NCCOR
National Collaborative on Childhood Obesity Research

Measures Registry User Guide: Individual Diet

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NATIONAL COLLABORATIVE ON CHILDHOOD OBESITY RESEARCH

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Introduction

SECTION 1

Introduction

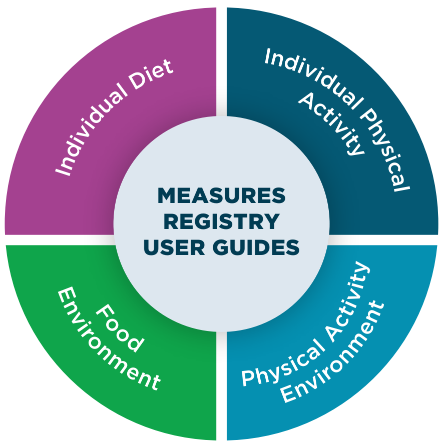
Measurement is a fundamental component of all forms of research and it is certainly true for research on childhood obesity. A top priority for the National Collaborative on Childhood Obesity Research (NCCOR) is to encourage the consistent use of high-quality, comparable measures and research methods across childhood obesity prevention and research.

NCCOR's Measures Registry—a free, online repository of articles about measures—helps achieve this aim. It is widely recognized as a key resource that gives researchers and practitioners access to detailed information on measures in one easy-to-search location. The Registry's measures focus on four domains that can influence childhood obesity on a population level:

- Individual Diet
- Food Environment
- Individual Physical Activity
- Physical Activity Environment

Even with this resource, however, it can be challenging for users to choose the most appropriate measures for their work. To address this need, NCCOR began the Measures Registry User Guides project in 2015. Organized by the same four domains as the Measures Registry, the User Guides are designed to provide an overview of measurement, describe general principles of measurement selection, present case studies that walk users through the process of using the Measures Registry to select appropriate measures, and direct researchers and practitioners to additional resources and sources of useful information (Figure 1). The User Guides will help move the field forward by fostering more consistent use of measures, which will allow for standardization, meta-analyses, and synthesis.

Figure 1: NCCOR Measures Registry User Guides



Overview of the Individual Diet Measures Registry User Guide

This User Guide is specific to individual dietary behaviors, for which a plethora of measures are available. Dietary behavior is complex, and so is its measurement.[1] Nonetheless, measuring dietary behaviors can provide extremely useful information. However, due to the varying characteristics, strengths, and weaknesses of different measures, and corresponding degrees of appropriateness for particular applications, choosing the most appropriate tool for a given population and purpose can be a challenging task. The goal of this User Guide is to help researchers and practitioners make effective use of the Individual Diet domain within the Measures Registry, as well as complementary resources, to select the best possible measures to conduct population surveillance of dietary behavior, to assess dietary determinants of disease and health outcomes, and to evaluate policy and program interventions. The User Guide also aims to help users consider salient issues related to administration of measures, data analysis, and interpretation and reporting of the resulting findings. The User Guide does not provide a comprehensive summary of each of the measures, an evaluation of the measures, or a compilation of research using the measures, but rather, addresses concepts associated with the measurement of dietary behaviors broadly.

The focus of this User Guide on individual diet differentiates it from the complementary Guide on measures of the food environment. As such, this Guide is aimed at providing guidance on measuring diet among individuals. However, it is important to note that, for the purposes of childhood obesity research, data are typically captured at the level of individuals, but inferences are made at the level of groups or populations. For example, in the National Health and Nutrition Examination Survey (NHANES), dietary intake data are collected from individuals for the purpose of generating estimates of intake of certain components, such as fruits and vegetables or sugar-sweetened beverages, among different subgroups of the population, as well as examining influences of sociodemographic or other characteristics on dietary behavior.[2] The measurement of dietary behavior at the level of individuals for the purposes of clinical assessment or counseling is outside of the scope of this Guide, though measures within the Registry may be applicable to these purposes. It is difficult to characterize the dietary behaviors of a given individual[3]; however, this is not necessary for research questions related to estimating consumption of particular dietary components in a population or assessing associations between dietary intake and other variables, for example.[1]

Within the Registry, dietary behavior measures are identified as tools and methods used to assess individuals' diets. For the purpose of this User Guide, *methods* relate to a particular approach to the collection of dietary behavior (e.g., food frequency questionnaire), and *tools* refer to a particular measure (e.g., Calcium Food Frequency Questionnaire). Many measures within the Registry reflect tools that are variations on the same method.

Organization of This User Guide

In addition to this Introduction, this User Guide includes the following sections:

- Section 2. Conceptualizing Individual Diet provides an overview of dietary behavior, which, for the purpose of this Guide, is defined primarily as *dietary intake* (e.g., foods, beverages, and supplements consumed by individuals and populations and associated details, such as contextual factors), but also related dietary behaviors (e.g., frequency of snacking, perceptions, and attitudes).
- Section 3. Dietary Variables of Relevance to Childhood Obesity briefly outlines the literature identifying links between diet and childhood obesity, as well as summarizing influences on dietary behavior.
- Section 4. Key Considerations in Measuring Dietary Behavior Among Children provides highlights of concepts relevant to studying diet, including unique considerations regarding the quality of data collected in studies of children.

NCCOR: WORKING TOGETHER TO REVERSE CHILDHOOD OBESITY

NCCOR is a partnership of the four leading funders of childhood obesity research: The Centers for Disease Control and Prevention (CDC), the National Institutes of Health (NIH), the Robert Wood Johnson Foundation (RWJF), and the U.S. Department of Agriculture (USDA). These four leaders joined forces in 2008 to continually assess the needs in childhood obesity research, develop joint projects to address gaps and make strategic advancements, and work together to generate fresh and synergetic ideas to reduce childhood obesity. For more information about NCCOR, visit www.nccor.org.

- Section 5. Overview of Individual Diet Measures provides details on methods and tools used to assess dietary intake and related dietary behaviors, including objective and self-report methods.
- Section 6. Evaluating Individual Diet Measures provides an overview of principles related to psychometric properties of measures, along with random and systematic measurement error. Evidence on the error properties of commonly used measures of dietary behavior is summarized, including considerations related to body mass index.
- Section 7. Selecting Measures outlines questions to consider in the process of determining which measure(s) are the most appropriate for a given study.
- Section 8. Considerations for Collecting, Analyzing, Interpreting, and Reporting Data on Individual Diet outlines factors to consider at various stages of study design and implementation, including strategies to enhance the quality of the data captured.
- Section 9. Case Studies presents potential scenarios to illustrate considerations involved in selecting appropriate measures of dietary behavior for different purposes. Both research- and practice-based examples are given. Considerations include the research aim or question, study design, study population, and specific dietary behaviors of interest.

- Section 10. Future Directions in Individual Diet Assessment provides a brief summary of salient considerations in choosing a dietary behavior measure and highlights ongoing research and developments to areas to advance this area of measurement.

- Section 11. Conclusion

- Section 12. Additional Resources on Individual Diet Assessment highlights key complementary websites, literature reviews, and other sources to support rigorous decision making in regard to selecting a dietary behavior measure.

- References

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Conceptualizing Individual Diet

For the purpose of this User Guide, dietary behavior is conceptualized primarily as *dietary intake*, though related dietary behaviors and attitudes (e.g., frequency of snacking) that may be relevant to the study of childhood obesity are also addressed.

Generally speaking, dietary intake refers to the foods, beverages, and, potentially, supplements consumed by individuals and populations. In conjunction with information on intake, there is often interest in the context of eating, such as when, where, and with whom meals and snacks are consumed, as well as other activities during eating, such as use of digital devices.

Many of the measures within the Registry focus on quantitatively assessing intake, for example, using 24-hour dietary recalls, dietary records, food frequency questionnaires, or screeners, for the purposes of arriving at estimated consumption of foods, food groups, and nutrients, or characterizing dietary patterns. For example, within the context of childhood obesity research, there is significant interest in quantifying consumption of sugar-sweetened beverages, including fruit drinks, flavored milks, soda, and energy drinks. The measures within the Registry are primarily those that involve self- (or proxy-) reporting of intake; however, objective methods for assessment are also briefly described in Section 5.

As outlined in the Measures Registry User Guide: Individual Physical Activity, physical activity is not directly *measured* in the same way that characteristics such as weight and height might be. The term *assessment*, which "refers to an appraisal or judgement," can be used to differentiate from *measurement*, which "involves collecting specific information about an object or event and typically results in the assignment of a number to that observation." Similar to physical activity, the measurement of dietary intake is typically referred to as assessment.

In assessing intake, researchers are interested in capturing specific items consumed, along with details such as how they were prepared and the quantities in which they were consumed. As noted in Section 1, such data are typically collected at the level of individuals, with inferences made at the level of groups or populations. With the necessary details to characterize foods and beverages, data collected from individuals can be linked with food composition and related databases to estimate intakes of foods and food groups, nutrients, and other dietary components. These estimates can be used to characterize dietary intake among populations or subpopulations (e.g., prevalences meeting recommendations related to nutrients or food groups); examine influences (e.g., age, gender, socioeconomic status, and education) on dietary intake; assess associations between dietary intake and outcomes (e.g., factors associated with body weight); and investigate the impacts of interventions (e.g., nutrition education and taxation of sugar-sweetened beverages) on intake.[1]

In addition to capturing details on the types of foods and beverages consumed, researchers and practitioners aim to understand how often different foods and drinks are consumed so that usual intake can be estimated. This is because primary interest is not typically in consumption on a given day (i.e., acute intake), but rather habitual or long-term intake over a given period of time. For example, in surveillance, researchers and practitioners are interested in whether individuals and populations meet food group recommendations and nutrient requirements on average over time, and in epidemiology, researchers seek to examine associations between usual diet and subsequent health- or disease-related outcomes. In some cases, such as some specific intervention studies, intake on a given day may be of interest. However, usual intake is typically of interest and is the focus of this User Guide.

Other measures within the Registry are intended to capture related behaviors, such as the frequency with which individuals visit fast food restaurants or consume snacks or meals while watching television. In addition, some measures capture eating attitudes (e.g., willingness to try new foods); food preferences (e.g., for salty or sweet foods); avoidance of particular dietary components (e.g., fat); diet knowledge and perceptions (e.g., regarding foods marketed as healthy); and other constructs that may influence eating patterns and body weight. Generally, measures within the Registry that include constructs such as attitudes also include some assessment of intake (e.g., a measure of attitudes toward fruits and vegetables may also query intake of fruits and vegetables). For some research questions, it may be necessary to use measures of dietary intake together with measures focused on related behaviors and attitudes.

