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Dietary assessment and validity: To measure what is meant to measure

By Maria Lennernäs

Abstract

Nutritional assessment is the interpretation of information obtained from dietary, biochemical, anthropometric and clinical studies. In individuals, qualitative or quantitative food consumption data may be collected by food frequency questionnaires or interviews (retrospective methods), by use of food records (prospective methods); weighed food record, estimated food record or menu record, or by observations. Nutrient values derived from food composition data or direct chemical analysis represent the maximum available to the body and not the amount actually absorbed and utilized. The design of the study is crucial and the methods for carrying it out are aimed at minimizing bias to improve internal and external validity.

This paper will focus on factors of importance to improve the internal validity of dietary assessment studies; selection of method; data collection, assessment of nutrient intakes from food consumption data and evaluation of data.

Introduction

A major distinction between food consumption and nutrient intake is at the level of analysis. When food consumption is measured, the nutrient intake of an individual is often estimated by use of food composition tables. In some cases, individuals are asked to keep samples of foods that they consumed, and the nutrient composition of these foods is analyzed. Food consumption differs from nutrient intake in that consumption is a behavior, and nutrient intake is an outcome; a result of the consumption behavior (1). Thus, individuals may have similar nutrient intakes, but display a variety of consumption behaviors, e.g. with respect to frequency and timing of eating, choosing between food items of similar type when purchasing, composition of meals and cooking techniques. Also, dietary intake may have different effects on body weight and nutritional status in individuals depending on energy expenditure, genetic and lifestyle factors.

Consequently, the general design of a nutritional or dietary assessment system, and the measurement or indices selected, should be dictated by the study objectives. The design of the study is crucial and the methods for carrying it out are aimed at minimizing bias to improve internal validity (2-9). This paper will focus on factors of importance to improve the validity of dietary assessment studies; selection of method; data collection, assessment of nutrient intakes from food consumption data and evaluation of data (10-11). Sampling of subjects, which is important for external validity, statistical assessments of precision and validity will be discussed elsewhere (12).

Nutritional assessment

Nutritional assessment can be defined as the interpretation of information obtained from dietary, biochemical, anthropometric and clinical studies (10).

As to the diet, food consumption may be measured at the national level *(per capita)*, household level, or individual level (13). In individuals, qualitative or quantitative information may be collected by self-report data obtained by food frequency questionnaires or interviews (retrospective methods) or by use of food records (prospective methods); weighed food record, estimated food record or menu record. Data may be collected by observation methods or by reports from relatives and family members close to the target subject of the study. The latter is sometimes the case in children and elderly people (10).

Study design

The general design of the assessment system and the measurement, indices or variables selected should be dictated by the study objectives (2-10). The objectives might be to assess past or present dietary intake, long-term effects of diet on nutritional status parameters, diet as an initiator or promotor of cancer, the impact of interventions on dietary intake in a specific high-risk group, etc.

The variables selected to reflect "eating behavior" or "diet" determines the dietary assessment method and the time frame of a study. Dietary variables may be selected food items or categories of food items, selected nutrients, the "usual" intake of energy and nutrients, periodicity and timing of eating, etc. When it is of interest to study determinants and also consequences of eating behavior, comprehensive dietary surveys are needed. They include assessment of dietary intake, food-related behavior, nutritional status parameters (anthropometric, biochemical, behavioral, physiological and clinical parameters) and also information on lifestyle, demographic and other factors of interest.

Bias

The design of the study is crucial and the methods for carrying it out are aimed at minimizing bias. Once a design is named, then the paper must meet design criteria. Bias refers to a distortion in the estimate of an effect measure – or variable – that is reported to be higher or lower than it would be if we could obtain a less biased or unbiased estimate.

Maria Lennernäs, Dr Med Sci, Swedish Dairy Association (Svensk Mjölk), Stockholm, Sweden and Department of Medical Sciences, Nutrition Unit, Faculty of Medicine, Uppsala University. *Correspondence:* Torsgatan 14, SE-105 46 Stockholm, Sweden.
E-mail: maria.lennernaes@mejerierna.se

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Figure 1. Examples of errors that might occur in dietary assesment studies.

