. Additional consumer communication materials will be developed to provide advice to consumers about food choices that promote health and decrease the risk of chronic disease.

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Appendix E-5: Public Comments

As a government advisory panel, the Dietary Guidelines Advisory Committee (DGAC) is required by the Federal Advisory Committee Act (FACA) to conduct an open process in which the public may participate. The public does this through submitting written and oral comments to the Committee.

The first public comment was submitted to the public comments database on October 17, 2008. Thereafter, the Committee received written comments from the public continuously and at a steady pace throughout their deliberations. Comment submissions increased noticeably in response to each call for public comments. These calls were released through six *Federal Register* notices announcing upcoming public DGAC meetings.

Comment submissions were collected through a newly developed electronic database designed for this purpose and located at www.dietaryguidelines.gov. The motivation for developing this database was to help reduce the burden on the public for submitting comments, especially cumbersome paper submissions; to provide a central place for storing all comments; to allow continual public access to all comments; and to allow the DGAC to have full access to comments and accompanying reports, research, and other support material. This database is the most efficient, open, and transparent public comment collection system to date.

Each comment submitted to the database was categorized within one or more of 14 key topic areas. This allowed anyone interested in a particular topic to efficiently navigate to the selected topic area and view comments assigned to that section without having to spend time combing through all the comments. A query function on this “filing” system also allowed staff to generate topic-specific reports of public comments for various time periods. This report feature proved valuable for the DGAC members, who could easily access and review comments about a certain key topic area that pertained to their subcommittee’s work.

The 14 topic areas were: alcoholic beverages, carbohydrates, eating patterns, energy balance/physical activity, evidence-based review process, fats, fluids and electrolytes, food groups, food safety, minerals, nutrient density/discretionary calories, protein, vitamins, and “other.” Most of these key topic areas were further categorized into subtopics. For example, under carbohydrates, additional category selections included added sugars, fiber, whole grains, glycemic index, and low carbohydrates. This function allowed staff to generate reports on specific issues within topic areas.

Although comments could be submitted continually, each *Federal Register* notice announcing an upcoming DGAC public meeting included a final date for comment submissions. This ensured timely transmission of comments to the DGAC before the meeting. In general, the ending submission date was set at close of business 6 calendar days before each DGAC meeting date. This allowed all comments to be posted and comment reports to be generated and sent to Committee members with sufficient time for comments to be reviewed before the meeting. Comments that were submitted later than the time specified in the *Federal Register* notice were considered by the Committee for the following public meeting date. Public comment reports by key topic area were made available to Committee members before each DGAC meeting and more frequently during the large time spans between the third and fourth DGAC meeting and the fourth and fifth DGAC meeting. Comment submission for the sixth meeting ended 13 days before the May 12, 2010 meeting because the Committee needed additional time to consider the comments before completing their chapters for their DGAC Report.

When organizations or individuals submitted comments to the electronic database, they were required to complete three fields—organization type, key topic, and summary comment. Comments could not exceed 2,000 characters. Other fields were optional. Submitters also were able to upload an attachment for comments that exceeded 2,000 characters or for other support material the submitter desired to share with the Committee. Disclaimers were posted in multiple places alerting the submitter to heed copyright laws.

A small team of staff reviewed each comment submission. Comments that were offensive in nature were not posted. Comments that were inappropriately categorized in a key topic area(s) were correctly categorized. Duplicate submissions that were obvious errors in the submission process also were not posted. Of the nearly 1,000 comments received over the 1½ year DGAC period, 774 comments were posted. Of these comments, large numbers addressed food groups and eating patterns, specifically plant-based diets and a focus on the total diet approach. Many comments suggested that the *Dietary Guidelines* emphasize physical activity and energy balance, and that they should focus on calorie density, weight, and the impact of obesity on health. Examples of other comments included those on sugar, sodium, potassium, fats, individual vitamins and minerals, and offered suggestions for best food safety practices, ways to communicate the guidelines, and how messages could affect policy. All public comments will continue to be available on the *Dietary Guidelines* website at www.dietaryguidelines.gov.

