Measurement Error Webinar Series

Accounting for measurement error in dietary intake data

September 20-December 6, 2011

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Webinar series goal
- Provide participants with an understanding of:
  - The sources and magnitudes of dietary measurement errors
  - How measurement error may affect estimates of usual dietary intake distributions
  - How measurement error may affect analyses of diet-health relationships
  - How the effects of measurement error may be mitigated

Today’s objective
- Participants will gain an understanding of:
  - The concept of usual dietary intake
  - Sources of measurement errors and their impact
  - Concepts underpinning approaches to reducing and correcting for measurement error

Introduction to measurement error in dietary intake data

Sharon Kirkpatrick
National Cancer Institute

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.
Outline

- Introductory concepts
- Usual intake
- Measurement error
- The structure of measurement error
- Accounting for measurement error
- Summary & series overview

INTRODUCTORY CONCEPTS

Two main areas of interest

- Describing usual intake distributions: mean, percentiles, proportion above or below a threshold
- Estimating diet-health relationships: regression coefficients

Two main areas of interest - caveat

- For estimating usual intake distributions or diet-health relationships, draw upon data for a population/group of interest rather than a standalone individual
- In contrast to clinical settings, where interest is in a standalone individual and only his or her data

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

Main versus reference instrument

- Main instrument
  - The primary dietary assessment instrument
- Reference instrument
  - An instrument used to calibrate or validate the main instrument
  - Assumed to provide estimates that are closer to the underlying truth than the main instrument (alloyed gold standard)
Instruments drawn upon in this series

24-hour recall (24HR)
- Main instrument for estimating usual intake distributions
- Reference instrument for estimation of diet-health relationships using food frequency questionnaire as main instrument
- For future studies, main instrument for assessing diet-health relationships

Food frequency questionnaire (FFQ)
- Main instrument for assessing diet-health relationships
- Supplemental instrument for studying diet-health relationships using a short-term instrument as the main instrument

Recovery biomarker (reference instrument)
- Specific biologic product that is directly related to intake and not subject to homeostasis or substantial interindividual differences in metabolism
- Examples:
  - Doubly labeled water for energy intake
  - Urinary nitrogen for protein 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

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

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

- Population monitoring and surveillance:
- Diet-health research, e.g., cohort or case-control studies:
- Dietary recommendations intended to be met over time
- Hypotheses based on long-term intake

Challenges to estimating usual intake

- Not directly observable

- Typically rely on self-report instruments
  - Measure usual intake with error

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

24-hour recall (24HR)

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

#### Food records/diaries
- Less cognitively challenging (does not rely on memory)
- Rich detail → fewer assumptions required in converting to nutrient and food group intake
- Aims to capture current diet (often over several consecutive days)
- Recording may affect intake (reactivity)
- Expensive to code (until recently)

### Challenges to estimating usual intake
- Self-report instruments used to assess usual dietary intake are affected by several types of measurement error
  - If we ignore this error, our results may be biased
Using observed rather than true intake can lead to erroneous conclusions.

Regression using observed rather than true intake produces:
- Attenuated slope estimate
- Loss of power to detect relationship between a dietary exposure and an outcome

Self-report instruments used to assess usual dietary intake are affected by several types of measurement error.

Need to understand and address error to avoid biased results.

What is measurement error?
- Difference between the true value and the value obtained from a measure

Random error
- An unpredictable source of error that contributes variability
- Instrument may be accurate (i.e., unbiased), but may not be precise
**Random error**

- An unpredictable source of error that contributes variability
  - Instrument may be accurate (i.e., unbiased), but may not be precise

If an instrument has only random error, the average of many repeat measures approximates the true value.

**Systematic error (bias)**

- A source of error in which measurements consistently depart from the true value in the same direction
  - Instrument is inaccurate (i.e., biased)

If an instrument has systematic error, the average of many repeat measures does not approximate the true value.