Collection of food consumption data

* Foods or eating events are omitted (over- or underestimated)
* Food types are not sufficiently described (content and type of fat, salt, dietary fibre, ingredients)
* Amounts of foods are not correctly quantified (pictures, drawings, standard portions)
* Time frame and number of observations is not adequate (past, current, habitual diet; group level; individual level)
* Method not designed to assess certain nutrients (salt, fatty acids, food supplements), it needs to be completed by target questions
* Design of questionnaires "shapes" diet (preprinted alternatives for foods, portion sizes and number of meals)
* The study itself affects dietary intake (burdensome to weigh food, obscuring to report diet)
* Interviewers probe for information to a varying degree, "leading questions" are not consistently used

Coding and calculation of data

* Wrong food code selected in nutrient database (type of spread, milk powder instead of consumption milk, low-fibre instead of high-fibre bread)
* Database values differ from nutrients in consumed foods due to seasonal variations, gains and losses during storage and cooking, use of standard recipes
* Volume to weight conversion factors may be wrong
* Categorization of eating events is not reliable and does not reflect types of foods and key nutrients consumed

Conclusions from dietary assessment studies

* "Current" diet instead of past diet is used to explain the initiation of a cancer that was initiated 20-30 years ago
* Dietary intake assessed on group level (e.g. one observation per individual) is used to explain data that require repeated measurement on the individual level (relationship between diet and nutritional status/disease)
* Dietary intake (exposure variables) and nutritional status or health (outcome variables) are falsely "assumed" to show a linear dose-response relationship Nutrient values derived from both food composition data and direct chemical analysis represent the maximum available to the body and not the amount actually absorbed and utilized
* Conclusions should be supported by measures of nutritional status and energy expenditure

Thus, a study that is sufficiently unbiased is internally valid. Likewise, the research report should include information necessary for a skilled reader to evaluate potential sources of bias and the degree to which internal validity is questionable. It follows that the critique should be targeted toward evaluating these same sources of potential bias (2,4-8).

The three major sources of bias are *a)* selection bias (the manner in which subjects are selected in a study population), *b)* measurement bias (systematically or random errors in data collection or treatment of data), *c)* confounding bias. A confounding factor operates through its association with both the independent (exposure) and dependent (outcome) variables, producing an indirect statistical association.

Precision

The errors that affect the precision of a dietary method are *random*. The dispersion (variation) around the true value expresses the precision. The less random variation, the greater the precision and the reliability.

The precision is a function of the measurement errors and uncertainty resulting from true variations in daily nutrient intakes. Consequently, although the dietary survey results from two separate occasions may disagree, the method may not be imprecise: the food intakes may indeed have changed. In free living conditions, true precision cannot be determined because replicate observations of the same eating events are impossible (11,14). For a group of individuals, true variability arises because dietary intakes differ among individuals (between- or inter-subject variation) and within one individual over time (within- or intra-subject variation).

In general, the precision of a dietary assessment method depends on the time frame of the method, the population group under study, the nutrient of interest, the technique to measure (estimate) foods and quantities consumed. As to the time frame, a seven-day rhythm in food intake related to work and leisure is often the case (15).

Probably, monthly and seasonal rhythms of human food intake exist, being regulated by endogenous (e.g. female menstruation cycle) and environmental (rainfall, cold, changes in light and darkness) factors (16). Still, "how many and which days" is a question difficult to answer since data on longer than 24-hours rhythms of food intake seem to be lacking (17-18).

Validity

The errors that affect the validity of a dietary method are *systematic*. Validity can be assessed when the true state can be measured (which in practice is very difficult to do). *Accuracy* is a quantitative measure of the validity of an instrument. Accuracy = measured value – true value.

Validity is of importance in the design of nutritional assessment systems because it describes the adequacy with which any measurement or index reflects the dietary or nutritional parameter of interest. In other words, validity describes the degree to which a dietary method measures what it purports to measure. Quantitative methods (recalls or records) are designed to measure actual or usual nutrient intakes at an individual or group level, depending on the number of measurements days, and/or the size of the study group.

Dietary history or *food frequency questionnaire* provide retrospective information on food consumption patterns during a longer, less precisely defined time period. Such methods are most appropriate for measuring average use of foods (sometimes for estimation of nutrient intakes) on both an individual and a group basis (10).

Measurement of a relative validity

It is difficult to measure the absolute validity of dietary intake. Using multiple methods for assessment therefore helps to counteract and detect systematic biases. In this approach, a "test" dietary method is evaluated against another "reference" method. The reference method chosen must also be designed to measure similar parameters over the same time frame as the test method. However, good agreement between methods does not necessarily indicate validity: agreement may merely indicate similar errors in both methods. On the other hand, poor agreement between the two methods suggests that at least one of the dietary methods is invalid (3,19-21).

