Principles of Dietary Assessment

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Assessment of Dietary Intake

- Collection of information on foods and beverages consumed
- Consumption data are used to compute the intake of:
  - energy
  - nutrients
  - other food components
  - foods, food groups, whole diet/dietary patterns
- Basic methods have been used for decades; refined based on current technology

Components of Food

- Energy
- Major energy sources: *protein, carbohydrate, fat, alcohol*
- Nutrients: *vitamins, minerals, amino acids, fatty acids*
- Additives: *preservatives, colors, flavor enhancers*
- Agricultural chemical contaminants: *pesticides, herbicides*
- Microbial toxin contaminants: *aflatoxins*
- Inorganic contaminants: *heavy metals, PCBs*
- Chemicals formed in processing or cooking food: *heterocyclic amines*
- Natural toxins: *plant products*
- Other natural compounds: *cholesterol*

Basic Dietary Assessment Methods

- Current diet
  - *24-hour dietary recall*
  - *food record*
  - based on foods and amounts actually consumed by a person on one or more specific days
- Habitual diet
  - *diet history*
  - *food frequency questionnaire*
  - based on a person's *perceptions* of usual intake over a less precisely defined period of time

Recall and Record – General

- Most epidemiologic studies of diet and disease: *relative* rankings of food and nutrient intakes are adequate for determination of odds ratios or relative risks – FFQ is appropriate
- Some situations (e.g., comparing nutrient intakes with dietary recommendations or evaluating the effectiveness of dietary interventions), estimates of *absolute* intake are required – recalls or records are the methods of choice

Recall and Record – General

- *Open ended* – can accommodate any level of food description detail that is necessary for addressing the research question
- Also can accommodate any extent of diversity in the study population
- Permits flexibility for data analysis – data can be analyzed by nutrients, foods, food groups, or meals

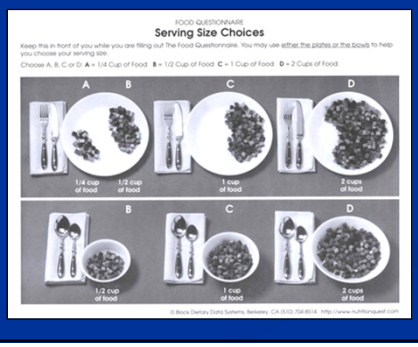
24-Hour Dietary Recall

Principles

- Person recalls food and beverage intake during the previous 24 hours
- Usually conducted during an interview
  - in person
  - by telephone (reduces travel; subjects may be less likely to modify their intake)

Food Quantities

- Use techniques to enhance portion size estimation
  - household measures
  - food models: 2D, 3D
  - food photographs



Dietary Recall

Practical Aspects

- Typically conducted through a personal, in-depth interview using an open format
- May be obtained interactively using computer software that prompts the interviewer to collect all necessary information about foods consumed
- Well-trained interviewers are crucial – probing questions are required to help person remember all foods consumed, without leading the respondent

Dietary Recall

Practical Aspects

- Days of the week should be equally represented – should include a weekend day
- Recalled day usually is defined as when the respondent gets up one day until he/she gets up the next day
- No prior notification should be given to subjects
  - might help memory of some
  - others might change their usual diet

Practical Aspects

USDA 5-step Multiple-pass method

1. Quick list: an uninterrupted listing by the subject of foods and beverages consumed
2. Forgotten foods list: queries subject on categories of foods that frequently are forgotten
3. Time and occasion at which foods were consumed
4. Detail cycle: elicits descriptions of foods and amounts eaten, aided by the interactive use of a sheet containing pictures of sample portion sizes
5. Final probe review

Strengths and Uses

- Design is appropriate for describing the mean intakes of large groups of subjects
- ≥2 days provide data on within- and between-individual variation
- Open interviews provide detailed information on specific foods, including less frequently eaten foods
- Information on when and where foods were eaten

Strengths and Uses

- Administration time is short: 20-30 min
- Time period is well defined
- Required memory span is short
- Literacy is not required
- Not culture- or ethnic-specific

Weaknesses

- Respondent recall depends on short-term memory
- Subject must be willing and able to recall diet
- Some subjects have little awareness of what they eat
- Portion size is difficult to estimate accurately

Weaknesses

- More representative of group than individual intake
- Represents intake at one period – not usual intake
- One day's intake for each subject does not supply information on *within*-person variation and will overestimate *between*-person variation
- >100 days may be needed to obtain a valid estimate of intake for some nutrients (e.g., vitamin A)