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Dietary Variables of Relevance to Childhood Obesity

Rates of obesity among children in the United States[4] have motivated extensive research to understand influences on body weight, as well as interventions to prevent excess weight gain in childhood.[5]

An array of factors contributes to obesity among this population at the individual, familial, school, and governmental levels.[5,6] These contributors may both include, and can influence, dietary behavior. Understanding dietary behaviors, their associations with other factors related to obesity, and how these behaviors are influenced by interventions is thus an important piece of the puzzle in our efforts to advance childhood obesity prevention efforts. For example, there has been attention to how diet quality, fast food consumption, and intake of sugar-sweetened beverages relate to weight gain among children, as well as the extent to which interventions can shift these dietary behaviors and associated weight-related outcomes. There has also been attention to whether differences in eating patterns might contribute to disparities in obesity among different racial and ethnic groups and geographical areas.[7]

Dietary behaviors salient to obesity are relevant beginning in infancy; for example, breastfeeding has been shown to be a protective behavior against weight gain in childhood.[8] Researchers also have paid attention to the role of timing of introduction of solid foods and subsequent development of obesity. However, this relationship remains unclear, with a recent study by researchers at the Centers for Disease Control and Prevention finding no association between timing of introduction and obesity at age 6 years.[9] In toddlers, low fruit and vegetable consumption and high consumption of energy-dense foods[10–13] are predictors of weight status in later childhood stages.

The dietary behaviors associated with overweight and obesity among school-age children are similar to those observed in toddlers,[14,15] in addition to frequent consumption of energy-dense foods, predominantly those high in fat, sugar, and/or salt[16] as well as sugar-sweetened beverages. Recent research has focused on consumption of sugar-sweetened beverages in particular, as they are a primary source of added sugars among youth, and evidence suggests that these beverages significantly contribute to weight gain.[17] Low intake of fruits and vegetables, which is influenced by food-related attitudes and taste preferences,[18,19] also correlates with the consumption of highly-processed, energy-dense fast foods among this age group.[20]

Dietary behaviors, attitudes, and related factors play a larger role in dietary intake and obesity risk as children reach adolescence. Diet-related behaviors, such as excessive snacking, frequent eating at restaurants, and intentional diet restrictions for weight loss purposes are associated with increased risk of weight gain.[21–23] Dietary intake, related behaviors, and attitudes are often interlinked and influence one another, with a possible overall impact on weight. For example, an adolescent trying to lose weight may intentionally restrict food choices, which is associated with an increased likelihood of consuming a poor diet and eventual weight gain.[22]

A wide array of influences affect dietary behavior, as conceptualized by social-ecological models of behavior.[24,25] Ecological models aim to describe human behavior at multiple levels, including the intrapersonal, interpersonal, organization, community, and policy levels.[26] For example, dietary behavior at the individual level is influenced by federal, state, and local governments; industry and media; health care professionals and resources; community organizations, schools, and peers; parents; and families.[5] Most models focus on the interplay of multiple factors at multiple levels that influence individual behavior, with potential for overlap or interaction across levels,[27] postulating that changes at both individual and broader societal levels are needed to enable individuals to successfully enact and sustain behavior change. The social-ecological model can be applied to conceptualize the role of dietary behavior in the context of childhood obesity, helping researchers and practitioners to consider multiple levels of influence on individual dietary behaviors among children and youth when designing studies to better understand these influences, as well as interventions to address them.[28,29] The inherent complexity of dietary behaviors and obesity suggests the need for comprehensive approaches to measurement, taking a systems perspective[30] to consider, for example, how an intervention targeting a specific component such as sugar-sweetened beverages affects other aspects of the diet. This has implications in terms of the capacity of measures to capture the total diet broadly, an issue discussed in Section 5.

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Key Considerations in Measuring Dietary Behavior Among Children

In most research relevant to dietary behaviors, self-report measures are used. This is because it is generally not possible to objectively assess usual intake in community-dwelling individuals.

Various considerations come into play in assessing dietary intake using self-report (Box 1). These considerations may have particular salience depending on the age of children and their respective cognitive skills, as well as literacy and numeracy. Errors in the capture of children's intake may include under- and over-reporting of foods and beverages, incorrect identification of foods, and portion size misestimation.[31] Commonly consumed foods and beverages may be reported, even if they weren't consumed during the time period of interest.[31] In addition, measurement of children's dietary behavior may be affected by motivation to provide accurate information. In sum, intake may be either under- or over-estimated and this may vary by age, dietary component, and in relation to the tool used for assessment.[31]

In assessing diet among infants and toddlers, measures are typically completed using proxy-reporting by parents or caregivers, except perhaps in the case of observation. Parents or other caregivers may not accurately report their children's intake, with potential misreporting particularly for eating occasions for which they were not present.[32] This becomes a more significant issue as children get older and spend more time away from parents, for example, in early care and education settings. Additionally, caregivers who report their children's food intake are susceptible to many of the sources of error that affect reporting of their own diet, including social desirability biases,[33] because of concerns that their child's eating patterns and weight might be perceived negatively. For example, Börnhorst et al. used the Goldberg equation to classify parent proxy reports as plausible, under-reported, or over-reported, based on energy estimates from 24-hour recalls completed for children aged 2 to 9 years.[34] Under-reporting was positively associated and over-reporting was negatively associated with z-score for body mass index. Further, proxies who perceived their children as overweight were more likely to be classified as under-reporters.

School-age children may be enthusiastic about reporting their dietary intake.[36] However, depending on the method used, their developmental stage may hinder their ability to accurately report food intake and related behaviors. Potential factors affecting reporting include variable levels of literacy,[32,37,38] limited attention span,[32] and inadequate concepts of time and memory.[39] It has been suggested that children begin to be able to conceptualize time at the age of around 7 or 8 years.[31] However, at this age, the time periods for which children can report their intake are likely to be limited.[31] Limited knowledge of food preparation methods and ingredients may also pose a barrier to accurate reporting of details of foods and beverages consumed.

Adolescents may be less interested in reporting their intake, increasing the risk of reporting error.[36] Further, their diets may be less structured and more variable than those of younger children,[32,37] and this complexity may be difficult to capture, for example, with tools administered a single time or that do not consider complexities such as snacking between meals. Additionally, weight management and restrained eating efforts, which are much more frequent among adolescents than younger children, as well as weight status, may bias reported intake.[32,36] Technology-enabled tools, such as food records on mobile devices, developed for use with this population may help lessen some of these barriers to the capture of accurate dietary data, for example, by increasing engagement and motivation.[40]

Children of all ages struggle with portion size estimation[32,38] (as do adults). The literature on the utility of training or the use of portion size aids that reflect typical portion sizes consumed by children is mixed, with the overall conclusion that this aspect of dietary assessment poses an ongoing challenge.[31,41]

Social desirability bias is an additional issue that cuts across population groups. It is possible that this source of bias is becoming more of an issue due to increasing rates of, and stigma related to, overweight and obesity,[42] as well as constant media (including social media) attention to food and diets, as well as body shapes and sizes.[43] A study conducted using data from the mid-1990s and early 2000s found higher under-reporting of protein in the later time period among adults, which the authors suggested might reflect growing misreporting of other macronutrients, potentially due to heightened awareness of dietary intakes due to public health

BOX 1: FACTORS THAT CAN INFLUENCE THE QUALITY OF DATA ON DIETARY INTAKE BEHAVIOR

COGNITIVE ABILITIES: The capacity to learn, remember, and pay attention. Immature cognitive skills in young children necessitates proxy reporting, and still-developing cognitive skills in older children may limit options for independent self-reporting.

LITERACY: Ability to read and write. Essential for completion of most self-administered tools.

NUMERACY: Ability to understand and manipulate numbers. Critical to self-administration of most dietary assessment tools, particularly when calculations to average frequency of intake and typical portion sizes over time are required.

PROXY REPORTING: Provision of data on dietary behavior by someone other than the person of interest. The extent to which the proxy has first-hand knowledge of the person of interest's diet can impact the accuracy of reporting, as can other sources of bias such as those related to body weight or portion size estimation.

RECALL BIAS: Lapses in memory, either short-term in reporting of intake for a recent period (e.g., yesterday) or long-term in reporting of intake for a longer period (e.g., the past year).

REACTIVITY: Tendency to change one's behavior in response to monitoring or the expectation of being measured. When the intention is to capture usual intake, data collected using food records can suffer from reactivity bias. When the intention is to support self-monitoring for the purpose of enabling behavior change, reactivity is the desired effect.

RETENTION INTERVAL/RECENCY: The length of time between the dietary behavior of interest and reporting of that behavior. Longer retention intervals (i.e., lower recency) may reduce children's ability to accurately report.

SOCIAL DESIRABILITY BIAS: Tendency to respond in a way perceived to be socially desirable. "Social desirable responding is presumed when an individual reports never performing a behavior that most everyone performs at least occasionally or reports always performing a behavior that most people usually perform but omit occasionally."[35] For example, consumption of foods and beverages perceived as less healthy, or "bad," may be under-reported, whereas consumption of foods and beverages perceived as "good" may be over-reported.

campaigns.[44] Further research is needed to understand secular trends in misreporting among children, particularly in the age of social media.

Research in children suggests social desirability is an issue affecting this population. For example, social desirability (measured using a questionnaire) has been associated with lower accuracy of reporting (potentially under- or over-estimation) of dietary intake on 24-hour recalls among fourth-grade children.[45,46] Scales to assess social desirability bias can be administered in nutrition research as a means of better understanding this possible source of error.[35,47–49] Also possible is social desirability-related misreporting of other variables of interest, such as weight,[37] with implications for study findings. Weight perceptions and bias may interact with social desirability,[46] leading children and youth to report lower energy intakes if they perceive themselves as overweight.[50] More research is needed to investigate this complex interaction and its implications for dietary data.[35] However, researchers can aim to reduce this source of under-reporting by maintaining neutrality in describing the study and not promoting perceived desirable responding,[37] as well as by measuring and adjusting for social desirability.[35,47–49]

With technological innovation in the assessment of diet,[51] such as web-based 24-hour recalls[52,53] and mobile food records,[54,55] it is becoming feasible to collect dietary data in a broader range of studies and settings than previously possible. Technological developments have been targeted to engage children in particular in more accurately self-reporting their diets.[40] For example, recent innovations have incorporated animated avatars or cartoon characters, interactive questionnaires, and the addition of narratives to engage children during the completion of assessments.[40] However, technology does not mitigate all of the challenges in accurately assessing diet, and it remains critical to ensure that the measure chosen is well-suited to the research question, the study population, and the setting.[40,56,57] Although the Measures Registry does not categorize methods and tools that incorporate technology, the developments in this area suggest this as a potential focus of the Registry and similar tools in the future.

With these various considerations in mind, Box 2 outlines potential strategies to enhance the accuracy of data captured in studies of children's dietary behaviors. Within Section 5, we briefly highlight unique considerations related to specific types of measures for use with children. Section 11 provides a list of selected resources that can be used in combination with the Measures Registry and this User Guide to help inform measurement of dietary behaviors in children. This list includes numerous reviews related to assessment in children specifically.

