PART D. Section 1: Energy Balance and Weight Management

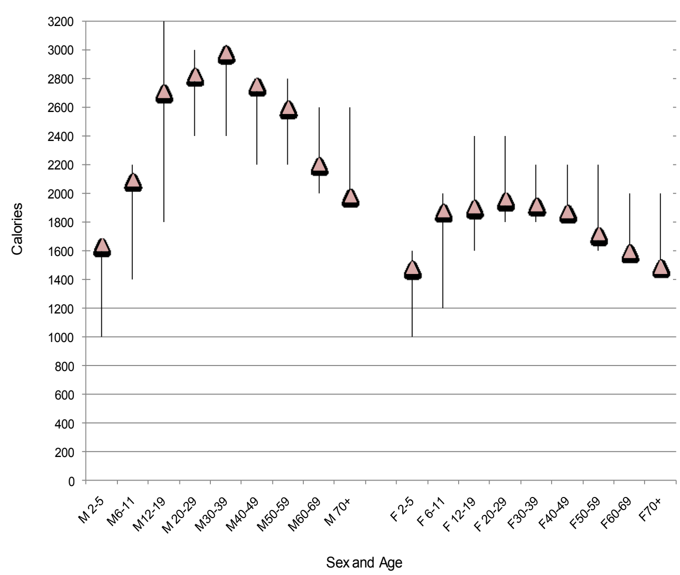
Introduction

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 (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

Figure D1.1 shows mean energy intake is within recommended ranges for all age and sex groups, with intakes at the higher end of the range for younger males and females and at the lower end of the range with increasing age.



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 (US).

Although the US 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 US 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 US are insufficient. As indicated in the 2008 National Health Interview Survey (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; Butte, 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 US, energy intakes are exceeding energy expenditure for many Americans. Moreover, recent data from the National Health and Nutrition Examination Survey (NHANES) 2005-2006 (NCI, 2010) indicates that many of the top food sources of calories among the US 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 foods among US 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
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% of energy for all persons in descending order are listed. Specific foods contributing at least 2% of energy for any given subgroup are then also listed in *italics*.
[c] Specific foods contributing at least 1% 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% orange/grapefruit juice.
Source: National Cancer Institute (NCI). Food Sources of Energy Among US 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 US 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 US 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 US. 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 Nutrition Evidence Library at www.nutritionevidencelibrary.com. 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 DGAG 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 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 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 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.

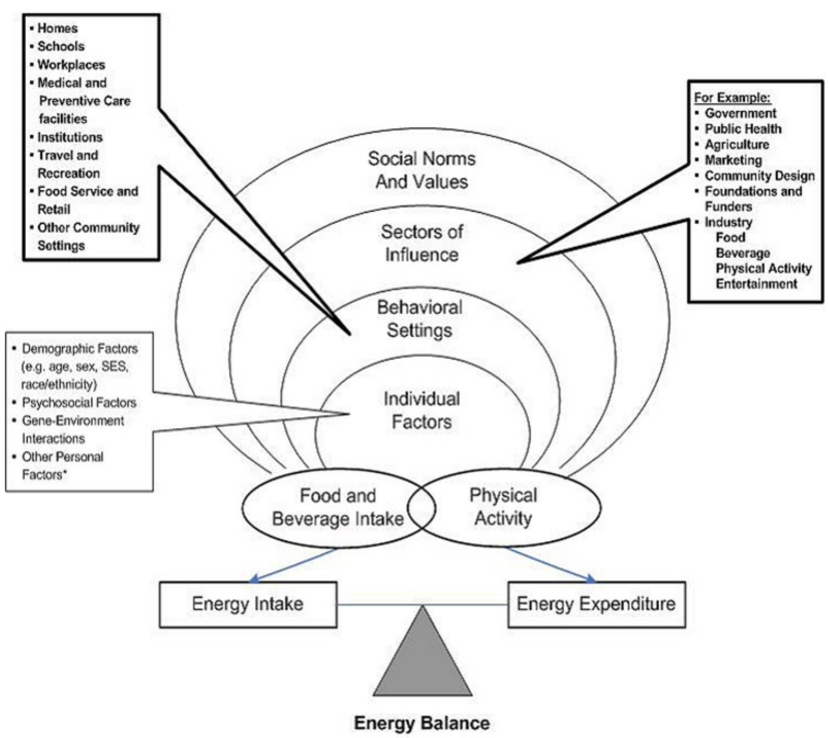
Review of the Evidence

Background

Very few American children or adults currently follow the US 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

