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CHAPTER 2

Identifying and Using Indicators to Assess Program Effectiveness

Food Intake, Biomarkers, and Nutritional Evaluation

Alyson Young and Meredith Marten

Introduction

Accurate information about dietary determinants and behaviors of people in specific populations is necessary for nutrition policy and effective nutrition intervention programs. The utility of an evaluation depends on its ability to provide reliable, reproducible, and timely information for making the needed decisions. Program evaluations fall into two general categories: (1) evaluations to improve an ongoing program and (2) evaluations to assess the impact of a program. Ongoing program evaluations are commonly referred to as "formative evaluations," while the impact assessments are called "summative evaluations" (see Sahn, Lockwood, and Scrimshaw 1984; Habicht, Pelto, and Lapp 2009; and Rossi and Freeman 1999 for guides to developing evaluation strategies). Whether data is being used for improvement or impact assessment, monitoring and evaluation requires appropriate indicators for the establishment of population baselines for the characteristic under consideration as well as follow-up evaluation. The indicators identified in this chapter can be used for both estimating population baselines and assessing the impact of nutritional interventions (examples of nutritional program effectiveness assessments include Berri et al. 2004; Penny et al., 2005; Gibson 2011; Gunaratna et al. 2010; and Masset et al. 2012).

Selecting an Indicator

Since the field of nutrition epidemiology emerged as a recognized domain in the 1980s, research into methods of dietary exposure assessment and the application of these techniques to population-based research has become a prolific area of investigation. As a result, a variety of methods are in use to measure diet in cohort, cross-sectional, and intervention studies, where the aim is to assess contemporaneous diet (Bingham 1987; Cameron and van Staveren 1988; Gibson 2005; Willett 2012; Margetts and Nelson 1997; McNutt, Zimmerman, and Hull 2008; Preedy, Hunter and Patel 2014). Methods generally involve either collation of observations from a number of separate investigations, for example records, checklists or 24-hour recalls; or attempts to obtain average intake by asking about the usual frequency of food consumption, as in the diet history and food-frequency questionnaire. All methods of dietary assessment require some estimate of the weight of food consumed, and to determine nutrient or other food component intake, either an appropriate description for use with food tables or an aliquot for chemical analysis is necessary. The investigator should keep several considerations in mind when choosing an indicator for assessment:

• Scale of analysis: Byers (1998) notes that the measures that are useful for monitoring and surveillance at the population level are often quite different from those that are useful for assessing the diet or nutritional status of individuals. Researchers therefore need to keep in mind the final scale of analysis and determine whether a selected indicator will provide information that is relevant to the goals of monitoring and evaluation.

• Cost: The researcher needs to consider the cost of each indicator in terms of both monetary budgets and human capacity. Calculation of costs should consider collection equipment and personnel, transport and storage costs (including data storage and archiving), laboratory fees or assay costs, data analysis, and any necessary training.

• Ease/frequency of monitoring strategies: It is important to balance the frequency of data collection for indicators with the relative ease of data collection/participant burden. Detailed indicators such as biomarker data and observed weighted food records can yield detailed and highly accurate data, but can also entail considerable time investments on the part of participants and researchers.

• Triangulating methods: Each indicator used for monitoring program effectiveness has strengths and shortcomings. Triangulation (using more than one indicator to assess a particular outcome variable) is often a good way to overcome shortfalls in particular research methods or provide context for the results of a specific indicator. This approach has been particularly fruitful with regard to dietary intake and diversity, where issues of recall bias may influence study results (regarding triangulation and using biomarkers to offset measurement error, see Johns and Eyzaguirre 2007; Keog, White, and Rodwell 2013; Saracci 1997; Freedman et al. 2010).
Specific Methods for Assessing Program Effectiveness

Dietary Diversity and Food Intake

Dietary diversity is identified as the number of either unique foods or food groups consumed by an individual or household during a given period of time. The most common methods for estimating dietary intake are food diaries or surveys of food consumption, observed weighed food records, and weighed food records. Dietary intake information is often used for assessing the adequacy of food supply, improving nutritional quality, setting targets for food production, monitoring progress toward production targets, and assessing food distribution within a population; it is also a basis for food regulations and guidelines developed for nutrition education.