Food Record

Principles

- Detailed listing of all foods and beverages consumed by a person on one or more days
- Intake recorded by the subject at the time the foods are eaten to minimize reliance on memory
- Requires subjects to be trained in methods of keeping complete and accurate records
- Portion sizes described in household measures (glass, bowl), utensils commonly found in home (measuring cups and spoons, ruler), and informal measures (numbers, pieces, scoops)

Food Record

Practical Aspects

- Multiple days are required to be representative of usual intake; should include a weekend day
- No more than 3 or 4 consecutive days usually are included due to respondent fatigue
- Respondents must be trained to record the level of detail necessary to describe the foods and amounts consumed accurately
- Record should be checked in detail at the end of the recording period by a dietitian, and coded for computer analysis as soon as possible

Practical Aspects

- Food records can be used to estimate a person's intake
- Number of days required to obtain nutrient estimates with a high probability of being within 20% of a person's true, long-term intake:
  - 7-14 random days for energy
  - 10-27 days for protein
  - 10-23 days for fat
  - 20-50+ days for cholesterol, vitamins

Practical Aspects

- In *principle*, records can provide a reasonable estimate of a person's intake
- In *practice*, the number of days required often is prohibitive
- Number of days required is considerable for energy, macronutrients
- Number of days required is extremely large for micronutrients

Food Record

Strengths and Uses

- Two or more days of recording provide data on within- and between-person variation in dietary intakes
- Multiple days of recording may allow persons to be classified according to their usual intakes
- 1- or 2-day records kept intermittently over a year may provide a reasonable estimate of usual intake

Food Record

Strengths and Uses

- Provides data on less frequently eaten foods
- Does not rely on memory
- Time period is defined
- Portions can be measured or weighed to increase accuracy – detailed information

Food Record

Weaknesses

- Respondents must be literate, highly cooperative, and motivated
- Response bias may occur due to overrepresentation of more highly educated persons interested in diet and health
- Foods consumed away from home may be less accurately reported

Food Record

Weaknesses

- Usual eating pattern may be influenced by the recording process
- Record keeping increases subject burden – may adversely affect response
- Accuracy of records may decrease as the number of days increases
- Moderate underreporting may occur in certain groups (e.g., overweight/obese)

Food Record

Food Frequency Questionnaire

Principles

- Underlying principle in epidemiologic studies – long-term diet is the most relevant exposure, rather than intake on a few specific days
- Sacrifice more accurate intake measurements obtainable on one or a few days in exchange for more crude information over an extended period of time

Principles

- Easier to describe one's usual frequency of consuming a food than to describe foods eaten at a specific meal in the past
- *Generic* as opposed to *episodic* memory
- General questions about whether a specified food is eaten almost never, is eaten frequently, or something in between

Principles

- Estimates how frequently certain foods and beverages are consumed during a specified period – usually the past 12 months
- Food list may include only items high in certain nutrients (e.g., fat, calcium), or it may attempt to represent overall diet
- Nutrient values must be assigned to each food listed

Food Frequency Questionnaire

Principles

- Initial questionnaires did not include quantitative estimates of portion sizes – *non-quantitative*
- Currently, most include an estimation of portion sizes – *semi-quantitative*
- Inclusion of portion sizes is problematic – errors inherent in the estimation of portion sizes may outweigh the variance in the intake of most foods

Food Frequency Questionnaire

Practical Aspects

- Dietary data from FFQs can be used to rank persons according to their intake of specific foods or nutrients – this is the primary objective in most epidemiologic studies
- Also can be used to estimate absolute intakes with *post hoc* statistical methods, with limitations
- Dietitians are not required for the interview
- May be mailed; accompanying instructions are important

Practical Aspects

<u>Two basic components of the questionnaire</u>

1. List of foods and food groups

2. Set of responses, assessing:

    - frequency of consumption

    - quantity/portion sizes

Food List

- Comprehensive assessment of intake (food list) has the following advantages:
  - impossible to anticipate at the beginning of a study what questions regarding diet will be of interest at the end of the study
  - total food intake (energy) may be related to the disease outcome and/or is needed to adjust specific nutrient intakes
- List should be short enough to prevent subject fatigue, but comprehensive enough to adequately capture the nutrients of interest

Frequency Response Section

<u>Multiple-choice response format</u>

- Number of options ranges from 5 to 10
- Too few categories (too broad) decreases discrimination capacity of the questions
- Too many categories can be overwhelming for the respondent
- Greater detail at the high-frequency end

APPENDIX 5–1
1980 Nurses' Health Study Dietary Questionnaire.