Figure D1.2 depicts the socioecologic model that provides a framework in which to develop, implement, and evaluate comprehensive interventions. The model stresses that society is composed of interconnected elements – individual, interpersonal, organizational, community, and social – that invariably affect one another. A comprehensive intervention should consider how all these levels of influence can be addressed to support long-term healthful lifestyle choices. Examples are provided at each level of the socioecological model for consideration in obesity prevention interventions. Items to consider at the individual level include demographic factors such as age, sex, socioeconomic status, and race/ethnicity; psychosocial factors; gene-environment interactions; and other personal factors such as culture and acculturation, biobehavioral interactions, and social, political, and historical contexts. Next, behavioral settings should be considered during intervention planning, and these include locations such as homes, schools, workplaces, medical and preventive care facilities, institutions, travel and recreation, food service and retail, and other community settings. Third, an intervention planner should consider various sectors of influence such as government, public health, agriculture, marketing, community design, foundations and funders, and industry. The final element in this framework is social norms and values.

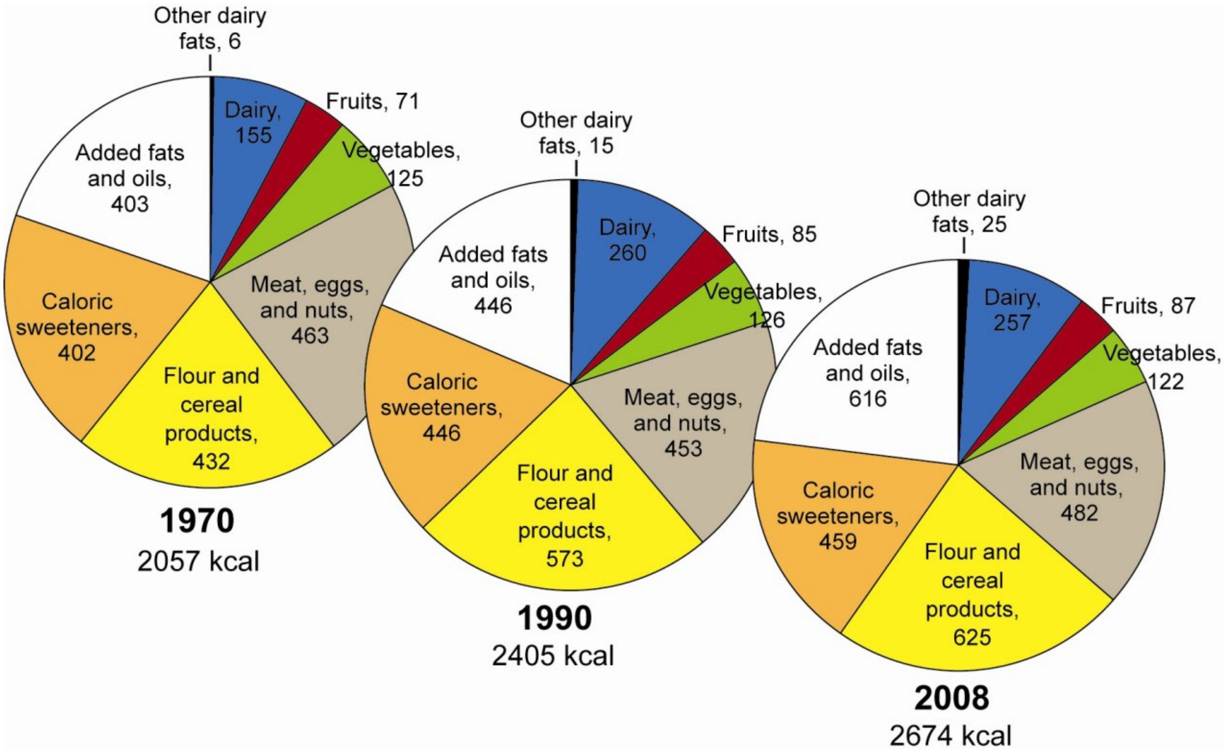


Source: Centers of Disease Control and Prevention. Division of Nutrition, Physical Activity, and Obesity. *State Nutrition, Physical Activity and Obesity (NPAO) Program: Technical Assistance Manual*. January 2008. Accessed April 21, 2010. http://www.cdc.gov/obesity/downloads/TA_Manual_1_31_08.pdf - pg 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 US 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 US Dietary Guidelines (Figure D1.4). Average daily per capita calories, adjusted for spoilage and other waste, increased from 2,057 in 1970 to 2,674 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 US food availability in 1970, 1990 and 2008, adjusted for spoilage and other waste



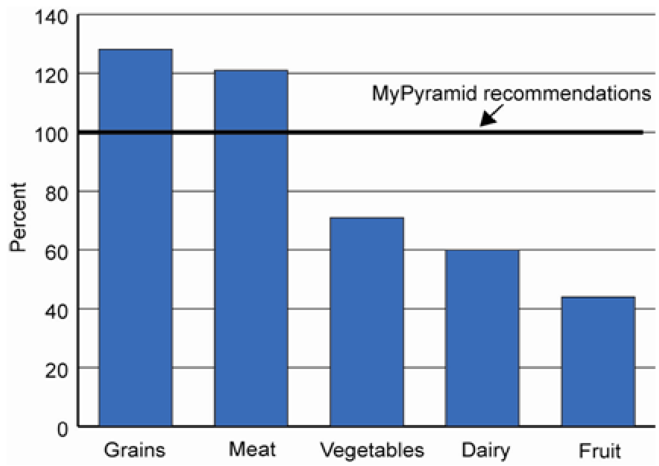
Source: ERS Food Availability (Per Capita) Data System http://www.ers.usda.gov/Data/FoodConsumption/.

Figure D1.3. Data points. All values in Calories.

Year	**1970**	**1990**	**2008**
Food component:			
Dairy	155	260	257
Fruits	71	85	87
Vegetables	125	126	122
Meat, eggs, and nuts	463	453	482
Flour and cereal products	432	573	625
Caloric sweeteners	402	446	459
Added fats and oils	403	446	616
Other dairy fats	6	15	25

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

Figure D.1.4 provides the loss-adjusted per capita food availability in comparison to MyPyramid recommendations for a 2000-calorie diet. Availability of grains (128%) and meat (121%) were above recommendations, while availability of vegetables (71%), dairy (60%), and fruit (44%) were below recommendations.



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 spend 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 US 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. 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 US marketplace

Food item	Portion size (year)	Portion size (year)	Percent increase
