Methods of Measuring Usual Dietary Intake for Risk Assessment

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Objectives

- Describe major dietary assessment approaches used in population studies
- Highlight strengths and weaknesses
- Describe and discuss innovative methods
  - Collecting data
  - Analyzing data
I gather inaccurate data for a living. Luckily no one realizes it.

Your glass is half full.
Main Dietary Assessment Methods in Population Studies

- Food records or diaries
- 24-Hour dietary recalls
- Food frequency questionnaires (FFQs)
- Brief methods
Food Diaries or Records

• Variations in approach
  – Trained or untrained respondents
  – Detailed review or not
  – Highly standardized coding rules or not
  – Layout of record, instructions
  – Development of electronic methods: PDA, cell phones
  – Quality and completeness of nutrient database
Food Diaries or Records: Strengths

- Intake is quantified, detailed
- Could be relatively accurate
- Data are rich
  - Nutrients
  - Cooking practices
  - Meal and eating frequency
Food Records/Diaries: Weaknesses

- Recording influences diet (reactive tool)
  - Biased measurement
- Requires literacy
- High respondent and investigator burden
- Multiple days required to estimate usual intake
- Sample selection bias
- Completion worse over time
- Underreporting is typical
  - Worse with overweight/obese
24-Hour Dietary Recalls

• Variations in approach
  – Training of interviewers
  – Standardization of probing questions
  – Multiple passes through the day
  – Computer vs. paper/pencil administration
  – In-person vs. telephone
  – Portion size models or measurement aids
  – Quality and completeness of nutrient database
  – Development of self-administered automated systems
24-Hour Dietary Recall: Strengths

- Intake is quantified, detailed
- Data are rich
  - Nutrients
  - Cooking practices
  - Meal and eating frequency
- Does not affect eating behavior
- Lower sample selection bias than record
  - Literacy not required (if interviewer administered)
  - Respondent burden relatively low
24-Hour Dietary Recall: Weaknesses

- Imperfect knowledge and memory
- Multiple days required to estimate usual intake
- Costly to administer
  - Highly trained interviewers
- Some evidence that reporting declines with multiple administrations
- Underreporting is typical
  - Worse with overweight/obese
Food Frequency Questionnaire (FFQ)

• Variations in approach
  – Number of foods, clarity of questions
  – Portion size questions: pictures vs. text description
  – Time frame
  – Development of food list, nutrient database
  – Type of administration: computer vs. paper
  – Specificity to population of interest
  – Supplement intake
  – Food preparation
FFQ: Strengths

- Low respondent burden
- Attempts to estimate “usual” individual intake of foods with one administration
- Information on total diet queried
  - Depends on food list
- Does not affect eating behavior
- Low cost of administering/processing
  - Machine-readable scanned forms
  - Computer-generated data
FFQ: Weaknesses

- Lacks detail
  - Finite food list
  - Details of cooking methods, specific food types lost
- Cognitively complex
- Requires literacy
- Severe measurement error: prone to bias
- Different FFQs can behave quite differently
- Different populations respond differently
Biomarkers

- **Recovery:** represent 1:1 intake exposure
  - Very few available
- **Concentration:** reflect the biological response to intake
  - Cannot be used to assess amount consumed
  - Correlate to amount consumed
  - May reflect short or long term intakes
  - Some are appropriate for risk assessment
- **Tightly controlled:** no relationship to intake
Isn’t There ANYTHING Better Than This?

I AM YOUR IDEA.
ONE DAY YOU’LL LOOK FOR ME AND I’LL BE GONE
Innovative Ideas in Dietary Assessment

- Web-based, automated FFQs
- Self-administered, automated, web-based, 24-hour dietary recalls
- Real time data collection of food records
- Voice recognition software
- Combining methods
  - FFQ with 24-hour recalls
Please check the box next to each food that you ate at least once in the past 12 months.