To measure relative validity of dietary assessment methods biochemical markers are used: 24-hour nitrogen excretion, 3-methylhistidine excretion, urinary mineral excretion and fatty acid content of adipose tissue (22-24). The (expensive) doubly labelled water method enables total, long term (10-15 days) average energy expenditure (TEE) to be measured under free-living conditions (25).

Consumed amounts of foods

To characterize the average usual intake of a large group, one single *24-hour recall* per individual is appropriate, provided the sample is representative of the population of the study, and all days of an "eating-cycle" equally represented (weekdays, seasons, work days, days off).

Depending on the day-to-day variation within individuals, and thus the number of measurement days, repeated 24-hour recalls or *replicate* weighed or estimated food records can be used to determine actual or usual nutrient intakes of an individual. *Repeated* measurements are needed to assess nutritional status, or when data should be related to biological indicators or health parameters within the same individual (10).

The *dietary history* and the *food frequency questionnaire* can be used to assess usual food consumption patterns over a relatively long time period. With certain modifications they can also be used to provide an estimate of usual intakes of nutrients.

In the weighed food record scales are used. When foods are not weighed in observation, record or recall methods, drawings, photographs or household measures are used to estimate consumed amounts of foods and beverages. Consumed volumes are subsequently converted into weight by using of density factors (26). Sometimes standard portions are used (not reflecting the true portion sizes at the individual level).

Nutrient intakes – food consumption data

Energy and nutrient intakes are calculated from quantitative food consumption data by using food composition data from tables (27) or correspondent nutrient data bases (28). Such data on food composition are based on quantitative nutrient analysis of samples of foods more or less representative of the average composition of a particular foodstuff on a year-round, nationwide basis (or market basis).

Both random and systematic errors may occur in food composition data including inadequacies in the sampling protocols and analytical methods, use of incorrect conversion factors, inconsistencies arising from methods of food preparation and decisions about the proportions of ingredients in standard recipes.

When nutrient information for metabolic studies is required, or when values for specific nutrients are not available, direct chemical analysis of individual food items or composite diets must be performed. Chemical analysis can also be used to validate energy and nutrient intakes calculated from food composition data. Perfect agreement between these two methods is unlikely because of variations in recipes (prefabricated food, restaurant food, home-cooked food), seasonal and regional variations in food composition, nutrient gains and losses during storing and cooking.

Measurement errors

Systematic and random errors may occur across all stages of a study (2,7,8,10). Such errors refer to the sampling of subjects, the methods and time frame of a study, the respondents' ability to report data, the investigators' skill in collecting, coding, computing and interpreting data. Also characteristics of the individual, e.g. being lean or obese, male or female, are considered to affect the validity of data (25,29).

Random errors, unlike systematic errors, can be minimized by increasing the number of observations. In contrast, systematic errors may exist for only certain respondents, specific interviewers or specific food types. Systematic errors may be possible to correct when detected. Figure 1 shows examples of errors that might occur.

Discussion

This paper highlights and exemplifies factors that might affect the internal validity of a dietary assessment study at different stages, with the focus on the design, collection, coding and interpretation of data. The importance of describing the dietary assessment procedure adequately in scientific papers is discussed (3-7). To design and perform dietary assessment studies, and to obscure bias, it is necessary to have insights into the structure of a nutrient data base and knowledge about nutrient composition in food types. This is sometimes not the case when dietary assessment is "adopted" in studies originating from other scientific disciplines and perspectives.

False conclusions may be drawn in studies because nutrient values derived from both food composition data and direct chemical analysis represent the maximum available to the body and not the amount actually absorbed and utilized (10). The response of the body is probably not "linear" and depends on internal factors such as metabolic state, energy expenditure, circulation rhythm factors, nutritional status. Other factors like sleep habits and drug use may interfere.

Sometimes when an association between food exposure and disease is suggested, the dose and duration of nutrient exposure (diet) is poorly assessed. "False causal relationships" also affect the foods that are easiest to remember and report. In such cases, "omitted" foods may be confounding factors. The role of energy expenditure is often overlooked, the dose and duration of exercise being poorly assessed when relationships between diet, serumlipids and obesity are discussed (25).

Furthermore, timing and periodicity of eating is overlooked in dietary surveys (15,17,18). It is time to go beyond "the mean-seven day intake" to describe and categorise human eating behavior.

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