Dietary Assessment:

Developing, Validating, and Improving a 24-hour Web Food Report Questionnaire

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ABSTRACT

Precise and accurate assessment of usual energy and nutrient intake among free living populations remains a major challenge for the study of diet and disease. The food frequency questionnaire (FFQ) carries a relatively low cost and participant burden, but it is much less accurate than multiple 24-hour telephone recalls (24TR). However, 24TRs are usually prohibitively expensive for large studies, and carry a high participant burden. Consequently, there remains a great need for alternative self-report approaches. Emerging web technology and internet penetration provide an opportunity to reduce dietary measurement error while increasing participant and investigator convenience. We developed the 284-item 24-hour Web Food Report Questionnaire (WFRQ) and conducted a pilot comparative validation study (n=51) examining energy and nutrient intake estimates from three WFRQs and the NCI Dietary History Questionnaire (NCI-DHQ) compared to three interviewer-administered 24TRs. Mean intake estimates were similar between the 24TR and the WFRQ but significantly lower with the NCI-DHQ for many nutrients. Correlations with the 24TR ranged from 0.24 to 0.73 and were typically lower with the NCI-DHQ than the WFRQ. Compared to estimated energy requirements the 24TR, WFRQ, and NCI-DHQ under-reported energy intake by 15%, 19%, and 25%, respectively. On average the WFRQ took 10 minutes to complete. A more in depth examination of reported foods and food amounts consumed, comparing 24TRs and WFRQs collected for the same day (n=46), revealed that the 24TR better captures foods used as additions, food-types, and for some foods, portion amounts. Incorporating more food detail and more effective portion size aids may improve the validity of the WFRQ. At the same time, refining the mapping of the WFRQ food items and portion categories to our food and nutrient database may also reduce measurement error. The WFRQ ‘beta’ version is promising for research use in large studies involving free living populations.

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OVERVIEW OF DISSERTATION

This dissertation is organized into five chapters. The first chapter presents a review of the literature with a focus on providing the rational for valid dietary assessment, the need for new methods to use in large epidemiologic studies, and the promise of increasing web access and emerging web and other technologies. The second chapter describes the development of a 24-hour Web Food Report Questionnaire (WFRQ). The third chapter describes the study design and findings of a pilot comparative validity study comparing habitual energy and nutrient intake estimates obtained from the National Cancer Institutes' Dietary History Questionnaire (NCI-DHQ) and the WFRQ against the interviewer-administered multi-pass 24-hour telephone dietary recall (24TR). To better understand the underlying causes of measurement error between the WFRQ and the 24TR, the fourth chapter extends the analyses of Chapter 3 by examining energy and nutrient intake estimates and food groups and serving size concordance between WFRQs and 24TRs that were collected for the same day. The fifth and final chapter summarizes the overall results, their implications, and potential future directions for web-based dietary assessment.

CHAPTER 1: BACKGROUND AND LITERATURE REVIEW

INTRODUCTION

Recent changes in dietary patterns, coupled with changes in physical activity behaviors, have led to substantial increases in disability, premature mortality, and economic costs associated with obesity and chronic conditions.[1-5] As part of this, rapid changes in portion sizes and specific dietary behaviors such as breakfast skipping, availability of energy dense foods, and eating meals prepared outside the home have exacerbated the complex interaction of biologic, behavioral, and environmental factors influencing diet-disease relationships and energy intake. Over the past several decades, the growth of population-based epidemiologic nutrition studies have increasingly clarified the role of diet in obesity and chronic disease and have been used to establish recommendations and policies for dietary practices.[1,6] In addition, nutritional surveillance systems have been established to monitor progress towards achieving recommended dietary public health goals and tracking changes in dietary factors over time.[7]

However, a key challenge in these epidemiologic studies is the ability to precisely and accurately assess usual food and nutrient intake. The food frequency questionnaire (FFQ) approach is generally relied on for assessing food and nutrient intake in studies because it is the only assessment method that is feasible for use in large studies where participant burden and measurement costs are critical considerations. Unfortunately, in recent years it has become apparent that the FFQ approach is inadequate. Results from a number of studies conducted over the past ten years suggest the error associated with FFQs is far greater than previously thought.[8-13] This has led a number of leading scientists to conclude that research examining the association of diet to health outcomes has been seriously undermined by our reliance on FFQs.[14-16] The misclassification resulting from measurement error can lead to potentially spurious risk estimates (differential misclassification) or, more likely, attenuated or obscured diet-disease associations due to random error (non-differential misclassification). Thus, the reliance on imperfect dietary intake assessment methods for etiologic investigations is of great concern.[17-22]

Novel and innovative approaches to improving the validity, utility, and feasibility of dietary assessment are needed, particularly those that focus on common and important food groups' and nutrients. Food diaries and the telephone 24-hour dietary recall are currently the gold standards for assessing dietary intake by self-report, even though they too under-report energy, food, and nutrient intake. Using the 24-hour recall for epidemiologic cohort studies, surveillance, and clinical research is resource intensive for the participant and the researcher, especially for etiologic studies where seven to ten recalls are needed to accurately capture usual (habitual) dietary intake for many nutrients.[17] Capitalizing on the increasing use of the internet may be one innovative approach to improving the feasibility of the self-report 24-hour dietary assessment. Internet penetration in the U.S. as of May, 2013 was 85%, and may be an underestimate due to access in non-household locations, such as work or library. Dietary assessments on the web may reduce participant burden by offering more flexibility, while improving the timeliness, quality control, data management, data analyses, and overall cost associated with dietary assessments.

BACKGROUND

The literature examining the relationships between energy and nutrient intake to obesity and chronic disease is extensive and growing. In addition to more and more nutritional studies, there is also a rising interest in expanding beyond specific nutrient and disease relationship research and into improving our understanding of the roles of behavioral eating patterns, policy, environmental factors, and there their complex interactions. All these studies are premised on collection of valid and reliable data, a consistent challenge as it pertains to individual dietary assessment and an emerging challenge for examining behavioral eating patterns. The spread of the web may provide a future alternative to continue research in these areas and potentially improve on current widely used dietary assessment methods. Diet/eating pattern-disease relationships, dietary assessment methods, and potential of the web are described below.

Diet and chronic disease

Large observational, cohort, and clinical studies are instrumental in understanding the causal relationships between diet and chronic conditions like hypertension, hyperlipidemia, cardiovascular disease, diabetes, cancers, osteoporosis, oral health, and others.[1,23,24] In 2003, the World Health Organization released a report outlining the evidence and recommendations for addressing diet, nutrition, and chronic disease prevention, including the complex interactions with environmental factors that affect excess weight gain.[1] Table 1.1 summarizes the strength of evidence between selected dietary nutrients and chronic conditions. In many cases the evidence is convincing such as increased consumption of saturated- and trans-fatty acids leads to increased cardiovascular disease or high alcohol consumption increases the risk of certain types of cancer.[1] Yet, other diet-disease relationships remain unclear or have yet to be well examined. Examples include the role of fruit and vegetable consumption with some cancers or the high intake of dietary fiber on type 2 diabetes and cardiovascular disease.[1] The report also recognizes the need for improved nutrition surveillance systems to monitor population progress toward healthy dietary intake, behaviors, and environment.[1,7]

Energy balance and caloric intake

As seen in Table 1.1, the rising rates of obesity and its association with numerous chronic conditions and mortality is a major public health concern in the United States and the rest of the world.[1,25-30] Overweight and obesity have been rising in the US since the 1960's with a sharp increase beginning in the 1980's.[31,32] From 1960 to 1980, body mass index (BMI) increased at about 1% per decade.[31] Starting about 1980, body mass index rose *0.5% to 1 % per year*.[32] This trend has been observed by gender, race/ethnicity and in all age groups including children.[31-34] Currently, 35.7% of US adults are obese while 31.8% US children and adolescents are at risk for overweight (BMI for age at 85th percentile of higher) or are overweight (BMI for age at 95th percentile or higher).[32,34,35] However, these most recent assessments in adults and children suggest the rates of obesity may be starting to plateau.[32,34,35] Despite slowing trends, the human and economic burden of obesity in the U.S. is enormous and will impact chronic disease and overall health for decades to come.[4,29,32,34,36-38]

Obesity is the net result of energy imbalance with greater energy intake relative to energy expenditure. In trying to understand the etiology of obesity and potential strategies to reduce obesity, it is increasingly clear that energy intake behaviors are driving obesity rates.[39] Estimates indicate that in the best case scenario only about 50% of energy expenditure is modifiable while energy intake is entirely under voluntary control.[40] Among US adults from 1971-1975 to 1999-2002 daily energy intake per person has increased approximately 200 kcal in men and almost 300 kcal in women.[41,42] Similar increases have been observed among Whites and Blacks.[43] This has stabilized from 1999 – 2008.[44] Although trends in regular and leisure-time physical activity have increased slightly, overall trends in physical activity appear to be declining when accounting for transportation, occupational, and in-home activity.[39,42-46] Bleich et al suggests that increases in obesity are about 75% attributable to increased caloric intake and 25% attributable to declines in physical activity.[39] This highlights the importance of increasing our understanding of factors influencing caloric intake and developing strategies to combat these factors.

Changes in dietary patterns since 1971 have affected energy intake. From 1971 through 1999-2000, contributions to overall energy intake have increased for carbohydrates while decreasing for fat and protein.[47] In 1999-2000, the distribution of energy intake among macronutrients in the US adult population was 50%, 33%, and 15% for carbohydrates, fat (total and saturated), and protein, respectively.[47] Through 2007-8, these have shifted moderately with slightly less carbohydrate intake and a 0.3% increase intake in protein.[48] During 1994 to 1996, the top five foods contributing to energy intake among US adults were yeast bread, beef, sweets and desserts, soft drinks, and milk.[49] This has changed little by 2007-8 with the exception of less milk consumption and more alcohol consumption.[50] Of increasing concern is the rise in consumption of energy dense nutrient poor (EDNP) foods like sugar-sweetened beverages and sweets and desserts. Results from the 1999-2000 NHANES indicate that 25% of energy intake is attributable to these foods along with alcohol consumption. Recently, this has declined to 22%.[50] Not included in these estimates are the salty snacks such as potato chips, corn chips, and popcorn. Tied to this is the increased use of high fructose sugars that are common ingredient of these EDNP foods.[51] Growing energy intake is further compounded by the steady increase in food portion sizes observed at home, restaurants, and fast food outlets.[52,53] From 1977 to 1996, energy from meals consumed away from home increased from 23% to 36%.[52] Overall, increases in portion sizes were greatest for soft drinks and fruit drinks but were also observed for snacks, burgers, and Mexican foods. Portion sizes of ready-to-eat prepared foods such as beer, soft drinks, pizza, French fries, steak, muffins, pasta, and chocolate chip cookies were 35% to 700% greater than recommended FDA or USDA portion sizes.[53] Chronic exposure to increased portions leads to increased energy intake and likely contributes to sustained weight gain.[40,54] Over the last 30 years, changes in portion sizes along with the number of eating occasions have contributed to overall energy intake among American adults.[55,56] To fully understand the impact of these changes to dietary quality and quantity, precise and accurate assessment of dietary components and amounts is essential.

Further complicating the picture of dietary and energy intake is the interaction of foods and portions sizes with biologic, behavioral, and environmental factors.[54,57,58] In very young children the influence of hunger and satiety lead to self-regulation of energy intake. But, as early as 3 and 4 years of age learned behaviors such as rewarding children for cleaning their plates or adults, instead of children, allocating food portions may start to negate self-regulation of intake.[58] Another factor may be changing perception of the appropriate food portion size.[59] As people become more accustomed to the larger portion sizes these become the norm and are consumed regardless of hunger or satiety cues. The confluence of these learned behaviors and environmental cues suggest that eating behavior is not readily modifiable but more automatic.[57] Several studies have demonstrated sustained energy increases associated with short-term and long-term increases in portion sizes.[54,58,60] This is compounded by the consumption of EDNP foods. Portion size and food energy density are independently associated with increased energy intake, thus in combination provide a potent mixture for increasing overall energy intake.[58]

Monitoring these macro behaviors through dietary assessment will be essential in identifying behavioral and environmental strategies to improve dietary quality, reduce caloric intake, and reduce the burden of obesity and chronic diseases. In the following sections, commonly used energy and dietary assessment methods are described.

Dietary Measurement Methods

The importance of accurate and precise dietary assessment cannot be understated. At a minimum, we need to understand, to the best of our ability, the types, directions, and underlying causes of misclassification associated with contemporary dietary assessment methods. The primary dietary intake assessment methods used in nutritional epidemiology include 24-hour dietary recalls, food records, food frequency questionnaires and dietary history questionnaires. Biomarkers and doubly-labeled water are also used to examine specific nutrient intake and overall energy intake and are often used as criterion measures for validating the other dietary intake methods.[61] Table 1.2 provides a brief overview of the procedures, uses, strengths, and limitations of the methods. Each is discussed in greater detail below.

Biomarkers and Doubly-labeled water

A variety of biochemical measures are available to assess energy and nutrient intake. They have the advantage of being an independent measure directly linked to dietary intake and they are not biased by the self-reporting behaviors required for other assessment methods. However, many can only discriminate between high and low intakes. Additional considerations are the temporal relations between the markers and dietary intake, within-subject variation, biologic confounders like smoking, and sample preparation. Despite these limitations doubly labeled water is considered the gold standard for measuring total energy expenditure and many biomarkers are also used as the gold standard in validation studies of the self-report dietary assessment methods.

The doubly labeled water (DLW) method is premised on the principle of energy balance: energy expenditure and metabolizable energy intake are equal under stable body weight. It is a form of indirect calorimetry using two stable isotopes (^2H_2O and $H_2{}^{18}O$) to determine the rate of carbon dioxide production over days or even weeks.[62-64] Participants are required to ingest a small amount of deuterium labeled water and periodically, whether over hours or days, collect urine specimens. A stabilizer must be added to the specimen and it must be refrigerated to minimize decomposition. Using mass spectrometry, changes in the water isotopes are measured over time and a standardized equation is used to calculate oxygen uptake and total energy expenditure. Because of the participant burden, the material and laboratory requirements, and the complexity of sample collection, preparation, and analyses this method is very expensive and not conducive to large nutritional epidemiologic studies. Furthermore, it is unable to examine the foods contributing to energy intake.

Many nutrient biomarkers can be assessed from urine, blood, and adipose tissue.[22] As with DLW, these measures are considered direct, objective, and independent measures of dietary nutrients compared to the self-report survey methods described below. Urinary nitrogen is used as a marker for dietary protein while sodium and potassium can also be measured from urine. Biomarkers measured from blood include the plasma carotenoids (alpha-carotene, beta-carotene, lycopene, beta-cryptoxanthin, zeaxanthin + lutein), plasma ascorbic acid, red blood cell folate, alpha tocopherol, and gamma tocopheral.[22]

These blood serum biomarkers are sensitive to dietary intake over several weeks' time and longer. They can also represent important nutrients for research and various domains of the diet. The primary limitation of these biomarkers for large epidemiologic studies is their cost, participant burden, and not reflecting the scope of dietary intake foods and nutrients. To achieve the latter, multiple different biomarkers must be collected and analyzed further exacerbating costs.

Dietary Recalls and Food Records

Dietary recalls and food records are similar in that individuals are usually asked to report their food and beverage intake over a 24-hour period, the key difference being that participants complete food records *during* the 24-hour period while dietary recalls are interviewer-administered and ask individuals to report dietary intake from *midnight to midnight the prior day*. The 24-hour dietary recall methodology, such as the USDA 5-step multiple pass method or the University of Minnesota's Nutrition Data Systems for Research (NDS-R) 4-step multiple pass method is widely considered to be the most accurate self-report measure of dietary intake and, in lieu of laboratory measures, is used as the gold standard when validating other self-report dietary assessment methods even though it is still known to underreport energy and dietary intake.[13] The 24-hour dietary recall can be conducted in-person or over the telephone and requires about 20 minutes from the participant and another 20 minutes of staff time in call attempts and post-interview procedures.[65] A recent study, however, found the USDA multi-pass 24-hour recall to take 30-60 minutes with the participant.[66] Telephone dietary recalls are typically unannounced, conducted by a trained dietary interviewer, and use a standardized structured interview with probes to elicit complete recall of foods and beverages consumed. Using the NDS-R multiple pass procedure as an example, participants are first asked to list all foods and beverages consumed during the previous 24 hour period (first pass).[67] The list is then reviewed to make any additions or corrections (second pass). More detailed probes elicit portion sizes and food preparation methods (third pass) while the final pass (fourth pass) reviews all the information collected to make any final adjustments.[67] Prior to the recall, food portion estimation visual aids (e.g. plastic food models, portion photos, etc.) are sent to participants and are used to help better estimate food portions.

Portion sizes

Accurate assessment of portion sizes is a critical and significant factor contributing to under-reporting of food and nutrient intake in all self-report dietary assessment methods, with the possible exception of weighed food records. Thus, determining the best tools to assist participants in better estimating portion sizes is essential. A study by Harnack et al found in a restaurant setting that use of the standard three-dimensional food models resulted in greater portion size underestimation compared to larger food models thus highlighting the importance of appropriate visual aids for portion size estimation.[68] Compared to weighed average caloric intake of 998 kcals, the average estimated caloric intake was 599 kcals for the commonly used food models and 728 kcals for the larger size models.[68] Misreporting also depends on the type of food as intake of amorphous foods may be more difficult to estimate. In a study conducted by Hernandez et al, the use of computer images compared to actual foods found absolute errors in portion size estimate ranging from 22% to 69% depending on the food type. Furthermore, the error could be an over- or under-estimate.[69] For example, bagel portions were overestimated while cheese cube portions were underestimated. Unfortunately, identifying the most effective visual aids is difficult since direct comparisons have not been made and because their use may depend on the target populations, recall time frames, feasibility, and costs.[69-71]

The *food record method* involves brief advance training with the participant on how to complete the food record form. At the time of consumption during the specified 24-hour period participants are instructed to record all foods and beverages eaten, including method of preparation, cooking, brand names, and details of amounts consumed. Food portions are either estimated using household measures, like measuring cups, or are weighed. After the food records are completed, the study staff reviews the records for clarification and missing information prior to coding for nutrient calculations. Entering food records into an electronic database for further analysis can be time-consuming for the researcher. Although food records document daily dietary intake, they are often used over three, four, or seven consecutive day periods. But, the longer the collection period, the more onerous for the participant and the greater potential for reduced compliance or participant reactivity (i.e., changing dietary patterns). In comparison, to overcome this issue the 24-hour recall method employs the use of unannounced recalls over a longer period of time (weeks, months, or seasonally during the year) thus making it a better criterion method than the food records for assessing usual dietary intake. The 24-hour recall also has the advantage of not requiring a population be able to read or write.

