

National Cancer Institute

measurementERRORwebinar series

## Estimating usual total nutrient intakes from supplements and diet

Regan Bailey, PhD, RD  
Kevin Dodd, PhD

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES  
National Institutes of Health

### Presenters and Collaborators

Sharon Kirkpatrick  
*Series Organizer*

Regan Bailey	Laurence Freedman	Douglas Midthune
Dennis Buckman	Patricia Guenther	Amy Subar
Raymond Carroll	Victor Kipnis	Fran Thompson
Kevin Dodd	Susan Krebs-Smith	Janet Tooze



measurementERRORwebinar series

measurementERRORwebinar series



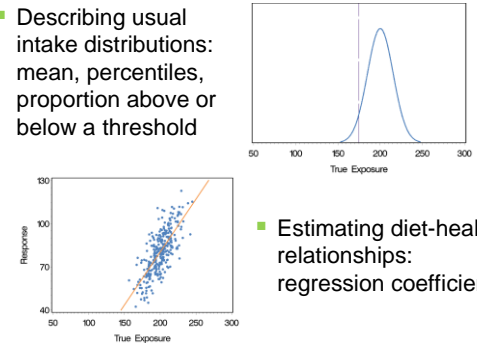
This series is dedicated to the memory of **Dr. Arthur Schatzkin**

In recognition of his internationally renowned contributions to the field of nutrition epidemiology and his commitment to understanding measurement error associated with dietary assessment.

Introduction

### Two main areas of interest

- Describing usual intake distributions: mean, percentiles, proportion above or below a threshold



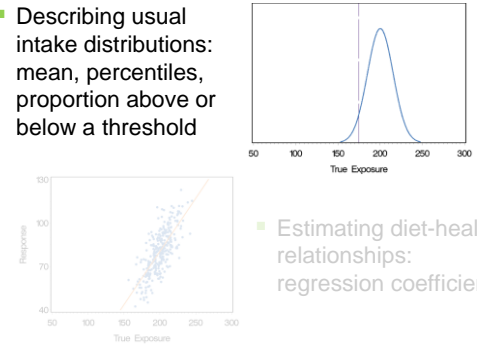
- Estimating diet-health relationships: regression coefficients

measurementERRORwebinar series

Introduction

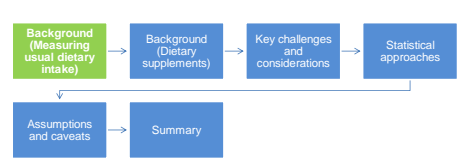
### Two main areas of interest

- Describing usual intake distributions: mean, percentiles, proportion above or below a threshold



- Estimating diet-health relationships: regression coefficients

measurementERRORwebinar series



## BACKGROUND: MEASURING USUAL DIETARY INTAKE

measurementERRORwebinar series

Background: measuring usual dietary intake

### Two types of self-report instruments

- **Short-term instruments**  
(e.g., 24-hour recalls, food records, food diaries)
  - Often used in population surveys for monitoring health and nutrition
- **Long-term instruments**  
(e.g., food frequency questionnaire)
  - Often used in large cohort or case-control studies to examine diet-health relationships

measurementERRORwebinar series

7 Estimating total usual nutrient intake distributions from diet and supplements

Background: measuring usual dietary intake

### 24-hour recall (24HR)

- Less cognitively challenging (relies on short-term recall)
- Rich detail → fewer assumptions required in converting to nutrient and food group intake
- Aims to capture recent diet
  - Need more than one to assess usual intake
- *Expensive to collect and code (until recently)*

measurementERRORwebinar series

8 Estimating total usual nutrient intake distributions from diet and supplements

Background: measuring usual dietary intake

### Food frequency questionnaire (FFQ)

- Aims to capture long-term intake
- *Inexpensive to administer*
- Cognitively challenging
- Affected by recent diet
- Finite food list
- Lack of detail → assumptions required in converting to nutrient and food group intake

measurementERRORwebinar series

9 Estimating total usual nutrient intake distributions from diet and supplements

Background: measuring usual dietary intake

### Daily vs. episodic consumption

- **Consumed nearly daily by nearly all persons**
  - E.g., vitamin C, total grains, total vegetables, solid fats, added sugars
- **Consumed episodically by most persons**
  - E.g., vitamin A, whole grains, dark green vegetables, fish
- **Consumed episodically by ? persons**
  - Supplements

measurementERRORwebinar series

10 Estimating total usual nutrient intake distributions from diet and supplements

Background: measuring usual dietary intake

### Usual dietary intake

Average or long-run intake (*habitual intake*) over a specific period of time

```

    graph TD
      A[Usual dietary intake] --> B[Population monitoring and surveillance:]
      A --> C[Diet-health research, e.g., cohort or case-control studies:]
      B --> D[Dietary recommendations intended to be met over time]
      C --> E[Hypotheses based on long-term intake]
    
```

measurementERRORwebinar series


11 Estimating total usual nutrient intake distributions from diet and supplements

Background: measuring usual dietary intake

### Challenge

**Usual intakes are not directly observable**

- Self-report dietary assessment instruments measure usual intake with error
- If ignored, this error can bias results
- Statistical modeling methods can be used to correct this bias



measurementERRORwebinar series

12 Estimating total usual nutrient intake distributions from diet and supplements

Background: measuring usual dietary intake

### Some existing methods

- U.S. National Research Council (NRC)/ Institute of Medicine (IOM)
- Iowa State University (ISU) Method
- U.S. National Cancer Institute (NCI) Method
- EFCOVAL Consortium Multiple Source Method (MSM)
- Statistical Program for Age-adjusted Dietary Assessment (SPADE)

13 Estimating total usual nutrient intake distributions from diet and supplements

Background: measuring usual dietary intake

### Accounting for nonlinear transformations

The diagram illustrates the process of accounting for nonlinear transformations. It shows three density plots. The top-left plot, 'Original Scale', shows a skewed distribution of 'Folate Intake' (0 to 1500) with a peak density of approximately 0.001. A blue arrow labeled 'Transform' points to the top-right plot, 'Transformed Scale', which shows a normal distribution of 'Transformed Folate Intake' (1.40 to 2.80) with a peak density of approximately 0.001. A blue arrow labeled 'Backtransform' points from the transformed scale back to the original scale, resulting in a skewed distribution similar to the original one.