**Key measurement error terms**

- **Random error:**
  - Within-person random error

- **Systematic error:**
  - Person-specific bias
  - Constant additive error
  - Intake-related bias

**Within-person random error**

- True usual intake for an individual
**Introduction to measurement error in dietary intake data**

**Measurement error**

**Within-person random error**

- **Random error:**
  - Within-person random error

**Key measurement error terms**

- **Random error:**
  - Person-specific bias
  - Constant additive error
  - Intake-related bias

**Person-specific bias (systematic)**

- Defined by personal characteristics

**Constant additive error (systematic)**

- Occurs equally for all participants

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Introduction to measurement error in dietary intake data

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- Systematic error:
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Impact of measurement error
- Random error can be dealt with by averaging across repeat measures
- This is not the case for systematic error

The ideal instrument has only random error

The structure of measurement error

\[ R_{ij} = \beta_0 + \beta_1 T_i + u_i + e_{ij} \]

\[ R = \text{reported intake} \]
\[ T = \text{truth} \]
\[ i = \text{person}, j = \text{day} \]
How can we study error in a given instrument?

- Validation studies: examine measurement error structure by comparing self-report instrument with a reference instrument
- *Alloyed gold standard* used to estimate truth

| More extensive self-report instrument | Recovery biomarker |

261 men and 223 women aged 40-69 years living in Montgomery County, Maryland

- Assessed measurement error structure of:
  - Interviewer-administered 24HR
  - FFQ (Diet History Questionnaire)

**OPEN study design**

**Self-report instruments:**
- 24HR (2 repeats)
- FFQ (2 repeats)

**Recovery biomarkers:**
- Doubly labeled water (2 repeats for n=25)
- Urinary nitrogen (2 repeats)

**OPEN findings: Structure of measurement error**

- 24-hour recall (24HR)
- Food frequency questionnaire (FFQ)

**OPEN findings: Attenuation and correlation**

- **Attenuation factor:** the degree to which a regression coefficient is biased to the null (attenuated) due to measurement error
  - Closer to zero = more attenuation
- **Correlation between self-report and truth:** related to statistical power to detect diet-health relationships
  - Closer to zero = less powerful the study will be (i.e., need larger sample size)

**Energy underreporting**

- Results of OPEN (and other large validation studies) suggest a tendency toward serious energy under-reporting at the group level:
  - 24HR by 10%
  - FFQ by 30%
- Part of systematic error – due to sources of group-level bias
OPEN findings: Attenuation and correlation

- Attenuation factors and correlation coefficients are substantially better (closer to 1) for repeated 24HR compared to FFQ.

OPEN findings: hypothetical scenarios (men)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>1 FFQ</th>
<th>2 FFQ</th>
<th>1 24HR</th>
<th>4 24HR</th>
<th>14 24HR</th>
</tr>
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<tbody>
<tr>
<td>Energy</td>
<td>.08/.20</td>
<td>.09/.21</td>
<td>.18/.34</td>
<td>.30/.45</td>
<td>.36/.49</td>
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<tr>
<td>Protein</td>
<td>.16/.32</td>
<td>.17/.34</td>
<td>.20/.37</td>
<td>.37/.51</td>
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<tr>
<td>Protein Density</td>
<td>.40/.43</td>
<td>.49/.47</td>
<td>.23/.38</td>
<td>.50/.55</td>
<td>.68/.65</td>
</tr>
</tbody>
</table>

Summary: Measurement error structure

- Main sources of error for dietary components for which we can assess measurement error structure:
  - 24HR: random within-person error
    - Can be mitigated by repeats and averaging
  - FFQ: systematic error
    - Unaffected by averaging
    - Unless we have a reference instrument with only random error, cannot correct for systematic error
    - Available for only 2 to 3 dietary components

Studies using 24HR as main instrument:
- Intake distributions closer to truth because can account for random error
- Less bias and more power to detect diet-health relationships

Use the instrument with the smallest systematic error (i.e., 24HR)
- Assume it is unbiased
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Implications for study design and analysis

- Use of 24HR with repeats for estimation of usual intake distributions
- Efforts to make collection of multiple 24HR from large samples in diet-health studies feasible
  - Development of statistical techniques for the use of short-term instruments (e.g., 24HR) as main instrument in diet-health studies
- Use of 24HR as a reference instrument for studies using FFQ as the main instrument