In addition to written comments, oral comments were solicited; 51 of the 58 organizations or individuals who registered to present oral testimony delivered 3-minute presentations on the first day of the second DGAC meeting, which was held January 29-30, 2009. These comments are summarized in the January Public Meeting Minutes found at www.dietaryguidelines.gov.

All of the oral and written comments provided by the public were valuable in that they helped the Committee gather background information and understand consumer perceptions. They also highlighted and ensured consideration of topics deemed to be important by the submitters of comments from a variety of backgrounds and focus areas.

Appendix E-6: Biographical Sketches of the 2010 Dietary Guidelines Advisory Committee Members

Linda V. Van Horn, PhD, RD, LD, Chair

Dr. Van Horn is a Professor in the Department of Preventive Medicine, and the Associate Dean for Faculty Development at the Feinberg School of Medicine at Northwestern University, Chicago. Dr. Van Horn received her doctorate from the School of Public Health at the University of Illinois, Chicago and her master's in exercise physiology from the University of Pittsburgh. Her undergraduate degree is in dietetics, from Purdue University, West Lafayette. She also is a registered and licensed dietitian.

Dr. Van Horn's expertise extends across many areas of nutrition research, medical nutrition education, and public health policy relevant to the work of the Dietary Guidelines Advisory Committee. She is a clinical nutrition epidemiologist who has conducted population level research and clinical trials in the prevention and treatment of cardiovascular disease, obesity, and breast cancer. She specializes in research on women and children and is currently the principal investigator in the Women's Health Initiative Extension Study and the Dietary Intervention Study in Children follow-up study. Her research focuses on the benefits of a fat-modified diet that is high in fruits, vegetables, and fiber-rich whole grains as part of a low risk lifestyle to prevent cardiovascular disease, obesity and cancer. In addition to her comprehensive nutrition expertise, she has demonstrated successful leadership through multiple research teams.

Naomi K. Fukagawa, MD, PhD, Vice Chair

Dr. Fukagawa is a Professor of Medicine, the Acting Director of Gerontology, and the Associate Program Director for the Clinical Research Center at the University of Vermont and Fletcher Allen Health Care. She received her medical degree from Northwestern University and her doctorate in nutritional biochemistry and metabolism from the Massachusetts Institute of Technology. She is a board-certified pediatrician, but has focused her research on age-related issues.

Dr. Fukagawa is an expert in nutritional biochemistry and metabolism. Her expertise spans several areas including protein and energy metabolism; oxidants and antioxidants; and the role of diet in aging and chronic diseases, such as diabetes mellitus. She has chaired the National Institutes of Health Clinical Research Centers' Committee and is currently a member of the National Institutes of Health Integrative Physiology of Diabetes and Obesity Study Section.

Cheryl Achterberg, PhD

Dr. Achterberg is the Dean and Professor of the College of Education and Human Ecology at The Ohio State University. She received her doctorate in nutrition from Cornell University and her master's in human development from the University of Maine at Orono.

Dr. Achterberg is an expert in health behavior research. Her studies have evaluated consumer understanding of the dietary guidelines as well as the impact of behavior on the dietary patterns of varying groups, including low-income, young children, and elderly Americans. She has served as a Panel member for the World Health Organization for setting international guidelines for Developing Food Based Dietary Guidance. She has been a resource to the Institute of Medicine as an invited panelist for numerous workshops. She has also worked with the United Nations as an expert in nutrition education and community interventions.

Lawrence J. Appel, MD, MPH

Dr. Lawrence Appel is a Professor of Medicine, Epidemiology, and International Health (Human Nutrition), Division of General Internal Medicine, and Director of the ProHealth Clinical Research Unit at the Johns Hopkins Medical Institutions. Dr. Appel received his medical degree from the New York University School of Medicine and his master's of public health from Johns Hopkins University. He is also a practicing internist and a certified specialist in hypertension.

The focus of Dr. Appel's career has been to conduct research pertaining to the prevention of hypertension, cardiovascular disease, and kidney disease, typically through lifestyle modification. His research evaluates the health effects of dietary patterns, macronutrient intake, weight loss, and dietary electrolytes, such as sodium and potassium. He has a strong interest in research methods, particularly the evaluation of scientific evidence. Dr. Appel served on the 2005 Dietary Guidelines Advisory Committee where he was a member of the science review subcommittee and was the Chair of the electrolytes subcommittee. In addition, he has served on several committees for the Institute of Medicine, including the Dietary Reference Intake Panel for electrolytes and water, which he chaired.