14 Estimating total usual nutrient intake distributions from diet and supplements

### Objectives

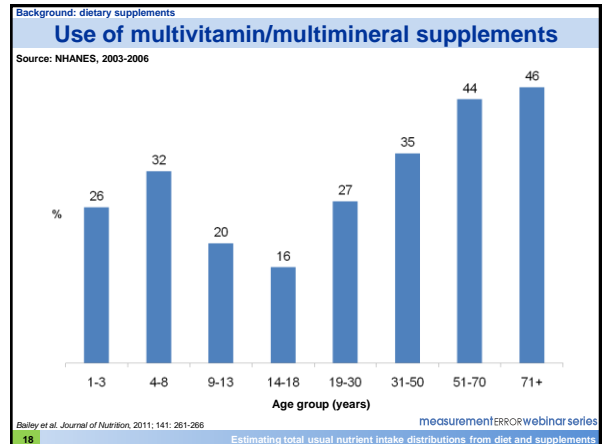
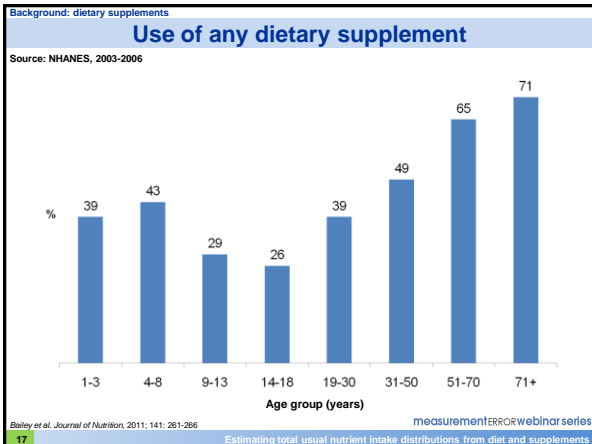
- Provide background information on dietary supplement use in the U.S. using the National Health and Nutrition Examination Survey (NHANES)
- Identify key challenges and considerations in combining dietary and supplement intake data
- Explain statistical approaches to estimating total nutrient intakes
- Describe assumptions and caveats of current techniques of estimating total nutrient intakes

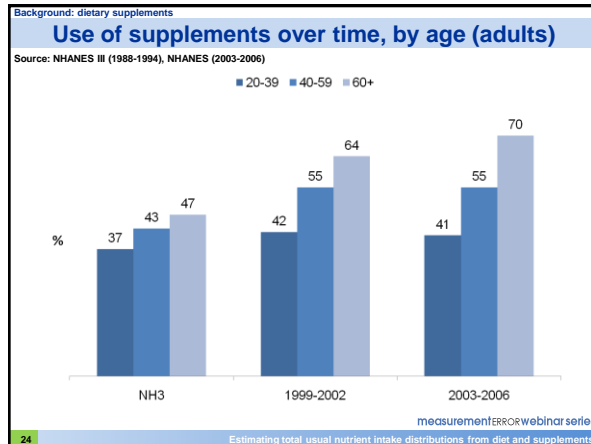
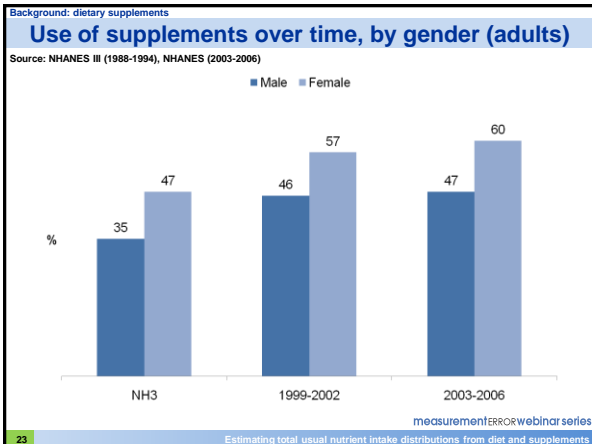
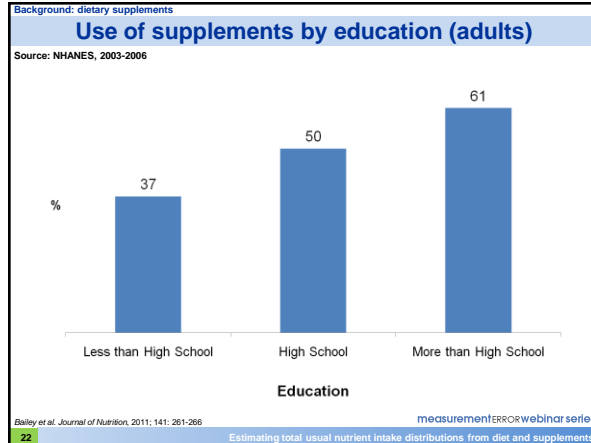
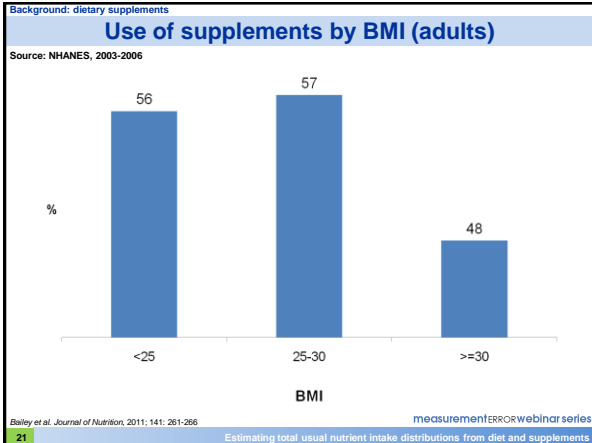
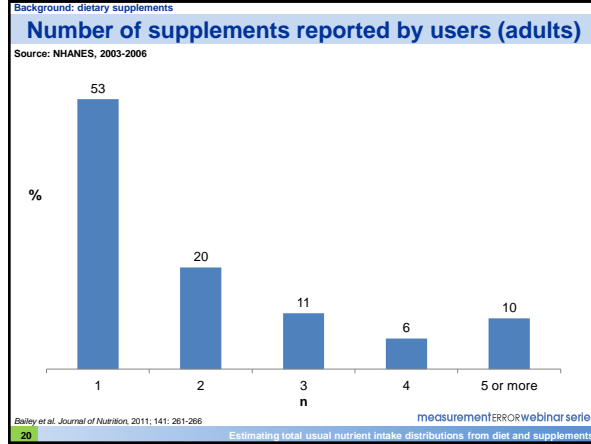
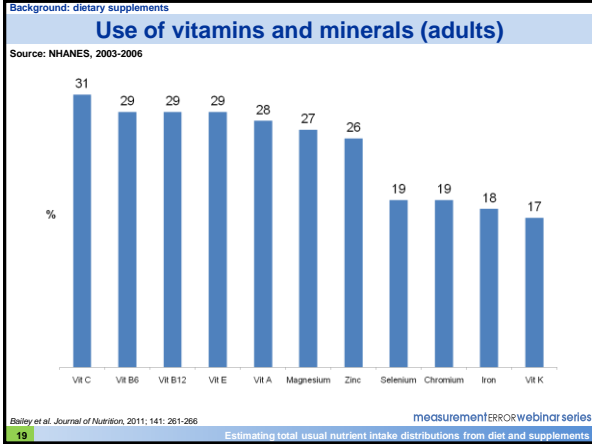
15 Estimating total usual nutrient intake distributions from diet and supplements