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 US 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 US 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 US. 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 an 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; Hannum, 2004) and one case-control study (Pearcey, 2002). The studies were conducted in the US. 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 US, New Zealand, and the United Kingdom. Studies ranged in sample size from 902 (Oken, 2007) to 50,277 (Hu, 2003), and one study included only men (Koh-Banerjee, 2003), 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; Albertson, 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 5am and 10am on weekdays and 5am and 11am on weekends. The studies were conducted in the US, 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 US, 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 US, 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 five year follow up period. Increased variety of snack food was associated with increased weight gain over a five to nine year follow 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 US 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 US men over 10 years. An increased number of eating occasions in addition to three standard meals was associated with a higher risk of 5-kg 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 US 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) 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 US, 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 Institute of Medicine (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 pre-pregnancy 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 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 US given the small size of the effect, large inter-individual variability in maternal postpartum weight changes, and the fact that in the US, 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 and Kakuma, 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 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 showing 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 kg and in the second one it was -0.2 kg. 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 pre-pregnancy weight, one found that exclusive breastfeeding was not associated with weight change from pre-pregnancy to 1 to 2 years postpartum. A second study found that breastfeeding at 1 year was associated with -1.2 kg of weight retention at 1 year postpartum, compared with a weight accretion of 2 kg among women formula feeding during the same period. A third study found that breastfeeding was associated with reaching pre-pregnancy 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 co-morbidities 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 US youth have changed significantly over the past several decades. National health and nutrition surveys of US 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 sugar, and sodium, and in many cases, low in nutrient density (e.g., soda/energy/sports drinks). The National Health and Nutrition Examination Survey (NHANES) of US 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 US 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 US 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
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% of energy for males 2-18 years old in descending order are listed. Specific foods contributing at least 2% of energy for any given subgroup are then also listed in *italics*.