Roger A. Clemens, DrPH

Dr. Clemens is the Associate Director of Regulatory Science and an Adjunct Professor of Pharmacology and Pharmaceutical Science at the University of Southern California. In addition, he is the Vice President of Science & Technology for PolyScience Consulting LLC (consultants) and consulting Scientific Advisor for E.T. Horn (sales organization of raw materials and ingredients). He received his doctorate of public health in nutrition and biological chemistry and his master's of public health in nutrition at the University of California, Los Angeles.

Dr. Clemens has extensive experience at the interface of nutrition, food science and technology, and health. He has expertise in food toxicology and food safety, as well as practical knowledge of food production and food regulations. He is a spokesperson for the American Society for Nutrition and the Institute of Food Technologists.

Miriam E. Nelson, PhD

Dr. Nelson is the founder and Director of the John Hancock Research Center on Physical Activity, Nutrition, and Obesity Prevention and an Associate Professor at the Friedman School of Nutrition Science and Policy at Tufts University. She is an Adjunct Professor in the Tisch College of Citizenship and Public Service. Dr. Nelson received her doctorate and master's degrees in nutrition from Tufts University.

Dr. Nelson recently served as Vice Chair of the first *Physical Activity Guidelines for Americans* Advisory Committee (PAGAC) chartered by HHS. She is a leading authority on physical activity and energy balance. Her work with the PAGAC provides continuity by bridging the work of the PAGAC and the Dietary Guidelines Advisory Committee.

Sharon (Shelly) M. Nickols-Richardson, PhD, RD

Dr. Nickols-Richardson is an Associate Professor and Coordinator of the Graduate Program in Nutrition in the Department of Nutritional Sciences at The Pennsylvania State University. She received her doctorate and her master's in foods and nutrition at The University of Georgia. She is also a registered dietitian.

Dr. Nickols-Richardson's expertise focuses on dietary and physical activity determinants of bone density. She also has expertise in dietary intervention for obesity and nutrition over the lifecycle from child nutrition to older adults. She served the Institute of Medicine as a consultant on the Dietary Reference Intake book *The Essential Guide to Nutrient Requirements*.

Thomas A. Pearson, MD, PhD, MPH

Dr. Pearson is the Senior Associate Dean for Clinical Research and the Albert D. Kaiser Professor in the Department of Community and Preventive Medicine and Director of the Rochester Clinical and Translational Science Institute at the University of Rochester School of Medicine and Dentistry. He received his medical degree, his doctoral degree in epidemiology, and his master's in public health from Johns Hopkins University.

Dr. Pearson is an epidemiologist specializing in lipid metabolism and the prevention of cardiovascular disease. He contributed significantly to the American Heart Association's guidelines for prevention of heart disease and stroke. His public health interests include investigating the impact of these guidelines on Americans. His expertise spans both nationally and internationally, as is evident in his contributions as current Chair of the National Forum for Heart Disease and Stroke Prevention.

Rafael Pérez-Escamilla, PhD

Dr. Perez-Escamilla is a Professor of Epidemiology and Public Health and the Director of the Office of Community Health at the Yale University School of Public Health. He is also the Director and Principal Investigator of the Connecticut NIH EXPORT Center of Excellence for Eliminating Health Disparities among Latinos (CEHDL). Dr. Perez-Escamilla received his doctorate in nutrition and his master's in food science from the University of California at Davis.

Dr. Perez-Escamilla is a nationally and internationally recognized scholar in the area of community nutrition for his work in food safety, obesity, diabetes, and food security. He has specialized experience with Latinos and low-income Americans, as well as numerous international populations. Dr. Pérez-Escamilla was a member of the 2009 Institute of Medicine/National Academy of Sciences Pregnancy Weight Gain Guidelines Committee and has served on editorial boards of the *Journal of Nutrition*, the *Journal of Human Lactation*, and the *Journal of Hunger and Environmental Nutrition*. Dr. Pérez-Escamilla is a trustee of the Pan American Health and Education Foundation based in Washington DC, has been a senior advisor to a number of community nutrition programs as well as household food security measurement projects, and has been a major advisor to master's and doctoral students from all over the world.