BOX 2: POTENTIAL STRATEGIES TO ENHANCE ACCURACY OF DIETARY BEHAVIOR DATA AMONG CHILDREN

- Ensure tools are tailored to the target group in terms of demands related to attention span, literacy, numeracy, and other factors influenced by developmental stage and corresponding cognitive skills.
- Take advantage of technology (e.g., web-based recalls, mobile food records, skin scanner technology, "gamified" programs) if applicable to the target group to reduce burden and improve motivation and engagement. However, new challenges that can be introduced by technology (e.g., related to Internet connectivity or computer literacy) also need to be considered.
- Provide clear instructions, complemented with hands-on training if necessary. This extends to proxy reporters in studies in which children cannot report independently.
- Use portion size aids appropriate to the population. Training in portion size estimation may be helpful to reduce error associated with this component of assessment.
- Allow adequate time for completion, recognizing that children may need more time to complete assessments than adults due to less mature cognitive skills.
- Use techniques to reduce social desirability bias, such as using neutral probing and querying an array of food and drink items rather than focusing narrowly on specific items of interest, particularly when these may be perceived as unhealthy (e.g., sugar-sweetened beverages).
- Be aware of potential sources of error and interpret and report the data accordingly.

5

Overview of Individual Diet Measures

Measures of dietary behavior differ in terms of the specific dimensions or facets of behavior they are able to capture. As noted previously, for most research applications with relevance to characterizing dietary behavior, the aim is to capture usual or habitual dietary intake.

Quantifying frequency of consumption as well as the amount consumed provides the capacity to link to databases to estimate intake of foods, food groups, nutrients, and other dietary components (though attention must also be paid to issues such as the currency and comprehensiveness of such databases).

Addressing research questions may require querying the total diet (possibly including vitamin and mineral supplements) or consumption of specific dietary components, such as fruits, vegetables, sugar-sweetened beverages, fat, fiber, or sugar. Further, there may be interest in characterizing diet quality or dietary patterns more holistically, which requires data on the multiple foods and beverages that make up eating patterns. With respect to specific dietary components, it is salient to consider whether those of interest are consumed regularly by most members of the population of interest or are episodically-consumed. This has implications for assessment in terms of the need to capture multiple days of consumption or a long enough period of time such that consumption days are included. Additionally, depending on the research question, there may be a need for attention to temporal patterns in consumption at the level of meals, days of the week, seasons, and across the lifecycle. Finally, contextual factors, such as where foods or beverages are obtained, with whom meals are consumed, where meals are consumed (i.e., at home versus away from home), and the use of electronic devices while eating may be relevant to a given research question.

In most research relevant to dietary behaviors, self-report measures are used. This is because it is not possible to objectively assess usual intake in free-living individuals. Depending on the measure, self-report data can also capture temporal patterns and contextual factors that are of interest in many studies. We briefly describe available objective measures and their utility before reviewing commonly used self-report measures of intake, along with considerations related to technological innovations and highlights of specific considerations related to children.

Getting started:

Carefully considering measures to be used for all variables and collaborating with statisticians early in the process can help ensure that data are collected, analyzed, and interpreted in a way that leads to the most robust evidence possible for informing obesity prevention.

Objective Measures of Dietary Intake

The identification of biomarkers and their application in diet assessment (Box 3) are active areas of inquiry.[58–61] Recovery biomarkers[62] are recognized as objective measures of true intake for energy and a few nutrients, including protein, potassium, and sodium. Energy intake is estimated using the doubly-labeled water (DLW) technique[63] whereas the collection of 24-hour urine samples is used for protein,[64] potassium, and sodium.[65,66] The collection of recovery biomarkers is costly and burdensome for researchers and respondents and not feasible for most studies. Further, recovery biomarkers (and other types of biomarkers) do not provide information on what individuals actually eat and drink, nor contextual factors of salience to understanding how to intervene to shift eating patterns.[67] Their usage for research in which the aim is to examine eating patterns, influences on those patterns, and the potential value of interventions for altering them is thus limited. Recovery biomarkers are, however, extremely useful for validation studies[62–64] to assess error in self-report measures, and they can also be used to reduce error in self-report data when they are available for a study subsample.

Several relatively large recovery biomarker-based validation studies have been conducted and the data pooled for analyses,[65,66] lending insights into error in commonly used

BOX 3: OVERVIEW OF BIOMARKERS RELEVANT TO THE ASSESSMENT OF DIETARY INTAKE BEHAVIOR

- **RECOVERY BIOMARKERS:** Biologic products that are directly related to intake and provide unbiased estimates of true intake.[62]
- **CONCENTRATION BIOMARKERS:** Biologic products reflecting the concentration of a chemical or compound in blood, urine, or tissues after metabolism.[62] Indirect measures of intake.
- **PREDICTIVE BIOMARKERS:** Biologic products that have a stronger relation with intake than concentration biomarkers but do not provide unbiased estimates of true intake. For example, predictive biomarkers have been proposed for sugars (urinary sugar)[68,69] and whole grains (plasma alkylresorcinols).[70] Such biomarkers are postulated to improve estimation of associations between diet and health.
- **METABOLOMICS:** Methods used to identify metabolites in biological fluids (e.g., blood, saliva, urine) that are produced through metabolism of foods, as well as toxins and medicines.[71] Pinpointing metabolites that vary by dietary pattern has been proposed as a means of advancing understanding of diet and health relationships, as well as discovering novel biomarkers for intake of foods, such as red meat or vegetables.[71,72]

measures such as 24-hour recalls and food frequency questionnaires. The results of such studies are briefly summarized in Section 6.

Concentration[62] and predictive[68,69] biomarkers represent additional classes of indicators increasingly used in the measurement of dietary intake.[59,60] However, these do not have the same direct link with intake as recovery biomarkers and do not represent markers of true intake. These biomarkers can be useful, however, in combination with self-report measures in studies requiring the assessment of dietary intake; this is an area of ongoing research and discovery. Further, metabolomics has been recognized as a promising area in nutrition research, with the potential to lead to the discovery of novel biomarkers for intakes of foods, as well as to enhance understanding of how diet influences disease.[71,73] Other innovations include the application of spectroscopy to dietary assessment, with the development of techniques to measure skin carotenoid status as a biomarker of intake,[74,75] for example. Research with children has suggested high concordance between skin and serum carotenoids, suggesting that skin carotenoids could be used as a marker of fruit and vegetable consumption.[74,76] Skin carotenoids have been used in combination with digital photography-based measures of fruit and vegetable intake to assess the influence of an intervention on children's intake.[77,78] Although these innovations are promising in terms of improving dietary assessment in the future, current research continues to rely primarily upon self-report.

Observation represents an additional objective measure of dietary behavior that can be useful for documenting true intake for comparison to self-report. Indeed, observational assessments of children's eating and diet-related behaviors are often used to indicate objective truth for the evaluation of other dietary assessment methods.[79] Researchers either observe participants' dietary behaviors directly (e.g., videotaping child's food selection, sitting in a classroom while children eat lunch) or indirectly (e.g., discreetly weighing food containers before and after consumption to calculate precise measurement of food eaten). Importantly, observation can allow measurement of misreporting of foods (unlike the recovery biomarkers described above). However, for situations in which interest is in intake for the purpose of understanding usual diet and eating patterns, the application of observation is limited.

Self-Report Measures of Dietary Intake

Commonly used self-report measures of intake include 24-hour dietary recalls, food records/diaries, food frequency questionnaires, and brief instruments (often referred to as screeners). Each tool has advantages and disadvantages,[80] though it should be noted that some of the traditional limitations of tools have been addressed in the last decade or so due to technological innovations in dietary assessment described briefly in this section. Despite such innovations, all self-report measures capture intake with error; the type and extent of error depends on the tool and its characteristics (Section 6). Choosing the best possible measure for the given research application and target population and using

Resource Tip:

The National Cancer Institute's Dietary Assessment Primer provides a thorough overview of the characteristics of each of the self-report measures discussed.

Consult the Primer for details about the measures and recommendations for their appropriate usage and analysis for measuring dietary behavior.

appropriate statistical methods can help to reduce this error and its effects on study findings.

A means of categorizing diet assessment tools is whether they assess short-term or long-term intake. Tools assessing intake over the short-term include 24-hour recalls and records/diaries, whereas those assessing intake over a longer period include food frequency questionnaires and screeners. Recalls and records/diaries are intended to capture intake over a day or a number of days. With food frequency questionnaires and screeners, respondents are prompted to report on their usual intake of a list of foods and drinks, aiming to estimate the frequency of consumption of foods and beverages over a period such as a month or a year, perhaps also with queries regarding typical portion size.

To address challenges in assessing dietary intake among children, multiple methods may be used for data capture. For example, records are sometimes kept to assist with completing recalls, as highlighted later in this section. This is distinct from the use of data from different measures in analysis, which is mentioned in Section 8 and in the Case Studies (Section 9).

With all self-report methods, children may misreport intake because of social desirability biases.[81] To consider the potential impact of social desirability on intake in data analyses, a study may include a measure of this bias in conjunction with a measure of intake to characterize and adjust for this source of error.

Method: 24-Hour Dietary Recalls

Example tools: Automated Multiple-Pass Method (AMPM),[82–84] Automated Self-Administered 24-Hour Dietary Assessment Tool (ASA24),[52] Nutrition Data System for Research (NDSR),[85] various paper-based versions.

The 24-hour dietary recall is aimed at capturing a comprehensive and detailed accounting of all foods, beverages, and in some cases, supplements, consumed on a given day.

Regarding usual intake, a single recall among a group can provide an estimate of mean usual intake, but for estimates related to the distribution of usual intakes (e.g., prevalence below/above a threshold), it is necessary to collect repeat recalls from at least a subsample to enable accounting for day-to-day variation in intake. For episodically consumed dietary components (i.e., components such as dark-green vegetables that are consumed irregularly by most persons in the target group), it may be necessary to collect additional replicate recalls to achieve a sufficient number of recalls that include that food or nutrient. For non-episodically consumed components (i.e., components such as refined grains or added sugars that are consumed regularly by most persons in the target group), this is not the case.

Traditionally, 24-hour recalls have been administered by an interviewer. Multiple-pass methods are used to improve accuracy[1] and may be implemented using computerized systems. For example, the Automated Multiple-Pass Method (AMPM), developed by the U.S. Department of Agriculture (USDA), is a computerized method for interviewer-administered recalls that employs five steps to enhance complete recording as well as reduce burden for respondents.[82–84] The steps include a quick list, which is a "mind dump" of all foods and drinks consumed the prior day; a probe for forgotten foods; a time and occasion pass that organizes the foods and drinks according to eating occasion; a detail cycle that probes for details, including how the food or beverage was prepared, the amount consumed, and anything added; and a final probe for anything else consumed but not yet reported. For the reporting of portion sizes, aids are usually used. These may include common household items, such as measuring cups and spoons and pictures or food models. In relation to true intake determined by observation, data collected using AMPM have been found to be relatively accurate for energy, protein, carbohydrate, and fat among men regardless of body mass index.[86] AMPM is the method used to collect dietary intake data within What We Eat in America, the dietary component of NHANES.[2] Other systems, such as the University of Minnesota's Nutrition Data System for Research (NDSR),[85] also employ multiple-pass methods to enhance the completeness of recalls. AMPM and NDSR offer the advantage of automated coding based on details provided for each food and beverage, eliminating the need for manual coding. Recalls can also be collected by interviewers using paper or computers or mobile devices, with multiple passes recommended. In this case, manual coding of each item reported is needed to enable linkage to a food composition and other relevant databases. This is labor- and time-intensive and thus, costly.