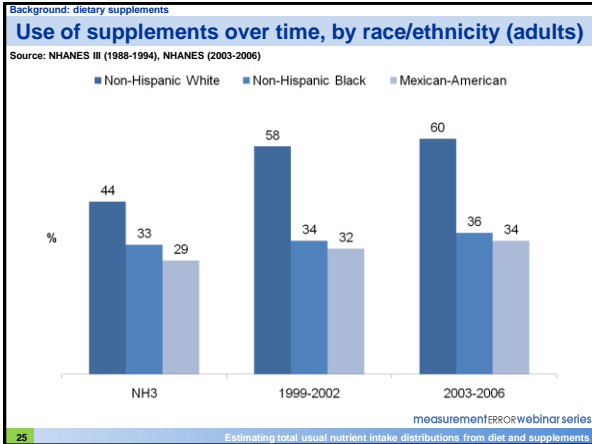
The flowchart shows a sequence of steps: 'Background (measuring usual dietary intake)' leads to 'Background (dietary supplements)', which leads to 'Key challenges and considerations', which leads to 'Statistical approaches'. From 'Statistical approaches', the flow goes to 'Assumptions and caveats', which then leads to 'Summary'. There is also a feedback loop from 'Statistical approaches' back to 'Background (dietary supplements)'.

## BACKGROUND: DIETARY SUPPLEMENTS

16 Introduction to measurement error in dietary intake data







Background: dietary supplements

### Implications of supplement use

- More than half of adults (19+ years) in the U.S. use dietary supplements
- Estimated 35% of children (1 -13 years) report use of supplements
- The contribution that dietary supplements make to nutrient intakes cannot be ignored!

measurmentERRORwebinar series

Background: dietary supplements

### Special considerations with dietary supplements

- For some nutrients, portion of intake from supplements may be large (e.g., vitamin D)
- Some supplements have large doses of nutrients
- Adequacy and excess are underestimated if only food sources are considered
  - Adequacy typically assessed using the Estimated Average Requirement (EAR)
- Some Tolerable Upper Intake Levels (ULs) defined only for supplement-derived nutrient intake (e.g., magnesium, folic acid)

measurmentERRORwebinar series

Background: dietary supplements

### Total nutrient intake

- Food
- Beverages (including water)
- Fortified foods
- Dietary supplements
- Some medications
  - Both prescription and over-the-counter

measurmentERRORwebinar series

Background: dietary supplements

### Usual total nutrient intakes

- Limited research exists contribution of dietary supplements to total nutrient intakes
- Perception that handling supplement data is challenging

measurmentERRORwebinar series

Background: dietary supplements

```

    graph LR
      A[Background (measuring usual dietary intake)] --> B[Background (dietary supplements)]
      B --> C[Key challenges and considerations]
      C --> D[Statistical approaches]
      D --> E[Assumptions and caveats]
      E --> F[Summary]
    
```

### KEY CHALLENGES AND CONSIDERATIONS

measurmentERRORwebinar series

Key challenges and considerations

### Most common ways to assess supplements

- Frequency questionnaire
  - Supplements have the potential to be episodically consumed
  - Length of use may be important
  - Supplement use is aggregated
  - Used most often
- 24-hour recall (24HR)
  - Administered with food recall
  - Emerging

measurement error webinar series

31 Estimating total usual nutrient intake distributions from diet and supplements

Key challenges and considerations

### Most common ways to assess supplements

- Frequency questionnaire
  - Supplements have the potential to be episodically consumed
  - Length of use may be important
  - Supplement use is aggregated
  - Used most often
- 24-hour recall (24HR)
  - Administered with food recall
  - Emerging