There are additional considerations with the 24-hour dietary recalls and food records. Day-to-day within-person variation of dietary intake is substantial for most foods and nutrients thus multiple dietary recalls or food records (e.g. 7-10 days) are usually required.[17,72] For example, an accurate assessment (≤ 10% misclassification) of cholesterol would take 10-13 recalls and for β-carotene 16-21 recalls while for energy intake 4-5 recalls and carbohydrates 3-4 recalls.[72] Unfortunately, so many recalls are generally well beyond what is feasible for most studies. One or two 24-hour recalls have proven sufficient for assessing group or population means, such as for public health surveillance, and in epidemiologic studies, at least three 24-hour recalls is considered acceptable for assessing an individuals' usual dietary intake.

Although a number of studies have provided good support for the validity of dietary recalls and food records, when compared to observed intake or biochemical measures, there has been a consistent finding of under-reporting of intake with these methods.[13,73-89] Figures 1.1a and 1.1b show results from the OPEN (Observing Protein and Energy Nutrition) study where the 24-hour telephone dietary recall is compared against total energy intake measured using the doubly-labeled water method and protein intake assessed using the urinary nitrogen method.[13] This has been the most extensive validation study of the 24-hour recall conducted to date and the results clearly demonstrate under-reporting of total energy intake by 12% in men and 16% in women. Protein intake estimates were under-reported by 12% and 11% in men and women, respectively.[13] In another study, the average of four seasonal 24-hour recalls compared to serum and dietary carotenoids and tocopheral biomarkers resulted multivariate adjusted correlations ranging from 0.04 to 0.74.[90] This suggests that the 24-hour telephone recalls may work well for total energy intake and macronutrients but are still limited for examining less commonly eaten nutrients.

Dietary History Interview

The detailed dietary history interview, developed by Burke in 1947, was designed to assess an individual's usual diet by collection of a 24-hour dietary recall, a menu recorded for 3 days, and

a checklist of foods consumed over the previous month, and required approximately an hour to complete.[91] A trained interviewer elicits detailed information not only about typical foods consumed but also preparation of those foods and seasonal variation in foods eaten. Although diet history questionnaires yield reasonably valid food and nutrient intake estimates, it is not widely applied in epidemiologic research due to the time and expense.[92-99]

Food Frequency Questionnaires

The food frequency questionnaire (FFQ) methodology grew from the dietary history questionnaire approach, examines usual dietary intake, and is the most widely used methodology in epidemiologic studies and for local or state-based public health surveillance. It is a self-administered survey that involves asking participants to report how often, on average, they ate specific food items during a defined time period (e.g. past week, month, or year). The number of food items included range from 5 to 350 with a median of 79.[100] The FFQs with fewer items are often screeners targeting specific foods like fruits and vegetables.[101-104] The more widely used FFQs range from 60 to more than 120 food items and can take 60 minutes to complete.[66,105] Advantages of the FFQ include only one administration of the instrument, its self-administered nature, and the close-ended format allowing for minimal staff time and expense for processing. The main limitation of the FFQ is the higher degree of measurement error compared to 24-hr recall and food records. Of 200 FFQ validation articles reviewed by Cade et al., most compared nutrient intake estimates from FFQs with multiple 24-hour recalls or food records, generally finding low ($r < 0.3$) to modest (0.3 – 0.6) correlations.[100] In the study where biomarkers of carotenoids and tocopherols were used, the NCI DHQ had multivariate adjusted correlations ranging from 0.09 to 0.72 and consistently underperformed compared to the four 24-hour telephone recalls.[90]

Similar results were observed from the 1997-1998 Eating at America's Table Study where the widely used Block, Willett, and NCI Dietary History Questionnaire (DHQ) were compared to four 24-hour dietary recalls.[77] The four recalls were collected three months apart (i.e., one for each season). Table 1.3 presents selected deattenuated correlations between the three food frequency questionnaires and the average of the four 24-hour telephone dietary recalls. In this study the NCI DHQ and the Block performed best yet their deattenuated energy adjusted correlations with the 24-hour dietary recall still were 0.45 to 0.49 for energy intake, 0.53 to 0.80 for macronutrients, and 0.28 to 0.83 for micronutrients.[77] Crude correlations for all these would be much lower.

When validating FFQs against doubly labeled water and biomarkers, results from recent studies suggest the measurement error associated with FFQs is considerably greater than for dietary recalls and food records.[8-13] Again, Figures 1.1a and 1.1b compare the NCI DHQ and the 24-hour recall and against 'true' total energy intake and protein intake. Crude correlations for total energy intake were 0.39 for men and 0.24 for women for the 24 hour recall while only 0.19 for men and 0.10 for women with the DHQ.[13] Similarly, for protein intake the crude correlations were 0.41 and 0.26 for men and women with the 24-hour recalls and 0.33 and 0.22 with the DHQ.[13] Thirty-five percent of men and 23% of women were found to under-report both energy and protein intake on the DHQ whereas 9% of men and 7% of women were defined as under-reporters with the 24-hour dietary recalls.[13] Some potential factors contributing to FFQ underreporting include recall and social desirability bias, missing or phantom foods not included on the FFQ or not remembered by participants, and poor estimation of portion sizes. The 24-hour dietary recall reduces recall bias by using the shorter time frame, allowing participant's to list all foods they can remember and not just select from a limited list, using extensive interviewer probing, and includes the use of food visual aids to facilitate better portion size estimates. Most FFQs have 3-6 portion size categories from which to choose and do not use visual aids. Despite these limitations, *the FFQ continues to be the method of choice in large epidemiological studies because of their feasibility and low cost*.

In summary, the food frequency questionnaire is the method of choice for examining diet-disease relationships in large cohort or clinical studies. The 24-hour recall is most often used in smaller epidemiologic studies or for nutritional surveillance where group means are of primary interest. Clearly both these methods have limitations that result in underreporting of actual dietary intake and such measurement error most often attenuates the diet-disease relationship or, in the case of surveillance, results in consistent under-, or in some cases, over-reporting of important population nutritional markers. Consequently, there remains a great need for alternative self-report approaches to assessing dietary intake, perhaps a hybrid of the 24-hour recall and the FFQ, capitalizing on the strengths of shorter recall with enhanced collection of foods and food detail but using a more user-friendly and cost-efficient method.

Capitalizing on the Internet and the World Wide Web (Web)

Internet (or 'Web')-based dietary assessment appears to be the methodology of choice for innovative future research. This approach would capitalize on the increasing use of the internet and could be a feasible and potentially more valid strategy across the multiple disciplines of public health surveillance, epidemiologic research, clinical studies, and even clinical management.[106-110] Recent estimates suggest that 85% of the U.S. population use the internet or e-mail, a likely conservative estimate since it may miss access venues such as work, school, and local community.[111] Consumers and providers are increasingly utilizing the web.[112,113 114-116] There is, however, concern about the Digital Divide, the gap between those with and without Internet access (Figure 1.2). Younger, wealthier, more educated, and White populations have greater access.[117,118] But, these divides have been narrowing. Since 2006, the divide between those 65+ years of age and those 18-29 years of age decreased from 55% to 42%. The gap between people not graduating from high school and college graduates dropped from 47% to 37% while that for those earning less than $30,000 per year and those earning more than $75,000 decreased from 42% to 20%. There has also been increased geographic penetration with the difference between suburban and rural internet use going from 14% in 2006 to 6% in 2013. It is likely these divides will continue to narrow with time and, using the penetration rates of television and telephones as a model, perhaps in the next 10-15 years.[119]

As web-technology improves, the potential advantages of web-based surveys compared to FFQs and the 24-hour dietary recall (telephone or interviewer-administered) are reduced costs, ease and effectiveness of e-mail reminders and data processing, dynamic error checking capability, automated skip patterns, use of pop-up instructions, inclusion of visual cues or prompts, ability to customize surveys to particular populations, and convenience to respondents (Table 1.4).[106,107,110] These benefits can reduce bias and error through improved data quality control (built-in data range checks), reduced social desirability and interviewer bias, and more accurate responses using cognitively tailored designs capitalizing on web technology.[107] Other benefits include participant convenience, and efficiencies in data collection, management (e.g. data automatically processed to ready-to-analyze data sets), and analyses (e.g., preliminary data manipulation and reports can be automatically generated and included in analysis datasets).

However, many of these potential strengths remain to be fully examined.[110,120] For example, with emerging web technology, extensive development and pretesting to understand the effects of the technology on cognitive understanding, usability, participant convenience, and data quality is needed.[110] If probability samples are required for research studies such as done for nutrition surveillance, a mixed mode methodology may be required or mail/phone contact may be required to initially contact subjects and cost savings may be limited. If the research study uses a convenience sample or an already identified populations (e.g. clinical and cohort studies) web surveys are likely to be more efficient. Researchers must also remain cognizant of issues ranging from the Digital Divide to appropriate web-design to user capability and interest to ethical concerns.[106-108,110,118] For example, 58% of adult Americans access the web through mobile devices such as cell phones and tablets and this will require tailoring the web-design and user-interface to these devices.[121] As Internet access and web-use become more prevalent these issues are likely to diminish. Furthermore, epidemiologic studies recruiting a defined population and can provide Internet access, e-mail accounts, and Web training to reduce bias. Ethical (privacy, data security, informed consent) and technology issues (use of different browsers and monitors) are also potential challenges.[106,122] Every day, from on-line shopping to banking, the sophistication of current technology already addresses privacy and security issues through use of personal identification numbers (PINs) and data encryption techniques. Finally, web surveys still maintain many limitations associated with other self-report survey methods such as order of items, response sets, survey length, question design and content, especially if sensitive in nature. These are not intrinsic features of web technology but cut across all survey modes and must be addressed when developing a web-based survey. Table 1.4 provides a summary of potential advantages and disadvantages of web surveys but these will be dependent on the type of survey being developed, the intensity of the technology applied, and the populations being targeted.

Several web-based dietary intake instruments for adults have been developed over the past few years, many being direct modifications of existing pencil-and-paper. [123-133] One example is adaptation of the NCI DHQ to the web creating the Web*DHQ. The modifications took greater advantage of web and programming capabilities by breaking the FFQ into 17 food group and supplement sections, each starting with a screener checklist.[129] The screener was used to direct additional subject questioning to the foods selected on the screener checklist. Such skip patterns were also used when gathering greater detail about each food item such as frequency, portion size, and preparation. The Web*DHQ is built off the well-validated paper and pencil version but it has not been validated against the original version or any other dietary assessment methods. However, usability testing does suggest that the Web*DHQ takes less time to complete than the 60-90 minutes needed for the paper and pencil DHQ plus, since the responses are entered electronically, it has queries for unanswered items and a software package has been developed linking the survey to a food and nutrient database and allowing for basic calculations and analyses.[129] This eliminates the optical screening and data cleaning associated with the paper and pencil version.

Such migrations of FFQs to the web are receiving good user acceptability and there may be a learning effect as users become more accustomed to the instrument.[125,134] Comparative validity studies have been performed with several of these web dietary assessment tools but room to improve remains as energy and intake estimates and correlations remain comparable to existing FFQ’s and 24-hour FFQs when compared against 24-hour recalls or food diaries.[123-125,127]

NCI is developing a more intensive web dietary assessment method, the Automated Self-administered 24-hour (ASA-24) dietary recall. It is designed to mimic the multi-pass 24-

hour telephone recall but be self-administered on-line.[128] Extensive validation studies of the ASA-24 are in progress and it still remains to be seen how valid such an automated self-administered system would be compared to the telephone interview method and whether or not this will be more convenient for participants. Preliminary validations of the early ASA-24 versions are finding modest correlations and usability based on computer literacy and length of time a concern for multiethnic older adults.[128,135,136]

Less intensive 24-hour web dietary assessment methods remain a practical approach for use in large epidemiologic or other studies.[127,134] The most developed and evaluated tool so far is the DietDay, a multi-pass, web-based 24-hour self-administered recall *based on a questionnaire format instead of being open-ended*.[134] DietDay contains 9,349 foods and more than 7,000 food images in 61 modules. The food images are used to help estimate portion sizes. Recalls are anchored around the time of day: midnight to 11am, 11am to 5pm, and 5pm to midnight. [134] Validity and usability of the DietDay were good although the actual time to complete a recall was not reported.[133,134] Pearson correlations for energy intake against doubly labeled water (DLW) were 0.41 for three DietDay recalls and 0.33 for the NCI-DHQ. The average overall DietDay estimated energy intake was 2,222 kcal per day which was 9% lower than the total energy expenditure of 2,445 kcal per day derived from DLW a difference similar to what was found when comparing the interviewer-administered multi-pass 24hour dietary recall to DLW in the OPEN study.

Conclusion

Much remains to be learned about the relationship between diet and chronic diseases. A goal of using new technology like the web for survey research is to improve data quality, provide a better survey experience for the participant, and increase efficiency.[110] A web-based 24-hour dietary assessment is innovative and necessary for the future of epidemiologic studies. It has potential to reduce measurement error, capture detailed dietary intake, and evaluate habitual dietary, all in a timely and cost-efficient manner.

Coupled with the explosion of the Internet, a web-based dietary assessment is an exciting and innovative methodology for future research and may result in a more practical and, potentially more valid, dietary assessment method for large epidemiologic studies. The key will be, especially for large studies, designing an instrument that is as precise and accurate as the current optimal method of the 24-hour dietary recall yet which greatly minimizes the participant and investigator burden. A hybrid method such as a web-based 24-hour food report questionnaire that can be administered multiple times could be the answer.

Table 1.1: Selected diet and chronic disease associations (WHO, 2003)

	Obesity	Type 2 diabetes	Heart disease	Cancer	Dental disease	Osteo-porosis
High intake of energy dense foods	C↑					
Saturated fatty acids		P↑	C↑			
Trans fatty acids			C↑			
Dietary cholesterol			P↑			
Fish and fish oils			C↓			
High intake of non-starch polysaccharides (dietary fiber)	C↓	P↓	P↓			
Free sugars					C↑	
Whole grain cereals			P↓			
Vitamin D					C↓	C↓
Folate			P↓			
High sodium intake			C↑			
Salt-preserved foods and salt				P↑		
Calcium						C↓
Fruits (including berries) and vegetables	C↓	P↓	C↓	P↓		
Whole fresh fruits					P-NR	
Sugar sweetened soft drinks and fruit juices	P↑				P↑	
Unfiltered boiled coffee			P↑			
High alcohol intake			C↑	C↑		C↑
Heavy marketing of energy dense foods and fast food outlets	P↑					
Overweight and obesity		C↑	C↑	C↑		

C↑: Convincing evidence of increased risk; C↓: Convincing evidence of decreased risk; P↑: Probable evidence of increased risk; P↓: Probably evidence of decreased risk; P-NR: Probable evidence of no relationship.

Table 1.2: Uses and methodologic strengths and limitations energy and dietary assessment for epidemiologic studies and surveillance.

Procedures	Uses	Strengths/Limitations
Doubly-labeled water		
Oral administration of water labeled with deuterium, a stable isotope of hydrogen, and the stable oxygen isotope ^{18}O. Urine specimens are collected variably within hours or over days and excreted deuterium is measured. Standard equations for indirect calorimetry are used to assess energy expenditure.	Gold standard measure of energy intake and expenditure. Assess ***actual*** (***daily)*** or ***usual*** energy expenditure	**Strengths:** Direct measure of energy expenditure, no recall bias, and non-invasive. **Limitations:** High participant burden, very expensive, does not elucidate components of energy intake, and collection of urine samples may be burdensome requiring appropriate collection, storage, and analysis.
Biomarkers		
Methods depend on the biomarker being used but most frequently use individual blood or urine specimens. Specimens must be collected, stored, prepared to minimize contaminations or degradation, and analyzed using sophisticated laboratory techniques such as high performance liquid chromatography.	Assess ***usual*** nutrient intake over weeks or months. Gold standard for specific nutrients.	**Strengths:** Direct measure of nutrients, no recall bias, variance sources more easily identified and minimized, and some biomarkers have high precision. **Limitations:** Invasive, high cost per analysis, usually one nutrient per analysis, few biomarkers reflect truly long-term dietary intake, and complex procedures needed to ensure integrity of the sample and appropriate analysis.
24-hour Recall		
Subjects recall food intake of the *previous 24-hours* through a telephone or face-to-face interview. A multiple pass methodology is used to more fully elicit food details. Portion sizes are estimated using food visual aids such as models, photos, or drawings. Energy and nutrient intake are determined using food and nutrient databases.	Assess ***mean energy, food, nutrient intake*** for groups using 1-2 recalls (observational studies, including surveillance). Three or more recalls needed to assess individual ***usual*** intake. Can capture dietary behaviors like eating breakfast, snacks, and eating away from home.	**Strengths:** Captures good food detail, can accommodate reporting of any food consumed, relatively low respondent burden (20-40 minutes), can be used with illiterate populations, and method has become standardized and includes direct data entry using dietary analysis software. **Limitations:** Relies on memory, need three or more recall to assess usual intake increasing costs and participant burden, social desirability bias Expensive, portion-size estimation may be poor, recall bias, social desirability effects.

Table 1.2 (continued): Uses and methodologic strengths and limitations energy and dietary assessment for epidemiologic studies and surveillance.

Weighed or Estimated Food Record		
Subjects are instructed *in advance* on how to record of all food and beverages "as eaten" (including snacks) over periods from 1-7 days. Foods are weighed or estimated using household measures. Food samples can also be saved for nutrient analyses. Measurement tools may be provided (i.e. measuring cups, food scale). Reviewed by trained nutritionist to ensure adequate detail. Energy and nutrient intakes are calculated using food and nutrient databases.	Assess ***actual or usual*** intakes of individuals, depending on the number of measurement days. Can capture dietary behaviors like eating breakfast, snacks, and eating away from home. Gold standard for documented dietary intake.	**Strengths:** Does not rely on memory, can accommodate reporting of any food consume and can capture portion sizes well. **Limitations:** Accuracy depends on subject ability to estimate quantities or weigh/save foods, as time frame grows so does participant' burden and study expense, reporting may decline over time, subjects must be literate, individuals may change their eating patterns (reactivity), entering data for analysis is time consuming (20-30 minutes/record).
Dietary History		
Open-ended interview method consisting of a 24-h recall of actual intake, plus information on overall usual eating pattern, followed by a food frequency questionnaire to verify and clarify initial data. Usual portion sizes recorded in household measures. Energy and nutrient intake calculated using food and nutrient database.	Assess ***usual*** energy, food, or nutrient intakes over a relatively long period of time.	**Strengths:** Can collect great detail about individual eating habits including food preparation and seasonal food variations. **Limitations:** Labor intensive, time-consuming (often lasting more than 60 minutes), recall bias, and results depend on skill of the interviewer.
Food Frequency Questionnaire		
Uses comprehensive or specific food items list to record intakes over a day, week, month, or year. Information is obtained by interview or self-report. Predominantly close-ended measures. Questionnaire can be semiquantitative when subjects asked to quantify usual portion sizes of food items, with or without food models.	Assess ***usual*** intake. Provides qualitative, descriptive data of foods or classes of foods over a long time period. Primary method for large epidemiologic studies, including surveillance	**Strengths:** Quick, easy, affordable, and can assess current and past diet. **Limitations:** Not useful in young children and other population subgroups, cannot assess meal patterning, larger questionnaires take 45-60 minutes to complete, and least valid compared to other methods.

Table 1.3: Selected correlations between the food frequency questionnaires compared to four telephone 24-hour dietary recalls by gender and adjusted for energy intake.

