Estimating usual total nutrient intakes from supplements and diet

Regan Bailey, PhD, RD
Kevin Dodd, PhD

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

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

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

Two main areas of interest

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

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

### 24-hour recall (24HR)

- Aims to capture recent diet
  - Need more than one to assess usual intake
- Rich detail → fewer assumptions required in converting to nutrient and food group intake
- Expensive to collect and code (until recently)

### 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

### 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

### Usual dietary intake

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

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

**Background: Dietary Supplements**

- Use of any dietary supplement

  ![Graph](image)

  Source: NHANES, 2003-2006

- Use of multivitamin/multimineral supplements

  ![Graph](image)

  Source: NHANES, 2003-2006
**Background:** dietary supplements

*Use of vitamins and minerals (adults)*

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>NH3</th>
<th>1999-2002</th>
<th>2003-2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin C</td>
<td>31</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>Vitamin B6</td>
<td>29</td>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>Vitamin B12</td>
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<td>27</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>29</td>
<td>26</td>
<td>29</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>26</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Magnesium</td>
<td>19</td>
<td>19</td>
<td>18</td>
</tr>
<tr>
<td>Zinc</td>
<td>18</td>
<td>19</td>
<td>17</td>
</tr>
</tbody>
</table>

**Number of supplements reported by users (adults)**

<table>
<thead>
<tr>
<th>Number</th>
<th>NH3</th>
<th>1999-2002</th>
<th>2003-2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>3 or more</td>
<td>45</td>
<td>47</td>
<td>55</td>
</tr>
</tbody>
</table>

**Use of supplements by BMI (adults)**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>&lt;25</td>
<td>56</td>
<td>57</td>
<td>48</td>
</tr>
<tr>
<td>25-30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;30</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Use of supplements by education (adults)**

<table>
<thead>
<tr>
<th>Education</th>
<th>NH3</th>
<th>1999-2002</th>
<th>2003-2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than High School</td>
<td>37</td>
<td>50</td>
<td>61</td>
</tr>
<tr>
<td>High School</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than High School</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Use of supplements over time, by gender (adults)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH3</td>
<td>35</td>
<td>47</td>
</tr>
<tr>
<td>1999-2002</td>
<td>46</td>
<td>57</td>
</tr>
<tr>
<td>2003-2006</td>
<td>47</td>
<td>60</td>
</tr>
</tbody>
</table>

**Use of supplements over time, by age (adults)**

<table>
<thead>
<tr>
<th>Year</th>
<th>20-39</th>
<th>40-59</th>
<th>60+</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH3</td>
<td>37</td>
<td>43</td>
<td>47</td>
</tr>
<tr>
<td>1999-2002</td>
<td>42</td>
<td>55</td>
<td>64</td>
</tr>
<tr>
<td>2003-2006</td>
<td>41</td>
<td>55</td>
<td>70</td>
</tr>
</tbody>
</table>
Estimating total usual nutrient intake distributions from diet and supplements

Background: dietary supplements

Use of supplements over time, by race/ethnicity (adults)

- 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!

Implications of supplement use

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)

Total nutrient intake

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

Usual total nutrient intakes

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

KEY CHALLENGES AND CONSIDERATIONS

Assumptions and caveats
**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

**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

**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
Estimating total usual nutrient intake distributions from diet and supplements

Key challenges and considerations:

Nutrient from food sources = often skewed

<table>
<thead>
<tr>
<th>Density</th>
<th>Folate Intake</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>250</td>
</tr>
<tr>
<td>500</td>
<td>750</td>
</tr>
<tr>
<td>1000</td>
<td>1250</td>
</tr>
<tr>
<td>1500</td>
<td></td>
</tr>
</tbody>
</table>

Transformed single-day calcium intake from food sources

Corresponds to 711 mg

Nutrient from food sources = easy to transform

Transformed single-day calcium intake from food sources

Corresponds to ~200 mg

Corresponds to ~600 mg

Nutrient from supplements ≠ easy to transform

Transformed calcium dosage from dietary supplements

Nutrient from supplements ≠ easy to transform

Transformed estimated usual intake of calcium from dietary supplements
Key challenges and considerations

Complications of skewed 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

Key challenges and considerations

Total nutrient intake distributions

- Between- and within-person variation
  - Usual intake
  - True usual intake for a population

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

Mean % difference from label for 18 nutrients in adult MVMM

- Percent Difference from Label (Error Bars represent SEM)
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?