In addition to details on foods and beverages, 24-hour recalls can provide insights into patterning of food intake, such as the consumption of meals and between-meal snacks, as well as the distribution of food intake across the day. Probes can be included to capture contextual factors, such as where meals were eaten (e.g., home, school, fast food restaurant) and with whom, the source of the major ingredients for each item consumed, and the use of electronic devices during the consumption of meals and snacks. The 24-hour recall methodology may also integrate the reporting of vitamin and mineral supplement intake. This may be a separate module that follows the food and beverage recall and prompts respondents to report supplements taken the previous day, along with pertinent details such as the brand, dosage, and amount taken.

Sources of error in 24-hour recall data include imperfect short-term memory, inaccuracies in portion size estimation, and social desirability biases that may contribute to misreporting of some foods and beverages. Recalls have been shown to capture dietary intake with less bias than do food frequency questionnaires (Section 6). Thus, they are recommended for various applications, including those in which the research question relies on quantitative estimation of intakes among a population or subpopulation.

Barriers to the administration of recalls, particularly in large-scale research initiatives, have traditionally related to the significant cost for trained interviewers, as well as coders in circumstances in which coding is not automated. However, technological innovation in dietary intake has led to the development of web-based self-administered recall tools that eliminate the need for trained interviewers and coders. For example, in the United States, the Automated Self-Administered 24-hour Dietary Assessment Tool (ASA24)[52] has been developed and is freely available to researchers, enabling the collection of recall data in a range of studies. ASA24 adapts the AMPM, with modifications made to facilitate self-administration (e.g., respondents first report meal occasions and related details, such as time and location, move on to report the foods and beverages consumed at each meal, and then complete a detail cycle, followed by forgotten foods). ASA24 provides the opportunity to collect data across studies using the same tool, lending to comparability of data with the potential for building a stronger evidence base that can be synthesized to arrive at important conclusions regarding diet and other factors as well as the potential for interventions to affect diet. With similar tools adapted (ASA24-Canada and ASA24-Australia) or developed (e.g., MyFood24 in the UK[53]) elsewhere, the potential for standardized data can extend beyond borders, facilitating pooling of data or cross-country comparisons.

ASA24 was initially modelled on a recall system developed for children.[52,87] However, evaluative efforts with technology-based recalls, such as ASA24, among children are thus far limited[88–90] and have not clearly identified the age at which children can complete a self-administered recall independently. Prior research has suggested that children may be able to independently complete recalls beginning at the age of 10 years[91] and in NHANES, independent reporting is used beginning at the age of 12 years.[2] Programs such as ASA24 may help to motivate children to report their intake due to their interactive nature; however, the multiple steps in completing recalls may lead to boredom or fatigue regardless of the use of technology. Evaluation of ASA24 among adults through an observational feeding study has shown that it performs well in relation to true intake and interviewer-administered recalls.[92] It has also been shown to be feasible for use in large-scale community-based data collection among adults.[93] Nonetheless, given the unique considerations in assessing diet in children, further evaluation is needed.

Efforts to enhance methods of administering 24-hour recalls using technology are being complemented by those to improve portion size estimation among children.[38] Given that misreporting of portion size can be an important contributor to error, these are likewise important advances and an area for ongoing research.

In summary, 24-hour recalls can be useful for collecting dietary intake among children, but careful attention should be paid to administration to collect the most accurate data possible (Box 4).

Method: Food Records/Diaries

Example tools: Technology Assisted Dietary Assessment (TADA),[54, 55] various paper-based forms

Similar to 24-hour recalls, food records or diaries (referred to as records subsequently, for simplicity) are intended to capture a detailed account of all foods, beverages, and possibly, supplements consumed on one or more days. Records are often kept for a period of one, three, or seven days. The distinction between recalls and records is that with a recall, the respondent reports (i.e., recalls, relying on memory) what was consumed yesterday (or over the past 24 hours) whereas with a record, the respondent keeps track of (i.e., records in real time) what he or she consumes. Typically, respondents are given a recording form along with instructions prompting for specific details, such as how each item consumed was prepared. The completion of food records requires literacy and numeracy. Portion size can be estimated using household measures, pictures, or other aids, or respondents may be requested to weigh all items using scales or volume measures. In some studies, research staff review the completed records with participants to fill in missing details. Multi-day weighed records are sometimes referred to as a gold standard for the evaluation of other dietary measures. However, given that all self-report methods are affected by error,[65,66,96] it is inaccurate to refer to any such methods as gold standards.

BOX 4: USING 24-HOUR RECALLS WITH CHILDREN

- For interviewer-administered recalls, interviewers must be trained, experienced, and follow protocols. Data collectors should be familiar with common foods and beverages consumed by children and the details needed to code them.
- For technology-based self-administered recalls, the tool should be intuitive for and appealing to children. Testing with the target group is critical to ensure feasibility.
- When using self-administered recalls, training prior to the collection of study recalls may be useful. For example, completing a practice recall in the presence of a researcher can help a child to learn the flow of the program. Study staff should be very familiar with the tool and able to provide necessary supports.
- For young children who are unable to report their own intake, proxy reporting is necessary. The involvement of children is important as they become more independent and parents or other caregivers are not present for all eating occasions. For older children, the involvement of a proxy may be viewed as an intrusion.[94] NHANES uses proxy reporting for children younger than age 6 years, proxy-assisted recalls for children ages 6 to 11 years, and self-report for those ages 12 years and older.[2]
- Young children have limited concepts of time as well as limited ability to recall prior food consumption. Recency appears to affect children's ability to accurately report. As a result, collecting data for the past 24 hours starting from the time at which the recall begins may be preferable to reporting for the prior day, midnight to midnight.[95] ASA24, for example, provides an option for reporting for the past 24 hours.
- The use of neutral probing may help to avoid social desirability bias. A measure of social desirability bias may be used to assess this source of error.
- Probing for details that children are unlikely to know (e.g., what oil was used to prepare the food?) may lead to lower accuracy. In interviewer-administered recalls, interviewers should be trained to probe for only the information necessary to code the item. However, encouraging recollection of the context for food consumption (e.g., meal occasion, location) may be helpful in reducing errors in recall.
- Portion size estimation is very difficult for children (as with adults). Prior training may be helpful, but this remains a challenging area within dietary assessment.[37]
- Boredom and fatigue are possible with the multiple steps involved in completing recalls, as well as in studies involving the completion of multiple recalls.[31] In studies involving multiple recalls, training effects are also possible, with declining quality of data as the number of recalls increases.
- In some situations, it may be possible to obtain complementary information from other sources, such as school food services for foods and beverages served on the recalled day. The use of food and beverage descriptions, portion sizes, and USDA standard recipes can allow for more precise coding and reduce probing for food details and portion sizes.

Similar to recalls, data from records can provide insights into behaviors such as meal patterns and snacking and contextual factors such as where meals were eaten and with whom, and other activities during consumption, such as television watching. Unlike recalls though, data collected using records can be affected by reactivity in that individuals may change their eating behavior in response to tracking or monitoring. For some intervention studies, this form of self-monitoring and its implications for eating patterns may be the desired effect of the use of food records. However, in studies aiming to capture usual intake, reactivity is a source of error. As with recalls, data collected using records can be affected by inaccuracies in portion size estimation (if estimated rather than weighed), and social desirability biases likely contribute to misreporting of some foods and beverages.

Food records have also been affected by technological innovation with the advent of mobile device-based records, which may rely on images taken by the respondent before and after consumption of foods or beverages.[97] Records require a significant coding effort. Thus, efforts are underway to automate coding using image-based assessment and image recognition. As capabilities related to image processing and recognition continue to evolve, tools such as the Technology Assisted Dietary Assessment (TADA)[54,55] have the potential to shift methods of diet assessment with

Combining Methods

- Some researchers have used record-assisted recalls in an attempt to enhance accuracy of data collected from school-age children.
- In such studies, children are instructed to complete a written food record/diary.
- The record/diary is used to probe for food and beverage details, portion sizes, and forgotten foods and beverages during the subsequent completion of the recall.[126–130]
- An evaluation of this approach found that recalls may not add significantly to the accuracy of records, and that the use of records as a memory cue should be considered in the context of the additional burden imposed, as well as the potential to elicit reactivity.[131]
- Further research to better understand the utility of multiple methods for data capture among children is warranted.

adolescents, who increasingly have access to mobile devices such as smartphones. Such advances may be useful for improving children's engagement in dietary assessment, with potential benefits for the accuracy of the data collected. However, ongoing monitoring of the diet using a program on a mobile device may change the dietary patterns that are of interest in a study.

As with recalls, various considerations should be accounted for in using food records with children (Box 5) to maximize the accuracy of the data.

BOX 5: USING FOOD RECORDS WITH CHILDREN

- Completion of food records requires a minimum level of literacy and the ability to legibly write[39,98] what was consumed (or to search or browse for foods and beverages, in the case of technology-based approaches). Children must also have some basic knowledge of foods and how they are prepared, and the ability to quantify intake.
- For young children who are unable to report their own intake, proxy reporting is necessary. The involvement of children is important as they become more independent and parents or other caregivers are not present for all eating occasions.
- The burden associated with the completion of food records may result in compliance issues. As children get older and become more independent, they may be irritated by the need to record their intake at multiple points throughout the day.[37]
- The accuracy of dietary records may be improved with initial training and follow-up review and verification of all details with the child or proxy. As with recalls, probes should be phrased in a neutral manner to avoid eliciting social desirability or other forms of bias.
- With multiple days of recording, boredom and fatigue are possible.

Method: Food Frequency Questionnaires

Example tools: Diet History Questionnaire (DHQ), EPIC Food Frequency Questionnaire, Harvard Food Frequency Questionnaire, Multiethnic Cohort (MEC) Food Frequency Questionnaire

The aim of food frequency questionnaires is to gather information about the frequency with which different foods and beverages are consumed over some period of time, often the last month or year. Frequency questionnaires may prompt about typical or usual portion size, sometimes using images intended to facilitate accuracy of reporting. Questions regarding how often supplements are taken and usual dosages may also be included. Frequency questionnaires are typically self-administered. Depending on the comprehensiveness of the items included and their representation of the foods consumed by the target group, they may capture total diet or particular aspects of the diet. A questionnaire aimed at capturing total diet can be lengthy, requiring 30–60 minutes to complete. Given linkage to a food composition database, estimated nutrient intakes can be generated, though these have been shown to be affected by significant bias, at least for energy and the nutrients for which recovery biomarkers have been identified.[65,66] Thus, estimating mean intake among populations using frequency data is not recommended. Unlike the short-term methods, food frequency questionnaires generally do not provide insights into aspects such as patterning of meals and snacks, where foods and beverages are eaten and sourced, other activities engaged in while eating, and similar constructs that may be salient to obesity-related research. In terms of technology in food frequency questionnaires, this is typically limited to web-based administration.