Nutrient	Women			Men		
	DHQ	Block	Willet	DHQ	Block	Willet
Energy (unadjusted)	0.48	0.45	0.18	0.49	.045	0.20
Protein	0.60	0.53	0.54	0.57	0.61	0.58
Carbohydrate	0.69	0.66	0.63	0.63	0.64	0.67
Fat	0.66	0.67	0.65	0.62	0.55	0.60
Saturated fat	0.66	0.65	0.66	0.68	0.67	0.66
Polyunsaturated fat	0.64	0.48	0.47	0.61	0.33	0.52
Fiber	0.77	0.80	0.68	0.80	0.77	0.73
Vitamin A	0.62	0.50	0.54	0.69	0.65	0.51
Calcium	0.73	0.66	0.67	0.81	0.72	0.79
Sodium	0.53	0.44	0.28	0.41	0.28	0.30

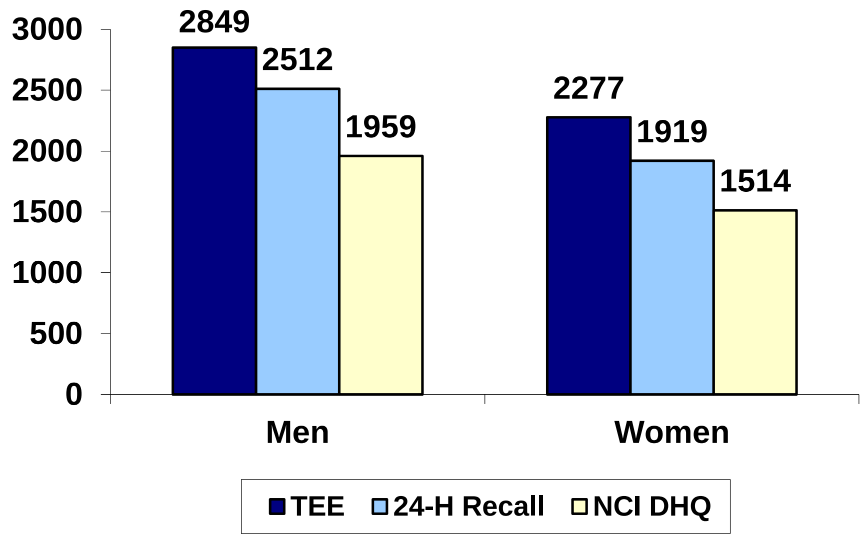
Subar et al, 2001
DHQ = National Cancer Institute Dietary History Questionnaire

Table 1.4: Strengths and limitations of web-based surveys

Strengths	Limitations
• Potential to reach wide audience • Participant convenience ○ Effect on response rate not clear • Reduced administration costs • Automated data processing and analysis costs • Automated follow-up procedures • Use of rich multimedia and/or interactive graphics • Real time - ○ dynamic edit checks, ○ routing/skip patterns, ○ fills (varying item content based on prior responses), ○ randomization (varying order or form of items presented to subjects), ○ customized feedback • Improved data quality • Removal of interviewer effects and potential social desirability	• Disparate internet penetration and use ○ Not representative of general population ○ Survey results not generalizable • Web/e-mail oversaturation • Development costs may be higher ○ Extensive usability and cognitive pretesting ○ Widespread survey use would defray costs • Implementation technically more involved • Minimal motivating, probing, & clarifying compared to well-trained interviewers. • Ethical and data privacy concerns

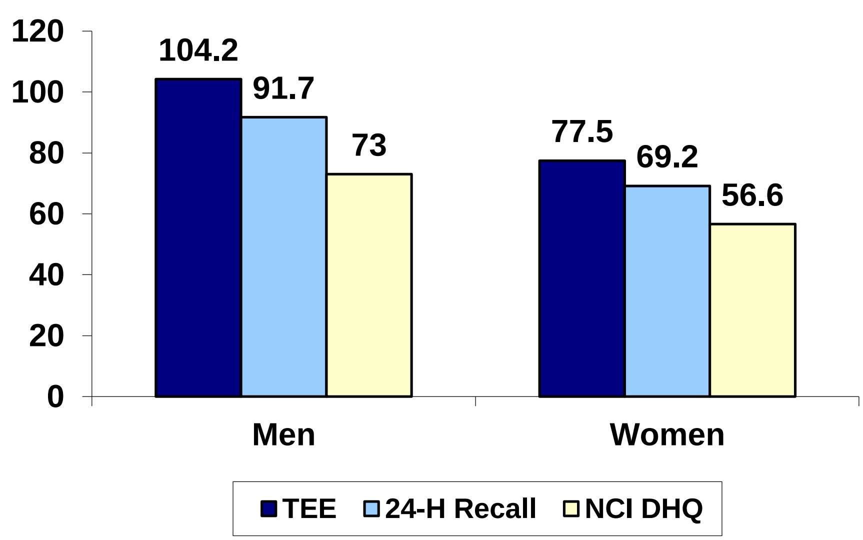
Fricker and Schonlau, 2002; Couper M, 2008; Dillman DA, 2007

Figure 1.1a: Average energy intake estimates (kcal per day) from the OPEN Study.



Subar et al, 2003
TEE = total energy expenditure determine from doubly labeled water method
24-H Recall = average of four 24-hour telephone recalls collected 3 months apart
NCI DHQ = National Cancer Institute Dietary History Questionnaire; average of 1 or 2 DHQ's

Figure 1.1b: Average protein intake estimates (grams per day) from the OPEN Study.



Subar et al, 2003
TEE = total energy expenditure determine from doubly labeled water method
24-H Recall = average of four 24-hour telephone recalls collected 3 months apart
NCI DHQ = National Cancer Institute Dietary History Questionnaire; average of 1 or 2 DHQ's

Figure 1.2: Demographics of internet and e-mail usage in the United States, April-May 2013.

Demographics of internet users

% of adults in each group who use the internet (the number of respondents in each group listed as "n" for the group)

		Use the Internet
All adults (n=2,252)		**85%**
a	Men (n=1,029)	85
b	Women (n=1,223)	84
Race/ethnicity		
a	White, Non-Hispanic (n=1,571)	86[c]
b	Black, Non-Hispanic (n=252)	85[c]
c	Hispanic (n=249)	76
Age		
a	18-29 (n=404)	98[bcd]
b	30-49 (n=577)	92[cd]
c	50-64 (n=641)	83[d]
d	65+ (n=570)	56
Education attainment		
a	Less than high school (n=168)	59
b	High school grad (n=630)	78[a]
c	Some College (n=588)	92[ab]
d	College + (n=834)	96[abc]
Household income		
a	Less than $30,000/yr (n=580)	76
b	$30,000-$49,999 (n=374)	88[a]
c	$50,000-$74,999 (n=298)	94[ab]
d	$75,000+ (n=582)	96[ab]
Urbanity		
a	Urban (n=763)	86[c]
b	Suburban (n=1,037)	86[c]
c	Rural (n=450)	80

Source: Pew Research Center's Internet & American Life Project Spring Tracking Survey, April 17 – May 19, 2013. N=2,252 adults. Interviews were conducted in English and Spanish and on landline and cell phones. Margin of error is +/- 2.3 percentage points for results based on internet users.

Note: Percentages marked with a superscript letter (e.g., [a]) indicate a statistically significant difference between that row and the row designated by that superscript letter, among categories of each demographic characteristic (e.g. age).

CHAPTER 2: DEVELOPING A 24-HOUR WEB FOOD REPORT QUESTIONNAIRE

INTRODUCTION

Recent changes in dietary patterns, combined with changes in physical activity behaviors, have led to substantial increases in disability, premature mortality, and economic costs associated with obesity and chronic conditions.[137] Over the past several decades, the growth of population-based epidemiologic nutrition studies have increasingly clarified the role of diet in obesity and chronic disease and have been used to establish recommendations and policies for dietary practices.

The most valid approaches to assess dietary intake in free living populations are food records and the 24-hour telephone dietary recall.[138] Food records document daily dietary intake and are often used over three, four, or seven consecutive day periods. But, the longer the collection period, the more onerous for the participant and the greater potential for reduced compliance or participant reactivity (i.e., changing dietary patterns). The 24-hour recall method overcomes this issue by employing the use of unannounced recalls over a period of time (weeks, months, or seasonally during the year). However, day-to-day within-person variation of dietary intake is substantial for most foods and nutrients thus multiple dietary recalls or food records (e.g. 7-10 days) are usually required to assess individuals' dietary intake.[17,72] In epidemiologic studies, at least three 24-hour recalls are considered acceptable for assessing an individuals' usual dietary intake but, at approximately 25 minutes per recall, in large studies this still poses significant participant burden and investigator labor-costs for data collection and coding. Thus, neither food records nor the 24-hour recall are ideally suited for large epidemiologic studies.

Food frequency questionnaires (FFQs) have become the method of choice for large studies. They are self-administered and ask participants to report how often, *on average*, they eat specific food items during a defined time period (e.g. past week, month, or year), are usually administered once, require about 60 minutes to complete, and minimize data processing because they consist of close-ended questions that can be easily key entered or optically scanned reducing staff time and processing expense. The main limitation of the FFQ is the higher degree of measurement error compared to 24-hr recall and food records, raising significant concerns about their validity. [8-13] Recall bias, poor portion size estimation, missing or phantom foods, and social desirability bias are believed to be the primary culprits of measurement error. In the OPEN (Observing Protein and Energy Nutrition) study by the National Cancer Institute, 35% of men and 23% of women were found to under-report both energy and protein intake on the widely used Dietary History Questionnaire FFQ compared to biomarkers.[13] This was only 9% and 7% of men and women, respectively, with the two 24-hour dietary recalls collected in this study.[13] This has led a number of leading scientists to conclude that research examining the association of diet and health outcomes has been seriously undermined by our reliance on FFQs. [14-16,19]

The 24-hour dietary recall is believed to have less measurement error because participants are asked to report all foods they can remember eating during a shorter time frame (past 24 hours). Also, extensive interviewer probing is conducted to ascertain food additions (e.g. sugar added to coffee); food preparation method (e.g. fried, baked, broiled); ingredients used in preparation (e.g. type of milk used in preparing hot cocoa) and other food detail (e.g., brand of breakfast cereal, whether skin eaten on chicken, etc.). To assist respondents in reporting food amounts, food visual aids are usually used during the interview. In contrast, most FFQs have 3-6 portion size categories from which to choose and do not use visual aids. While the 24-hour recall remains the standard for self-report dietary assessment, *FFQ's, despite their limitations, continues to be the method of choice in large epidemiological studies because of their feasibility and low cost*.

Given this landscape, the current challenge facing investigators is how to continue advancing the field of nutritional epidemiology by improving the validity, efficiency, and cost-effectiveness of our dietary assessment approaches. Rapid technological innovation coupled with increasing internet penetration and use has great potential to enhance dietary recall. As web-technology improves, the potential advantages of web-based surveys are reduced costs, ease and effectiveness of e-mail reminders and data processing, dynamic error checking capability, automated skip patterns, use of pop-up instructions, inclusion of visual cues or prompts, ability to customize surveys to particular populations, and convenience to respondents (Table 2.1).[106,107,110] These benefits can reduce bias and error through improved data quality control (built-in data range checks), reduced social desirability and interviewer bias, and more accurate responses using cognitively tailored designs capitalizing on web technology.[107] Other benefits include efficiencies in data collection, management (e.g. data automatically processed to ready-to-analyze data sets), and analyses (e.g., preliminary data manipulation and reports can be automatically generated and included in analysis datasets). Participant convenience is also essential. Currently, over 85% of Americans have home internet access and internet reach is even broader when considering access in work, school, and community settings and through expanding wireless technologies.[111]

This has inspired several new tools like the Web*DHQ, a photo web-based version of the NCI-DHQ (Web-PDHQ), the Web-based DietDay 24-hour recalls, and the Automated Self-Administered 24-hour Dietary Recall (ASA-24).[123,131,133,139-141] The Web*DHQ is a direct modification of the NCI-DHQ for the web thus it retains the 12 month recall period. The Web-PDHQ also retained the 12 month recall period with the addition of food item pictures representing two different portion sizes.[123] Among 214 people, the estimated energy and nutrient intake of the Web-PDHQ was under-reported compared to telephone recalls and correlations ranged from 0.10 to 0.57, with an energy intake correlation of 0.18.[123] The ASA-24 is modeled after the traditional interviewer administered 24-hour dietary recall with an open-ended question format and use of the multi-pass approach to collection of information. Consequently, the time required to complete the ASA-24 is approximately 20-30 minutes per recall.[140] The validity of the ASA-24 is currently under investigation. The Web-based DietDay 24-hour recall is a self-administered, web-based multi-pass instrument anchored by meal times. It contains

9,349 foods and more than 7,000 food images. There appears to be good acceptability and usability based on completion rates of eight recalls over a 2-month period although the time to complete a single survey has not been reported.[134,142] Compared to doubly-labeled water, the DietDay under-reported energy intake by 9% (2,222 kcal vs. 2,445 kcals) and had a Pearson correlation of 0.45. In the same study, the NCI-DHQ under-reported energy intake by 27% and had Pearson correlation of 0.33.[133] This is a promising dietary assessment approach.

There are several new tools under development attempting to use real-time digital photography to capture food intake content and amounts among adults and these have potential for accurate food and nutrient intake estimates. [143-151] The Remote Food Photography Method (RFPM) with ecological momentary assessment (EMA) developed and tested by Martin and colleagues is promising.[152] Participants receive unannounced personalized EMA prompts to digitally photograph their upcoming meal. The use of EMA can reduce missing data, recall bias, and reporting bias over time (i.e., fatigue bias). In a free living situation with 51 participants over 6 days, the RFPM underestimated energy intake by 3.7% compared to doubly labeled water. However, validation of other nutrient intake was conducted in a laboratory setting. The same is true for the other studies employing digital imaging. They have yet to be tested in a free living population where meals, beverages, and snacks are consumed in a variety of settings (i.e. restaurant, movie theatre, car, couch, etc.) or in a variety of ways such as communal sharing of popcorn or chips. Feasibility of these in large epidemiologic studies remains a concern. As an example, in the RFPM participants are asked to take pictures of foods eaten throughout the day using a mobile phone containing a digital camera. Appropriate training and equipment is required so that photos are taken before and after the meal, the food items are separated as best possible, reference markers are included in the photos, and photos are taken from a similar angle. The images are sent to a study center where a combination of automated assessment and trained staff code the foods and portion sizes to calculate food and nutrient intake. [146] None of the new technological tools appear to be simultaneously addressing validity while also adequately improving participant burden, staff burden, and cost-effectiveness.

In this paper, we describe the pilot development of an automated 24-hour Web Food Report Questionnaire (WFRQ) which capitalizes on the efficiency and usability of the FFQ, the shorter 24-hour recall period that allows for enhanced collection of foods and food details, and the user-friendly and cost-effective capabilities of web access and technology. The proposed WFRQ is a hybrid of the standard FFQ and the 24-hour dietary recall method. Typical FFQs, like the NCI DHQ, ask for recall over the past year and, to be feasibly implemented, have limited choices in food items and portion sizes. Not only are they time-consuming to complete, 68 minutes for the NCI DHQ, but compared to biomarkers they also under-report energy and food intake by over 30%.[13,153] Using a 24-hour recall period should improve reporting of energy and food intake due to less recall bias, as was observed with the 24-hour telephone recall in the OPEN Biomarker study. Use of web-based technology should also reduce measurement error by incorporating greater food item and portion size selections and should reduce the participant burden by including checklists and skip patterns to report only on the limited number foods consumed during the prior 24 hour period. Additionally, researcher burden should be less since the electronic WFRQ could include quality checks at data entry and back-end programs can be developed to automatically process the data into research datasets and/or dietary assessment reports. Our goal is to increase the validity, efficiency, and cost-effectiveness of dietary assessment in free living populations. To the best of our knowledge no such tool is available.

METHODS

Guiding Principles and Getting Started

In this exploratory effort to develop the 24-hour Web Food Report Questionnaire (WFRQ), our guiding design principles were ensuring validity of the instrument compared to the 24-hour telephone recall, good usability for participants and investigators (i.e. efficiency and cost-effectiveness), and the feasibility and expediency of developing the WFRQ. Two approaches to creating a new dietary assessment instrument are: 1) develop and validate a new instrument or 2) adapt a previously developed instrument. [100,154] We chose to capitalize on the significant amount of research that went into developing the National Cancer Institute Diet History Questionnaire (NCI-DHQ), which appears to be as good or superior to the other available FFQs.[66,77,155,156] The NCI-DHQ was designed in the mid-1990's to assess usual dietary intake of Americans over the past 12 months. Given the rigorous data-based approach used to develop the original NCI-DHQ, the cognitive testing, usability studies, and numerous validation studies, we believe the NCI-DHQ provides a solid foundation that can be adapted to a 24-hour recall period.

In adapting the NCI-DHQ, we used a multi-step process: 1) develop a food list, 2) determine portion size response categories, 3) create the web-based instrument, 4) develop a food and nutrient database, 5) create a coding manual mapping the WFRQ responses in the Nutrition Data System for Research (NDSR), a nutrient calculation software application, and 6) pilot test the for usability. Additional steps routinely used in developing dietary assessment instruments include examining multiple questionnaire formats to determine the best food item ordering within the survey and conducting cognitive testing. These latter steps were not completed as part of this exploratory study. Again, we relied on the extensive research that went into developing the NCI-DHQ including food lists, portion sizes, testing different formats, and cognitive and usability testing. Having identified the well-validated NCI-DHQ as a model, we built off its web version, the DHQ*Web, which is identical in content to the original machine-readable paper-and-pencil version NCI-DHQ.

Developing a Food List

The primary challenge of developing the WFRQ is identifying food items for inclusion in the instrument. The goal is to develop a list that captures intake of common or important foods that contribute to energy and nutrient intake (i.e., validity) and yet does not contain a burdensome number of items (i.e., practicality). We built from the 124 food items within the NCI-DHQ that were determined using a data-based approach with the 24-hour dietary recall data collected as part of the 1994-96 Continuing Survey of Food Intake of Individuals (CSFII). A total of 5,261 individual food codes in the CSFII database were categorized into 336 food groups, allowing for lumping foods with similar usage and nutrients, and then examined to identify the proportion of total nutrient intake contributed by each food group. After assessment of which food groups were important contributors to nutrient intakes 255 of the food groups were selected for inclusion.[153,156] This data-based approach has the advantage of considering both nutrient composition and frequency of consumption with the resulting food list applicable to the general U.S. population.[157] Further in-depth cognitive research was conducted to test the effects of grouping versus splitting, and also nesting, of these 255 food items on accuracy of reporting and this led to the final 124-item NCI-DHQ.[153,156]

In developing the food list for the 24-hour WFRQ, we retained the core food sections and food groups of the NCI-DHQ, but made numerous modifications to capture the benefits of using a 24-hour time frame, the web, and to include foods that have become more widely used over the past 15 years. The NCI-DHQ is divided into fifteen primary areas asked in the following order: 1) beverages, 2) fruits, 3) vegetables, potatoes, and dried beans, 4) soups, chili, and Mexican foods, 5) rice, pasta, and pizza, 6) cereal, pancakes, and breads, 7) peanut butter and jelly, 8) cold cuts, luncheon meats, and hot dogs, 9) meat, poultry, and fish, 10) eggs and meat alternatives, 11) chips, pretzels, and other snacks, 12) yogurt and cheese, 13) sweets, baked goods and desserts, 14) spreads, dressings, and other foods, and 15) vitamins and supplements. The WFRQ contains the first 13 sections. Section 14 was incorporated throughout the other sections and, at this time, we did not include Section 15.