Frequency distributions of responses (%) are also given for this population.

For each food listed, check the box indicating how often, **on average**, you have used the amount specified **during the past year**. If your intake of a food item has greatly increased or decreased during the past 10 years, indicate this in the last 2 columns.

FOOD AND AMOUNTS	Average use last year								
	6+ per day	4–6 per day	2–3 per day	1 per day	5–6 per week	2–4 per week	1 per week	1–3 per month	Almost Never
Dairy Foods Skim or low fat milk (8 oz. glasses)	0	1	12	20	5	12	6	5	39
Whole milk (8 oz. glasses)	0	0	4	10	2	8	7	7	62
Yoghurt, (1 c.)	0	0	0	2	1	8	9	20	61
Ice cream (½-c.)	0	0	0	3	3	18	22	32	22
Cottage cheese (½-c.)	0	0	1	3	3	18	17	29	28
Hard cheese, plain or as part of a dish (slice or servings)	0	0	3	12	13	36	20	11	5
Margarine (pats added to food or bread)	2	4	28	23	9	11	4	3	17
Butter (pats added to food or bread)	1	2	10	10	4	7	4	5	58
Fruits Fresh apples or pears (1)	0	2	3	15	6	27	19	20	11
Oranges (1)	0	0	2	11	4	22	19	23	19
Orange or grapefruit juice (small glass)	4	3	4	35	9	19	10	10	13
Peaches, apricots or plums (fresh, ½-c. canned, or dried)	0	1	1	3	2	14	19	32	30
Bananas (1)	0	0	0	6	4	23	25	27	15
Other fruits (fresh, or ½-c. canned)	0	0	2	9	6	24	23	23	14
Vegetables String beans (½-c.)	0	0	0	2	3	30	46	16	3
Broccoli (½-c.)		0	0	1	1	16	42	29	11
Cabbage, cauliflower, brussels sprouts (½-c.)	0	0	0	1	1	12	34	37	15
Carrots (whole or ½-c. cooked)	0	0	0	3	4	21	39	26	7
Corn (ear or ½-.c)	0	0	0	0	1	13	38	32	15
Spinach or other greens (½-c.)	0	0	2	10	8	21	30	20	10
Peas or lima beans (½-c. fresh, frozen or canned)	0	0	0	1	1	15	39	29	15
Yellow (winter) squash (½-c.)	0	0	0	0	0	4	14	34	48
Sweet potatoes (½-c.)			0	0	0	1	4	29	67
Beans or lentils, dried (½-c.)	0	0	0	0	0	3	12	36	48
Tomatoes (1) or tomato juice (4 oz.)	0	0	1	11	12	33	24	15	4

Willett, 2013

Portion Size Information

- Generally, individuals are unable to describe portion sizes accurately
- They have difficulty conceptualizing specified serving sizes (sm, med, lg)
- Substantial within-person variation exists in portion sizes for most foods

Food Frequency Questionnaire

Portion Size Information

- Several studies have indicated that portion size data provide little additional information in ranking persons
- Portion sizes vary less among individuals than do frequencies of use – portion size data are relatively unimportant
- If the amount of variation due to error exceeds the amount of information gained on true variation in portion sizes, validity actually can be reduced

Strengths and Uses

- Assesses long-term and usual food intake
- Persons can be ranked according to nutrient intake relative to other members in the group
- Can be self-administered (in-person or by mail); trained personnel are not needed
- Respondent burden generally is low; small time commitment
- Can be automated easily (machine readable)
- Relatively inexpensive

Weaknesses

- Memory of food use in the past is required
- Quantification of portion sizes might be less than accurate
- No information on day-to-day variation in intake is provided
- Not suitable for groups who consume ethnic-specific foods that are not on the food list

Food Frequency Questionnaire

Weaknesses

- Validity is highly dependent on the selection of foods on the list
- Longer food lists and longer reference periods often lead to overestimation of intake
- Cognitive processes for answering questions about food frequency may be more complex than those about the daily food pattern
- Current intake may bias the recollection of past intake