<table>
<thead>
<tr>
<th>Fruits</th>
<th>Vegetables, Potatoes, Dried Beans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applesauce</td>
<td>Soup, Chili, Mexican Foods</td>
</tr>
<tr>
<td>Apples</td>
<td>Rice, Pasta, Pizza</td>
</tr>
<tr>
<td>Pears (fresh, canned, or frozen)</td>
<td>Cereal, Pancakes, Breads</td>
</tr>
<tr>
<td>Bananas</td>
<td>Peanut Butter, Jelly</td>
</tr>
<tr>
<td>Dried fruit</td>
<td>Cold Cuts, Luncheon Meats, and Hot Dogs</td>
</tr>
<tr>
<td>Peaches, nectarines, or plums</td>
<td>Meat, Poultry, Fish</td>
</tr>
<tr>
<td>Grapes</td>
<td>Eggs and meat alternatives</td>
</tr>
<tr>
<td>Cantaloupe</td>
<td>Chips, pretzels, and other snacks</td>
</tr>
<tr>
<td>Melon, other than cantaloupe</td>
<td>Yogurt and Cheese</td>
</tr>
<tr>
<td>Melon, other than cantaloupe (such as watermelon or honeydew)</td>
<td>Sweets, Baked Goods, Desserts</td>
</tr>
<tr>
<td>Dried fruit, such as prunes or raisins (not including dried apricots)</td>
<td>Spreads and Dressings</td>
</tr>
<tr>
<td>Peaches, nectarines, or plums</td>
<td></td>
</tr>
<tr>
<td>Grapes</td>
<td></td>
</tr>
</tbody>
</table>
You ate apples in the past 12 months.

How often did you eat apples?

- 1-6 times per year
- 7-11 times per year
- 1 time per month
- 2-3 times per month
- 1 time per week
- 2 times per week
- 3-4 times per week
- 5-6 times per week
- 1 time per day
- 2 or more times per day

Each time you ate apples, how many did you usually eat?

- Less than 1 apple
- 1 apple
- More than 1 apple

Continue
Web-Based, Automated FFQs

- Advantages beyond paper and pencil:
  - Cleaner data
  - May take less time to complete
- Disadvantages beyond paper and pencil
  - (It’s still an FFQ)
  - Computer access and related technology issues
NCI’s Vision for an Automated Self-Administered 24-Hour Recall (ASA24)

• 24-HRs that are automated AND self-administered:
  – Complete system for probing, coding, analysis
  – Accessible on the Web, publicly available
  – Easily updated

• Adaptable to other languages

• Modeled after dietary surveillance systems in NHANES (AMPM)

• Multiple 24-HRs could be collected for minimal cost
Please tell me what you had to eat or drink yesterday, Richard. Let’s start with the kind of meal it was.

Click on a meal, Snack or Just a drink from this list.
Lunch

What time did you eat lunch?

Select the hours, minutes and whether lunch was AM or PM.

Click the  button when you are finished.
**ASA24**

### MEALS
- Breakfast
- Brunch
- Lunch
- Dinner
- Supper
- Snack
- Just a drink

### MY SELECTIONS

<table>
<thead>
<tr>
<th>▼ Lunch 12:30 PM</th>
</tr>
</thead>
</table>

### FOODS
- Beans, peas, nuts, soy products
- Beverages
- Breads, other baked goods
- Cereals and energy bars
- Chicken, turkey, poultry
- Condiments, Salsa, Sauces
- Dairy, dairy substitutes
- Desserts and sweets
- Eggs
- Ethnic Foods
- Fats, Oils, Dressings, Spreads
- Fish, shellfish
- Fruit
- Meat
- Pancakes, waffles, crepes
- Pasta, noodles, and spaghetti
- Rice and other grains
- Salads
- Salty snacks
- Sandwiches
- Soup
- Sugars and sweeteners
- Vegetables and vegetable juice
<table>
<thead>
<tr>
<th>MEALS</th>
<th>MY SELECTIONS</th>
<th>FOODS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast</td>
<td></td>
<td>▼ Lunch 12:30 PM</td>
</tr>
<tr>
<td>Brunch</td>
<td></td>
<td>▼ Beverages</td>
</tr>
<tr>
<td>Lunch</td>
<td></td>
<td>▪ Beer, wine, cocktails, liquor</td>
</tr>
<tr>
<td>Dinner</td>
<td></td>
<td>▪ Coffee, specialty coffees</td>
</tr>
<tr>
<td>Supper</td>
<td></td>
<td>▪ Juice, juice drinks</td>
</tr>
<tr>
<td>Snack</td>
<td></td>
<td>▪ Milk, all types</td>
</tr>
<tr>
<td>Just a drink</td>
<td></td>
<td>▪ Milk drinks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Rice milk, rice drinks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Smoothies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Soda, pop, soft drinks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Soy milk, soy drinks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Tea, hot &amp; iced</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Breads, other baked goods</td>
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<tr>
<td></td>
<td></td>
<td>▪ Cereals and energy bars</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Chicken, turkey, poultry</td>
</tr>
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<tr>
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<td></td>
<td>▪ Eggs</td>
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<tr>
<td></td>
<td></td>
<td>▪ Ethnic Foods</td>
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<tr>
<td></td>
<td></td>
<td>▪ Fats, Oils, Dressings, Spreads</td>
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<tr>
<td></td>
<td></td>
<td>▪ Fish, shellfish</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Fruit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Meat</td>
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<tr>
<td></td>
<td></td>
<td>▪ Pancakes, waffles, crepes</td>
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<tr>
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<td></td>
<td>▪ Pasta, noodles, and spaghetti</td>
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<tr>
<td></td>
<td></td>
<td>▪ Rice and other grains</td>
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<td></td>
<td>▪ Soup</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Sugars and sweeteners</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Vegetables and vegetable juice</td>
</tr>
</tbody>
</table>

Click the disclosure triangle to reveal or hide more choices.
“Soda, pop, soft drinks.”