Because of improved and more detailed recall of a 24-hour time frame and the ability to automate skip patterns, the vast majority of changes involved splitting food groups into separate items (e.g., Italian foods into lasagna, stuffed shells, stuffed manicotti, and ravioli and tortellini) or collecting greater detail within food groups (e.g. specific cold breakfast cereals). The splitting of food groups was guided by recent work of Harnack and colleagues in developing an interviewer-administered one-day food questionnaire, similarly based on the NCI-DHQ. Figure 2.1 demonstrates the splitting of Mexican foods which have become more widely consumed throughout the U.S. since the mid-1990's. We added new foods such as sports and energy drinks, bottled ice tea, eggplant, zucchini, squash, mango, blueberries, raspberries, and others. We also incorporated into food items details on the use of fat-types (i.e., fat-free, lean, regular) and dressings, spreads, sweeteners, sauces, and other food additions. For example, the food detail captured about the type of milk consumed included chocolate milk, whole milk, 2% fat milk, 1% fat milk, skim milk or nonfat milk, soy milk, rice milk, and other (Figure 2.2). Table 2.2 lists the main food group sections and some key modifications built in to the 284-itme WFRQ. Since the development of the WFRQ, the NCI-DHQ has an updated food list based on more recent data and including 134 food items and is now called the NCI-DHQII.[158] Of the NCI-DHQII food list updates, we had already incorporated all of them with the exception of burgers coming from fast food places or other restaurants, adding asparagus, subcategorizing regular and lowfat/fat free mayonnaise or margarine, and subcategorizing different types of artificial sweeteners.

Determining Food Portion Size Categories

Portion size is a critical factor contributing to under-reporting of energy and nutrient intake in all self-report dietary assessment methods and is subject to substantial misreporting. Through cognitive testing, the NCI-DHQ determined the quantified ranges of "less than 1 cup", "1 to 1 ½ cups", and "More than 1 ½ cups", rather than the less quantitative categories of "small", "medium", and "large", were easier for participants to answer.[153] As with the food list, a data-based approach was used to determine these portion size ranges by looking at the distribution of food portions consumed by survey participants aged 19 years and older. For each food group the 25th and 75th percentiles of gram weight were used as cut-points to define the three portion size ranges.[155]

Using three portion-size categories was appropriate for the 12-month NCI-DHQ. However, the 24-hour time frame of the WFRQ allows for better participant recall and is likely to generate a wider yet more specific range of portion size estimates. Given the importance of capturing accurate portion sizes we maintained quantified range options, as done in the NCI-DHQ, but enhanced the range and gradations of portion sizes and also included an open-ended answer for the highest portion size category. With carrots, for example, we have 12 close-ended portion size selections plus the open-ended category as compared to the three categories in the NCI-DHQ. Soft drinks are an extreme example of our modifications. The NCI-DHQ portion size categories for soft drinks are “less than 12 ounces or less than one can or bottle”, “12 to 16 ounces or one can or bottle”, and “more than 16 ounces or more than one can or bottle”. In the WFRQ, soft drinks are first categorized into general sizes (i.e. 12 ounce cans, 16-20 ounce bottles, and 12, 20, and 32 ounce soda fountain sizes) (Figure 2). Within each of these categories are additional response sets for the number of drinks consumed, ranging from 0 to 6 or more drinks. Finally, participants can select as many categories as apply such as three 12 ounces cans, one 20 ounce bottle, and one 32 ounce fountain drink. For the most part, the number of portion size categories ranged from 6 to 12. We did not provide portion size visual aids either as a stand-alone booklet or embedded within the WFRQ. We did, however, include written tips on portion sizes. For example, ‘Three ounces of meat is about the size of a deck of cards’ or ‘1/2 cup of fruit is about the size of a computer mouse’. This is a potential area for future development.

Several FFQ’s adjust energy, food, and nutrient intake for potential gender differences based on data suggesting that male and female definitions for portion sizes such as ‘small’ or ‘medium’ are truly different. This is primarily an issue for instruments providing only a few close-ended portion size categories. This does not apply to the 24-hour telephone recall which involves in-depth probing for portion sizes. Similarly, we believe it does not apply to the WFRQ because most food items have at least six different quantitative portion size selections and is open-ended for the higher amounts.

Web Development and Administration

The WFRQ was programmed by the Data Collection and Support Services (DCSS) within the Division of Epidemiology & Community Health at the University of Minnesota and using DatStat Discovery™ Research Management System (Datstat™), a commercially available off-the-shelf software solution for designing and implementing internet-based surveys.[159] Datstat™ is a good platform for building our preliminary WFRQ because the questionnaire could be readily constructed at low cost (i.e., feasible and expedient).

Our approach during this phase of the WFRQ development was to capitalize on 1) the basic web and technological strengths of the DatStat™ software, 2) design a user-friendly format and administration process, and 3) address data confidentiality and security.

In creating the WFRQ, we took advantage of the programming to generate automatic skip patterns, query respondents about completing questions, and support navigation throughout the questionnaire to correct or modify responses as well as start, stop, and start again at any time during the questionnaire. We explicitly separated the 13 food areas and began each with a screener checklist of the foods within the section based on the approach by the Web*DHQ. Usability testing of the Web*DHQ found the instrument easier and faster to complete that the machine-readable paper-and-pencil version. The checklist provides the first set of skip patterns for the respondent. They are only asked more detail about foods selected on the initial screener (i.e. more specific food types, portion sizes and amounts, and preparation procedures). Similarly, when asked about more food detail, additional skip patterns were employed for certain food items requiring even greater detail such as type of Mexican food eaten (i.e. tacos, burritos, enchiladas, fajitas, etc.) or types of soft drinks consumed (colas with sugar, others with sugar, colas without sugar, and others without sugar). For cold breakfast cereals we included a drop-down box listing the 20 most common Brand cereals but also left a write-in category for cereals not listed. For efficiency and to minimize participant key entry error, we limited 'write-in' categories. Cold breakfast cereal was the only food item with a write-in category, otherwise only the high end of portion size ranges were open for 'write-in' responses. We did not, at this time, set a maximum portion size value that through a dynamic edit check could trigger a participant query about the accuracy of their response. The dynamic edit checks were only used to query participants if a question was left unanswered such as if a participant checked they had eaten an apple but failed to answer the apple food detail questions. After programming, each web survey section was reviewed and tested by the study investigators to ensure items were accurate, did not contain programming errors, and were user-friendly.

The WFRQ administration was designed for remote location use at the participants' convenience but within the specific time frame set by the investigator. Participants were asked to report all foods and beverages they ate or drank from 12:00am to 11:59pm (midnight to midnight) yesterday. Therefore all questions referred to thinking about what they ate or drank yesterday. DatStat™ was programmed so that the respondent must submit (i.e., complete) a WFRQ by the end of the day *following* the 24-hour recall period; otherwise, as is the case with the telephone recall method, the opportunity will be missed and the participant will have to wait for the next email invitation to complete a recall. While in the WFRQ, participants could navigate the instrument in order to correct or modify answers, and could to start, stop, and re-start the survey at their convenience during the predetermined 24-hour time frame. However, once the participant selects the 'Submit' icon at the end of the survey, no further changes were allowed. We also included a survey progress bar so that respondents could see how far along they are in the survey.

From the participant perspective, the WFRQ was designed to be user-friendly and secure. In addition to a participants' ability to move in and out and through the WFRQ, it can be easily accessed at their convenience and from many locations (i.e. home, work, school, coffee shop, library, and possibly mobile devices). Furthermore, and importantly, with the DatStat™ solution, a unique participant identification number (PIN) is created for each participant to access the WFRQ and Secure Sockets Layer (SSL) encryption is used during all internet data transmission (i.e. from participant to server and from server to investigator). Participants will get their PIN through e-mail notification. The data are collected and stored in electronic format on secure, password protected servers that have registered site certificates from VeriSign Internet Trust Services. Thus, participant data security and confidentiality concerns are rigorously addressed.

For the investigator, this level of security is also crucial. In addition, the use of data queries (as described earlier) potentially provide higher quality data and less missing data and, once a participant 'Submits' the data, it is automatically and immediately loaded into a database that can generate Excel and SAS data formats allowing for quicker data processing. These strengths greatly enhance usability for the investigator.

Food and Nutrient Database

A key component in the development of the WFRQ is creating a food and nutrient database that includes nutrient values for each item in the instrument. Although a food and nutrient database was developed for the NCI-DHQ, we used the comprehensive research-quality food and nutrient database developed and annually updated by the University of Minnesota, Nutrition Coordinating Center (NCC). [160] For analyses of food, nutrient, and energy intake, this database is linked to the Nutrition Data System for Research (NDSR), also developed by NCC.[160] The database contains over 18,000 foods organized into 9 groups and 166 subgroups and with values for 155 nutrients, nutrient ratios, and other food components.[160] Using this extensive and detailed database we matched the food items of the WFRQ as closely as possible to a food description within the linked NDSR food and nutrient database and its corresponding nutrient components and values (nutrient string). A straightforward example would be matching fruits or vegetables in the WFRQ with those in the NDSR database. Matching mixed dishes, such as burritos, was more challenging because within the NDSR there are multiple types of burritos based on the meat, cheese, tortilla, and other ingredients used. NCC nutritionists have created a default option in the NDSR database for when the type of food (i.e., burrito) is unknown. The default nutrient string is data-driven based on consumption patterns or, in a few cases, based on professional judgment on what type of food is most commonly consumed. In the cases where the WFRQ food category would be considered 'unknown' we relied on the NDSR default category unless we determined another food nutrient string was more appropriate. In the case of other discrepancies within the WFRQ, study investigators adjudicated and determined the appropriate coding of nutrient strings. We established a code book that details the matching of the WFRQ foods with the NDSR database for use in analyses.

Usability Test of the WFRQ

The WFRQ was piloted with a convenience sample of 20 adults consisting of experts in dietary assessment and lay persons located throughout the country. The participants were provided with personal identification numbers (PINs) to access the WFRQ. After completing the survey, participants were asked to answer several questions about usability as well as provide additional feedback via e-mail and interviews. The participants found the WFRQ easy to use, fast (approximately 10-15 minutes), and the food checklists as good recall prompts. Suggested areas for improvement included smaller portion size options, the use of more open-ended responses, and consideration of a time-of-day format. No systematic administration or content problems were encountered by participants. In preparation for a small scale study to evaluate the comparability of the WFRQ with the 24-hour dietary recall method we fine-tuned some food detail and portion size sections of the WFRQ but reserved major format changes for future development.

DISCUSSION

Summary

By building from the already well-tested and established NCI Dietary History Questionnaire and using the DatStat^{TM} software solution, we were able to efficiently and feasibly develop a beta 24-hour web food report questionnaire. Our usability testing with a mixture of nutrition experts and lay people suggests good face validity and the WFRQ can be completed in less than 15 minutes compared to 68 minutes for the NCI DHQ.[77]

Challenges in Development

A data-based approach was used to develop the NCI-DHQ. In our development of the WFRQ we have used that approach as a foundation but have also clearly deviated from it. We kept all the food groups originally derived for the NCI-DHQ but also recognize the new types of foods that have permeated American diets since 1994-6. Produce such as squash, mangoes, and berries are more widely and readily available year round. Mexican food is more prevalent. Sports drinks, energy drinks, and pre-prepared ice teas are ubiquitous. The true contribution of these 'new' foods to the American diet remains to be determined but it is reassuring to see that the WFRQ contains almost all the food list updates of the recently released NCI-DHQII. Furthermore, because of our shorter recall period, we still added more food detail and portion size selections. Again, these were not data-driven at this time.

We have taken the next step with the WFRQ by conducting a preliminary comparative validity study using the current self-report gold standard of the 24-hour telephone recall (24TRs). At least three WFRQs and three 24TRs were administered among 62 adults. The results will be reported in a subsequent paper and will help us better understand if the increased food detail or use of more portion size categories results in comparable intake estimates and good macro- and micronutrient correlations. It will also help us further refine the WFRQ by guiding us as what to keep, add, or remove.

Such a preliminary study will not, however, help us address pertinent technological issues. For example, with emerging web technology, extensive development and pretesting to understand the effects of the technology on cognitive understanding, usability, user capabilities, participant convenience, and data quality is needed.[110] There are also the ethical issues of privacy, data security, informed consent, and access as well as hardware and software issues like use of different browsers and monitors. How these impact participation remains unknown. But, as internet access and web-use become more prevalent these issues are likely to diminish. Every day, from on-line shopping to banking, the sophistication of current technology and user's is growing.

Finally, web surveys will still suffer the limitations associated with other self-report survey methods such as order of items, response sets, survey length, and question design and content, especially if sensitive in nature. These are not intrinsic features of web technology but cut across all survey modes and must be addressed during an ongoing iterative process of web-based survey development. This future development can include more fully utilizing technological capacity like including visuals in the survey and creating a food and nutrient database, analysis software, and report system all directly linked into the WFRQ.

Conclusion

Much remains to be learned about the relationship between diet and chronic diseases. A goal of using new technology like the web for survey research is to improve data quality and reporting validity, provide a better survey experience for the participant, and increase efficiency.[110] The WFRQ is new and necessary for the future of epidemiologic studies. It has potential to reduce measurement error, capture detailed dietary intake, and evaluate habitual dietary, all in a timely and cost-efficient manner. Coupled with the explosion of the Internet, a web-based dietary assessment is an exciting and innovative methodology for future research and may result in a more practical and, potentially more valid, dietary assessment method for large epidemiologic studies. The key will be, especially for large studies, designing an instrument that is as precise and accurate as the current optimal method of the 24-hour dietary recall yet which greatly minimizes the participant and investigator burden. A hybrid method such as a web-based 24-hour food frequency questionnaire that can be administered multiple times could be the answer.[107,161,162]

Table 2.1. Strengths and limitations of web-based surveys

Strengths	Limitations

• Potential to reach wide audience
• Participant convenience
  ○ Effect on response rate not clear
• Reduced administration costs
• Automated data processing and analysis costs
• Automated follow-up procedures
• Use of rich multimedia and/or interactive graphics
• Real time -
  ○ dynamic edit checks,
  ○ routing/skip patterns,
  ○ fills (varying item content based on prior responses),
  ○ randomization (varying order or form of items presented to subjects),
  ○ customized feedback
• Improved data quality
• Removal of interviewer effects and potential social desirability
	• Disparate internet penetration and use
	  ○ Not representative of general population
	  ○ Survey results not generalizable
	• Web/e-mail oversaturation
	• Development costs may be higher
	  ○ Extensive usability and cognitive pretesting
	  ○ Widespread survey use would defray costs
	• Implementation technically more involved
	• Minimal motivating, probing, & clarifying compared to well-trained interviewers.
	• Ethical and data privacy concerns

Fricker and Schonlau, 2002; Couper M, 2008; Dillman DA, 2007

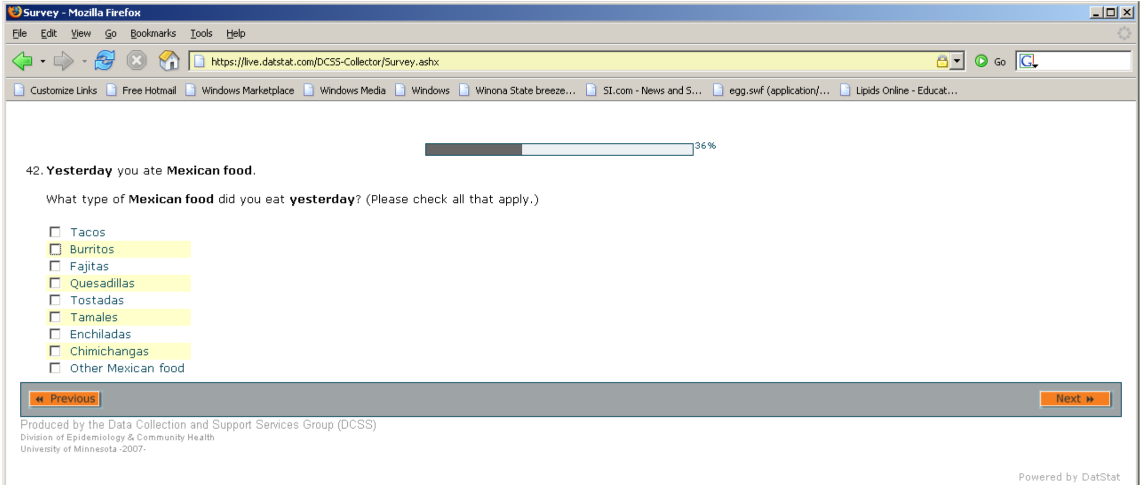
Table 2.2: Food list modifications on the web 24-hour dietary assessment compared to the NCI Dietary History Questionnaire

Food Section	Modifications to the web 24-hour dietary assessment
Beverages	• Add carrot juice • Ungroup fruit juice: apple, grape, pineapple, and other • Ungroup fruit drinks: cranberry cocktail, Hi-C, Sunny D, Lemonade, Kool-aid, and other • Add milkshakes and malts • Add hot chocolate and hot cocoa • Ungroup soft drinks: colas, non-colas, diet Colas, and diet non-colas • Add sports and energy drinks • Add wine type: Red, White, other • Add hard lemonade and malt beverages • Add tap or bottled water • Include expresso, cappuccino, etc with coffee • Add bottled iced tea • Add type of tea (i.e., black, green, other)
Fruits	• Add mango • Ungroup dried fruits: raisins, prunes, apricots, others • Ungroup peaches, nectarines, and plums • Ungroup melons: cantaloupe, honeydew, watermelon, and other • Add blueberries, raspberries, and blackberries • Add pineapple
Vegetables, potatoes, and dried beans	• Ungroup greens: spinach, turnips, collard, chard/kale, other • Ungroup lettuce: romaine, iceberg, other • Add cucumbers • Ungroup cauliflower and 43russels sprouts • Add dark orange (winter) squash • Add eggplant, zucchini, and summer squash • Ungroup French fries, home fries, has browned potatoes, and tater tots • Ungroup baked, boiled, and mashed potatoes
Chili, Mexican foods, and soups	• Ungroup Mexican foods: tacos, burritos, fajitas, quesadillas, tostadas, tamales, enchiladas, chimichangas, and other
Rice, pasta, and pizza	• Ungroup rice and cooked grains: white rice, brown rice, fried rice, and other; bulgar, cracked wheat, millet, or other • Ungroup lasagna, stuffed shells, stuffed manicotti, and ravioli/tortellini • Group lomein and ramen with pastas and spaghetti • Ungroup pizza: cheese-only, vegetarian, or meat

Table 2.2 (continued): Food list modifications on the web 24-hour dietary assessment compared to the NCI Dietary History Questionnaire

Cereal, pancakes, and breads	• Ungroup oatmeal, grits, and other cooked cereals • Add specific brands of cold cereals • Ungroup pancakes, waffles, and French toast • Ungroup bagels and English muffins • Add bread-type: white, cracked wheat/wheat, and 100% whole grain
Peanut butter and jelly	• Moved peanut butter into 'cereal' section • Incorporated jelly and jams into other sections, where appropriate
Food Section	**Modifications to the web 24-hour dietary assessment**
Cold cuts, luncheon meats, and hot dogs	• Ungroup turkey and chicken cold cuts • Add detail to 'other cold-cuts': bologna, salami, corned beef, pastrami, other type, and mixed types
Meat, poultry, and fish	• Ungroup ground chicken and turkey • Ungroup chicken: baked, broiled, roasted/stewed, or fried • Add chicken detail: drumsticks, wings, breasts, thighs, nuggets, fingers/strips, and other • Ungroup veal, venison, and lamb • Add detail to fish NOT FRIED: dark meat, light meat, and shrimp/lobster/squid/shellfish
Eggs and meat alternatives	• Add egg-type: fried, scrambled, boiled, poached, quiche/soufflés/fritter, egg salad, and other
Chips, pretzels, and other snacks	• Ungroup potato chips, corn chips, and other snack chips • Ungroup nuts and seeds: peanuts, walnuts, cashews, almonds, sunflower seeds, and other
Yogurt and cheese	• None
Sweets, baked goods, and desserts	• Ungroup frozen yogurt, sorbet, and popsicles/ices • Ungroup ice cream, ice cream bars, and sherbet • Ungroup cookies and brownies/dessert bars • Ungroup donuts/sweet rolls/Danishes and pop tarts • Ungroup sweet muffins and dessert breads
Vitamins and supplements	• Did not include in web assessment

Figure 2.1. Screen shot of the Web Food Report Questionnaire demonstrating the splitting of Mexican foods and the collection of food amounts and details.