■ Want average daily exposure: ideally can be obtained using both sources of information

measurement error webinar series

32 Estimating total usual nutrient intake distributions from diet and supplements

Key challenges and considerations

### Error structure in reporting dietary supplements



measurement error webinar series

33 Estimating total usual nutrient intake distributions from diet and supplements

Key challenges and considerations

### Implications of measurement

- Both 24HR and frequency methods are subject to different types of measurement error
- Data may be collected over two different periods of time
- Nutrient estimates from the two instruments may not be directly comparable, and simply adding them together may not be a satisfactory approach


measurement error webinar series

34 Estimating total usual nutrient intake distributions from diet and supplements

Key challenges and considerations

### Challenges and considerations with supplements

- Reports accepted as “truth”
- Altered distributions of intake
- Moving targets = reformulations
- Default values in databases and reports
- No single comprehensive database
- Bioavailability
- Analytical vs. labeled values



measurement error webinar series

35 Estimating total usual nutrient intake distributions from diet and supplements

Key challenges and considerations

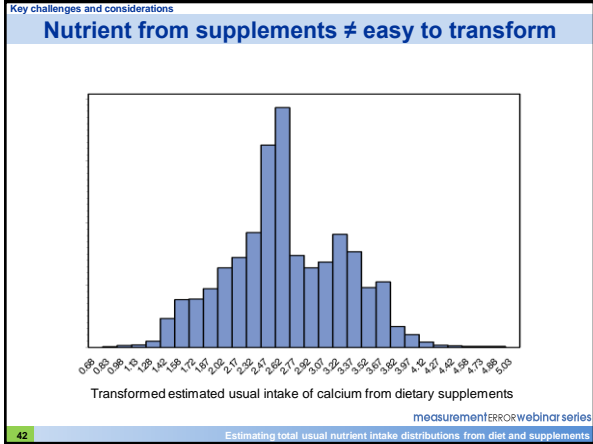
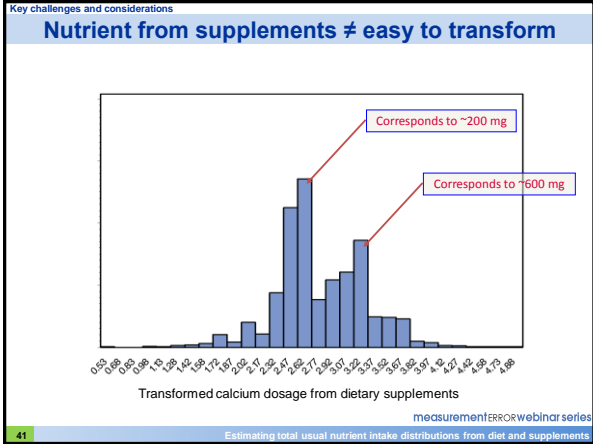
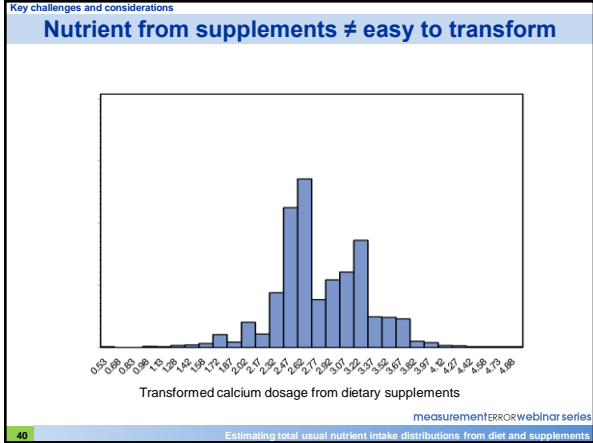
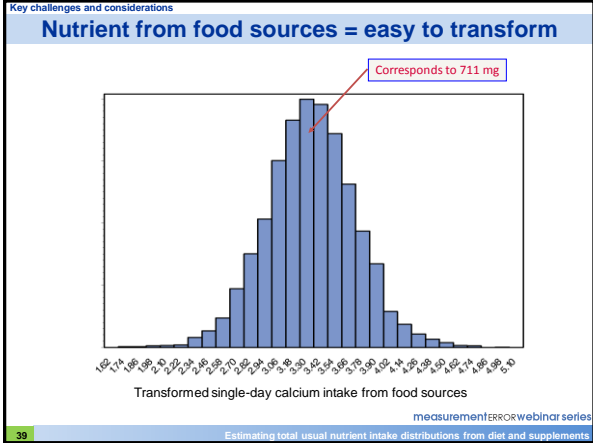
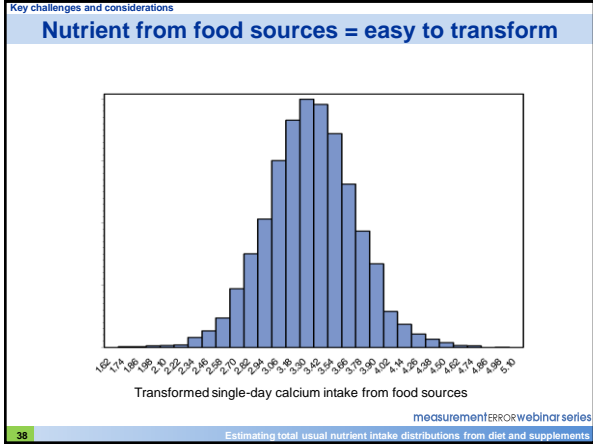
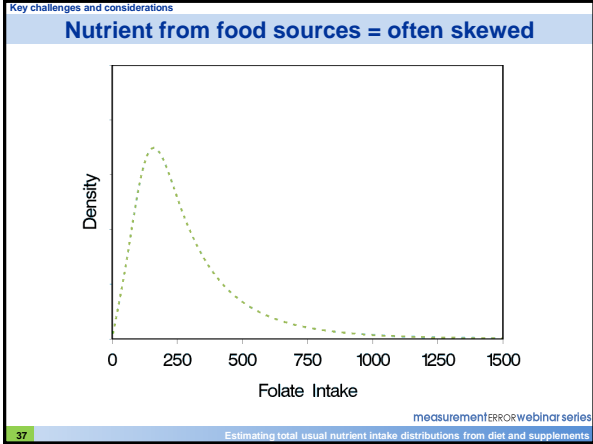
### Challenges and considerations with supplements