Intake is normally measured by estimating current diet (prospective analyses) or past diet (retrospective analyses). Information on dietary intake and dietary diversity is collected using a range of methods. The majority center on identifying a dietary diversity score (DDS), food frequency score, or food consumption score (FCS). The DDS involves simple counts of food groups consumed over a certain reference period by an individual or a household. The FCS, measured at the household level, combines the measurement of dietary diversity, the frequency with which different foods are consumed, and the relative nutritional importance of various food groups. Measurement tools are widely available from several sources, including the CDC, FAO, and USAID (see the resources section at the end of this chapter for links to sites with survey instruments and guidelines for use).

Dietary recall

Collecting survey data about dietary intake is straightforward compared to biological indicators. Training field staff is not complicated and the questions are not especially intrusive or burdensome (Swindale and Bilinsky 2006). Furthermore, dietary recalls can be conducted face to face or by telephone or web-based multi-pass interviewing systems (Preedy, Hunter and Patel 2014). Personal digital assistants (PDAs) and handheld devices such as smartphones and tablets are also becoming a popular way to quickly and effectively collect dietary intake and other nutritional data. A number of companies produce software for different operating systems (Android, iOS, Windows) that are relatively inexpensive to purchase while providing basic nutritional analyses and data recording capabilities. There are some limitations to digital data collection however—handheld devices can be expensive, often entail additional training for respondents and investigators, and require regular charging and data download/backup to function effectively (see Fowles and Gentry 2008; McClung et al. 2009 for a discussion of the feasibility and accuracy of PDAs in dietary assessment).

It should be noted that recall bias can also be an issue with food diaries and dietary intake interviews (see Brown 2006; Illner et al. 2010; Kipnis et al. 2002; Kirkpatrick et al. 2014; and Poslusna et al. 2009 regarding bias in dietary report instruments), so information on food consumption should be collected using the previous 24-hour period as a reference period and efforts should be made to validate survey responses (such as combination with weighed food records). When using the 24-hour recall method, the interviewer should first determine whether the previous 24-hour period was “typical” for that individual or household. If it was a special occasion, such as a funeral or feast, or if most household members were absent, another day should be selected for the interview (Swindale and Bilinsky 2006).

Weighed food record / Observed weighed food records

These methods require that all food and drink (including dietary supplements) consumed during a specified period are weighed and recorded along with detailed information on the methods of food preparation by either the participant (basic weighed food record) or a trained observer (observed weighed food record). The recorded data are converted to daily calorie and nutrient intake using food composition tables (see the list of resources for specific tables). Weighed food records are less prone to issues of recall bias because they are based on either actual or usual intakes of individuals. However, they are more time-consuming and expensive than dietary recall methods because they require estimation and accurate measurement of all food that has been consumed.

Biomarkers

A biomarker is clinically defined as a biological characteristic that can be objectively measured and serves as an indicator of normal biological processes, pathogenic processes, or responses to therapeutic interventions. Biomarkers can be broadly characterized into three groups: those that measure physical or genetic traits (anthropometric indexes, metabolic gene polymorphisms), those that measure chemical or biochemical agents in the biological system (plasma retinol, iron, zinc), and those that assess a measureable physiologic function (test of night vision, cognitive assessment) or future clinical risk (BDWG 2001; Potischman 2003). Biomarkers are most commonly used to assess dietary exposure, composition, and sufficiency regarding antioxidants, vitamins, minerals, and micronutrients; fatty acids; plant polysaccharides and phytochemicals; and food contaminants.

Biomarkers’ contributions to the overall goal of the evaluation can be roughly grouped into three categories: (1) measuring exposure (e.g., baseline information on dietary presence/absence or sufficiency/insufficiency, or on physiologic response to a clinical condition or intervention), (2) establishing relative nutrient status, or (3) estimating direct and indirect physiological effects of an item that has been consumed. Some of the more common biomarkers used in assessing program effectiveness include dietary fatty acid composition; vitamin A, iron,
iodine, and zinc levels; and measures of energy expenditure and metabolic markers (e.g., doubly labeled water, 24-hour nitrogen, and 24-hour urine potassium) (see Bingham 2002; Kant 2010; Spencer 2008 et al.; Yetley and Johnson 2011 for examples of dietary biomarkers and bioactive compounds).