Contributors to error in data collected using food frequency questionnaires include imperfect long-term memory and the cognitive tasks associated with averaging frequency of consumption (and possibly amounts typically consumed) over a period of time such as a month or a year. Given that the list of foods and beverages is finite, error can come about if the questionnaire does not appropriately cover items commonly consumed by the target population. Thus, it is important the questionnaire is tailored to the target population. However, this tailoring, resulting in many different food frequency questionnaires for use with different populations, may pose a barrier to comparison across studies and pooling of data.

The tasks involved in completing food frequency questionnaires may not be well suited to children depending on their age and development. Young children have limited concepts of time[31] and concepts of memory that are not fully developed.[36] As a result, food frequency questionnaires querying about a long period of time are problematic. When these questionnaires are used, shorter time periods with meaningful start and end dates that provide cues to memory may be helpful.[94] However, even with shorter time periods, children may not have developed the cognitive skills, including recalling recent intake of foods, averaging frequency of consumption over the reference period, taking into account weekday and weekend differences, and seasonal differences in frequency, to complete frequency questionnaires accurately.[99] Children may also not have a good understanding of composite foods used in such questionnaires.[94] The length of some frequency questionnaires may result in boredom and fatigue, leading to poor compliance or reporting quality among youth.[39] In addition, when portion size is queried, the use of sizes not tailored to children can potentially result in systematic overestimation of intake.[39]

Method: Screeners

Example tools: Adolescent Food Habits Checklist, Block Screener for Kids, NCI Fruit/Vegetable/Fat Screener

Screeners are brief instruments that enable the collection of basic information about particular foods or beverages or other dietary behaviors. Screeners may query the frequency of intake of certain foods or beverages and thus may be thought of as short food frequency questionnaires, usually without questions regarding portion sizes. Alternately, screeners may ask about dietary practices, including routine use of items such as butter on bread. Similar to food frequency questionnaires, screeners tend to be self-administered. However, they can be very quick to complete (i.e., less than 15 minutes). As with food frequency questionnaires, information regarding patterning of food consumption and other contextual information are not collected unless queried separately.

Data collected using screeners are affected by similar sources of error as those collected using food frequency questionnaires. They cannot be used to estimate total diet. Screeners may be of particular use for dietary components that are not widely spread through different sources in the food supply, such as sugar-sweetened beverages, whereas they are likely to be less useful in terms of quality of data for components such as fruits and vegetables that can be consumed in many different forms and as part of mixed dishes. As with frequency questionnaires, the use of screeners to estimate mean intakes among populations or subpopulations is not recommended.

One dietary screener, the DSQ developed by NCI,[100] can provide quantitative estimates of intake, converted from frequency responses using scoring algorithms derived from NHANES age- and sex-specific portion sizes. This questionnaire is currently being tested for validity among children. However, given their shared characteristics with food frequency questionnaires, the use of screeners with children may not be optimal. They are by definition shorter than frequency questionnaires so may reduce burden and resulting potential loss of interest among children. However, the cognitive challenges in averaging frequency of intake over time persist, as do issues with conceptualizing time and recalling intake.

Method: Measures Querying Related Dietary Behaviors

Example tools: Children's Eating Behavior Questionnaire, Children's Eating Attitudes Test (ChEAT)

Questionnaires may be used to identify or assess diet-related behaviors, including responsiveness, enjoyment, preferences, and attitudes toward food; snacking; restrictive behaviors; social pressures and norms surrounding food consumption; and satiety and hunger. These measures vary greatly in length and complexity, and may require parental assistance if the child does not yet have the cognitive skills to comprehend the content, or if the content has not been tailored to a younger audience. The use of age-appropriate measures in conjunction with parental perception may be useful in capturing more involved psychological constructs. Similar to other methods of measurement, questionnaires assessing diet-related behaviors may be influenced by the respondent's body mass index[101] (or that of the proxy reporter) and social desirability biases.

6

Evaluating Individual Diet Measures

In examining the appropriateness of different measures for assessing dietary behavior, we are interested in their psychometric properties. These include *validity* and *reliability*, and the associated concept of *measurement error*.

Validity refers to the extent to which a measurement reflects true dietary behavior. There are different types of validity (Box 6) and they are tightly linked to one another.

Reliability refers to the consistency with which a behavior is measured (Box 7). Different types of reliability may be particularly salient depending on the research question and study design.

Within the field of dietary intake assessment, we often discuss the extent of *measurement error* in self-report data.[102] Measurement error refers to the difference between the true value of a parameter, such as intake of a dietary component, and the value estimated using a measure, such as a 24-hour recall or food frequency questionnaire. There are two types of measurement error: random and systematic. With *random error*, the errors may be in the direction of under- or over-estimation. If a sufficient number of observations are available, the errors will average to zero. Thus, the measurements are not precise but they are not biased. For dietary intake data, day-to-day variation in what individuals eat and drink is the main source of random error, affecting primarily short-term instruments. In other words, intake captured on a given day is affected by excess variation due to differences in what individuals consume from day to day (known as day-to-day, or within-person, variation). Random error is related to the reliability of data collected using a measure.

With *systematic error*, measurements depart from truth in a consistent direction such that the data are biased (thus, systematic error is also known as bias) toward either under- or over-reporting. Contributors to systematic error within dietary intake measures include recall biases, reactivity, social desirability biases,[35] cognitive abilities such as limited attention span, food and body attitudes and perceptions, body weight status,[38,103] and food habits and the complexity of diet.[36] In capturing children's dietary behaviors, whether the child or parent reports dietary behavior can also play a role,[104] as can the recency of the reporting period[95,105] and the use of portion size aids designed for adults.[41] Systematic error is related to the validity of data collected using a measure.

BOX 6: TYPES OF VALIDITY

- **CRITERION-RELATED VALIDITY:** Extent to which a measure is predictive of an external criterion and is accurate. To assess criterion-related validity, the extent to which a measure agrees with another valid measure is assessed. An example within dietary behavior is examination of the criterion validity of intake data captured using a self-report measure compared to documented true intake ascertained using an objective measure, such as data from a recovery biomarker or observation.
- **CONSTRUCT VALIDITY:** Extent to which observed relationships between the measure (e.g., a scale) and other variables are as expected. For example, the relationship between measured eating attitudes and dietary intake might be assessed.
- **CONTENT VALIDITY:** Whether items accurately represent the underlying construct (e.g., a particular dietary behavior) that is being measured. For example, depending on the definition employed, a measure of sugar-sweetened beverage consumption should include fruit juice and flavored milk, as well as soda.
- **FACE VALIDITY:** Extent to which a measure has conceptual validity. This is often assessed through a review by expert judges. Face validity might also pertain to a questionnaire about sugar-sweetened beverages, for which there is a lack of consensus on definitions.

BOX 7: TYPES OF RELIABILITY

- **INTER-RATER RELIABILITY:** Agreement among raters. Within the context of dietary behavior, this might be relevant in a situation in which multiple trained observers document intake. Inter-rater reliability can be assessed using a correlation coefficient or Cohen's kappa.
- **TEST-RETEST RELIABILITY:** Correlation between two administrations of the measure to the same respondent, or repeatability. Test-retest reliability is of relevance in studies in which dietary behavior is measured at multiple time points, for example, to detect change before and after exposure to an intervention. Test-retest reliability can be assessed using a correlation coefficient.
- **INTERNAL CONSISTENCY:** Extent to which items within a measure (e.g., a scale) measure the same behavior. Internal consistency is relevant, for example, to a scale intended to measure various aspects of dietary patterns through different subscales (e.g., fruit/vegetables, dairy products, meats) and can be assessed using Cronbach's alpha.

In selecting measures to assess dietary intake or other diet-related behaviors, it is critical to consider psychometric properties, including whether evaluation of these properties has occurred within similar populations as the target study population and how the psychometric properties were examined (e.g., against what reference measures and using what statistics or other procedures). Different properties may be particularly salient to the study design. For example, test-retest reliability is an important component to consider in the selection of a measure used in cohort or intervention studies, in which multiple points of data collection are required. Further, measures of dietary behavior (aside from intake) should be assessed for construct validity because of the ambiguity underlying some concepts (e.g., food addiction, eating attitudes) that cannot be assessed through biological markers.[106]

Validation Studies

Studies to assess the extent of error in measures are referred to as validation studies. In dietary intake assessment, validation studies include a reference measure that is a marker of true intake, such as a recovery biomarker. A number of biomarker-based validation studies have been conducted to assess error in self-report measures. Many of these have been completed among adults and tend to show that data collected using 24-hour recalls are affected by significant random error but less systematic error or bias than data captured using food frequency questionnaires.[65,66,107,108] Food records share characteristics with 24-hour recalls in terms of bias, with the exception of the contribution of reactivity. Screeners cannot be assessed using recovery biomarkers because they do not capture total diet. Findings from biomarker-based studies with adults, including pooled validation studies, have informed recommendations to avoid basing estimates of energy intake on self-report data given known biases.[67] However, results for other dietary components, such as protein density and potassium, show that these are less biased,[65,66] indicating that self-report data have value for understanding eating patterns more broadly. Validation studies also have informed strategies related to combining instruments[109] and the use of appropriate analytic techniques to mitigate error.[1,110,111]

Measuring diet is complicated when the intent is to examine relationships with body weight or characteristics related to body weight because it has been demonstrated that body mass index is a strong predictor of misreporting of dietary intake, and particularly of energy misreporting.[36,103,112] A systematic review of the validity of self-report methods for energy intake in relation to doubly labeled water drawing upon studies conducted with children from birth to age 18 years[113] found both under-reporting and over-reporting of intake that ranged from 2 percent to 59 percent, depending on the self-report measure and the study population. The authors concluded that the 24-hour recall, using multiple passes and proxy reporters, was the most accurate method for young children, whereas weighed food records were most accurate for older children. However, as noted, the evidence suggests that, overall, self-report is not the optimal method of assessment of energy intake. Other indicators, such as changes in weight, are a preferred measure of energy balance in relation to other factors, such as interventions.