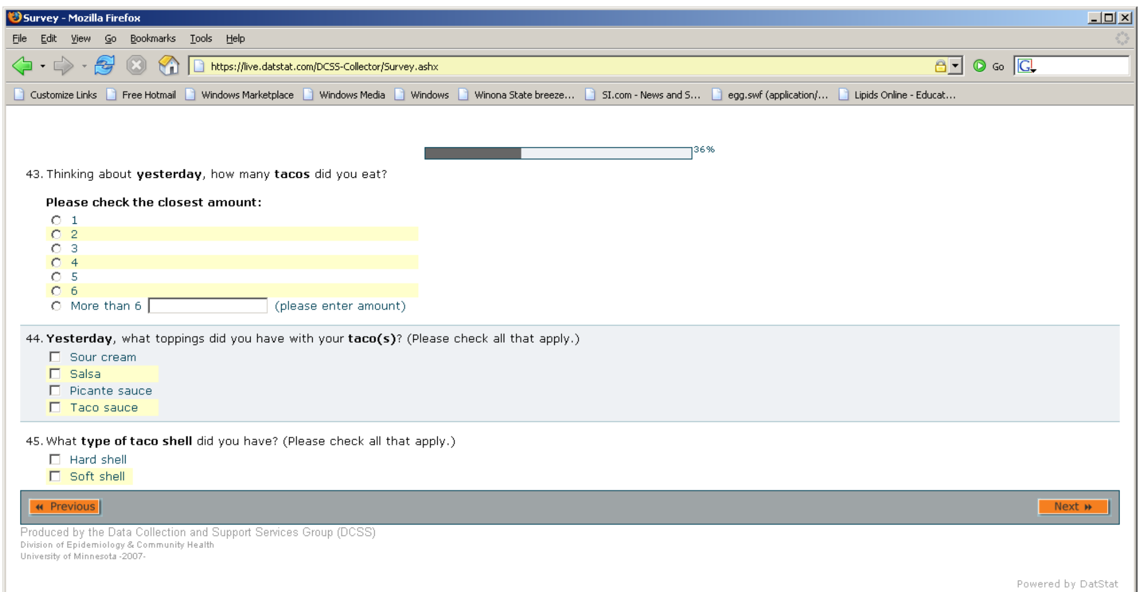


Figure 2.2. Screen shot of the food detail captured in the Web Food Report Questionnaire on the amount and type of milk consumed the previous day.

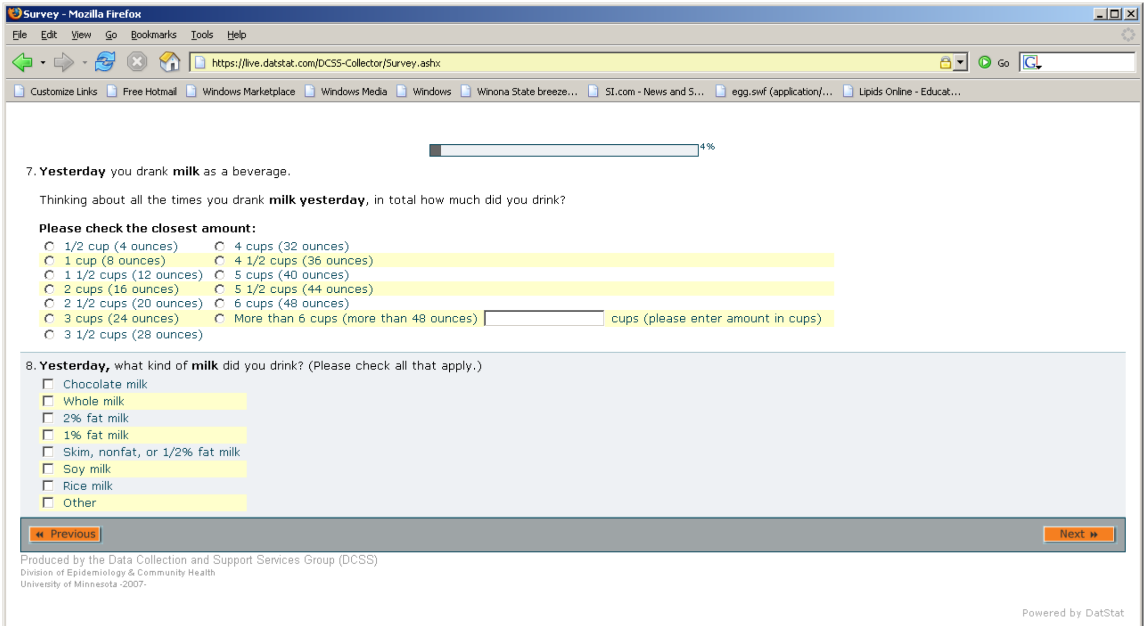
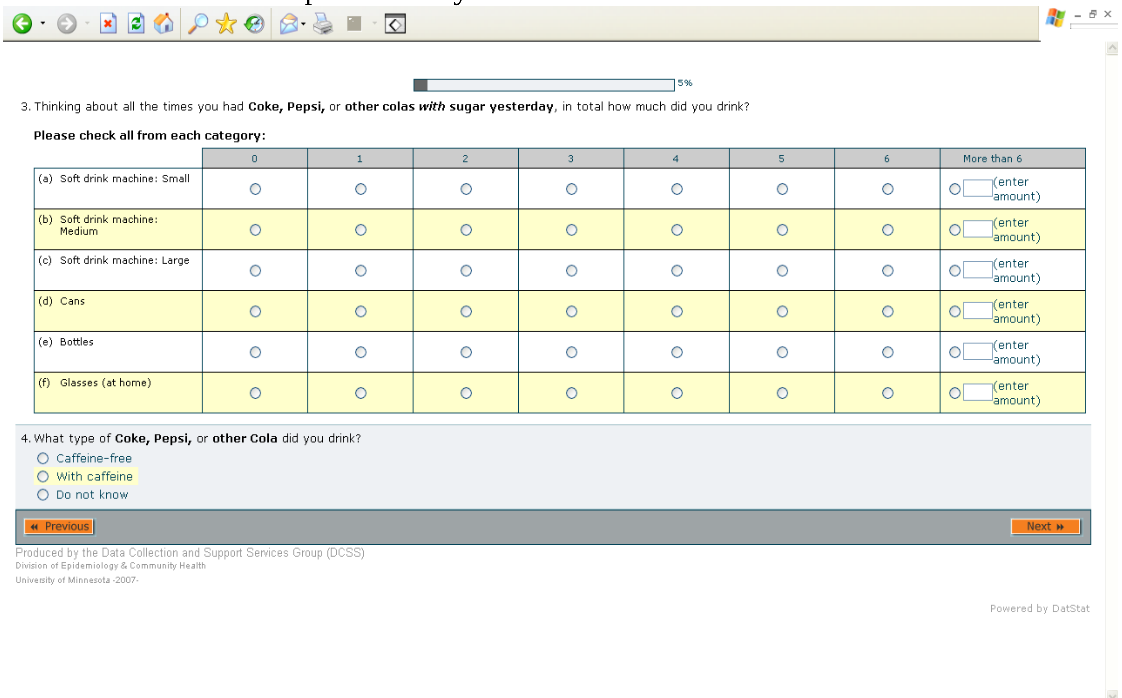


Figure 2.3. Screen shot from the Web Food Report Questionnaire of the soda size and amounts consumed the previous day.



5%

3. Thinking about all the times you had **Coke, Pepsi,** or **other colas *with* sugar yesterday**, in total how much did you drink?

Please check all from each category:

	0	1	2	3	4	5	6	More than 6
(a) Soft drink machine: Small	○	○	○	○	○	○	○	○ (enter amount)
(b) Soft drink machine: Medium	○	○	○	○	○	○	○	○ (enter amount)
(c) Soft drink machine: Large	○	○	○	○	○	○	○	○ (enter amount)
(d) Cans	○	○	○	○	○	○	○	○ (enter amount)
(e) Bottles	○	○	○	○	○	○	○	○ (enter amount)
(f) Glasses (at home)	○	○	○	○	○	○	○	○ (enter amount)

4. What type of **Coke, Pepsi,** or **other Cola** did you drink?

- ○ Caffeine-free
- ○ With caffeine
- ○ Do not know

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Division of Epidemiology & Community Health
University of Minnesota -2007-

Powered by DatStat

CHAPTER 3: PRELIMINARY VALDIATION OF THE 24-HOUR WEB FOOD REPORT QUESTIONNAIRE AGAINST THE 24-HOUR TELEPHONE RECALL AND THE DIETARY HISTORY QUESTIONNAIRE

INTRODUCTION

Food frequency questionnaires (FFQs) remain the primary option to examine usual dietary intake and diet-disease relationships in large epidemiologic studies, especially with free-living populations. Commonly used FFQs include the National Cancer Institute Dietary History Questionnaire (NCI-DHQ), the Harvard Food Frequency Questionnaire and the Block Food Frequency Questionnaire.[66,77,129,157] These FFQs assess intake over the previous 12 months and are typically designed for self-administration, can be completed in a limited amount of time, and their close-ended format allows for optical scanning or key entry. These attributes all minimize participant, study staff, and researcher time and expense for data collection and processing. There are, however, serious concerns regarding the validity of intake estimates from FFQs for some key nutrients which has led some to conclude that research examining the associations of diet and health has been undermined by our reliance on this method.[9,14,16]

Currently the most valid approaches to assessing habitual dietary intake in free living populations are multi-day food records and multiple interviewer administered 24-hour dietary recalls.[163,164] Their primary strength is reduced recall bias because they draw on short-term memory. By using trained interviewers, 24-hr recalls may also reduce social desirability bias and, if administered unannounced, may limit changes in dietary behaviors.[61] They also do not require participants to read or write and are relatively brief at 20-30 minutes.[17,160] Unfortunately, the 24-hour interviewer-administered recall is impractical for use in large epidemiologic studies, especially those attempting to assess an individuals' habitual dietary intake. Depending on the nutrient of interest anywhere from 3 to 20 recalls by highly trained interviewers are required to assess an individuals' habitual dietary intake thus cumulative participant and researcher time and labor costs are extensive.[165,166]

Several new technologies, including greater use of the internet, have recently been developed or are being explored as potential approaches to increase validity, reliability, and/or efficiency of dietary intake assessment. Many remain developmental and have not been validated or examined in free living populations thus their utility, particularly for large epidemiologic studies, remains unknown. The Web-based, automated, self-administered 24-hour recall instrument called DietDay is the furthest along having been evaluated for validity against the NCI-DHQ, doubly-labeled water, and other biomarkers in the Energetics Study.[131,133] Good user acceptability suggests low participant burden although the actual participant, staff, and researcher burden has not yet been reported.[134]

Concurrently, yet independently, with the Energetics Study, we also developed a 24-hour Web Food Report Questionnaire (WFRQ). The primary purpose of this paper is to report on a preliminary validation study comparing habitual energy and nutrient intake collected using the WFRQ to the telephone 24-hour dietary recall (24TR). In addition, we also contrast the results of the WFRQ and the 24TR to those of the NCI-DHQ and the 24TR to examine how well the WFRQ and the NCI-DHQ perform relative to the 24TR.

METHODS

Development of the Web Food Report Questionnaire

The development of the 24-hour Web Food Report Questionnaire has been reported in depth elsewhere (Chapter 2). Briefly, the WFRQ was adapted from the Web-based version of the NCI Dietary History Questionnaire (NCI-DHQ). The NCI-DHQ was rigorously developed using data-based methods to determine the food lists and portion size categories, has had extensive cognitive and usability testing, and has performed better in validation studies relative to other general population-based food frequency questionnaires.[139] The NCI-DHQ contains 124 food items, quantitative portion size categories, and is arranged in 15 food sections: 1) beverages, 2) fruits, 3) vegetables, potatoes, and dried beans, 4) soups, chili, and Mexican foods, 5) rice, pasta, and pizza, 6) cereal, pancakes, and breads, 7) peanut butter and jelly, 8) cold cuts, luncheon meats, and hot dogs, 9) meat, poultry, and fish, 10) eggs and meat alternatives, 11) chips, pretzels, and other snacks, 12) yogurt and cheese, 13) sweets, baked goods and desserts, 14) spreads, dressings, and other foods, and 15) vitamins and supplements. An updated NCI-DHQII is now available from NCI and includes 134 food items based on NHANES 2001-2, 2003-4, and 2005-6 data.[158] A web version of the NCI-DHQ has been developed with positive usability results. The web version (Web*DHQ) includes the use of a food screener checklist prior to each section in the Web*DHQ. The new paper and pencil NCI-DHQII and Web*DHQII have not had any additional cognitive, usability, or validity testing.

In adapting the Web*DHQ we changed the time frame to the 24 hours of the previous day and maintained the first 13 food sections while incorporating spreads, dressings, and other items commonly added to foods (Section 14) throughout the first 13 sections. We did not include a dietary supplement section at this time. We did use the food section screeners. The most significant modifications were adding greater food detail, including preparation and food addition detail, including more current and widely available food items, and adding a wider range with finer gradients of portion size categories. For example, we split food items on the Web*DHQ such as ‘Mexican foods’ into tacos, burritos, fajitas, quesadillas, tostadas, tamales, enchiladas, chimichangas, and other. Some food items that have become more widely available in the United States since the NCI-DHQ’s original development were added. These additions included sports drinks, energy drinks, a variety of berries, and squash and zucchini. As a result the WFRQ has 284 food items.

Instead of having only three portion sizes like the NCI-DHQ we had at least six categories and often 10-12 categories plus an open-ended answer for the highest portion size category. Soft drinks are an example of our modifications. The NCI-DHQ portion size categories for soft drinks are “less than 12 ounces or less than one can or bottle”, “12 to 16 ounces or one can or bottle”, and “more than 16 ounces or more than once can or bottle”. In the WFRQ, soft drinks are first categorized into general sizes (i.e. 12 ounce cans, 16-20 ounce bottles, and 12, 20, and 32 ounce soda fountain sizes). Within each of these categories are additional response sets for the number of drinks consumed, ranging from 0 to 6 or more drinks. Finally, participants can select as many categories as apply such as three 12 ounces cans, one 20 ounce bottle, and one 32 ounce fountain drink. For the most part, the number of portion size categories ranged from 6 to 12. We did not provide portion size visual aids either as a stand-alone booklet or embedded within the WFRQ. We did, however, include written tips on portion sizes. For example, 'Three ounces of meat is about the size of a deck of cards' or '1/2 cup of fruit is about the size of a computer mouse'.

The WFRQ was developed using the DatStat Discovery™ Research Management System (Datstat™), a commercially available off-the-shelf software for designing and implementing internet-based surveys. Our pilot usability testing found the WFRQ clear, easy to use, and fast.

Pilot Validation of the Web Food Report Questionnaire

Our primary hypothesis was that the Web Food Report Questionnaire (WFRQ) captures habitual dietary intake, defined as the average of three unannounced assessments on two weekdays and one weekend day, equally well as the criterion standard of the telephone administered 24-hour recall (24TR). We also examined how well the NCI-DHQ compared to the 24TR.

We conducted a non-randomized observational prospective validation study among 61 participants recruited from a convenience sample of adults whose children were enrolled in an etiologic study of adolescent obesity, Identifying Determinants of Eating and Activity (IDEA).[167] Inclusion criteria included ability to read and speak English, daily access to the Web, e-mail and telephone, and no extended travel or activities during the study period that would alter routine dietary habits or ability to access the internet. Interested participants were e-mailed additional information and a personal identification number (PIN) to enroll in the study on-line, including completion of the on-line Informed

Consent. The participants were provided gift card incentives up to $105. The study was approved by the University of Minnesota Institutional Review Board for Human Subjects.

Data Collection

We administered up to four 24-hour WFRQs, three 24-hour telephone recalls (24TR), and the NCI Dietary History Questionnaire (NCI-DHQ). Administration of the NCI-DHQ and collection of demographic information (height, weight, age, sex, education level, and leisure-time physical activity) occurred prior to the WFRQ's and 24TR's. The NCI-DHQ was completed at home by the participants and mailed back to the study staff. Participants were not contacted for verification or clarification of missing or ambiguous responses.

The WFRQ's and the 24TR's occurred from August through December 2007. We believed that the intensity and length of the 24TR protocol, with multiple passes and in-depth probing of dietary behaviors and intake, may improve accuracy of reporting on the WFRQ. Hence, we administered the WFRQs prior to collection of 24TRs. To elaborate, we administered the WFRQ's over a two week period, on non-consecutive days, unannounced, and these were completed before administering the 24TR. Where possible we included one same day administration of the WFRQ and 24TR, with the WFRQ being completed before conducting the 24TR. The same day administrations were timed to be the 3rd or 4th WFRQ and the 1st 24TR. The participant schedule ensured at least one weekend day and two weekday administrations of the WFRQ and the 24TR.