Methods of accounting for measurement error

1. Accounting for measurement error

   a. Addressing error in 24HR data

      - 24-hour recall (24HR)
      - Larger within-person random error
      - Smaller systematic error

      - Food frequency questionnaire (FFQ)
      - Smaller within-person random error
      - Larger systematic error

   b. If repeat measures available, can distinguish random from systematic within-person variation and correct for within-person variation

2. Estimating usual intake distributions

   - 24HR with repeats – general approach:
     - Separate within- and between-person variation
     - Estimate distribution of usual intake by removing within-person variation using statistical modeling
     - May also account for nuisance effects (e.g., day of week, recall sequence, interview mode)

   - Webinars 2, 3, 5

3. 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)

Describing intake distributions

- Distribution of added sugar intake, 2-8 year olds, NHANES 2003-04

- Single-day intake
- 2-day mean intake
- Usual intake

Teaspoons of Added sugars

Density
Examining for measurement error

**Estimating group mean intake**
- Assumption that 24HR is subject to random error only = unbiased for estimating group mean intake
  - Mean from single 24HR may be sufficient

**Addressing error in FFQ data**
- 24-hour recall (24HR)
  - Larger within-person random error
  - Smaller systematic error
- Food frequency questionnaire (FFQ)
  - Smaller within-person random error
  - Larger systematic error
- Use a reference instrument to distinguish the components of systematic error and correct intake estimates

**Estimating diet-health relationships**
- FFQ as the main instrument – general approach:
  - Adjust regression coefficients for bias due to measurement error (regression calibration)
    - Requires data from a reference instrument (e.g., 24HR) administered to a subsample (calibration substudy)

**Estimating diet-health relationships**
- Future studies using a 24HR (or other short-term instrument) as the main instrument – general approach:
  - Adjust regression coefficients for bias due to measurement error (regression calibration)
  - Information from FFQ may be used to supplement data from short-term instrument

**Alleviating the effects of measurement error**
- Combine self-report instruments (e.g., 24HR and FFQ) or self-report and biomarker data to:
  - Improve power to detect relationships
  - Increase precision of estimates, e.g., percentiles of the distribution
SUMMARY & SERIES OVERVIEW

Today’s webinar: summary of main messages
- Self-report instruments used to assess usual dietary intake are affected by several types of measurement error
- Ideal instrument has only random error (unbiased)
- Structure of error in 24HR makes it the best approximation of an unbiased instrument for estimation of intake distributions and diet-health relationships
- Use best instrument possible and statistical techniques to account for measurement error

Today’s webinar: the basics
- Usual dietary intake
- Random and systematic measurement errors and their impact
- Concepts underpinning approaches to reducing measurement error

Webinars 2-5
- Describing usual intake distributions for dietary components consumed daily and episodically
- Accounting for complex survey design
- Estimating total usual intake (diet and supplements)

Webinars 6-8
- Impact of measurement error on assessing diet-health relationships
  - Dietary components consumed daily
  - Episodically consumed dietary components
- FFQ as main dietary assessment instrument

Webinars 9-12
- Multivariate applications, e.g., diet quality indices
- Improving estimation by:
  - Combining instruments
  - Combining self-report and biomarker data
- Using 24-hour recalls in diet-health studies
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**Webinar resources**
- Series schedule
- Objectives and recommended readings
- Glossary of key terms and notation
- Archived webinars (slides and audio)

riskfactor.cancer.gov/measurementerror

**Other resources**
- National Cancer Institute method, references, and SAS macros
  riskfactor.cancer.gov/diet/usualintakes
- NHANES Advanced Dietary Analyses Tutorial
  www.cdc.gov/nchs/tutorials/dietary/advanced

**QUESTIONS & ANSWERS**
Moderator: Kevin Dodd

Please submit questions using the Chat function

**Next Session**
Estimating usual intake distributions for foods and nutrients consumed daily by most persons

Tuesday, September 27, 2011
10:00-11:30 EDT

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