[3]Specific foods contributing at least 1% of energy for males 2-18 years old in descending order: 100% 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 US 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 US 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
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% of energy for females 2-18 years old in descending order are listed. Specific foods contributing at least 2% of energy for any given subgroup are then also listed in *italics*.

[3]Specific foods contributing at least 1% 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% orange/grapefruit juice.

Source: Sources of Calories Among the US 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; Johnson, 2009; Savage, 2008a; Timpson, 2008). In a review of 10 validation studies, under-reporting 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 under-report 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 cut-offs 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 US 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 under-report energy intake and also tend to over-report 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 US, 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 cut-offs 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 cut-off (84.8% to 115.2% at 9 years of age). Those below the lower cutoff were classified as energy intake under-reporters, and those above were classified as energy intake over-reporters. Results showed that 58.4 percent (n=107) were plausible energy intake reporters; compared with 16.4 percent (n=30) who were under-reporters; and 25.1 percent (n=46) who were over-reporters. Notably, nearly two-thirds of implausible reporters were overweight (BMI>85th percentile), compared with only 31 percent of the total sample and 27 percent of the plausible energy intake reporters. Under-reporters of energy intake had significantly higher BMI, BMI z-score, and BMI percentile, and reported significantly lower energy intake versus both plausible and over-reporters. 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 under-reporting 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 under-reported 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 pre-pregnancy 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-feed 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/d 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 US 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 cut-offs 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 cut-off, and participants with implausible EI reports were excluded. (rEI outside +/- 18 to 23% of predicted E requirement). In this national survey of US 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 over-reporting at ages 3 to 11 years to under-reporting 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 (UK) 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 UK children, ages 7 to 18 years, and found that 64 percent were plausible reporters of energy intake, using a cut-off based on a ratio between energy intake and BMR (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 kcal/day more than those in the lowest quintile.

Three reports from the Avon Longitudinal Study of Parents and Children, ALSPAC, in the UK 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 under-reporters 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 EI was under-reported by 34 percent, compared with only 3 percent who over-reported energy intake. Again, a significantly greater proportion of children who under-reported 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; Johnson, 2009), under-reporters of energy intake were identified and excluded from the study (38%). Notably, under-reporters 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 under-reporters were excluded.

Accuracy in Reporting and True Associations

These reports illustrate the importance of excluding under-reporters 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 under-reporting 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 cut-offs 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; Johnson, 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 US 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 under-reporting 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 under-reporting 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; Birch, 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 kJ/g in the energy density of snacks consumed by children could translate into an increase in energy intake of 200 kJ/day (47.8 kcal/day) (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/gram or kcal/gram) and adiposity among youth (Alexy, 2004; Johnson, 2008a; Johnson, 2008b; Johnson, 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; Johnson, 2008b; Johnson, 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/g 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 kg and a 0.28 kg higher fat mass at 9 years of age after controlling for confounders. Children at 7 yrs of age who were in the highest quintile of pattern score (dietary energy density=10.67 $\pm$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 $\pm$0.87) (Johnson, 2008b). Finally, in a third report from the ALSPAC cohort at ages 10 to 13 years, Johnson et al. (2009) evaluated the effect of dietary energy density in relation to the effect of variants in a genotype associated with fat mass and obesity (the FTO genotype [rs9939609, A allele]). In this study, each 1 kJ/g higher dietary energy density at age 10 years was associated with 0.16$\pm$0.06 kg more fat mass at age 13 years, and each additional high-risk A allele of FTO independently associated with 0.35±0.13 kg 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; Johnson, 2008b; Johnson, 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; Johnson, 2008b; Johnson, 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 under-reporting of energy intake among overweight participants, difficulty in detecting minor over-consumption 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 over-reporting 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. 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 7 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; Johnson, 2008b; Karaolis-Danckert, 2007; Alexy, 1999; 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; Skinner, 2004; Wang, 2003). Fourteen of the studies were conducted in the US.