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)

Within-individual variability in 24HR:
- Cutpoint of interest
- Overestimation of tail probabilities
- Long right tail

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

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"

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
### When do you add supplements?

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

### 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

### 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

### Agreement between methods: % use

![Agreement between methods: % use](image)

- Any Use Cronbach $\alpha = 0.87$
- Calcium Cronbach $\alpha = 0.91$

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

![Agreement: calcium amount (mg) from supplements](image)

- Day 1: 138, 275, 295
- Day 2: 139, 278

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

![Total calcium intake: Girls, 14-18 years old](image)

- Combined: 901, 810, 887
- Users: 1165, 871, 1099
- Non-users: 810, 870, 801

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Measurement Error Webinar Series

10/18/2011
Estimating total usual nutrient intake distributions from diet and supplements

- 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

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”

Statistical approaches

Prevalence of inadequacy (% < EAR), women

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

Implications of modeling decisions
Estimating total usual nutrient intake distributions from diet and supplements

**Statistical approaches** — Research question: What is the mean calcium intake of women in the U.S., by supplement use?

- **Mean calcium intakes from food sources alone, by supplement use**
  - Project sponsored by Fortification Committee of the International Life Sciences Institute, North American Branch
  - Source: NHANES, 2003-2006

- **Mean calcium intakes from all sources, by supplement use**
  - Project sponsored by Fortification Committee of the International Life Sciences Institute, North American Branch
  - Source: NHANES, 2003-2006

**Statistical approaches** — Research question: What is the prevalence of inadequate calcium intake, by supplement use?

- **Prevalence of inadequate intakes of calcium (%<EAR) among women**
  - Source: NHANES, 2003-2006

**Statistical approaches** — Research question: What is the prevalence of inadequate intakes among women in the U.S.?

- 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

**Statistical approaches** — Research question: What is the prevalence of inadequate intakes among women in the U.S.?

- **Prevalence of inadequate intakes (%<EAR), women**

**Statistical approaches** — Research question: What is the prevalence of inadequate intakes among women in the U.S.?

- **Prevalence of inadequate intakes (%<EAR), women**

**Statistical approaches** — Research question: What is the prevalence of inadequate intakes among women in the U.S.?

- **Prevalence of inadequate intakes (%<EAR), women**

### 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

**Prevalence of inadequate intakes (%<EAR), women**

- **Dietary Folate**
- **Total Folate (Diet + DS)**

**Prevalence of inadequate intakes (%<EAR), women**

- **Dietary Folate**
- **Total Folate (Diet + DS)**

**Prevalence of inadequate intakes (%<EAR), women**

- **Dietary Folate**
- **Total Folate (Diet + DS)**
**Prevalence of inadequate intakes (%<EAR), women**

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>Non-Users</th>
<th>Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>19-30</td>
<td>26</td>
<td>21</td>
</tr>
<tr>
<td>31-50</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>51-70</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>71+</td>
<td>0.7</td>
<td>1.1</td>
</tr>
</tbody>
</table>

**Prevalence of excess intakes (%>UL), women**

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>Non-Users</th>
<th>Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>19-30</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>31-50</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>51-70</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>71+</td>
<td>0</td>
<td>6</td>
</tr>
</tbody>
</table>

**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

**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)

**Caveats**

- There is no one right way to handle dietary supplements
- Know your research question
- Know your sample
- Know your nutrient
SUMMARY

Background (measuring usual dietary intake)
Key challenges and considerations
Statistical approaches
Assumptions and caveats
Summary

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

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

SUMMARY

Thank you!

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

QUESTIONS & ANSWERS

Moderator: Susan Krebs-Smith

Please submit questions using the Chat function

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