For the WFRQ, at 2:00am of a selected day, participants received e-mail notification to complete the WFRQ by 11:59pm for the *previous day's* diet (midnight to midnight). As part of the study protocol, participants were instructed to check their e-mails every morning for an unannounced study e-mail containing a direct authentication link to the WFRQ for that selected day. Participants could start, stop, and restart at any point within the survey up to 11:59pm at which point, if they had not clicked 'Submit' to indicate completion of the survey, they were timed-out of the WFRQ. An unannounced back-up WFRQ was then scheduled. As part of the Datstat^{TM}, we monitored participants' progress throughout the selected day and sent up to two reminder e-mails to encourage completion.

The 24TR's were conducted as per the standardized protocol for the 24-hour telephone dietary recall using the Nutrition Data Systems for Research (NDS-R), a computer-based nutrient calculation software application developed by the University of Minnesota that allows for direct entry of dietary data into an electronic database and in a standardized fashion. All dietary interviews were conducted by nutritionists certified in the use of the NDS-R. Almost all 24TR's were conducted in the evenings and back-up 24TR's were scheduled if the initial selected day was not available.

Food and Nutrient Calculations: The NCI-DHQ's were optically scanned and the Diet*Calc Software Analysis program, developed by NCI specifically for this questionnaire, was used to compute food and nutrient intake estimates. The NDSR software application automatically entered 24TR dietary intake data into an electronic database. The NDSR application was then used to calculate food, and nutrient intake based on the comprehensive research-quality food and nutrient database developed and annually updated by the University of Minnesota, Nutrition Coordinating Center (NCC). The database contained over 18,000 foods organized into 9 groups and 166 subgroups and with values for 155 nutrients, nutrient ratios, and other food components.[67]

To calculate food and nutrient intake estimates for the WFRQ, responses from the WFRQs were entered into NDS-r using a set of coding rules established a priori. In short, the food items on the WFRQ were matched as closely as possible to a food within the NCC food and nutrient database. The NCC food and nutrient database includes defaults ('unknowns') for foods for which sufficient detail may be lacking (e.g. 'unknown' is available when it is not known whether an apple was eaten with our without skin). The defaults are based on the most common form of a food or way it is eaten in the US. These defaults were generally relied on in the matching process for foods with insufficient detail on the WFRQ to allow matching to a specific food or preparation method in the NCC database. In the case of other discrepancies within the WFRQ, study investigators adjudicated and determined the appropriate coding.

***Statistical Analysis*:**

For the main analyses, mean daily nutrient intake estimates were calculated from three completed WFRQs. Twelve participants completed four WFRQs. For these participants we randomly selected WFRQs to ensure two weekday and one weekend day were included in our main analyses. Mean daily nutrient intake estimates were also calculated from the three completed 24TR.

Mean intake estimates from WFRQ, 24TR, and DQC were calculated and compared by conducting two-tailed Student paired t-tests. The correlations between intake estimates from each diet assessment method were examined using Spearman Rank correlations (ρ) as some nutrients were not normally distributed. Nutrients examined in these analyses included total energy, macronutrients, and selected micronutrients. Additional analyses included a comparison of 2-day averages where all same day administrations were excluded.

To estimate the proportion of participants for whom energy intake appeared to be under-estimated with each diet assessment method, energy expenditure was estimated using the Harris Benedict equations and factors used in Institute of Medicine (IOM) equations for estimated energy requirements based on body mass index, age, and gender.[168] For these equations, physical activity level (PAL) is categorized as sedentary, low active, active, and very active and the PAL factors vary depending on body mass index, age, and gender. Our participants reported daily leisure-time physical activity (LTPA) per week, categorized into walking, moderate, and vigorous. Current CDC recommendations are 150 minutes of moderate activity per week, generally broken down as 30 minutes for 5 days, or 75 minutes of vigorous activity per week, 15 minutes per day over 5 days with

10 minute bouts at a minimum. Health benefits can be improved by doubling these recommendations. Using this as guidance, we defined the following categories:

Sedentary: None or missing LTPA or 30 minutes or less of walking per day or less than 30 minutes of moderate daily LTPA or 10 minutes or less of vigorous LTPA. These are mutually exclusive.

Low Active: Any combination of walking, moderate, or vigorous LTPA that meets the 150 - 299 minutes moderate or 75 - 149 minutes of vigorous LTPA over 5 days.

Active: Any combinations greater than 'moderate activity' and not including 'very heavy activity'.

Very Active: At least 60 minutes per day of vigorous activity.

Underreporting was defined as the ratio of reported energy intake (EI) to estimated energy requirements (EER). A ratio below 1 is considered underreporting. We also calculated 95% confidence intervals with p=0.05.

All analyses were performed using SAS. A p values of ≤0.05 was considered statistically significant.

A total of 63 participants enrolled in the study. Two participants never started the study. Of the remaining 61 active participants: 1) all completed three 24TR's (100% of active participants), 2) 54 completed at least three WFRQs (89% of active participants), 3) 60 completed at least two WFRQs (98% of active participants), and 4) 58 completed a NCI-DHQ (95% of active participants). The main results analyses were restricted to those who completed three TR's, three or more WFRQ's, and a NCI-DHQ (n=51; 95% of active participants).

RESULTS

The characteristics of the active study population and those included in the 3-day average and 2-day average analyses are provided in Table 3.1. In general, it is a population of well-educated, middle-age White women, who report being active during their leisure-time.

Three Day Average Comparisons

Table 3.2 details the Spearman correlations of the 3-day average WFRQ and the NCI-DHQ against the 3-day average 24TR for estimated energy and nutrient intake levels. Spearman rank correlations between the WFRQ and the 24TR ranged from 0.24 for sodium intake to 0.75 for vitamin C intake ($p < 0.05$ for all nutrients except sodium). Correlations for fourteen of twenty (70%) nutrient intake estimates were moderately good ($\rho \geq 0.50$). Correlations of the NCI-DHQ with the 24TR ranged from 0.34 to 0.68 ($p < 0.05$ for all nutrients). Correlations for seven of nineteen (37%) nutrient intake estimate correlations were moderately good ($\rho \geq 0.50$) at 0.50 or higher.

Compared to the 24TR, mean estimated energy intake was similar for the WFRQ (2004 kcal/day vs 1911 kcal/day; $p=0.12$) but significantly lower for the NCI-DHQ compared to the 24TR (2004 kcal/day vs 1763 kcal/day; $p <0.01$). The median energy intake estimates were somewhat closer with 1868 kcal/day for the 24TR, 1837 kcal/day for the WFRQ, and 1710 kcal/day for the NCI-DHQ.

There were no significant differences in estimates of mean macronutrient intake between the WFRQ and the 24TR (Table 3.2). For the NCI-DHQ, mean intake was significantly lower for carbohydrates (13%), protein (10%), total fat (11%), saturated fatty acids (14%), monounsaturated fatty acids (11%), and cholesterol (19%) (Table 3.2). With the exception of Vitamin A (369 mcg vs. 497 mcg; $p<0.01$), there were no significant differences in mean absolute intake estimates of micronutrients between the WFRQ and the 24TR. For the NCI-DHQ, mean intake estimates of vitamin C and potassium were significantly greater compared to the 24TR and significantly lower for folate and iron. Otherwise, there were no significant differences in mean micronutrient intake estimates between the 24TR and the NCI-DHQ (Table 2). Similar measures of Vitamin A intake were not available for the 24TR and the NCI-DHQ. Thus, 1 of 20 nutrient intake comparisons was significantly different between the 24TR and the WFRQ while 10 of 19 were when comparing with the NCI-DHQ.

Two Day Average Comparisons

Two day comparisons were conducted among the same 51 participants included in the 3-day analyses with the exclusion of the WFRQ and 24TR measures conducted on the same day (Table 3.3). For the 2-day comparisons of the WFRQ and the 24TR the correlations ranged from 0.14 to 0.70 with 8 of 20 (40%) having $\rho \geq 0.50$ (Table 3.3). Comparison of the NCI-DHQ with the 2-day 24HR average resulted in 7 of 19 (37%) nutrient intake estimates with $\rho \geq 0.50$ and ranging from 0.26 to 0.66 (Table 3.3).

Mean absolute energy intake was 1865 kcal for the WFRQ and 2000 kcal for the 24TR. These were not significantly different (Table 3.3). As with the 3-day averages, mean total energy intake estimates from the NCI-DHQ was lower (12%) compared to the 2-day average of the 24TR (1763 kcal vs. 2000 kcal).

Carbohydrate intake estimates were lower in the WFRQ (8%) and the NCI-DHQ (13%) compared to the 24TR. The remaining macronutrient intake estimates were similar for the WFRQ and the 24TR. Protein, saturated fatty acids, and cholesterol were 10%, 14%, and 21% lower in the NCI-DHQ compared to the 24TR, respectively (Table 3.3). Estimates of Vitamin E intake were 22% higher in the WFRQ compared the 24TR (9.8mg vs. 8.0mg; $p = 0.04$) while estimated Vitamin A (retinol) intake was 14% lower ($p=0.04$). All other micronutrient intake estimates were similar. In the NCI-DHQ, estimates of Vitamin C and potassium were higher than in the 24TR while estimates of folate and iron were lower (Table 3.3).

Underreporting of Energy Intake

Based on ratios of reported energy intake (EI) to estimated energy requirements (EER), with the 24TR 37 participants (73%) were considered under-reporter while 44 participants (86%) were considered under-reporters with the WFRQ and the NCI-DHQ. The overall ratios of EI:EER for the 24TR, the WFRQ, and the NCI-DHQ are 0.85, 0.81, and 0.75, respectively, indicating under-reporting of energy intake by 15%, 19%, and 25%. This did vary by gender and body mass index. Among men, the ratios were 0.91, 0.80, and 0.74 for the 24TR, WFRQ, and the NCI-DHQ. They were lower for women at 0.83, 0.81, and 0.75. As observed in other studies, we also see lower ratios for participants who are obese compared to normal body mass index (Table 3.4).

Usability

When completing the WFRQ, a participants start and end times were captured by the DatStat software. Among all participants who completed at least one WFRQ (n=61) a total of 240 WFRQs were completed. The median and mean (± standard deviation) complete times were 10.0 minutes and 10.8 minutes (± 4.9 minutes), respectively. The time to complete cut-points for the 75th percentile and the 90th percentile were 13 minutes and 16 minutes.

DISCUSSION

The potential benefits of a web-based dietary assessment include reduced costs, improved quality assurance due to automatic skip patterns and range checks, and reduced respondent and researcher burden for data collection and analyses. This pilot study examines the validity of a 284-item 24-hour web food report questionnaire (WFRQ) to assess dietary intake of American adults. Validity of the WFRQ was assessed by comparing the average nutrient estimates from three WFRQ’s with average nutrient estimates from three 24-hour telephone recalls (24TR) among a convenience sample of 51 participants.

The WFRQ performance relative to the 24TR is promising with significant energy and nutrient intake correlations where 70% were greater than 0.50. The NCI-DHQ also had significant correlations but only 37% were greater than 0.50. Mean and median energy and nutrient intake estimates from the WFRQ and the 24TR were similar for all but Vitamin A. From the NCI-DHQ, however, 10 of 19 mean energy and nutrient intake estimates significantly differed from the 24TR. When analyses were conducted using a 2-day average where the same day WFRQ and 24TR assessments were removed, the correlations between the WFRQ and 24TR were attenuated but remained significant. With the exception of carbohydrate intake, mean energy and nutrient intakes remained similar between the WFRQ and 24TR. In general, estimated underreporting of energy intake was greatest for the NCI-DHQ followed by the WFRQ and the 24TR.

Our pilot results suggest the WFRQ performs well compared to the 24TR and better than the NCI-DHQ compared to the 24TR. Usability appears good with an average completion time of about 10 minutes.

Several other web-based dietary intake instruments for adults have been developed over the past few years, many being direct modifications of existing pencil-and-paper FFQs.[123-130] The most developed and evaluated tool so far is the DietDay, a multi-pass, web-based 24-hour self-administered recall. Like the WFRQ, it is based on a questionnaire format instead of being open-ended.[134] DietDay contains 9,349 foods and more than 7,000 food images in 61 modules. The food images are used to help estimate portion sizes. Recalls are anchored around the time of day: midnight to 11am, 11am to 5pm, and 5pm to midnight.[134] Validity and usability of the DietDay were good.[131,133,134] Pearson correlations for energy intake against doubly labeled water (DLW) were 0.41 for three DietDay recalls and 0.33 for the NCI-DHQ. The mean DietDay estimated energy intake was 2,222 kcal per day which was 9% lower than the total energy expenditure of 2,445 kcal per day derived from DLW. The mean NCI-DHQ estimated energy intake was 1,783 kcal per day or 27% lower than DLW. These results suggests the DietDay may be performing better than the WFRQ since the difference between the DietDay and the NCI-DHQ reported energy intake is 20% while that for the WFRQ and NCI-DHQ is only 8%.

Usability is also important. Among free-living populations the length of time it takes to complete a dietary assessment is crucial. The average time to complete a DietDay assessment has not been reported. Completion time for the WFRQ averaged 10 minutes. Our goal was to create a method that took no more time to complete than an FFQ but had superior validity. Most FFQs range from 30-60 minutes to complete, thus equivalent to the time commitment for 3-6 WFRQs, while the 24-hour telephone recall takes 20-30 minutes to complete.[124,127,129] Depending on the nutrients being assessed, 2-3 non-consecutive assessments are sufficient to capture habitual intake; therefore our results suggest we achieved our goal.[165,166]

Participant perceptions of validity and ease of use are also important usability criteria. Among 261 participants using the DietDay, 75% found it easier to use than the NCI-DHQ, 81% reported it was easy to conduct 8 repeat assessments over two weeks, and 95% would recommend its use to friends or family.[134] A similar formal assessment was not conducted with the WFRQ. Additionally, the DietDay inclusion of photographs to facilitate food recognition and portion size estimation may make it more feasible and valid for use with low literacy participants.

Use of photographs and scaling images may improve recall of foods and portion sizes. Ease, clarity, and order of flow on each page and through the survey can improve the user experience and potentially reduce completion time. Assuring the instrument is compatible with internet browsers and screen size is essential, especially considering future development that might include Smartphone and tablet use and the increasing availability and convenience of accessing the internet throughout the United States. Inclusion of immediate user feedback and support tools for assisting with understanding the tool may also be useful although this could depend on the context of the instruments use and potential respondent biases that may occur. The DietDay has incorporated some of these other usability components. With the WFRQ, these are all areas where, in addition to improved content development, future development of the WFRQ could result in an even more valid and efficient dietary assessment tool.

Limitations

There remain a number of limitations to this study. First, the participants were a convenience sample of educated and already motivated parents who had enrolled their children in a study examining eating and physical activity behaviors and likely do not represent the general population. This study was, however, intended as a pilot for the development and preliminary assessment of a 24-hour web-based dietary intake instrument. Related to this are issues of online accessibility and literacy, especially for studies targeting free living populations. Internet penetration and use continues to expand within the United States. Currently, 85% of adult Americans report online use. There remains a digital divide by age, education, and income level but from 2000 to 2013, online use by those over 65 years of age grew from 13% to 56%, among those who attained a high school degree it increased from 34% to 78%, and among those making less than $30,000 per year online use rose from 17% to 76%.[111] This growth also suggests improved online literacy.

Second, measurement error plagues self-report dietary intake methods. Recall bias remains a concern, even for the 24TR, our criterion measure. Underestimates of portions amounts is the leading contributor to overall energy under-reporting and under-reporting in general varies by weight status, gender, social desirability, literacy, education, race/ethnicity, and other factors.[128] The multi-pass, in-depth probing of the 24TR is designed to minimize this as best possible yet the two largest studies examining reported of energy intake from the 24TR compared to doubly-labeled water (DLW) found average under-reporting to be between 12 and 23%.[13,164] Of greater concern is that measurement error between the self-report WFRQ and a self-report criterion measure, such as the 24TR, are likely to be correlated and lead to spuriously high correlations. This has been shown previously.[9] A current practice in dietary assessment validation studies is to account for within-person day-to-day variation that may result in underestimated correlation coefficients, known as 'attenuation bias'.[61] However, these methods assume that the reference method is unbiased but, as discussed above, this is not the case when comparing two self-report methods. Conducting such analytic adjustment would further compound any spurious high correlations. Given the promising results of the WFRQ, we believe a more rigorous validation of the WFRQ using DLW and biomarkers as criterion measures should be performed.

It is possible that coding WFRQ food items to the NDS-R system may have introduced measurement error. The level of specificity and detail of the food items in the NDS-R system is much greater than within the WFRQ making it difficult to precisely match the WFRQ with the NDS-R selections. However, such miscoding may have led to increases or decreases in estimated energy and nutrient intake and we are unable to determine any systematic bias in the coding process. Tied to this is that future iterations of the WFRQ will need to add new food items, including dietary supplement intake.

We also did not adjust for multiple comparisons which may have resulted in some statistically significant findings being due to chance. Had we applied the conservative Bonferoni method to address multiple comparisons, our significance level cut-point would have been $p \leq 0.0025$. This would have resulted in no significant differences in mean nutrient intake estimates between the WFRQ and 24TR and far fewer intake differences between the NCI-DHQ and 24TR. Correlations of 0.4 met the adjusted significance level yet determining a good correlation remains subjective, thus interpretation remains grounded on the correlation more than the significance level for these types of validation studies. Perhaps that is why adjustment for multiple comparisons is rarely, if ever, reported in dietary assessment validation studies.

We did not assess changes in mean reported energy intake over the course of the three WFRQ's or the 24TR. This can be examined in subsequent analyses. This has been reported with food diaries.[61] There is some evidence of this among Whites in the recent

DietDay study but not African Americans where the decay became apparent beginning with the fourth administration.[133]

Third, the study design required that all the WFRQ's be administered prior to beginning the 24TRs and with one WFRQ and 24TR on the same day. There is concern that this order may have resulted in improved dietary intake reporting on the 24TR, especially when administered on the same day. We are unable to assess the potential effect of our current design on improved 24TR reporting but, as this is our gold standard, it could be considered a strength of study because it leads to better reporting with our criterion measure. Future designs might consider variations in the order and timing of conducting the dietary assessments. However, we do believe the intensity of an interviewer administered 24-hour telephone recall would likely wash-out biases introduced by administering the WFRQs first, including for same day assessments.

Summary

The potential of the WFRQ is encouraging with moderate correlations compared to the 24TR, similar estimated energy and nutrient intake, and the average completion time of 10 minutes. Even in its preliminary design the WFRQ appears to have better validity than the NCI-DHQ relative to the 24TR. There is clearly room for improvement. Subsequent examination of reported energy, nutrient, food, and food amounts captured on the WFRQ and the 24TR, when they were administered for the same day, may pinpoint specific areas of improvement such as missing foods, inadequate portion size measures and aids, or misaligned coding of WFRQ foods and portions with the NCC food and nutrient database. A more efficient, versatile, and valid dietary assessment tool has great potential for use in large epidemiologic studies of diet-disease relationships and for ongoing population surveillance.

Table 3.1: Participant characteristics by overall study and the two and three day habitual analyses.