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; Skinner, 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; Alexy, 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 (1,892 vs. 2,157 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; Newby, 2004; Sugimori, 2004; Wang, 2003). Five studies were conducted in the US, 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; Newby, 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 fl oz 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 fl oz of 100 percent fruit juice had significantly higher energy intake (2,138 kcal) compared with children who did not consume 100 percent juice (1,828 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; Skinner, 2001; Sugimori, 2004; Welsh, 2005). Nine studies were conducted in the US, 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; Skinner, 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 US 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, particular soft drinks, has increased dramatically among US 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/day) behind grain-based desserts (138 kcal/d) and pizza (136 kcal/d). Across beverage categories, children ages 2 to 18 years consumed 173 kcal/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, 7 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 US, and the others were conducted outside of the US.

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 (Johnson, 2007; Kvaavik, 2005; Mrdjenovic, 2003; Mundt, 2006; Newby, 2004; Sugimori, 2004; Blum, 2005).

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 US 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 US 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 under-reporting 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 3 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 3 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. (1995and 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 with 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, vitamin 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 US 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 & 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, 11-17 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 type 2 diabetes. Overweight Latino youth (n=85, ages 11-17 years) were followed for two 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 grams/day) 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 US 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 US 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 under-consumed by US children, whose intake is far less than the recommended adequate intake (AI) of 14 grams of per 1,000 kcal. Thus, public health strategies to increase consumption of dietary fiber are vitally important to promote the health of US 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% 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: 5 review articles, 31 RCTs, and 1 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 US. 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: 2 review articles, 9 RCTs, and 1 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 the Australia, Denmark, Germany, Israel, New Zealand, the Netherlands, and the US. 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, nine RCTs, and four prospective cohort studies (Avenell, 2004; Dale, 2009; Due, 2008; Frisch, 2009; Halton, 2006; Halton, 2008; Hession, 2009; Lagiou, 2007; Lim, 2009; McAuley, 2005; Nordmann, 2006; Sacks, 2009; Shai, 2008; Tay, 2008; Trichopoulou, 2007). Studies were conducted in the Australia, Denmark, Germany, Greece, Israel, New Zealand, Sweden, and the US. 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 month) 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 the 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 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. 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; Ledikwe, 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 kcal per 100g. 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 kg to 1.5 kg 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 kg, compared to 4.0 kg among those in the middle tertile, and 2.4 kg 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 kg compared to 2.5 ±6.8 kg 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 on 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 type 2 diabetes 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 kg/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 invidivuals 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 kg. 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 US 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 thirteen 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.

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 six 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 six. There is every reason to believe that these guidelines promote healthy growth and development for children under age six.

Source: HHS, 2008. http://www.health.gov/paguidelines/committeereport.aspx

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 US 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 DG2010 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 calorically 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 ≥ 40) women continues to rise in the US, 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 US.

   Rationale: No nationally representative data are available to describe pre-gravid BMI and gestational weight gain patterns in the US 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 pre-pregnancy 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 (ED) 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 ED estimations has been largely justified on statistical and not physiological grounds (Ledikwe, 2005). Studies that have incorporated all beverages in the dietary ED estimations, including water (Iqbal, 2006) have yielded null results. Few studies have examined weight outcomes using different ED definitions, these studies have identified inconsistent results as a function of the ED definition used (Kant and Graubard, 2005).

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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 Drink	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: US 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.