When choosing an indicator, it is important for the researcher to understand how the biomarker relates to both dietary intake and the chronology of exposure. This includes whether the biomarker will be used to evaluate long-term nutritional status, recent dietary intake, effectiveness of dietary manipulation, or the efficacy of an intervention. For example, effective biomarkers for assessing program effectiveness should have (1) well-defined criteria for application at individual and population levels, (2) standardized methodologies, (3) evidence-based cutoffs to distinguish between “normal” status and varying degrees of deficiency or excess, (4) responsiveness to interventions that aim to improve status and prevent deficiency of a particular nutrient. Ultimately, the most effective biomarkers will act to guide resource allocation decisions and identify strategies for effective investment (see Raiten et al. 2011 on selection of biomarkers for program evaluation). Consideration should include the logistics of specimen collection and processing, including the type of specimen that needs to be collected for analyses (e.g., plasma, serum, bloodspots), the collection method (e.g., capillary sample, venipuncture, urine), proper storage and handling (e.g., finding out whether dilution, aliquoting, or hemolysate preparation is needed, or whether samples are sensitive to light, temperature, or oxygen). It is also important to identify whether analyses will be conducted in the field or a local laboratory, or else shipped out for analysis, and whether transportation of samples requires any special documentation or handling (Bingham 2002; Blanck et al. 2003; Jenab et al. 2009).

**Nutrition Analysis**

Nutrition analysis, or the process of determining the nutritional content of foods and food products, can be performed according to various certified methods (see Nollet 2004 for an overview of analytic methods). Nutritional analyses are commonly used to establish values for food labeling on menus and nutrition fact labels (IOM 2000, 2005). Program effectiveness evaluations can use nutritional analysis in conjunction with dietary intake measures to determine exact nutrient and energy composition of individual and household diets and estimate exposure to contaminants, phytochemicals, and the like. Nutritional analysis can be conducted by directly measuring food through chemical analysis in a laboratory or by comparing dietary ingredients to a database of known foods to estimate nutritional content.

Laboratory analysis, that is, chemical analysis of nutrient composition, becomes important when evaluation requires detailed information on food composition (e.g., fluctuations in nutrient composition and availability due to changes in agricultural production strategies or food processing practices). For example, aspects of cooking methods (e.g., times, temperatures) and processing (trimming meats, peeling fruits/vegetables, etc.) influence concentrations and oxidation states of food constituents such as vitamins, fatty acids, dietary fiber, starch, sugars, and cholesterol. Therefore, assays should be planned for those nutrients fundamental to the experimental hypothesis as well as nutrients known or suspected to influence outcome variables. Additional assays may be required to obtain reference points necessary for the nutrient parameters (e.g., if total fat will be calculated as a percent of total energy, total energy must be assayed in addition to total fat) (see Foote 1990; Holden 1995; and Phillips and Stewart 1999 regarding chemical analysis and laboratories specializing in nutrient analysis).

Commonly used reference databases for nutritional analyses include the USDA National Nutrient Database for Standard Reference and the Nutrition Analysis Tool (University of Illinois, Food Science and Human Nutrition Program). Also, a number of companies produce diet analysis software that allows users to calculate nutrient intake by comparing foods to proprietary databases. Online databases and desktop software can be lower-cost solutions to laboratory analyses when nutritional analysis is limited to basic calorie estimation and micronutrient analysis. It is important, however, that the researcher establish that the databases utilize nationally or internationally accepted reference standards, and know whether values are obtained from direct assays or imputed from “similar foods” or raw materials that constitute the foods (see Ahuja et al. 2013; Pennington et al. 2007; Leighton et al. 2013; Schakel, Sievert, and Buzzard 1988 regarding nutrient analysis protocols, reference standards, and food nutrient database design). Links to select databases are included in the resources section at the end of this chapter.

Turnkey nutrition analysis services, provided by a number of companies, offer inclusive nutritional analysis packages ranging from complete analysis of recipes based on ingredient lists, cooking methods, and serving sizes to full-scale data collection, storage, and analysis of population-level diet and activity data (see Falomir et al. 2012; Koenig et al. 2004).