F. Xavier Pi-Sunyer, MD, MPH

Dr. Pi-Sunyer is Professor of Medicine at Columbia University College of Physicians and Surgeons and Chief of the Division of Endocrinology, Diabetes, and Nutrition at St. Luke's-Roosevelt Hospital. He received his medical degree from Columbia University and his master's of public health from Harvard University.

Dr. Pi-Sunyer has expertise in obesity, type 2 diabetes, carbohydrate and lipid metabolism, and general medicine with over 350 research papers on these topics. He chaired a National Heart Lung and Blood Institute obesity treatment and prevention guidelines committee and is now on the NHLBI's task force on Combined Heart Disease Prevention Guidelines. He has served on the Institute of Medicine Dietary Reference Intake Panel on macronutrients. He has also served on the Food and Drug Administration's Science Board Advisory Committee to the Commissioner. He was also a member of the 2005 Dietary Guidelines Advisory Committee.

Eric B. Rimm, ScD

Dr. Rimm is an Associate Professor of Medicine at Harvard Medical School and an Associate Professor of Epidemiology and Nutrition at the Harvard School of Public Health. In addition, he is the Director of the Program in Cardiovascular Epidemiology. Dr. Rimm received his doctorate in epidemiology at the Harvard School of Public Health.

Dr. Rimm is a nutritional epidemiologist who studies the impact of lifestyle factors, particularly diet, that relate to the risk for obesity, diabetes, heart disease, and stroke. He has published extensively on the health effects of moderate alcohol consumption, whole grains, fatty acids, dietary fiber, antioxidants, Vitamin D, and the B vitamins. He has published more than 400 peer-reviewed manuscripts and previously served on the Institute of Medicine Dietary Reference Intake Panel for macronutrients. He serves as an Associate Editor for the *American Journal of Clinical Nutrition* and the *American Journal of Epidemiology*.

Joanne L. Slavin, PhD, RD

Dr. Slavin is a Professor in the Department of Food Science and Nutrition at the University of Minnesota. She received her doctorate and master's in nutrition science at the University of Wisconsin.

Dr. Slavin is an expert in carbohydrates and dietary fiber, and has published more than 150 articles in her field. Her research focuses on the impact of whole grain consumption in chronic diseases, such as cancer, cardiovascular disease, and diabetes, as well as the role of dietary fiber in satiety. Because of her expertise in the area of whole grains, she was an invited presenter to the 2005 Dietary Guidelines Advisory Committee.

Christine L. Williams, MD, MPH

Dr. Williams is Vice President and Medical Director of Healthy Directions, Inc., a non-profit organization dedicated to the health and nutrition of children and families. She was formerly a Professor of Clinical Pediatrics, and Director of the Children's Cardiovascular Health Center in the Department of Pediatrics and Institute of Human Nutrition at Columbia University, College of Physicians and Surgeons. Dr. Williams earned her medical degree from the University of Pittsburgh, and a master's of public health from Harvard University. She is a board certified pediatrician and is also board certified in preventive medicine and public health.

Dr. Williams' expertise includes nutrition in cancer prevention and preventive cardiology, especially hypercholesterolemia in children. She has knowledge of dietary requirements of children, particularly dietary fiber and fat. She also has expertise in obesity and public health. In addition, she has received the prestigious Preventive Cardiology Academic Award from the National Heart Lung and Blood Institute for her work in preventive cardiology for children.

Appendix E-7: Dietary Guidelines Advisory Committee Report Acknowledgments

Outside Expert Speakers to the DGAC

Pat Crawford, DrPH, RD
Adam Drewnowski, PhD
Michael Hamm, PhD
Frank Sacks, MD
Brian Wansink, PhD

Subject Area Experts/Consultants to the Subcommittees

Cheryl Anderson, PhD, MPH, MS
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