Food Frequency Questionnaire

New Technologies

New Technologies

- Computerized data entry
- Web-based dietary questionnaires
- Digital photography
- Portion size determination using digital images and photogrammetry

Computerized Data Entry

- Information from 24-hour dietary recalls can be directly entered using laptop or desktop computers
- Interactive software prompts interviewer to collect all necessary information about foods consumed
- Computer guides the interviewer through a series of menus to capture descriptive information
- Decreases potential for data entry errors; increases detail of dietary information collected

Web-based Questionnaires

Diet History Questionnaire II (DHQ II – NCI)

•FFQ consisting of 140 questions on food items

•Paper version has been available for many years

•Available on the web for research use – DHQ*Web
- automated skip pattern
- subjects queried to complete all questions
- prevents missing or inconsistent answers
- navigate within the instrument as needed
- log in any time to continue the questionnaire

•Analysis software (Diet*Calc) available online

http://appliedresearch.cancer.gov/dhq2/

Web-based Questionnaires

- Web-PDHQ – pictorial, web-based version of the DHQ
- CASI-DH – Computer-Assisted Self-Interview Diet History
  - web-based, multi-media
  - self-interview approach – no personnel required
  - meal-based – cues
  - picture-based – foods and portion sizes
  - audio component
  - fully quantitative
  - includes thousands of foods
  - does not truncate foods or frequencies of consumption

Web-based Questionnaires

- Automated Self-administered 24-hour Recall (ASA24™)
  - web-based
  - self-interview approach – no personnel required
  - graphic enhancements
  - animated character to guide participants
  - audio cues to enhance use in low-literacy populations
  - photographs to assist in reporting portion sizes
  - analysis files available on the researcher website
  - available free of charge to researchers

http://riskfactor.cancer.gov/tools/instruments/asa24/

Digital Photography

Digital Photography of Foods Method[1]

•Digital Images of foods taken before and after eating

•Transmitted to central location; linked to Food and Nutrient Database for Dietary Studies 3.0

•Rater estimates the percentage of the standard portion of each food

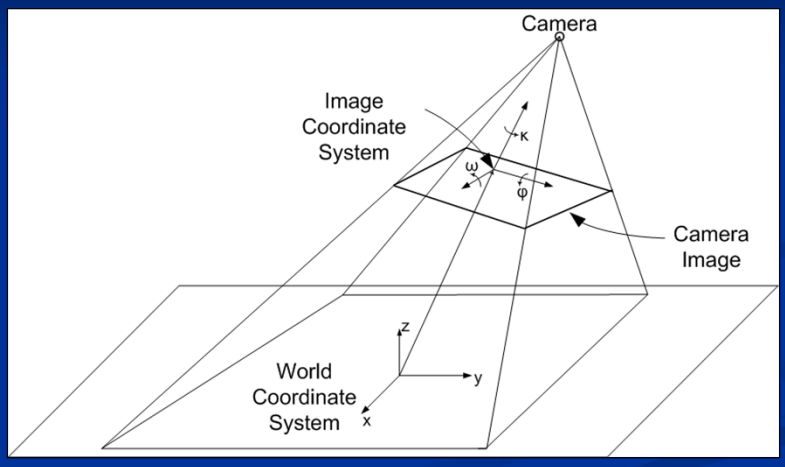
•Food Photograph Application automatically calculates the energy and nutrient content of foods

[1]Martin et al. J Hum Nutr Diet. 2014;27 Suppl1:72-81.

Digital Images/Photogrammetry

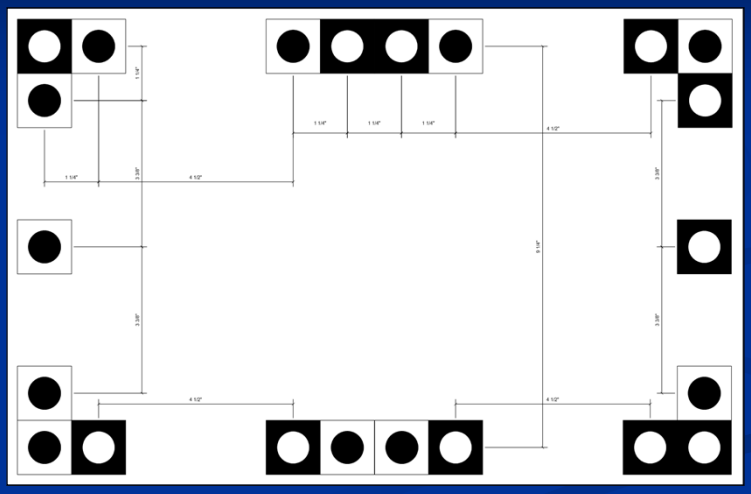
- Estimating portion size in dietary assessment is problematic
- Camera phones have become ubiquitous in American society
- Combination of camera phone digital images and close-range photogrammetry may facilitate portion size estimation