Characteristics	Active in Study (n=58)*	Included in 2- and 3-day analyses (n=51)
Age in years, mean (range)	46 (35-54)	46 (35-54)
Women, %	81	80
College degree or higher, %	76	70
White, %	98	100
Body mass index kg/m^2,mean (range)	25.1 (16.6 – 36.3)	25.3 (16.6 – 36.3)
Leisure Time Physical Activity:		
Sedentary % (n)	33% (19)	29% (15)
Low Active % (n)	21% (12)	24% (12)
Active % (n)	26% (15)	25% (13)
Very Active % (n)	21% (12)	22% (11)

* Although the overall study sample is 61 participants, 3 participants did not have demographic information and thus are not included in the table.

Table 3.2: Mean nutrient intake estimates of the Dietary History Questionnaire (NCI-DHQ), the ***3-day average*** web food report questionnaire (WFRQ), and the 3-day 24-hour telephone recalls (24TR), and Spearman correlations between the methods (n=51).

	24TR Mean ± SD	**WFRQ Mean** ± SD	**NCI-DHQ Mean** ± SD	**24TR vs WFRQ**† ρ	**24TR vs NCI-DHQ**† ρ
Total Energy (kcal/day)	2004 ± 549	1911 ± 479	1763 ± 623*	0.59	0.48
Macronutrients					
Carbohydrate (g/day)	260.5 ± 77.6	245.2 ± 66.6	226.4 ± 83.7*	0.62	0.63
Protein (g/day)	78.7 ± 22.0	76.8 ± 20.2	71.2 ± 24.2*	0.41	0.38
Total Dietary Fiber (g/day)	20.0 ± 7.6	19.8 ± 6.4	18.5 ± 8.5	0.56	0.57
Total Fat (g/day)	73.6 ± 27.7	71.5 ± 25.0	65.5 ± 29.8*	0.53	0.34
Saturated Fat Acids (g/day)	25.0 ± 10.1	23.8 ± 9.4	21.5 ± 10.8*	0.46	0.38
Monounsaturated FAs (g/day)	27.5 ± 10.8	25.8 ± 9.2	24.6 ± 11.0*	0.50	0.39
Polyunsaturated FA’s (g/day)	15.3 ± 8.1	15.7 ± 7.3	14.5 ± 7.8	0.56	0.34
Cholesterol (mg/day)	221.6 ± 112.0	208.6 ± 95.0	180.3 ± 83.1*	0.49	0.33
Alcohol (g/day)	4.0 ± 7.0	3.3 ± 6.1	3.9 ± 5.5	0.55	0.68
Micronutrients					
Vitamin A (mcg/day) [Retinol]	553.6 ± 273.4	473.6 ± 277.5*	---	0.73	---
Vitamin C (mg/day)	95.4 ± 54.5	98.5 ± 51.2	133.1 ± 128.1*	0.48	0.40
Vitamin D (mcg/day)	5.3 ± 3.4	5.1 ± 3.4	4.9 ± 3.3	0.75	0.65
Vitamin E (mg/day)	9.0 ± 6.4	9.5 ± 5.3	9.1 ± 6.6	0.47	0.46
Beta-carotene (mg/day)	4219 ± 3438	4330 ± 3948	4170 ± 3451	0.61	0.49
Potassium (mg/day)	2911 ± 831	2811 ± 670	3245 ± 1364*	0.60	0.48
Calcium (mg/day)	1036 ± 494	997 ± 433	973.8 ± 501.6	0.71	0.68
Sodium (mg/day)	3084 ± 929	2980 ± 932	2916 ± 1618	0.24[ns]	0.35
Folate (mcg/day)	537.0 ± 284.8	471.3 ± 191.8	358.1 ± 176.2*	0.52	0.56
Iron (g/day)	17.7 ± 8.7	17.2 ± 7.2	15.2 ± 6.7*	0.59	0.59

* $p < 0.05$ – mean intake significantly different from the 3-day 24-hour telephone recall
† All correlations are significant at $p < 0.05$ unless indicated otherwise ‘ns’.

Table 3.3: Mean nutrient intake estimates of the Dietary History Questionnaire (NCI-DHQ), the ***2-day average*** web food report questionnaire (WFRQ), and the 2-day 24-hour telephone recalls (24TR), and Spearman correlations between the methods (n=51).

	24-hour Telephone Recalls	**Web Food Report Questionnaire**	**Dietary History Questionnaire**	**24TR vs WFRQ† ρ**	**24TR vs NCI-DHQ† ρ**
Total Energy (kcal/day)	2000 ± 580	1865 ± 494	1763 ± 623*	0.51	0.46
Macronutrients					
Carbohydrate (g/day)	260.0 ± 83.2	238.0 ± 68.4*	226.4 ± 83.7*	0.55	0.60
Protein (g/day)	79.5 ± 25.1	76.0 ± 19.5	71.2 ± 24.2*	0.29	0.50
Total Dietary Fiber (g/day)	19.4 ± 8.0	19.9 ± 6.9	18.5 ± 8.5	0.56	0.53
Total Fat (g/day)	72.9 ± 28.0	70.2 ± 27.0	65.5 ± 29.8	0.43	0.32
Saturated Fat Acids (g/day)	25.0 ± 10.5	23.1 ± 10.5	21.5 ± 10.8*	0.30^{ns}	0.39
Monounsaturated FAs (g/day)	27.6 ± 11.8	25.3 ± 9.8	24.6 ± 11.0	0.39	0.37
Polyunsaturated FA's (g/day)	14.5 ± 7.0	15.6 ± 7.3	14.5 ± 7.8	0.50	0.28
Cholesterol (mg/day)	226.9 ± 127.7	204.9 ± 106.9	180.3 ± 83.1*	0.32	0.32
Alcohol (g/day)	3.9 ± 6.6	3.1 ± 6.0	3.9 ± 5.5	0.37	0.66
Micronutrients					
Vitamin A (mcg/day) [Retinol]	557.0 ± 304.9	480.5 ± 286.9*	---	0.64	---
Vitamin C (mg/day)	93.3 ± 63.1	95.3 ± 59.9	133.1 ± 128.1*	0.26	0.45
Vitamin D (mcg/day)	5.5 ± 3.3	5.2 ± 3.5	4.9 ± 3.3	0.70	0.59
Vitamin E (mg/day)	8.0 ± 5.2	9.8 ± 5.8*	9.1 ± 6.6	0.35	0.38
Beta-carotene (mg/day)	3565 ± 3295	3735 ± 3314	4170 ± 3451*	0.31	0.47
Potassium (mg/day)	2873 ± 883.9	2827 ± 656.3	3245 ± 1364*	0.53	0.47
Calcium (mg/day)	1011 ± 434.3	1015 ± 460.3	973.8 ± 501.6	0.68	0.64
Sodium (mg/day)	3095 ± 1075	2825 ± 1000	2916 ± 1618	0.14^{ns}	0.26^{ns}
Folate (mcg/day)	531.3 ± 315.1	471.9 ± 215.1	3582 ± 176.2*	0.43	0.47
Iron (g/day)	17.6 ± 8.6	17.5 ± 8.7	15.2 ± 6.7*	0.48	0.57

* $p < 0.05$ – mean intake significantly different from the 2-day 24-hour telephone recall
† All correlations are significant at $p < 0.05$ unless indicated as non-significant or 'ns'.

Table 3.4. Ratio of reported Energy Intake (EI) to Estimated Energy Requirements (EER)* for the 24-hour telephone recall, the Web Food Report Questionnaire, and the NCI Dietary History Questionnaire by gender and body mass index.

	EI:EER (95% CI)†		
	24-hour Telephone Recall	Web Food Report Questionnaire	NCI Dietary History Questionnaire
Total (n = 51)	0.85 (0.79, 0.90)	0.81 (0.75, 0.87)	0.75 (0.67, 0.82)
Men (n=11)	0.91 (0.80, 1.02)	0.80 (0.69, 0.92)	0.74 (0.58, 0.90)
Women (n=40)	0.83 (0.76,0.89)	0.81 (0.75,0.88)	0.75 (0.67, 0.83)
BMI < 25 kg/m2 (n=29)	0.87 (0.79, 0.95)	0.84 (0.76, 0.93)	0.77(0.69, 0.89)
BMI 25 – 29.9 kg/m2 (n=14)	0.85 (0.74, 0.95)	0.75 (0.67, 0.84)	0.68 (0.55, 0.81)
BMI 30 ≥ kg/m2 (n=8)	0.75 (0.65, 0.85)	0.79 (0.71, 0.88)	0.71 (0.55, 0.87)

* Estimated Energy Requirements are derived from equations provided in the Institute of Medicine Dietary Reference Intake for Energy, Carbohydrates, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids.

† Ratio of reported Energy Intake and Estimated Energy Requirements and 95% confidence intervals, $p \leq 0.05$.

CHAPTER 4: AN EXPLORATORY ANALYSIS OF REPORTED FOODS AND FOOD AMOUNTS ON THE WEB FOOD REPORT QUESTIONNAIRE TO IMPROVE ENERGY AND NUTRIENT INTAKE ESTIMATES

BACKGROUND

Valid and feasible approaches to assess habitual dietary intake in large studies are limited. Self-administered food frequency questionnaires (FFQs) are currently the most common approach, as interviewer-administered 24-hour telephone recalls, the self-report gold standard, requires multiple administrations for habitual intake and is expensive for large scale studies. However, FFQs are known to under-report energy and nutrient intake by more than 30%, raising concerns about their utility in understanding diet-disease relationships.

We recently reported on the development of a self-administered 24-hour web food report questionnaire (WFRQ) designed to improve dietary intake reporting while maintaining low participant and investigator burden. The WFRQ was modeled from the National Cancer Institutes' Dietary History Questionnaire (NCI-DHQ) but adapted for the web and to a 24-hour recall allowing for an increase from 124 food items to 284 food items and more refined portion size selections (NCI-DHQ reference). The results of a pilot comparative validation study against the multi-pass interviewer administered 24-hour telephone recall (24TR) found good agreement between the WFRQ and 24TR for habitual mean energy and nutrient intake, with the only notable difference being lower Vitamin A intake from the WFRQ. Correlations of intake estimates between the two instruments ranged from 0.24 for sodium to 0.75 for Vitamin D.

As part of the iterative WFRQ development process it is essential to examine sources of measurement error and, where appropriate, recommend how survey design and the effective use of web technology can minimize reporting and analytic bias of consumed foods, thereby improving energy and nutrient intake correlations and estimates. Reducing measurement error is a persistent challenge in dietary assessment.[61,100] Recall bias is a major source of error, especially for self-administered instruments. In the development of the WFRQ, we believed that using a 24-hour recall period and including more food and portion size options would help mitigate this error. This may be the case as comparison of the NCI-DHQ to the 24TR demonstrated less agreement in mean energy and nutrient intake, and lower correlations, than observed when comparing the WFRQ and the 24TR. Nonetheless, many WFRQ and 24TR correlations were in the modest range of 0.40 to 0.60. Potential factors influencing these correlations are recall of foods and food amounts consumed and missing food items on the WFRQ. Another potential source or measurement error might be the accurate coding of the WFRQ food items, additions, preparations, and serving amounts to the Nutrition Coordinating Centers (NCC) Food and Nutrition database.

In conducting the pilot validation study, the WFRQ and the 24TR were administered for the same day with 46 study participants. This provides the opportunity for a direct comparison of food and serving amount reporting between the two methods and could clarify areas of difference and potential improvements between the methods. The purposes of this paper are to 1) clearly identify and describe energy, nutrient, food group, and serving amount differences between the 24TR and the WFRQ collected for the same day, 2) examine potential causes for the discrepancies such as forgetting to report foods, amount of food detail (i.e. preparation, additions), serving amounts, or coding problems, and 3) where appropriate, recommend possible solutions to minimize measurement error, especially systematic measurement error, through survey design, coding of the WFRQ to the NCC food and nutrient database, or use of web technology.

METHODS

The development of the Web Food Report Questionnaire, implementation of the pilot comparative validation study, and the energy and nutrient analyses have been described in detail (reference above two chapters). In this paper, we examine the energy and nutrient intake and food group and serving amount reporting for the 46 participants who completed the 24TR and the WFRQ for the same day. Our analytic approach was to 1) estimate correlations of same day energy and nutrient intake, 2) examine reporting agreement between the same day 24TR and WFRQ for food groups and serving amounts, focusing on food groups related to lower energy and nutrient correlations, and 3) when possible, examine WFRQ coding practices to help understand sub-optimal agreement between the 24TR and the WFRQ food group and serving amount reporting.

Same Day Data Collection: Briefly, the WFRQ administration is less intensive than the interviewer-administered 24TR and was administered prior to the 24TR to minimize any effect on the completeness and accuracy of the WRFQ. Participants received an e-mail notification at 2:00am of the selected day to complete the WFRQ by 11:59pm for the previous days' diet. The WFRQ was developed using the Datstat™ software application which allowed us to monitor participants' progress throughout the selected day and sent up to two reminder e-mails to encourage completion. Once the WFRQ was completed, an 24TR was conducted as per the standardized protocol for the 24-hour telephone dietary recall using the Nutrition Data System for Research (NDSR), a computer-based nutrient calculation software application developed by the University of Minnesota that allows for direct entry of dietary data into an electronic database and in a standardized fashion.[160] If a 24TR could not be completed on the initially selected day, it was conducted during a subsequent WFRQ administration.

Food and Nutrient Calculations: Nutrient and food group intake estimates for both the 24TR and WFRQ were calculated using the University of Minnesota Nutrition Coordinating Center (NCC) Food and Nutrient Database, which support NDSR. The version of the NCC database used for this study contained over 18,000 foods with values for 155 nutrients, nutrient ratios, and other food components. The database is organized into 9 major food groups and 168 subgroups based on the recommendations made by the *Dietary Guidelines for Americans*, the *USDA Food Guide Pyramid*, and the Food and Drug Administration.[169,170] The major food groups are: 1)Fruits and Fruit Drinks, 2)Vegetables, 3)Grains, 4)Dairy and Nondairy Alternatives, 5)Meat, Fish, Poultry, Eggs, Nuts, and Seeds, 6)Fats, 7)Sweets, 8)Beverages, and 9)Miscellaneous. When available, serving amounts were assigned to each NCC food based on *Dietary Guideline for Americans* recommendations. The NDSR application was used to apply the NCC Food Group Serving Count System to generate food group, subgroup, and serving amount results for all 24TR reported food items.

To calculate food and nutrient intake estimates for the WFRQ, responses from the WFRQs were entered into NDSR using a set of coding rules established a priori. In short, the food items on the WFRQ were matched as closely as possible to a food within the NCC food and nutrient database. The NCC food and nutrient database includes defaults ('unknowns') for foods for which sufficient detail may be lacking (e.g. 'unknown' is available when it is not known whether an apple was eaten with our without skin). The defaults are based on the most common form of a food or way it is eaten in the US. These defaults were generally relied on in the matching process for foods with insufficient detail on the WFRQ to allow matching to a specific food or preparation method in the NCC database. Similarly, serving amounts on the WFRQ were matched as closely as possible with the serving amount metrics of the NCC food and nutrient database. After assigning the WFRQ food items and serving amounts to a corresponding NCC food and serving amount, the NDSR application was used to generate WFRQ energy and nutrient intake estimates and the food group, subgroup, and serving amount results in the same manner as was done with the 24TR.

Statistical Analyses: Mean energy and nutrient intake estimates from the same day 24TR and WFRQ were calculated and examined by conducting two-tailed Student paired t-tests. Spearman correlations were used to compare intake estimates between the 24TR and the WFRQ.

A descriptive approach was used to examine concordance in food subgroups and serving amounts between the 24TR and WFRQ. We examined overall percentage of agreement for food group reporting where consumption or no consumption was similarly reported by the 24TR and the WFRQ (i.e., both said 'Yes' or both said 'No'). There are no recommended cut-offs for assessing the overall percentage of agreement, therefore, for our purpose we decided than above 90% is very good, 80-89% is moderate, 70 –79% is fair, and less than 70% is poor. This measure does not, however, take into account agreement due to chance so we also calculated Cohen's kappa statistic (κ), a measure indicating the amount of agreement above chance between the 24TR and the WFRQ. A value of 1.0 is perfect agreement while 0.0 means the agreement is no better than chance. Negative values are when agreement is worse than chance. In some cases, cell sizes were too low to determine κ. The following values for κ were used to evaluate improvement upon chance agreement between the dietary methods: greater than 0.80 = very good, 0.61-0.80 = good, 0.41 - 0.60 = moderate, 0.21- 0.40 = fair, and less than 0.20 = poor.[171] The interpretation of overall percentage agreement and κ is meant to be a guide to assessing agreement. It does not distinguish between random and systematic differences. The nine major food groups and each food subgroup were examined. Where appropriate, food subgroups were combined and examined. For example, whole grain, some whole grain, and refined grain bread types (i.e. loaf-type and other breads) were combined and all types of dairy-based yogurts were combined. Groupings that could be used as part of the 2010 Healthy Eating Index (HEI) included total fruit, total vegetables, dark green and orange vegetables, whole grains, refined grains, total dairy, and total protein foods (i.e., meat and beans).[172] We also combined food groups for comparison with the main foods U.S. adults 19-50 years old most commonly consume related to energy and nutrient intake.[50] We calculated total mean serving amounts for food groups and subgroups. We also calculated mean serving amounts for food groups and subgroups where they where they were reported on both the 24TR and the WFRQ, thus eliminating any discordant reporting. This allowed for a more direct evaluation of reported serving amounts between the 24TR and the WFRQ.

All analyses were conducted using Microsoft Excel 2007.

RESULTS

Same Day Correlations

Table 4.1 presents mean energy and nutrient intake and Spearman correlations for the WFRQ and 24TR collected for the same day. The mean energy and nutrient intake estimates were similar between the two methods with the exception of estimated Vitamin A being significantly lower for the WFRQ than the 24TR (428 mcg versus 502 mcg). Spearman correlations ranged from 0.23 for Vitamin E intake to 0.85 for caffeine intake. All correlations were significant except for Vitamin E. The correlation for energy intake was 0.54. Nutrients with correlations less than 0.50 included protein, dietary fiber, total fat, saturated fatty acids, monounsaturated fatty acids, alcohol, vitamin C, vitamin E, potassium, sodium, folate, and iron.

Food Group and Serving Amount Analyses

Fruit (Table 4.2a): Overall percentage agreement for total fruit intake was 89% with κ=0.48. Twenty participants reported citrus juice intake but only seven reported intake with both the 24TR and the WFRQ (72% agreement; κ=0.33). Nine participants reported citrus juice intake on the 24TR but not the WFRQ. There is only one citrus juice specific food item on the WFRQ. Reported serving amounts of total fruit differed by less than 2% between the 24TR and the WFRQ when captured on both instruments. However, because of differential reporting, amounts of fruit consumed may be underestimated depending on the instrument used, especially for citrus juice.