Because of barriers to the use of recovery biomarkers and the lack of such markers for most dietary components, studies to evaluate the validity of self-report measures often use another error-prone self-report measure that is assumed to be less biased than the measure being evaluated as the reference. Such studies are sometimes referred to as comparative or relative validation studies.[1] The findings of these studies need to be interpreted carefully because it is not only true intake but also errors in the measures that can be correlated, possibly leading to misleading results. A number of studies of this nature have been conducted to assess how well self-report tools capture intake among children. For example, parental reports of beverage intakes among infants using a food frequency questionnaire compared to a three-day food record suggest higher correlations for milk than for water, juice/drinks, and soft drinks. Findings for different foods and nutrients tend to vary by dietary component and tool, with both under-reporting and over-reporting possible. A literature review conducted by the National Institutes of Health provides further details of validation studies conducted in various age groups, including infants and toddlers, preschoolers, school-age children, and adolescents.[114]

It should be noted that most validation studies have been conducted in the context of epidemiology, for example, to better understand the extent to which error attenuates (i.e., biases toward the null) observed relationships between dietary exposures and health or disease outcomes. Research examining error associated with being exposed to an intervention (i.e., intervention-related bias) is lacking. However, existing research (among adults) suggests that this error poses a problem in terms of contributing to differential error between intervention and comparison groups that can affect the results of analyses.[115] For example, in a randomized controlled trial, women who had been exposed to messages related to the benefits of fruits and vegetables subsequently reported higher intake of these foods on both frequency questionnaires and a targeted 24-hour recall compared to women not exposed to the potentially biasing messages.[116] Research is needed to understand intervention-related biases among children and to inform strategies to address them. Surprisingly little research has been conducted to examine the sensitivity of measures of dietary behavior to change, which is fundamental to assessing the impact of interventions.

Overall highlights from validation and other evaluative studies are outlined in Box 8.

In sum, it is critical in all research endeavors to consider the extent to which the measures to be used will provide high-quality data to address the research question. Examining the psychometric properties is a way to consider whether this is the case. The Measures Registry can be very useful in this regard because it provides an overview of available studies on validity and reliability for each included measure. It is important that researchers contemplating the use of a particular measure refer to the original citations to examine how measures were evaluated, in what populations, and the implications for fit for the given study.

BOX 8: HIGHLIGHTS FROM STUDIES TO ASSESS THE VALIDITY OF DIETARY INTAKE DATA COLLECTED USING SELF-REPORT TOOLS

- Validation studies of dietary intake measures using recovery biomarkers as a measure of true intake have illustrated the extent of error for energy and selected nutrients, including protein and potassium.[65,66,107,108] It has been well established that energy is reported with substantial error and for this reason, it is recommended that self-report data not be used to estimate absolute energy intake.[67]
- Misreporting has been shown to be associated with body weight status, with greater under-reporting of energy with higher body mass index. For this reason, it is challenging to assess associations between energy intake and body weight.
- Less is known about misreporting of foods but there is reason to believe that foods and beverages perceived as less healthy may be subject to greater error due to social desirability bias. Research with adults has suggested that under-reporters (based on the use of equations to predict metabolic rate) report foods rich in fat and/or carbohydrates (e.g., sugars, cakes, pastries, French fries) less frequently than do non-under-reporters. Further research is needed to better understand misreporting of particular dietary components.
- Cautions regarding misreporting associated with body weight status must be extended to analyses using variables that may be correlated with body weight, including race/ethnicity, education and other dietary behaviors, such as restrained eating behaviors or body image. For example, interrelationships among body weight and race/ethnicity may make it difficult to assess the contributions of dietary patterns to differential rates of obesity.

7

Selecting Measures

Selecting the most appropriate measure for assessing dietary behavior requires accounting for multiple considerations in terms of what data are needed and how they will be used. To help address these aspects, the following guiding questions are suggested. These questions are informed by those posed by Sternfeld and Goldman-Rosas[117] to guide the selection of appropriate measures for physical activity and sedentary behavior.

1. **What is the primary research aim or question?** Clearly defining the aim or question from the outset is critical to ensuring alignment with the measure of dietary behavior (and measures for other variables as well). Studies related to dietary behavior may be intended for surveillance or monitoring purposes, such as to estimate the frequency with which preschoolers consume juice, assess the usual intake of sugar-sweetened beverages among school-age children, or characterize perceptions or attitudes toward food and food consumption. Further, epidemiologic studies may be undertaken to examine relationships between dietary behaviors, conceptualized as exposures, and subsequent outcomes relevant to childhood obesity, while intervention studies aim to assess the impact of a given strategy to shift eating patterns.

2. **Is the target population made up of infants, toddlers, school-age children, and/or adolescents?** Age has an important bearing on cognitive abilities, as well as memory and concept of time, affecting whether it is possible to administer measures directly to children or whether parents or other proxy reporters need to be included. If a study will include children of various ages, considerations will be needed to tailor tools or methods of administration depending on literacy, numeracy, attention span, and related factors. For example, within NHANES, dietary recalls are proxy-reported, proxy-assisted, or completed by children independently, depending on age. Body weight is an important consideration given evidence that body mass index is a strong indicator of error in reporting of dietary intake. Characteristics that may be associated with body mass index, such as education and race and ethnicity, also should be considered.

3. **What is the study design?** Are the measures administered at one time or multiple times? Are measures collected cross-sectionally, prospectively, or retrospectively? For retrospective studies, food frequency questionnaires or screeners are the only possible self-report measures for dietary intake. Attention should be paid to potential sources of error, including the possibility that current intake may bias intake recalled for the past.

4. **In what setting will the research take place and how will this affect possibilities for data collection?** For example, it may not be possible to conduct rigorous observation or collect detailed intake data within a classroom setting depending on the number of children and the available resources for data collectors, though this could be alleviated with web-based tools, depending on the age and cognitive abilities of the children. If data are being collected online or by mail, this introduces complexities in terms of the possible measures that can be used.

5. **What settings are of interest?** For example, dietary behaviors at home, away from home, or at school? Do these need to be differentiated to address the research question, and how does this impact upon the measurement needs?

6. **Is the focus on the total diet or on specific dietary components of interest?** For example, does the research question pertain to total diet and/or diet quality or patterns or specific components of diet, such as foods or food groups, beverages, or particular nutrients? Are the components of interest episodically or non-episodically consumed by most in the population of interest?

7. **Is diet an independent variable, dependent variable, or covariate?** This has implications in terms of the effects of error and strategies to mitigate it, as alluded to in Section 8. Is particular statistical expertise required and if so, is it available?

8. **What parameters are of interest?** For example, estimates of intake, frequency of consumption, or some other behavior, such as snacking or characterization of the sources of nutrient-dense food consumption. Relatedly, what are the desired summary measures? For example, are mean usual intakes of fruits and vegetables among a group of interest, or is there a desire to estimate proportions above or below recommendations? What are the corresponding implications for data collection and analysis (e.g., the need for repeat short-term measures to estimate distributions of usual intake for the purposes of assessing the prevalence of a group with intakes above or below a recommendation)?

9. **Are related or complementary measures necessary to address the research question?** For example, are other dietary components (besides those targeted) of interest from the perspective of compensatory effects or trade-offs (e.g., in the case of interventions to reduce sugar-sweetened beverages)? Are other dietary behaviors aside from intake (e.g., those related to food preferences and attitudes) relevant to the interpretation of dietary intake data and to addressing the research question? Are other behaviors outside of diet, such as physical activity, important to addressing the research aim (e.g., are alterations in diet offset in some way by changes in activity level)?

10. **What are the logistical considerations and constraints, such as the time allocated to the measurement of dietary behaviors within a larger study, as well as budget and expertise?** Following Sternfeld and Goldman-Rosa,[117] this question is deliberately placed last in the list to encourage researchers to weigh logistical issues no more heavily than the considerations listed above. In other words, all salient details should be considered so that the final choice reflects the best possible measure given all factors at play.

Considering the questions above can help to narrow down the measures within the Registry to those consistent with the research aim, population, and dietary behaviors of interest. The Measures Registry provides information that can be easily scanned, with organization into sections providing an “At A Glance” overview of each measure, along with information on the design of the study in which a measure was developed or used, tips on how to use the measure, and as mentioned previously, a summary of available evidence on validity and reliability. It is also possible to compare across measures. After narrowing down the choice of measures to those best aligned with the research needs, the researcher can explore other resources, including citations listed in the Registry, in depth to consider fit in terms of specific dietary behaviors, the specifics of evaluations of psychometric properties, as well as whether the tools need tailoring and further evaluation prior to use with the target population. In cases in which tools are adapted, a decision needs to be made as to whether the tool has been changed to the extent that it requires further evaluation for validity and reliability. These details should then be included in any publications reporting on the use of the measure to allow for appropriate interpretation.

8

Considerations for Collecting, Analyzing, Interpreting, and Reporting Data on Individual Diet

Measure selection is critically important but is only one part of the process in terms of research related to dietary behavior. Considerations regarding how data will be analyzed should come into play early in the study design process. This is fundamental due to interconnections between the most appropriate analyses to arrive at the desired estimates, the measures used, and parameters for their administration (e.g., number of repeat measures of short-term instruments, timing of repeat measures within an intervention study, incorporation of biomarkers). Due to this link between data collection and analytic techniques, collaborating with statisticians early in the process is encouraged.

Detailed recommendations regarding the collection of dietary data for different types of studies are outlined in the National Cancer Institute's (NCI's) Dietary Assessment Primer.[1,56] For example, the Primer notes considerations relating to whether or not addressing the research question of interest requires estimation of usual intake distributions. If so, it is necessary to collect repeat recalls or records on at least a subsample of the target population and to conduct statistical modelling to account for day-to-day variation. In cohort studies aimed at enabling analyses between dietary exposures and outcomes, it is advisable to collect data using a recovery biomarker if possible, or a less-biased self-report measure compared to the main dietary instrument, among a subsample. Data from this calibration sub-study can then be used to conduct regression calibration to reduce error in data from the main dietary instrument. For epidemiologic studies, collecting concentration biomarker data also may be helpful in mitigating error. In intervention studies, it is important to consider the potential for differential biases in that those exposed to some intervention designed to alter eating patterns may misreport diet differently than those who were not exposed. Means of dealing with differential bias are not well developed. Thus, it is advisable to collect objective measures to corroborate dietary intake data whenever possible within intervention studies. This differential error can also come into play in observational studies in which groups compared differ with respect to factors that might affect reporting error. Consulting the Dietary Assessment Primer in combination with the Measures Registry can help researchers identify the broad range of considerations that should be taken into account when planning a study, choosing measures, and analyzing and interpreting data.

Once a measure has been selected, it is critical to consider how to optimize the data captured to the extent possible, again keeping in mind the particular challenges faced in characterizing dietary intake among children (see Section 4). Also of import are databases linked to measures of dietary intake to arrive at estimates of nutrient and food consumption. These databases should be current and comprehensive, to the extent possible given that this is usually out of the control of researchers. Key limitations for the estimation of certain dietary components should be outlined when reporting research results. Other issues related to processing of data, such as dealing with outliers, are highlighted in NCI's Dietary Assessment Primer.