Digital Images/Photogrammetry



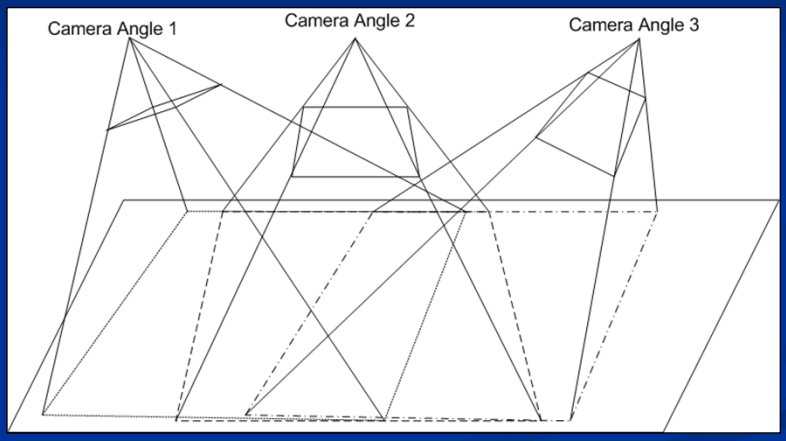
Using real world and digital image coordinate systems to determine camera location.

Digital Images/Photogrammetry



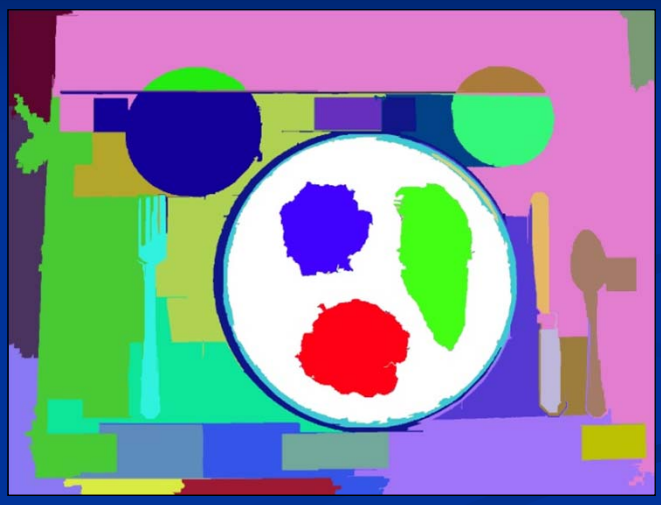
Placemat, incorporating monument points.

Digital Images/Photogrammetry



Multiple camera angles.

Digital Images/Photogrammetry



Food segmentation on a plate.

Food Composition Data Sources and Nutrient Computation Systems

Calculation of Nutrient Intakes

- Some instances: existing databases and computer software can be used (for standard summaries from 24-hour recalls or diet records)
- Other situations: structured questionnaire created for a specific application – may be necessary to assemble a special database

Variability of Nutrient Content

- Assumption – nutrient content of a specific food is fairly constant
- Not seriously violated for many nutrients
  - e.g., β-carotene: 3-4-fold difference
  - calculation of intake provides a reasonable estimate of true intake
- Other nutrients – assumption does not hold
  - e.g., selenium: 50-fold difference
  - calculation of intake unlikely to provide useful information

Variability of Nutrient Content

- Many major food constituents – dietary fats, carbohydrate fractions, calcium – assumption of constant nutrient content is not seriously violated
- For other foods, nutrient database designers have provided increasingly specific information
  - specific cuts of meat
  - specific methods of food preparation
  - specific manufacturers of prepared food

Calculation of Nutrient Intake

- Calculation of nutrient intakes from information on food consumption requires 2 components:

    1. Food composition data

    2. Computer software to perform calculations

Food Composition Information

- Food composition information needed for 2 general purposes:

    1. Analysis of open-ended dietary data – 24-hour recalls, dietary records
        - requires extensive and comprehensive database