As is the case with the other methods described in this chapter, decisions on selecting the appropriate method of nutrition analysis depend on the scale and specificity of information required. Laboratory analyses are best suited to projects that require detailed dietary monitoring, such as researching subtle changes in nutrient levels of foods, analyzing novel food sources, or studying nutrients not commonly reported on standardized food labels. Reference databases, in contrast, are more suitable for basic calculations of relative nutrient intake. Several questions should be considered when choosing a method for nutritional analysis: (1) What are the key nutrients in the study, and how much variability is expected in the levels of nutrients in foods that make up the diet? (2) Are exact nutrient levels important? (3) If differences among diets are vital, how far apart are the
nutrient levels that are being studied? Finally, (4) what is the scope and quality of available food composition data for key nutrients?

Selecting a Laboratory for Biomarker or Nutritional Analysis

In addition to identifying the costs and time required for analyses, the investigator should confirm that the chosen laboratory (1) shows analytical performance sufficient to accomplish the goal of the evaluation, (2) meets acceptable precision and bias requirements, including calibration processes that are traceable to nationally or internationally accepted reference materials, (3) uses statistical quality control charts to maintain accuracy among runs, and (4) uses meticulous and reproducible sample handling procedures (e.g., precise measurement of critical volumes, avoidance of carry-over contamination). Countless national and international laboratories can conduct biomarker and nutritional analyses, but there is no central list of available services. Investigators can identify local facilities through web searches and contacts with nearby research universities and/or local cooperative extension agents (see Blanck et al. 2003; Sauberlich 1999; Petersen 1996; Phillips and Stewart 1999 for further guidelines and criteria for selecting a laboratory for specimen analysis.)

Measurement Error and Reporting

There are ways of adjusting the effects of imperfect diet measurement in dietary assessments and food frequency data (see Murray 1998; Marshall 2003; Willett 2012 for standards in statistical analyses for nutritional epidemiology). For example, a measure of effect can be adjusted if a description of the type and degree of mismeasurement is available. If it is known that dietary exposure is over-reported by a certain percentage among controls and under-reported by a different percentage among cases, it is possible to control for the association of exposure and case status in the absence of measurement error. As Marshall (2003) notes, however, this adjustment is sensitive to imprecision in the assessment of the nature and extent of the measurement error. Modest imprecision in the estimation of measurement error can lead to significant fluctuations in adjusted relative risk estimates.

In terms of biomarker data and chemical analysis, measurement error is generally classified as either preanalytical or analytical (laboratory) error. Preanalytical error includes both biological and sampling errors, whereas analytical error focuses on the laboratory environment and includes method, instrument, reagent, and/or matrix effects (see Potischman 2003; White 1997; Marshall 2003 regarding analytical error). Common sources of laboratory variability include errors in specimen collection and storage and/or errors during specimen analysis (e.g., from differences in reagents, instruments, and interfering substances). Any errors in measurement or analysis should be included in the reporting of the results to aid interpretation of findings and comparison with other studies.

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Additional Resources

Food and Agriculture Organization (FAO)

National Cancer Institute
- NCI Diet History Questionnaire II: http://appliedresearch.cancer.gov/dhq2/
- NCI Dietary Assessment Calibration/Validation Register: http://appliedresearch.cancer.gov/cgi-bin/dacv/index.pl

Nutritional Analysis Tool (NAT v. 3): http://www.myfoodrecord.com/

UN-World Food Program (WFP)
- List of publications and policy on nutrition evaluation: http://www.wfp.org/policy-resources

USAID Food and Nutrition Technical Assistance (FANTA)
- Dietary diversity, food access, and provisioning: http://www.fantaproject.org/monitoring-and-evaluation

U.S. Centers for Disease Control and Prevention (CDC)
- CDC Nutrition Survey Toolkit: http://www.micronutrient.org/nutritionintoolkit/

U.S. Department of Agriculture (USDA)
- Database for the flavonoid content of selected foods: http://www.ars.usda.gov/ba/bhnrc/ndl
- Healthy Eating Index: http://www.cnp.usda.gov/HealthyEatingIndex.htm
U.S. Food and Drug Administration (FDA)
- Food resources: http://www.fda.gov/Food/
World Health Organization (WHO)
- Nutrition resources: http://www.who.int/nutrition/en/

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