This list is longer. Use your mouse to drag the scroll bar and you will see the rest of the list.

*Click on a food to see its picture.*
Coke (regular)."

This picture may not be an exact match, but that's okay.

Click the SELECT button at the bottom if you had Coke (regular).
You can add more foods and drinks to your lunch.

You can tell me the food by clicking on a FOODS category in this list. Or, you can type the name of a food in the search box above.

You can also click on a different meal, Snack or Just a drink.
### Breakfast
- 9:00 AM
  - Healthy Choice Almond Crunch cereal
  - Croissant (plain)
  - 2% milk

### Lunch
- 12:30 PM
  - Coke (regular)
  - Cheeseburger
  - Green beans

### Snack
- 3:00 PM
  - Mr. Goodbar chocolate bar
  - Poland Spring bottled water

### Supper
- 4:00 PM
  - Betty Crocker Hamburger Helper

You can add more foods and drinks to your supper.

You can tell me the food by clicking on a **FOODS** category in this list. Or, you can type the name of a food in the **search** box above.

You can also click on a different **meal**, **Snack** or **Just a drink**.

### Foods
- Beans, peas, nuts, soy products
- Beverages
- Breads, other baked goods
- Cereals and energy bars
- Chicken, turkey, poultry
- Condiments, Salsa, Sauces
- Dairy, dairy substitutes
- Desserts and sweets
- Eggs
- Ethnic Foods
- Fats, Oils, Dressings, Spreads
- Fish, shellfish
- Fruit
- Meat
- Pancakes, waffles, crepes
- Pasta, noodles, and spaghetti
- Rice and other grains
- Salads
- Salty snacks
- Sandwiches
- Soup
- Sugars and sweeteners
- Vegetables and vegetable juice
You clicked the STOP button to indicate you have finished entering everything you ate or drank yesterday from midnight to midnight.

If this is correct, click the OK button. If not, click the CANCEL button.

Are you sure you have finished entering everything you ate or drank yesterday from midnight to midnight?

CANCEL YES
Now we'll go through each of your food selections meal by meal to get more detailed information.

We've already completed Breakfast, so let's move on to Lunch.
Your next food is “Green beans.”

How were the green beans prepared?

Please click an option.

- Breakfast: 9:00 AM
  - Coke (regular)
  - Cheeseburger

- Lunch: 12:30 PM
  - Coke (regular)
  - Cheeseburger

- Green beans

- Snack: 3:00 PM
  - Mr. Goodbar chocolate bar
  - Poland Spring bottled water

- Supper: 4:00 PM
  - Betty Crocker Hamburger Helper

- Preparation?
  - Cooked
  - Creamed
  - Pickled
  - Raw
  - Don’t know
Was it fresh, frozen, canned, or dry?

Please click an option.
How much of the green beans did you actually eat?
Please click an option.
How much of the green beans did you actually eat?

Please click an option.

- Breakfast: 9:00 AM
- Lunch: 12:30 PM
  - Coke (regular)
  - Cheeseburger
- Green beans
- Snack: 3:00 PM
  - Mr. Goodbar chocolate bar
  - Poland Spring bottled water
- Supper: 4:00 PM
  - Betty Crocker Hamburger Helper

- Prepared with fat?
  - No fat or oil used
  - Animal fat/drippings
  - Butter
  - Margarine (including spreads)
  - Oil (any kind)
  - Shortening
  - Other fat or oil
  - Unknown fat or oil
  - Don't know if fat or oil was used

- Other additions?
  - Yes
  - No
  - Don't know

- Amount you ate?
  - 1/4 cup
  - 1/2 cup
  - 3/4 cup
  - 1-1/4 cups
  - 1 cup
  - 1-1/2 cups
  - 1-3/4 cups
  - 2 cups
  - More than 2 cups
  - Don't know

SELECT
ASA24

Next Steps

• Alpha (α) prototypes
• Conduct cognitive testing
• Expected completion: Summer 2007
• Validation planned
NCI Method to Estimate Usual Intake