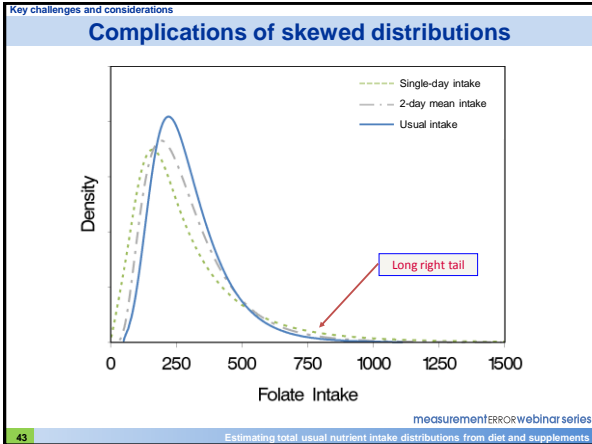
- Reports accepted as “truth”
- Altered distributions of intake
- Moving targets = reformulations
- Default values in databases and reports
- No single comprehensive database
- Bioavailability
- Analytical vs. labeled values



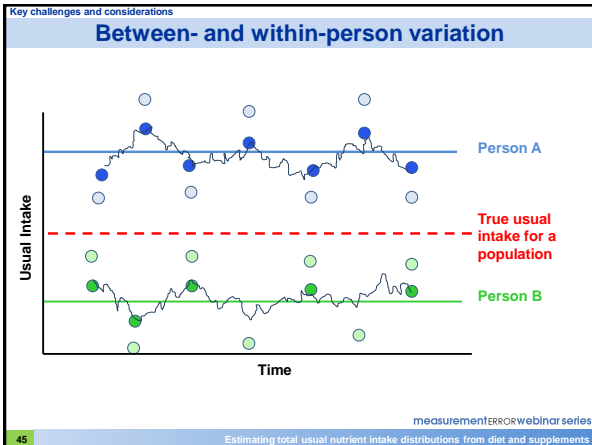
measurement error webinar series

36 Estimating total usual nutrient intake distributions from diet and supplements

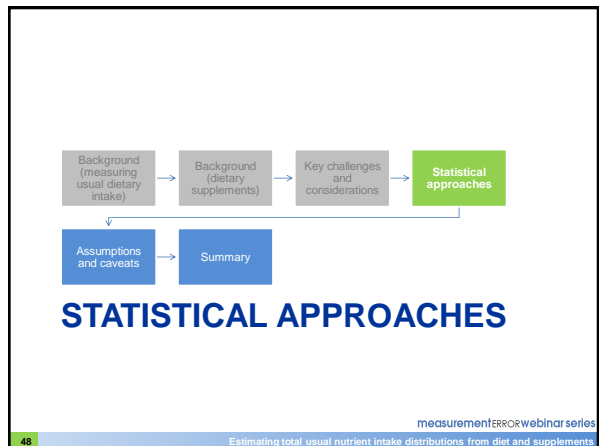
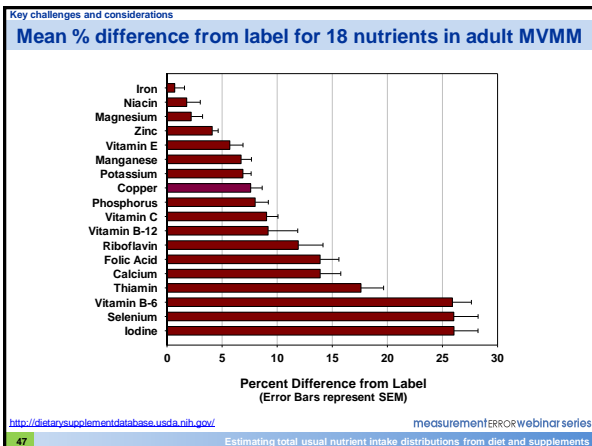




- Key challenges and considerations
- ### Total nutrient intake distributions
- Distributions from foods are not so spiked
    - Everyone eats, not everyone uses supplements
  - Supplements can severely alter nutrient intake distributions
    - Spikes and skews
  - Depending on how supplement data are collected, affects between- and within-person variation
- 44 Estimating total usual nutrient intake distributions from diet and supplements



- Key challenges and considerations
- ### Challenges and considerations with dietary supplements
- Reports accepted as "truth"
  - Altered distributions of intake
  - Moving targets = reformulations
  - Default values in databases and reports
  - No single comprehensive database
  - Bioavailability
  - Analytical vs. labeled values
- 
- 46 Estimating total usual nutrient intake distributions from diet and supplements





Statistical approaches

### Reminder

- The choice of methods of analysis should be based on your research question
  - Do you want the mean of the group?
  - Do you want the prevalence below or above a cut-point?
  - Do you want to describe the entire population?
  - Do you want to describe users and non-users of supplements?

measurement ERROR webinar series

49 Estimating total usual nutrient intake distributions from diet and supplements

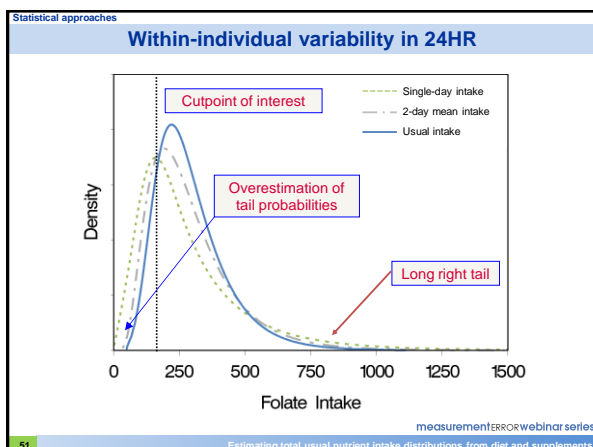
Statistical approaches

### How do we combine supplements and foods?

- Basic
  - Simply add nutrient intakes from food and dietary supplements
  - This strategy works if you want to describe the mean
  - Can be used with frequency questionnaire or 24HR
  - **Cannot** be used to assess the population distribution (i.e., <EAR or >UL)

measurement ERROR webinar series

50 Estimating total usual nutrient intake distributions from diet and supplements



Statistical approaches

### How do we combine supplements and foods?

- Adjusted
  - Estimate distribution of usual intake by removing within-person variation using statistical modeling
    - Can incorporate covariates
      - Allows different means for subpopulations, while pooling information about variance components
  - **Can** be used to assess the population distribution

measurement ERROR webinar series

52 Estimating total usual nutrient intake distributions from diet and supplements

Statistical approaches

### When do you add supplements?

- Before or after you adjust?
  - Before
    - Add the nutrient intakes from dietary supplements and then apply an adjustment procedure
      - “Add, then shrink”
  - After
    - Adjust the dietary nutrient intakes with an adjustment procedure and then add the nutrient intakes from supplements
      - “Shrink, then add”

measurement ERROR webinar series

53 Estimating total usual nutrient intake distributions from diet and supplements

Statistical approaches

### When do you add supplements?

- Before you adjust\*
  - Users and non-users have same mean total intake
  - Ignores a measured covariate
    - Potential bias
  - Multi-modal distribution