Increasingly, when investigators measure dietary intake, they are attempting to assess overall dietary or eating patterns

Resource Tip:

The National Cancer Institute's Measurement Error Webinar Series provides an in-depth overview of issues related to the analysis of dietary intake data, with the goal of sharing strategies to mitigate measurement error and its effect on study findings.

rather than quantifying consumption of particular aspects of diet, such as fat intake. As defined by the *2015–2020 Dietary Guidelines for Americans*, eating patterns "represent the totality of what individuals habitually eat and drink."[24] There is growing recognition that dietary components act synergistically and that eating patterns may be more strongly related to health than individual foods or nutrients. Measuring eating patterns is complex because they are characterized by multidimensionality and dynamism.[118] In other words, individuals eat and drink many different foods and beverages (i.e., multidimensionality), all of which have their own profiles in terms of nutrients and other dietary components such as phytochemicals. For some individuals, this complexity is compounded by the contributions of vitamin and mineral supplements to total intake. Further, eating patterns vary temporally (i.e., dynamism)—within a day, across days, across seasons, and across the lifecycle—possibly in relation to critical points, such as infancy or the transition to adolescence. Various methods for capturing patterns of dietary intake have been developed; these include the use of investigator-defined indices identified a priori to assess the quality of diet relative to some pre-determined criteria.[119,120] For example, the Healthy Eating Index-2010 assesses the alignment between dietary intakes and the Dietary Guidelines for Americans.[121–123] Data driven, or a posteriori approaches, include the use of statistical techniques, such as cluster and factor analysis, to look for patterns in data and relate these to health or disease outcomes.[119,120] Methods for capturing patterns is an area of ongoing inquiry, and approaches that embrace the true extent of multidimensionality and temporality[124] inherent in dietary patterns require further development.

Considerations regarding data interpretation and reporting are also important to contribute to a robust body of evidence with which to inform interventions for childhood obesity prevention. In interpreting the results of studies making use of measures of dietary behavior, it is key that measurement error, which is unavoidable in self-report measures, and its implications for study results are considered and discussed. Despite the fact that error implicit in the measurement of dietary intake among children has been long recognized, this is often not indicated when data are reported and inferences based upon them made.[31] This can lead to a confusing and contradictory body of literature. In the context of obesity, it is critical to consider potential interactions between body weight, or factors linked with body weight, and self-reporting of dietary behavior and the potential implications for the results (as well as whether a particular analysis is advisable given the likelihood of differential bias). In developing publications to share research findings, attention to the Strengthening the Reporting of Observational Studies in Epidemiology–Nutritional Epidemiology (STROBE-nut) guidelines[125] may assist in achieving improved transparency in terms of measures used, how they were administered, their psychometric properties in relation to the target population, and other salient issues necessary for the critical appraisal of any study making use of dietary behavior measures.

9

Case Studies

The following case studies have been designed to illustrate considerations influencing the selection of the most appropriate measure(s) for a given study based on the research aim/question, study design, and other characteristics. The focus in terms of measures is on methods more broadly (e.g., 24-hour recalls, food frequency questionnaires) rather than specific tools falling under the umbrella of each of these methods.

Black and white answers in terms of the most appropriate measure may not be possible, but the research aims and study constraints can help to narrow down the options. In all cases, issues related to children's ability to complete different types of tools and the potential for biases that may affect the study findings should be considered. The focus here is on the dietary measures and the examples assume that similar consideration has been given to measurement of other variables, such as health outcomes, physical activity, or features of the food environment.

Background A project team wishes to estimate average intake and main sources of dietary guidance-based food groups among children of varying ages, differentiated by sociodemographic characteristics. This is a surveillance effort with a large, cross-sectional sample designed to enable estimation among various subgroups. The intent is to capture all foods and beverages consumed across settings.

Considerations The dietary behavior of interest includes intake of multiple dietary components, including food groups such as fruits, vegetables, and dairy products. Thus, a measure that enables quantification of the total diet with the least bias possible is needed, suggesting a short-term measure (24-hour recall or food record). The focus on capturing various dietary components rules out screeners, which are also not recommended for estimating mean intakes among populations due to bias (the same is true of food frequency questionnaires).

Given the varied ages, proxy reporting will be needed for younger children.

Measure Selection The team has several possible options, each of which has specific strengths and limitations:

- Interviewer-administered recalls are possible, although they are expensive and intensive in terms of coding. Web-based self-administered recalls are another possibility. Proxy-assistance or other types of assistance or training may be needed to successfully implement this method.
- A food record also is possible, but parental assistance would be needed to address issues associated with literacy, numeracy, cognitive abilities, and attention span. Mobile device image-based food records are a possible method for older children.
- In studies combining different approaches, the implications of potential mode (i.e., paper- versus mobile device-based record) effects should be considered.

Because diet is the dependent variable and the team is interested in estimating intake in relation to sociodemographic variables, they will need to weigh the potential for differential biases in reporting (e.g., children with differing body weights or other characteristics may misreport differently). Working with a statistician to identify the most appropriate analytic approaches is recommended.

Given that only mean usual intakes (and not distributions of usual intake, for example, for estimating the proportion with intakes of fruit that meet recommendations) are required, the team will not need repeat measures of the short-term measures to account for day-to-day variation in diet.

Variation: If the team wishes to estimate distributions of usual intake so they can assess proportions of the sample who meet food group recommendations or other characteristics of the distribution beyond the mean, they will need to administer replicate recalls or records for at least a subsample. Two non-consecutive (to avoid autocorrelation or leftover effects) replicates or repeats among a representative subsample are typically adequate, but additional repeats may be required for foods that are more episodically consumed in the target population.

Background

A project team sets out to elucidate the relationship between diet quality and proximal markers of disease, such as blood glucose levels or markers of inflammation, among adolescents. The study is a prospective cohort, with a large sample. The intent is to capture all foods and beverages consumed across settings to enable the characterization of diet quality, for example, using a diet quality index.

Considerations

The dietary behavior of interest includes intake of multiple dietary components—in other words, the total diet. Thus, a measure that enables quantification of the total diet is needed. This suggests a leaning toward short-term measures. The focus on capturing the total diet rules out screeners.

Given that the age group is adolescents, self-administration is possible, though time and burden should be considered in terms of the impact on data quality.

Measure Selection

Feasible methods include self-administered 24-hour recalls, food records, or food frequency questionnaires. Interviewer-administered recalls would likely be cost prohibitive, and unless the food record involves technology-enabled automated coding, manual coding would require considerable resources. This narrows the choices to a self-administered 24-hour recall, mobile device-based (or otherwise automated) food record, or a food frequency questionnaire. A combination of methods could also be used.

Diet is the independent variable, or an exposure. As in all studies, strategies to arrive at the least-biased possible estimates of intake should be considered. Analytic techniques to mitigate error in such cases include regression calibration, which uses data from a reference measure from a calibration substudy to reduce error in the intake data collected using the main dietary measure for the study. For example, in a study using 24-hour recalls, biomarker data could be collected from a subsample to allow for calibration of the recall data, whereas in a study using food frequency questionnaires, 24-hour recall data may be collected from a subsample to allow for mitigation of bias in the frequency data.

In such studies, food frequency questionnaires traditionally have been used, at least with adults. However, with web-based tools, it is possible to use recalls or records either as the main instrument (which is desirable given that short-term data have been shown to be less biased than frequency data) or as a reference instrument for calibration purposes. Recalls and records also offer the advantage of greater comparability across populations and studies given that there is no finite food list. Food frequency questionnaires need to be tailored to the population of interest and this can limit comparability as well as the potential for pooling and harmonization across studies. Further, food frequency questionnaires may be cognitively difficult for children depending on their age.

CASE STUDY 3 **EXAMINING IMPLICATIONS OF MODIFICATIONS OF FOODS OFFERED FOR SALE IN VENDING MACHINES WITHIN AN INSTITUTION**

Background

A project team wishes to assess intake of sugar-sweetened beverages and alternatives before and after changes to vending machine policies in an institution, such as a school, university, workplace, or recreation center. This is an intervention study involving swapping out of energy-dense choices within vending machines for more nutrient-dense options, including replacing sodas and energy drinks with water. Given a systems perspective, the intent may be to capture intake across settings to allow the project team to account for trade-off effects. For example, reduced consumption of sugary beverages at school may be offset by increased consumption in other settings.

Considerations

The dietary behavior of interest could be conceptualized **narrowly** as intake of snacks and beverages, or **broadly** as the total diet. This would enable characterization of how the intervention relates to changes (if any) in sugar intake overall or diet quality more holistically. For example, reductions in soda consumption may be offset by increases in intake of juice or possibly other foods or beverages.

In addition, intake could be conceptualized either as quantitative estimates, requiring querying amounts consumed, or frequency of consumption of energy-dense snacks and beverages.

Depending on the target population within the institution of interest, investigators will need to consider whether self-reporting is possible. This will affect which measures can be selected. For example, self-administration is not possible for younger children.

Measure Selection

If the project team chooses a narrower focus, screeners could be used, which would reduce team and respondent burden but increase bias. This bias is less of an issue for items like sugar-sweetened beverages than for other dietary components (e.g., sugars, fruits and vegetables) that are distributed throughout many contributing food and beverage sources. Screeners may be difficult for children, depending on cognitive abilities to average intake over a long period of time.

If the team chooses a broader focus, a more comprehensive tool, such as 24-hour dietary recalls, food records, or food frequency questionnaire, is needed as such a tool allows interrogation of different aspects of the diet.

In this project, dietary intake is the outcome, and the study design is an intervention. As a result, respondents could potentially report differently after the intervention due to exposure to the intervention itself. However, given the environmental focus of the intervention (as opposed to nutrition education or counseling about reducing intake of energy-dense foods), this is unlikely unless the intervention is accompanied by an intensive marketing campaign. Nonetheless, the project team could complement the intake data with sales data from the vending machines. However, these data would be limited to the single setting within which the vending machines were modified, not to changes in consumption behaviors more broadly.

CASE STUDY 4 ASSESSING THE EFFECTS OF A HOME-BASED OBESITY PREVENTION PROGRAM ON PRESCHOOL CHILDREN'S DIETARY BEHAVIORS

Background

A project team is interested in examining the effects of a home-based obesity prevention program on preschool children's meal and snacking behaviors. This is an intervention study, with control and intervention groups. The control group receives minimal exposure to the study team (including nutritionists), whereas the intervention group receives intensive programming related to healthy eating patterns, parenting, and other potential influences on dietary intake among children and the family as a whole.

Considerations

The diet behaviors of interest could be conceptualized as patterns, in terms of meals and snacks (e.g., frequency of between-meal snacks). In this study, behaviors could be conceptualized in different ways. Depending on the information desired, the team could consider different measures:

- The diet behaviors of interest could be conceptualized as patterns, in terms of meals and snacks (e.g., frequency of between-meal snacks). Such behaviors could be measured by a questionnaire, to be completed by the parent or other proxy reporter, querying these behaviors specifically.