    2. Analysis of structured dietary data – FFQs
        - customized nutrient database must be created

Features of Nutrient Database

- Food composition data should be as accurate and up-to-date as possible
- Uniformity in determination of nutrient composition
- Comprehensive – no foods should have blank values
- Every nutrient value should be carefully documented so that the source of information can be verified, if necessary
- Specificity especially important for nutrients that are affected by manufacturing or processing

Sources of Food Composition Data

- Constructing food composition database for a specific application requires multiple sources of information, including:
  - government sources (e.g., USDA)
  - commercial sources (e.g., food manufacturers)
  - scientific literature (published values)

Computation of Nutrient Intakes - FFQ

- Total intake of a nutrient is calculated as the sum of the products of the frequency weight and nutrient content for each food:

  Σ (frequency weight x nutrient content)

- Frequency weights: assign weight of 1.0 to "once a day" and proportional weights to other responses:

  e.g., "2-3 times a day" = 2.5

- If separate portion size questions are asked, product for each food is multiplied by the weight proportional to the usual serving size

Computation of Nutrient Intakes - FFQ

	FOODS AND AMOUNTS	Never or less than once per mo	1-3 per mo	1 per wk	2-4 per wk	5-6 per wk	1 per day	2-3 per day	4-5 per day	6+ per day
A	Eggs (1)	○	○	Ⓦ	○	○	●	○	○	○
B	Whole milk (8 oz glass)	○	○	Ⓦ	○	○	Ⓓ	●	○	○
C	Ice cream (½ cup)	○	○	Ⓦ	○	●	Ⓓ	○	○	○

Figure 5–2. Example of calculation of daily cholesterol intake. From a food composition table the cholesterol contents are 1 egg = 274 mg, 1 glass of milk = 33 mg, ½ cup of ice cream = 29.5 mg. Thus, the average daily cholesterol intake for the person completing this abbreviated questionnaire would be: 274 mg × 1 + 33 mg × 2.5 + 29.5 mg × 0.8 = 380.1 mg/day. (From Sampson, 1985; reproduced with permission.)

Willett, 2013

Issues in Dietary Assessment

- Variation in diet
  - within- vs. between-person
  - energy/macronutrients vs. micronutrients
- Measurement error
  - random within-person: e.g., day-to-day variation in diet
  - systematic within-person: e.g., important food for a subject is omitted from the questionnaire
  - random between-person: may be due to random and systematic within-person error if it is distributed randomly across persons
  - systematic between-person: caused by systematic within-person error that is *not* randomly distributed across persons (e.g., questionnaire that omits important foods for a population)

Table 5. The effects of random and systematic between-person error in dietary intake on parameters to be estimated

	Type of between-person error	
Parameter to be estimated	Random	Systematic
Mean intake	Precision ↓	Validity ↓
Variation of intake	Validity ↓	No effect
Percentage of subjects below the Recommended Dietary Allowance	Validity ↓	Validity ↓
Association with health outcome	Validity ↓	No effect

Prepared by Jan Burema.

van Staveren & Ocke, 2001

Issues in Dietary Assessment

- Misclassification
  - shortcomings in nutrient databases
  - poor data quality control
  - insufficient number of days of diet records, recalls
  - questionnaires that correlate imperfectly with true dietary intake
- Correlated variables
  - all nutrients are positively correlated with some dietary components or nutrients (e.g., fat + energy) and negatively correlated with others (e.g., fat + fiber)
  - correlations may be so strong as to make it difficult or impossible to disentangle the two and determine which is the true etiologic agent

Approaches to Collecting and Handling Dietary Data

- At the design stage
  - use more than one dietary assessment instrument (e.g., FFQ + 24-hour dietary recalls)
  - include a biomarker of intake
- At the interim analysis stage
  - perform a validation of the main dietary assessment instrument
  - newer validation approaches use at least 3 sources of dietary information (“method of triads”)
- At the final analysis stage
  - use statistical approaches to minimize measurement error (de-attenuation, calibration)

Biomarkers

- Doubly labeled water ($H_2{}^{18}O$, ^2H_2O): energy
- Urinary nitrogen: protein
- Blood (serum, plasma, RBCs): various nutrients
- Adipose tissue: fatty acids
- Hair: heavy metals
- Toe nails: heavy metals
- Expensive, somewhat invasive, burdensome