\*Possible to do with users and non-users separately

measurement ERROR webinar series

54 Estimating total usual nutrient intake distributions from diet and supplements

Statistical approaches

### When do you add supplements?

- After you adjust
  - Users and non-users have different mean from foods and for total
  - Less complicated transformations


measurmentERRORwebinar series

55 Estimating total usual nutrient intake distributions from diet and supplements

Statistical approaches

### Using NHANES to calculate usual total nutrient intake

- Calcium Example: NHANES 2007-2008
  - Food and beverages
    - Two 24HR
  - Dietary supplements
    - 30-day frequency questionnaire (DSQ)
    - Two 24HR
  - Some medications
    - Antacids




measurmentERRORwebinar series

56 Estimating total usual nutrient intake distributions from diet and supplements

Statistical approaches

### Analysis strategy: calcium

- Basic
- Adjusted – NCI method
  - Add then adjust (Add, then shrink)
  - Adjust then add (Shrink, then add)
    - Covariates
      - Day of the week
      - Sequence of 24HR
      - Supplement user – from questionnaire (DSQ)
      - Amount of calcium from the 24HR

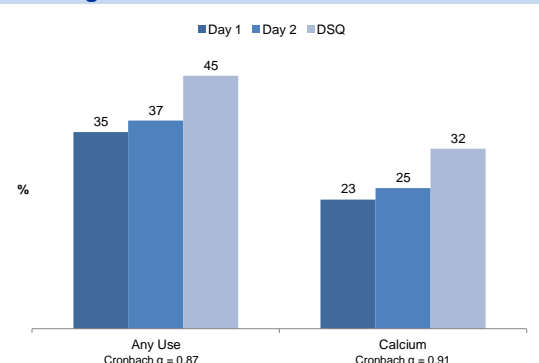


measurmentERRORwebinar series

57 Estimating total usual nutrient intake distributions from diet and supplements

Statistical approaches

### Agreement between methods: % use



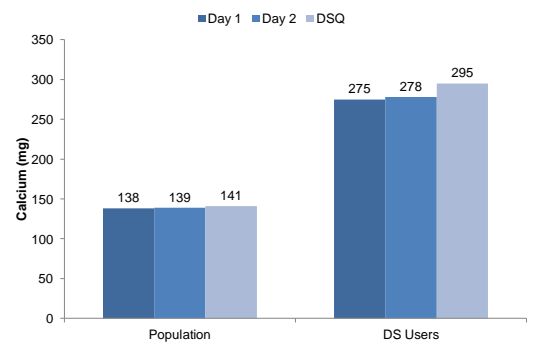
Method	Day 1 (%)	Day 2 (%)	DSQ (%)
Any Use	35	37	45
Calcium	23	25	32

measurmentERRORwebinar series

58 Estimating total usual nutrient intake distributions from diet and supplements

Statistical approaches

### Agreement: calcium amount (mg) from supplements



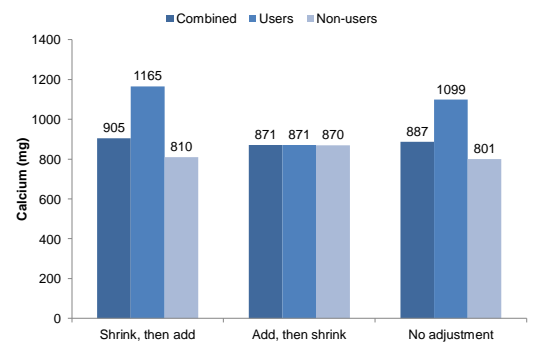
Group	Day 1 (mg)	Day 2 (mg)	DSQ (mg)
Population	138	139	141
DS Users	275	278	295

measurmentERRORwebinar series

59 Estimating total usual nutrient intake distributions from diet and supplements

Statistical approaches

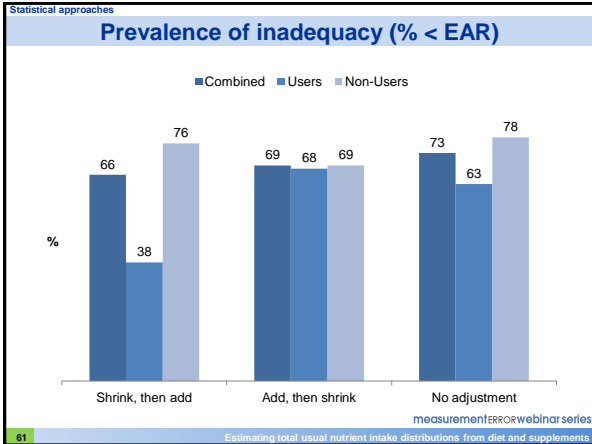
### Total calcium intake: Girls, 14-18 years old



Adjustment Method	Combined (mg)	Users (mg)	Non-users (mg)
Shrink, then add	905	1165	810
Add, then shrink	871	871	870
No adjustment	887	1099	801

measurmentERRORwebinar series

60 Estimating total usual nutrient intake distributions from diet and supplements



Statistical approaches

### Take-home messages

- Mean intakes for the total population are relatively similar regardless of analysis strategy
- Distributions are most affected by methods
  - Do not present <EAR or >UL using unadjusted intake data
  - Suggest modeling diet first, then add supplements