- Alternatively, with more intensive measures such as 24-hour recalls and records, the foods consumed at different meals and snacks as well as contextual factors, such as who the child ate with and whether he or she was using an electronic device (e.g., eating a snack in front of the television) could be considered. With a frequency questionnaire, the foods consumed over a period of time (e.g., before or after the intervention) could be assessed, but contextual factors could not.

- Finally, home observation could be used, with trained interviewers documenting meal and snack behaviors during times at which they are present in the home. However, this would be intensive and burdensome.

Measure Selection

Given that the target population is preschool children (and their parents and families), any questionnaires of behaviors more generally (e.g., frequency of snacking) or intake more specifically would need to be completed by proxy-reporters, with necessary considerations regarding error in reporting.

With this intervention design, parents may report their children's diets differently as a result of being exposed to the intervention than they did at baseline. Thus, complementary measures, such as in-home observation, may be beneficial to provide a means of corroborating (or not) changes in meal and snacking patterns from pre to post.

CASE STUDY 5 ASSESSING DIFFERENCES IN DIET QUALITY AMONG SUBGROUPS WITH DIFFERENT RATES OF OBESITY

Background

A project team would like to assess whether diet quality differs among adolescent children from different racial and ethnic subgroups with varying rates of obesity. The study makes use of NHANES data.

Considerations

In this case, the dietary measure is predetermined because the team is using NHANES dietary data, which are collected using 24-hour recalls. However, the case highlights various considerations that must be taken into account when comparing the dietary intake of groups differentiated by factors potentially related to body weight. Because body weight is strongly associated with misreporting, any such analyses must be undertaken and interpreted cautiously.

CASE STUDY 6 EVALUATING THE EFFECTS OF CALORIE LABELING WITHIN A GIVEN INSTITUTION ON ENERGY INTAKE

Background

A project team wishes to examine whether adolescents change their energy intake when menu calorie labeling is instituted, for example, within a cafeteria. This case is intended to illustrate the caveats related to measuring calorie intake using self-report data.

Considerations & Measures Selection

Given the known biases in self-report data, it is generally recommended that they not be used to arrive at absolute estimates of energy. However, in this case, intercept surveys could be used before and after the introduction of calorie labeling to assess changes in purchases. The team also could examine sales data to make these comparisons.

Further, the team could use dietary intake data to assess implications for diet quality more broadly. For example, if calorie labeling was effective in stimulating changes, did it encourage healthier choices overall, such as the consumption of more fruits and vegetables or higher diet quality, rather than merely encouraging lower-calorie choices?

CASE STUDY 7 ASSESSING CHILDREN'S FOOD PREFERENCES IN RELATION TO ADVERTISING

Background

A project team sets out to assess the preferences of preschool children for fruits, vegetables, and snacks after they were exposed to advertising of different types of foods, with and without cartoon characters and celebrities.

The study is a cross-sectional experimental design with control and comparison groups. Recruitment and study collection occur in an early care and education center. Children are invited to play a video game on an iPad that features or does not feature cartoon character or celebrity endorsements related to food. The diet behavior of interest, food preferences, is the dependent variable.

Considerations & Measures Selection

Given the age of the children, a questionnaire regarding food preferences is not feasible, though they could be prompted to choose between photos of different types of foods, indicating the one they would choose out of dyads differentiated by energy- and nutrient-density.

Alternatively, the children could be offered different snacks (fruit, vegetables, and snacks, some of which were highlighted by the cartoon characters or celebrities). The team could weigh the snacks served as well as leftovers (i.e., plate waste) so that intake can be quantified as an indicator of preferences.

Associations between exposure to cartoon characters and celebrities and food preferences could be examined by comparing preferences or intake between the experimental and control groups. With observed food intake, issues regarding differential biases in reporting of intake are not an issue.

CASE STUDY 8 ASSESSING THE IMPACT OF A BODY IMAGE-BASED PROGRAM ON ADOLESCENTS' DIETARY BEHAVIORS AND INTAKE

Background

The primary aim of this study is to assess changes in diet-related behaviors and intake before and after the implementation of an intervention to improve body image. This case is included to illustrate the potential impact of social desirability on youth's reporting of dietary intake, and why this should be considered in analysis of results.

Considerations & Measures Selection

Because older children and adolescents have greater concerns surrounding body image as compared to younger children, it is important to consider the role of social desirability in their reporting of diet-related behaviors and intake. This may be especially salient when they are queried about body image and weight-related constructs. To account for this source of bias, researchers may assess social desirability using established measures,[35,47–49] and stratify diet-related variables by social desirability categories. If youth with high social desirability significantly differ from youth with low social desirability on reporting of diet-related behaviors and intake, then this must be considered in the analysis of the intervention's effectiveness.

10

Future Directions in Individual Diet Assessment

Currently, a range of different tools are used in nutrition research with relevance to childhood obesity. This variability, combined with the use of tools that may not be optimal for the purpose and population, hinders the development of a cohesive evidence base to inform policies and programs for reducing childhood obesity.

To further this area of research, it is critical to use the best possible methods, along with appropriate analysis, interpretation, and reporting. This User Guide, along with other resources highlighted, is intended to help with this goal. Selection of measures will involve weighing various considerations, including logistical issues that may limit the feasibility of some measures in particular environments or populations, with the overall aim of arriving at the best measure for a given research study. The use of the Measures Registry along with this User Guide can also contribute to a greater standardization of measures, with positive implications for comparability of studies, potential for pooling of data to address questions that might not be feasible within any one study, and syntheses of evidence to inform interventions.

To assess dietary behaviors, we typically rely on self-report measures, which are known to be affected by error.[80] Sources of error in studies of children can include reliance on proxy reporters (who may have incomplete knowledge of true consumption). Further, tools may not be appropriate for use with particular age groups due to varying attention span, literacy, and numeracy. Factors that affect self-report data more generally, such as social desirability biases, also are sources of error. These errors can result in under- or over-estimation of intake of different dietary components. It has been well established that energy is reported with substantial error and for this reason, it is recommended that self-report data not be used to estimate absolute energy intake.[67] Misreporting has been shown to be associated with body weight status, with greater under-reporting of energy with higher body mass index.[65,112] For this reason, it is challenging to assess associations between intake and body weight. Cautions of this nature must be extended to variables that may be correlated with body weight, including race/ethnicity, education, and other dietary behaviors, such as restricted eating behaviors or body image. Estimates of other dietary components, such as protein and potassium, based upon self-report appear less biased compared to energy,[65,66] which supports the overall value of self-report for understanding dietary patterns. Less is known about misreporting of particular foods and beverages, and this is an area in which additional research is needed.

Study design must also be considered in selecting measures and analyzing and interpreting data. For example, caution is needed in approaching evaluations of the impact of interventions on intake, particularly in cases in which individuals have been counselled or otherwise encouraged to alter their eating patterns.[1] Differential exposure to the intervention can result in differences in error in reporting before and after or between intervention and control groups, with implications for the validity of comparisons.

Despite these caveats and challenges, measuring dietary intake in children is well worth the effort given the invaluable data yielded to inform policies and programs to prevent obesity.

Evolution in the Field of Dietary Assessment

The long-standing recognition of the limitations of self-report measures has fueled considerable efforts to improve them, for example, using technology to reduce researcher and respondent burden. The explosion of technology extends to children, for example, with the development of mobile device food records that can be used by adolescents to capture food intake in various settings. Portion size estimation is another area of ongoing inquiry, with links to technology through image-based assessment that may reduce error associated with traditional portion size aids. Work to better understand how children interact with dietary measures, such as the age at which they can independently respond to self-report measures, is also ongoing. However, it must be borne in mind that technology cannot address all limitations of self-report methods, and indeed, may introduce new challenges, for example, related to computer literacy.

Complementing efforts to improve methods and how they are used are significant efforts to enhance our understanding of error and approaches to mitigate it, for example, through combining measures to exploit the strengths of each as well as analytic techniques. The discovery of concentration and predictive biomarkers and other innovative methods that may help offset the effects of error in self-reported data in analysis is an ongoing area of research. Approaches to combine self-report and biomarker data have been developed for both epidemiologic and intervention research.

Despite these innovations, much work remains. Many studies to assess the psychometric properties of self-report methods with children have used other self-report tools as references, with limitations in interpretation due to the lack of an unbiased reference such as a recovery biomarker. Additional biomarker-based studies in children could help to further this evidence, though the number of dietary components for which unbiased references are available remains limited. To complement improvements in methods, additional research is needed to better understand misreporting of a broad range of dietary components, including foods and food groups, as well as to inform the evaluation of interventions by better understanding intervention-related biases and the sensitivity of measures to change.

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Conclusion

Improving methods of dietary assessment remains an active area of inquiry and this extends to research with children. Enhancing existing methods using technology is an area that will undoubtedly continue to develop, with implications for reducing respondent burden and more effectively engaging children. In the meantime, it is essential to select the best possible measure for the population of interest and to analyze and interpret the data in light of what is known about biases in self-report measures of dietary intake. The Measures Registry and other complementary resources can facilitate this goal, helping to build a stronger evidence base for the prevention of obesity.

12

Additional Resources on Individual Diet Assessment

Overview of Tools

- Thompson FE, Subar AF. Dietary Assessment Methodology. In: Coulston A, Boushey C, Ferruzzi M, eds. *Nutrition in the Prevention and Treatment of Disease. 3rd ed*. Oxford, UK: Academic Press, pp; 2003. 5-46. https://epi.grants.cancer.gov/diet/adi/thompson_subar_dietary_assessment_methodology.pdf.
- National Institutes of Health, National Cancer Institute Dietary Assessment Primer https://dietassessmentprimer.cancer.gov/

Data Analysis/Statistical Methods

- NHANES Dietary Tutorial (Basic & Advanced) http://www.cdc.gov/nchs/tutorials/dietary/
- Measurement Error Webinar Series http://epi.grants.cancer.gov/events/measurement-error/

Measurement Error in Dietary Intake Data: What it is and How to Mitigate it

- Measurement Error Webinar Series http://epi.grants.cancer.gov/events/measurement-error/

Other Registries and Compilations of Tools

- Dietary Assessment Calibration/Validation Register https://healthcaredelivery.cancer.gov/dacv/
- Register of Validated Short Dietary Assessment Instruments https://epi.grants.cancer.gov/diet/shortreg/

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Position Papers and Commentaries

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- Foster E, Adamson A. Challenges involved in measuring intake in early life: Focus on methods. Proc Nutr Soc. 2014;73(2):201-9. https://www.ncbi.nlm.nih.gov/pubmed/24555806

Reporting Guidelines

- Lachat C, et al. Strengthening the Reporting of Observational Studies in Epidemiology—Nutritional Epidemiology (STROBE-nut): An extension of the STROBE statement. PLoS Med. 2016;13(3): .e1002036. https://www.ncbi.nlm.nih.gov/pubmed/27270749

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