• New statistical method to estimate
  – Usual nutrient and food intake distributions for dietary surveillance or risk assessment
  – Individual usual nutrient and food intake for assessing the relationship between food intake and disease risk
Definition of Usual Intake

- Theoretical long-run average daily intake of a dietary component
- Common operational definition: average daily intake over past year
Usual Intake Distribution

• Needed to estimate proportion of the population above or below a particular cutoff
1-day vs. Usual Intake (UI) Distributions

Usual Intakes

One-day Intakes

Usual Energy Intake (kcal)
Evolution in Estimating Usual Nutrient Intake Distributions

- Generally uses 24-HR and/or records
- Average of a few single-day measurements
- Statistical modeling
  - National Research Council method
  - Iowa State University method
Statistical Modeling

• Removes day-to-day variability from 24-HRs

• Approach well-established for:
  – Most nutrients
  – Foods consumed daily by nearly everyone (such as total fruits and vegetables)

• Approach less well-established for episodically consumed foods
Estimating UI Distributions of Episodically Consumed Foods

• Small number of 24-HRs makes this difficult
  – large number of “zero” intakes observed
Challenge: Zero Single-Day Intakes

Spike at Zero

Whole Grains Men

Skewed Distribution

Source: EATS
Usual Intake = Probability × Amount

- Relative frequency of nonzero 24-HRs provides information about the distribution of consumption probability
- Amounts on consumption days always positive, so apply “nutrient” methods for distribution of usual consumption-day intake
- Combine both distributions to get distribution of usual intake
The NCI Method For Foods

Two-Part Nonlinear Mixed Model

Part I (Probability): Logistic regression with person-specific effects

\[ \text{logit}(24\text{-HR intake}) = \text{Intercept}_i + \text{Slope}_i \times \text{Covariate}_i + \text{Person-specific Effect}_i \]

Part II (Amount): Nonlinear mixed model as for nutrients

\[ \text{Transformed}(24\text{-HR intake}) = \text{Intercept}_{\|i} + \text{Slope}_{\|i} \times \text{Covariate}_{\|i} + \text{Person-specific Effect}_{\|i} + \text{Error}_{\|i} \]

Both parts estimated simultaneously (advantage over ISU method)
- Random effects can be correlated
- Two parts of the model can share covariates
NCI Method: Efficiently Accounts for Effects of Covariates on Usual Intake

- Separate estimation of usual intake distributions for subgroups may be impractical/inefficient
- Use of covariates in NCI method allows direct evaluation of covariate effects on usual intake, in addition to correction for measurement error
Food Propensity Questionnaire (FPQ)

- FFQ that does not query portion size
- Directly queries long-term frequency of intake
- Relatively low respondent/interviewer burden
- Can be used as a covariate in NCI model
Rationale for Using an FPQ as a Covariate

• Responses to FPQ are related to information from 24-HR
  – Probability
  – Amount

• Based on these relationships, FPQ responses act as covariates in model estimating individual usual intake from 24-HRs
Can We Trust the FPQ?

- Concerns about bias in FFQs when used to measure absolute intake
- In this case, FPQ being used:
  - In conjunction with another instrument
  - As covariate in model to predict probability and amount of food consumed
  - Nutrient or food group estimates from the FPQ are not used
Relationships Between Diet and Outcomes

- Challenge: usual intake is unobservable
  - have 24-HR intakes or FFQs instead
- Typical Response: Fit disease model to average of 24-HR intakes or FFQ
- NCI method suggests that at least 2 recalls and a FPQ might be useful
Effect of Measurement Error

-3 -2 -1 0 1 2 3
-3 -2 -1 0 1 2 3

Observed (red) vs true (blue) data

Source: Simulated data
Effect of Measurement Error

• Typically measurement error causes two things:
  – bias in the estimated exposure effect (flattened or attenuated true slope)
  – more variation about the flattened line, thus loss of statistical power for testing significance of the exposure effect
Summary: NCI Method

- Important assumption that 24-HR is an unbiased instrument for measuring usual intake
- Misreporting of energy on 24-HR suggests misreporting of some foods
- For foods reported with bias on 24-HR, estimates of usual intake will be biased
- FPQ may improve estimation
- Development of user-friendly software for this purpose
- Requires collaboration between statisticians and nutritionists
- October *Journal of the American Dietetic Assn*: 3 papers on this work: Dodd et al, Subar et al, Tooze et al
Conclusion

- A good estimate of usual intake is necessary for risk assessment
- Usual intake cannot be observed
  - Can be modeled
GOOD LUCK TO US ALL!