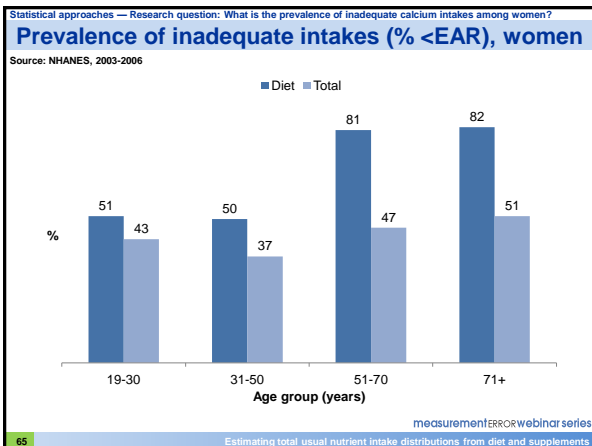
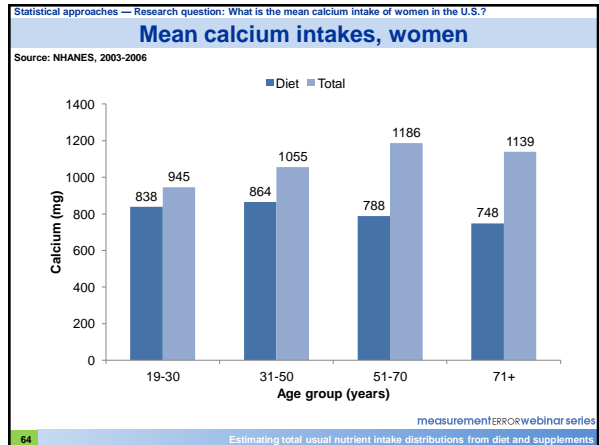
62 Estimating total usual nutrient intake distributions from diet and supplements

Statistical approaches

### NHANES calcium example, 2003-2006

- Calcium intakes
  - Diet from two 24HR
  - Supplement information only from a questionnaire
- Adjust dietary intake distributions
- Add average daily supplement exposure to the adjusted dietary intakes
  - “Shrink, then add”

63 Estimating total usual nutrient intake distributions from diet and supplements

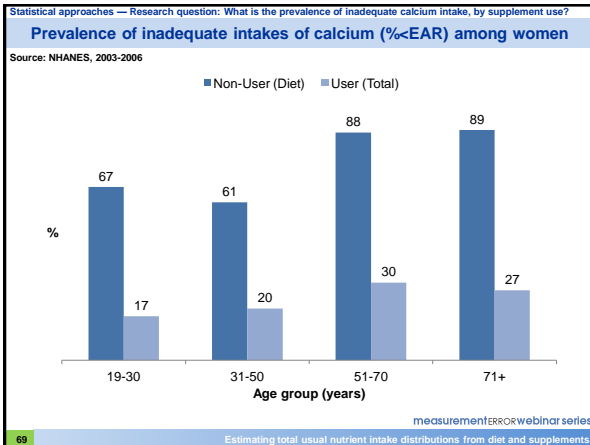
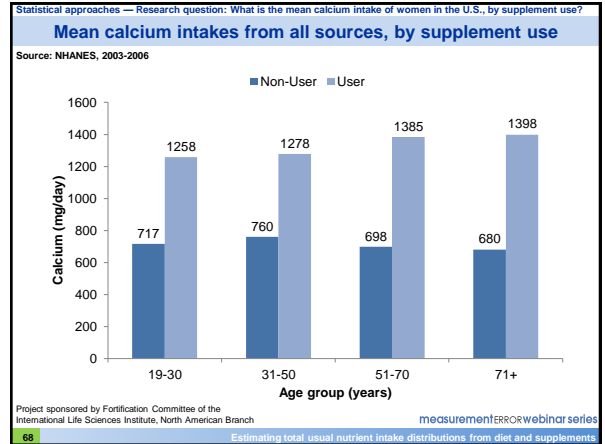
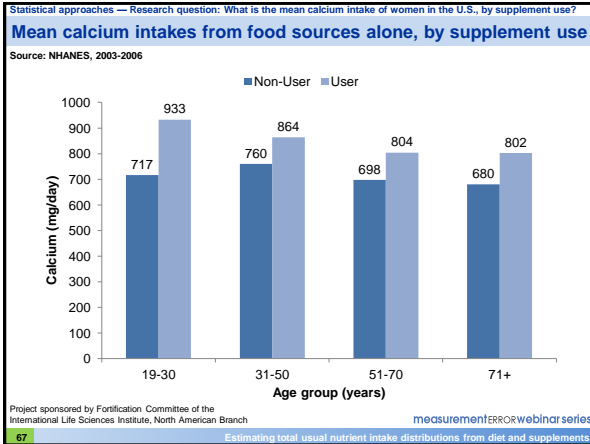


Statistical approaches

### Implications of modeling decisions

- Several studies indicate the users of supplements actually have higher nutrient intakes from foods than non-users
  - Consider modeling separately
  - Potentially include other covariates

66 Estimating total usual nutrient intake distributions from diet and supplements



Statistical approaches

### Data summary (e.g., women 71+ y)

- What is the prevalence of inadequate intakes of calcium among women in the U.S.?
  - Slide 65 – 51%
- What is the prevalence of inadequate intakes of calcium among women in the U.S., by supplement use?
  - Slide 69 – 89% among non-users and 27% among users

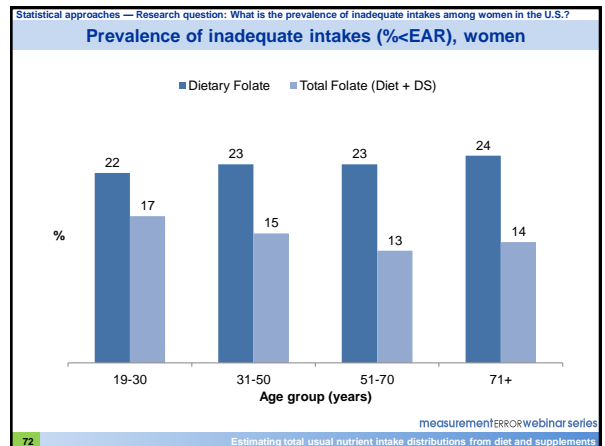
70 Estimating total usual nutrient intake distributions from diet and supplements

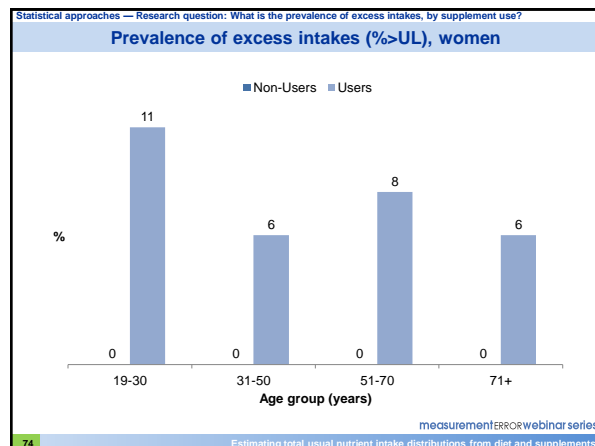
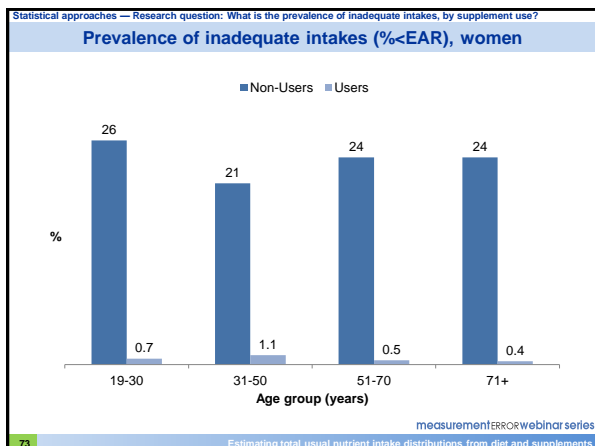
Statistical approaches

### Food folate vs. folic acid

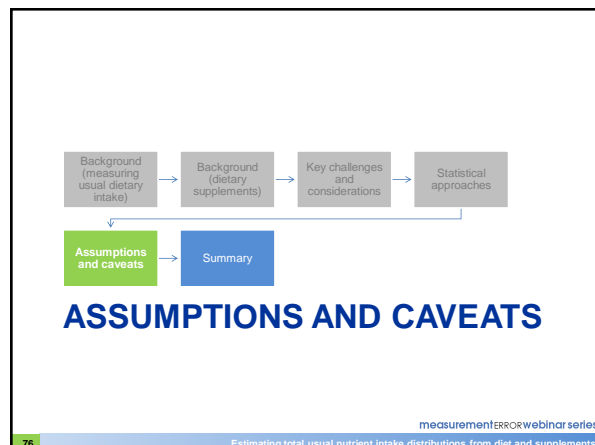
- Fortificant in food supply
  - Shifts the entire distribution curve
- Folate bioequivalence
  - 1 DFE = 1 µg food folate = 0.6 µg folic acid from supplements and fortified foods
  - EAR is in terms of DFE, but UL is ONLY for folic acid
  - 39% of the U.S. population uses a dietary supplement with folic acid

71 Estimating total usual nutrient intake distributions from diet and supplements





- Statistical approaches
- ### Data summary (E.g., women 19-30 y)
- What is the prevalence of inadequate intakes of folate among reproductive-age females 19-30 y in the U.S.?
    - Slide 72 – 17%
  - What is the prevalence of inadequate intakes of folate among reproductive-age females 19-30 y in the U.S., by supplement use?
    - Slide 73 – 26% for non-users, 0.7% for non-users
    - Remember 11% of users were above the UL compared to 0% of non-users
- 75 Estimating total usual nutrient intake distributions from diet and supplements



- Assumptions and caveats
- ### Assumptions and caveats
- Reported nutrient intake from food sources from 24HR are unbiased
  - Self-reported dietary supplement intake reflects true long-term supplement intake
  - Label declarations are accurate, or incorporate analytical values from the Dietary Supplement Ingredient Database project (slide 47)
- 77 Estimating total usual nutrient intake distributions from diet and supplements

- Assumptions and caveats
- ### Caveats
- There is no one right way to handle dietary supplements
  - Know your research question
  - Know your sample
  - Know your nutrient
- 78 Estimating total usual nutrient intake distributions from diet and supplements

**SUMMARY**

measurementERRORwebinar series

79 Estimating total usual nutrient intake distributions from diet and supplements

Summary

**Bottom line – accounting for supplements**

- More than half the U.S. population uses dietary supplements
- Must be included in nutrient intake estimates
- Must be accounted for when calculating prevalence of inadequate and excessive intakes of nutrients in a group

measurementERRORwebinar series

80 Estimating total usual nutrient intake distributions from diet and supplements

Summary

**Bottom line – methods**

- If you want the population mean – most strategies will work
- If you want total usual nutrient intake distributions
  - Adjust dietary estimates
  - Add dietary supplements

measurementERRORwebinar series

81 Estimating total usual nutrient intake distributions from diet and supplements

**Thank you!**

- Webinar
  - Kevin Dodd
  - Sharon Kirkpatrick
- Researchers
  - Alicia Carriquiry
  - Didier Garriguet
  - Janneke Verkaik-Kloosterman

measurementERRORwebinar series

82 Estimating total usual nutrient intake distributions from diet and supplements

**QUESTIONS & ANSWERS**

Moderator: Susan Krebs-Smith

Please submit questions using the *Chat* function

measurementERRORwebinar series

83 Introduction to measurement error in dietary intake data

measurementERRORwebinar series

**Next Session** Tuesday, October 25, 2011 10:00-11:30 EDT

**The problem of measurement error when examining diet-health relationships**

Laurence Freedman  
Gertner Institute for Epidemiology

National Cancer Institute

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES  
National Institutes of Health