Vegetable (Table 4.2b): Overall percentage of agreement for total vegetable consumption is 93% with κ=0.63. Dark green vegetables, tomatoes, legumes, other starchy vegetables, and other vegetables all had percentage of agreement of 80% or lower and fair to moderate κ. Although white potatoes had good agreement, 5 of 12 participants reported consumption only with the 24TR. Similarly, tomatoes, starchy vegetables including potatoes, deep yellow vegetables, and other vegetables were often captured only by the 24TR. For legumes this is the opposite with more reporting on the WFRQ than the 24TR. Where total vegetables are reported on both instruments, serving amount reporting is similar between the 24TR and WFRQ at 150.9 and 146.6, respectively. The 24TR does appear to capture about 20% more tomato consumption while the WFRQ captures over 40% more ‘Other Starchy Vegetables’ like corn and green peas. Dark green vegetables, dark yellow vegetables, and legumes are a key component of the USDA Healthy Eating Index.[172] The WFRQ captures almost 20% more consumption of these food subgroups compared to the 24TR (78% agreement; κ=0.51).

Grains (Table 4.2c): All participants reported some type of grain consumption. Agreement for total whole grains and total refined grains are moderate at 85% (κ=0.64) and 87% (κ=0.18). Reported amounts consumed, when reported on both the 24TR and the WFRQ, were 25% higher on the 24TR for whole grains (113.5 servings versus 85.4 servings) and 10% higher with the 24TR for refined grains (203.9 servings versus 182.7 servings). Thirty-six percent (10 servings) of the increase with 24TR reporting for whole grains is attributable to Ready-to-Eat Whole Grain Presweetened Cereal. Within grain subgroups, agreement for reported consumption of the grain, flour, and dry mixes was 74% (κ=0.48) and with the 24TR capturing 39% more servings for refined grains when consumption was reported on both the 24TR and the WFRQ. Similar moderate agreement was observed for loaf-type breads and rolls (80%; κ = 0.55), other breads (83%; κ = 0.62), crackers (89%; κ = 0.67), cereal (89%; κ = 0.76), and cakes, cookies, and pies (78%; κ = 0.57). With refined grain loaf-type breads and rolls and cakes, cookies and pies, when reported on both the 24TR and WFRQ, reported servings were higher with the 24TR. This was the opposite for pasta (22.6 vs. 30.7 servings).

Almost all main grain foods groups have discrepant reporting between the 24TR and the WFRQ. There was more captured on the 24TR alone for refined grain, flour and dry mixes (12 vs. 3 participants), refined loaf-type breads and rolls (8 vs. 2 participants), ready-to-eat unsweetened cereals (5 vs. 2 participants), total cakes, cookies, and pies (7 vs. 3 participants), and snack bars (3 vs. 0 participants).

There was very good reporting of snack chip consumption (93%, κ=0.83) but reported serving amounts were slightly higher with the WFRQ. Agreement for popcorn consumption was also excellent at 100% (κ=1.00). Only three participants reported popcorn consumption and the difference in reporting amounts was driven by one participant reporting 7.6 servings of popcorn on the WFRQ.

Dairy and Nondairy Alternatives (Table 4.2d): Reduced fat, low fat, and fat free milk were the most commonly reported and, when combined, reporting agreement between the 24TR and the WFRQ is 78% (κ = 0.51). Combining all cheese food subgroups also resulted in moderate agreement between the 24TR and the WFRQ (74%; κ = 0.43). With both milk and cheese, distinguishing between fat content appears poor. The WFRQ does have specific options for reporting the fat content for milk and cheese but not with many food detail items. A similar issue is observed with the various dairy yogurt food subgroups but when combined there is very good agreement between the 24TR and the WFRQ (κ = 0.85). Frozen dairy desserts is the other commonly reported food and it also has very good agreement (κ = 0.85) between the 24TR and the WFRQ.

For the combined milk and cheese food subgroups, reported servings consumption is similar where the foods are reported on both the 24TR and the WFRQ. Interestingly, with both the milk and cheese there is some differential reporting on the 24TR and WFRQ of foods consumed, with more foods captured on the 24TR only than the WFRQ only. Yet, these differentially captured foods only account for a small percentage of the reported servings consumed. With milk, the 24TR captures 49.7 servings of which 3.1 can be attributed to 6 participants while the WFRQ captures 45.2 servings of which 3.5 can be attributed to 4 participants. Reported servings consumed for dairy yogurt and frozen dairy desserts was 33% and 38% greater on the WFRQ compared to the 24TR, although each was only for 7 participants.

Meat, Fish, Poultry, Eggs, Nuts, and Seeds (Table 4.2e): Reporting of food subgroup consumption is fair to moderate, except for poultry which was good. After combining the beef subgroups, overall percentage agreement was 74% (κ = 0.46). Total pork consumption had moderate agreement (85%; κ = 0.37). Total cold cuts and sausage consumption has an overall percentage agreement of 80% (κ = 0.49). Reported egg consumption was similar at 78% and κ = 0.49, respectively, as was reported consumption of nuts and seeds at 80% (κ = 0.53). Overall percentage agreement of total poultry consumption was 85% (κ = 0.70).

All meat subgroups had discrepant reporting. It was balanced for total beef and total pork. More total cold cuts and sausage was captured with the WFRQ (7 participants vs. 2). The opposite was the case for nuts and seeds, total poultry, and eggs. There was substantial discrepant reporting with the latter two foods but these were only captured by the 24TR.

When captured on both the 24TR and the WFRQ, reported serving amounts were similar for total beef, total pork, eggs, and nuts and seeds. Reported serving amounts with the WFRQ were 28% greater for total poultry and 101% higher for total cold cuts and sausages. These meat subgroups accounted for 75% of the difference in reported serving amounts for all meat and legumes.

Fats (Butter, Margarine, Oil, Salad Dressing, etc.) (Table 4.2f): Overall percentage agreement for total fat consumption is excellent at 93% (κ=0.37) yet within the various fat subgroups discordance is higher and agreement is lower. Agreement is 72% (κ=0.20) for regular margarine consumption, 72% (κ=0.48) for oil, 67% (κ=0.09) for shortening, and 67% (κ=0.25) for regular butter and animal fats. On the WFRQ, these fats are mostly captured as food additions that do not distinguish between fat types. Therefore, the fat type subgroups are combined for the main fat food groups but overall percentage agreement still remains low ranging from 65% to 78% (κ = 0.22 to 0.55). Examining the combined groups, 9, 8, and 11 participants report margarine, oil, and butter and animal fat consumption, respectively, only on the 24TR. This compares to 2, 4, and 5 participants reporting these only on the WFRQ. This is reversed for reporting of shortening, salad dressing, and cream consumption.

Where consumed fats are reported on both the 24TR and the WFRQ, reported serving amounts are similar for margarine, salad dressing, and cream. Reported serving amounts are 15% higher on the WFRQ for oils and 20% on the 24TR for butter and animal fats. The differential reporting does substantially increase total reported serving amounts for all fat food groups. With total creams this can be attributed to a single outlier where the participant on the WFRQ reports consuming 8.7 servings compared to an overall average of about 1 reported serving/person.

Sweets (Candy, Honey, Sugar, Sweet Sauces, etc) (Table 4.2g): The most commonly consumed 'Sweets' food subgroups are candies, sugars, and the sugar additions of syrup, honey, jams, jellies, and preserves. Agreement on reported consumption of chocolate candies is very good between the 24TR and the WFRQ at 91% (κ=0.80). Non-chocolate candies had the same overall percentage of agreement but more relative discordance between the two instruments. For these Sweets subgroups, reported serving amounts, when captured on both instruments, are 33% and 100% higher with the WFRQ compared to the 24TR.

Agreement for sugars and sugary additions (i.e. syrup, honey, jam, etc.) were 80% (κ=0.59) and 85% (κ=0.63), respectively. The discordant reporting of these Sweets subgroups is balanced between the 24TR and the WFRQ. When captured on both the 24TR and the WFRQ, reported sugar serving amounts were 24.5 and 14.9, respectively. This is 39% under-reporting for the WFRQ. There is slightly more reporting of sugar additive amounts on the WFRQ compared to the 24TR.

Beverages (Coffee, Tea, Alcoholic, Soft Drinks, Fruit Drinks, Water, etc) (Table 4.2h): Overall agreement for consumption of soft drinks, fruit drinks, tea, and coffee was very good at 93% (κ=0.87), 97% (κ=0.78), 100% (κ=1.00), and 91% (κ=0.87). Amounts of consumption for fruit drinks, tea, and coffee were also very good. The amount of soft drinks consumed, however, was 48% higher on the WFRQ compared to the 24TR. Fortyfive participants reported water consumption, although only seven of them reported consumption on the 24TR. Serving amounts of water were 21% higher with the 24TR compared to the WFRQ. Overall percentage agreement for alcohol consumption was moderate with 93% (κ=0.48) for beer and 89% (κ=0.48) for wine but, even though infrequently reported, there is discrepancy in capture between the 24TR and the WFRQ.

Miscellaneous (Pickled Foods, Gravy, Sauces, and Condiments) (Table 4.2i): Sauces and condiments, pickled foods, soup broth, and sugar substitutes are the four commonly reported food subgroups in this category. Sauces and condiments were poorly captured on the WFRQ compared to the 24TR with only 61% agreement and κ=0.15. Of the 21 participants who reported consuming sauces or condiments, 18 only reported this on the 24TR. Soup broth was also poorly captured on the WFRQ with 10 of 15 participants only reporting consumption on the 24TR. For sauces and condiments, this resulted in substantially more serving amounts reported with the 24TR (33.9 versus 2.6). Even though there was more reporting of soup broth consumption with the 24TR, the reported total serving amounts were similar (8.8 servings versus 7.2 servings). Only 7 participants reported consumption of sugar substitutes like aspartame and saccharin, and agreement between the 24TR and the WFRQ was fair at 89% but κ=0.23. Total serving amounts reported were four times greater with the WFRQ compared to the 24TR. Overall percentage agreement for consumption of pickled foods was moderate at 80% (κ = 0.51) but reported serving amounts, when reported on both instruments, is 21 servings for the WFRQ and 8.9 servings for the 24TR.

DISCUSSION

In a pilot validation study, we demonstrated that the web food report questionnaire (WFRQ) compares well with the 24-hour telephone dietary recall (24TR) for ascertaining habitual dietary intake for many nutrients. However, there is room for improvement. To identify areas for improvement, we examined the energy and nutrient intake and correlations of 46 participants who had the 24TR and the WFRQ collected for the same day. With the exception of vitamin A intake, all other intake estimates were similar between the two instruments. However, several nutrients had correlations less than 0.50 including protein, total dietary fiber, total fat, saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs), alcohol, Vitamin C, Vitamin E, potassium, sodium, folate, and iron (Table 4.1).

Differences in reported amounts of food consumption between the 24TR and the WFRQ contribute to the lower energy and nutrient intake correlations observed in the same day analyses. Table 4.3 summarizes the leading food components consumed by Americans 19-50 years of age that contribute to intake of energy and other nutrients, where the 24TR and WFRQ correlations are less than 0.50. Table 4.3 also summarizes our findings of overall percentage agreement, κ, and the percent difference in total reported food amount consumption (i.e., [(24TR – WFRQ)/24TR] * 100). Our analyses were conducted based on serving amounts which is different from actual amounts consumed, thus a more qualitative interpretation of these findings is needed when drawing comparisons to overall energy and nutrient intake and correlations. In general, all nine major food groups from our analyses are important for intake of energy and various nutrients. Using vitamin E as an example (nutrient with non-significant correlation of 0.23),, we can see that intake of tomatoes (the leading source of vitamin E in the American diet) was poorly assessed with WFRQ in comparison to the 24TR, with a percent agreement of 67%, kappa of 0.29, and a notable discrepancy in servings consumed as estimated by the 24TR and WFRQ. Similar discrepancies are apparent for some other food categories that are major contributors to vitamin E in the American diet (cereal, 'cakes, cookies, and pastries', 'crackers, popcorn, and chips', 'nuts and seeds', and all the fats) This variation in reported food amounts likely explains in large part the poor correlation observed for vitamin E . Similar interpretations can be made for energy intake and the other listed nutrients.

Ultimately, to better understand the differences in reported serving amounts, we need to examine what is happening within each of the nine major food groups and their subgroups. To do this we examined agreement in reported foods and serving amounts consumed by the 46 participants completing the 24TR and WFRQ for the same day (Table 4.2a-i). Considerations when interpreting these findings include differential reporting of consumed foods between the instruments, the impact of this reporting on overall serving amount estimates, and, among foods reported on both instruments, differential reporting of serving amounts. Additional considerations are agreement for food groups that are the biggest contributors to energy and nutrient intake (Table 4.3).

Fruit and fruit juice: Total fruit consumption is a key component of the 2010 HEI. Fruit and fruit juice are leading consumed foods contributing to fiber, vitamin C, and potassium intake among U.S. adults 19-50 years of age (Table 4.3).[50] Reporting of total fruit consumed was good with 89% overall agreement, a 48% greater agreement than due to chance (i.e., κ). Similarly, agreement on reported amounts of fruit consumed was very good at 93 servings for the 24TR compared to 95 servings for the WFRQ, when captured on both instruments. Despite this, reported overall agreement and κ for citrus juice consumption were low at 74% and 0.33. Reasons for the discrepancy are not clear. The 24TR is anchored around meal times with intensive probing which may have led to improved capture of fruit juice consumption, however, the WFRQ alone also captured citrus juice consumption suggesting that the anchors and probing do not sufficiently explain the discordance. One possibility is that even with a 24 hour recall period, people may report foods they habitually eat (i.e., additions or phantom reporting) and not what was actually consumed. This has been suggested by other research. Orange and grapefruit juice would fit the profile as they are routinely eaten breakfast foods and 13 people reported their consumption on either the WFRQ or the 24TR alone. There is no obvious solution to this issue, especially if it occurs regardless of the instrument used.

Vegetables: Total vegetables and dark green vegetables are components of the 2010 HEI. Dark green vegetables, tomatoes, white potatoes, other vegetables, and legumes are leading foods contributing to fiber, vitamin C, vitamin E, potassium, and folate intake among Americans (Table 4.3).[50] Overall percentage of agreement of reported vegetables consumed was at or below 80% for 6 of the most commonly consumed vegetable subgroups. The 24TR captures more deep-yellow vegetables, white potatoes, and other vegetables while the WFRQ captures more legumes. Differential capture of dark green vegetables, tomatoes, and other starchy vegetables were more balanced between the instruments. For example, 5 people reported consumption of dark green vegetables only with the WFRQ and 4 people only with the 24TR. Vegetables are frequently consumed as part of salads, soups, stews, pizza, or other mixed dishes suggesting that much of the misreporting could be due to poor recall of vegetables included within mixed dishes. Some evidence of this can be seen with reporting of deep yellow vegetables where the 8 participants reporting with the 24TR *only* accounted for 2.2 servings whereas the 12 participants reporting on the 24TR accounted for 12.4 servings. This suggests participants recall eating ‘whole’ vegetables but not those included as part of mixed dishes such as carrots. The WFRQ could include food addition questions for more common foods usually found in salads, soups, and other mixed dishes. In addition, including options such as spinach or mixed greens, such as Spring mixes, may improve concordance between the WFRQ and the 24TR for dark green vegetables as these types of salads are commonly packaged for sale in grocery stores.

A similar issue may be occurring with the reporting of tomatoes and legumes, particularly as part of chili, pastas, and Mexican foods. However, the WFRQ includes specific types of pasta and Mexican foods. In reviewing the a priori coding of Mexican foods to the NCC food and nutrient database, the WFRQ Mexican food default was bean-based, as opposed to beef or chicken. It would be good to examine if different NCC foods may be more appropriate for WFRQ food items, particularly chili and ethnic foods.

There are reported serving amount discrepancies between the 24TR and the WFRQ for tomatoes, white potatoes, other starchy vegetables, and legumes. While some of this may be due to coding WFRQ serving amounts to the NCC food and nutrient database, especially for foods incorporated into mixed dishes or pastas, it is also likely that estimating serving amounts for more amorphous foods like other starchy foods (i.e., corn, peas, green beans) and legumes is a factor. Incorporating better portion size aids, such as graphics or photos, may yield improved serving amount estimates. The serving size category description used on the WFRQ, such as ½ an ear of corn, may also affect a persons' estimation, however, we based our categories the NCI-DHQ which went through extensive cognitive assessment and development.

Grains (Bread, Cereals, Pasta, Rice): As seen in Table 4.3, grain consumption among Americans 19-50 years old contribute substantially to intake of energy, protein, fats, fiber, vitamin E, sodium, folate, and iron, all nutrients with lower correlations in our same day comparison between the 24TR and the WFRQ.[50] Breads and rolls are either 1st or 2nd ranked food items consumed for energy, fiber, sodium, folate, and iron. Cakes, cookies, and pastries are the number one food consumed by Americans related to energy intake. Whole grains and refined grains are also two primary components of the 2010 HEI.[172]

All participants reported grain consumption. Total whole grain food group reporting had moderate agreement between the 24TR and the WFRQ (85%, κ=0.64), although distinction between 'whole grain' and 'some whole grain' subgroups was low. This may be a combination of participant recall and a coding issue of aligning the WFRQ to the NCC food and nutrient database because when these food subgroups were combined the agreement improves. This was also observed for whole grain crackers, snack bars, and 'cakes, cookies, and pies' where almost all reported consumption was only captured with the 24TR. There were not 'whole grain' reporting categories available on the WFRQ for these food subgroups or for other common foods like pasta, pizza, pancakes, bagels, and English muffins. The same applies to ready-to-eat cereals, although the inclusion of cereal types and brand names may have mitigated the discrepancies. The consumption of granola, either as a breakfast cereal or as an addition to yogurt, for example, is also not captured on the WFRQ. No refined grain cereal consumption was reported on either the 24TR or the WFRQ. Reported serving amounts of cereal were a concern, as the 24TR captures more servings than the WFRQ. This could be related to how portions were captured on the WFRQ. Ready-to-eat Presweetened Cereals, whole or some wheat accounts for almost 40% of the serving size discrepancy and portions are determined in ½ bowl portions. However, there is no portion size aid so these could be large or small bowls and the cross-walk to the NCC food and nutrient database may need to be changed.

Reporting agreement of refined grains consumption was similar to total grains at 87% ($\kappa = 0.18$). Capture of refined grain consumption by the 24TR was greater for 'grain, flour, and dry mixes', 'loaf-type bread and rolls', and 'cakes, cookies, and pies' and accounts for almost 70% of consumed refined grains. This is problematic because not only does this lead to more reported servings, affecting energy and nutrient intake estimates, but even when reported on both the 24TR and the WFRQ, the reported serving amounts were higher compounding the overall amount of servings reported. Serving amounts of 'grain, flour, and dry mixes' are less than one for 8 of the 12 participants reporting consumption only on the 24TR. This suggests use of this food subgroup as part of recipes and mixed dishes, likely a participant recall misclassification. This is not as clear cut for the other two food groups where reported serving amounts were equally distributed above and below one serving indicating more missed recall of entire food items on the WFRQ. Further examination of specific reported food items is required to better understand what food items were or were not reported on the WFRQ compared to the 24TR.

Reported serving amounts were higher for 'other breads' and pastas. Interestingly, participants who only reported other bread consumption on the 24TR alone, reported serving sizes less than one while those reporting on the WFRQ all reported serving sizes greater than one. This indicates that the 24TR captures the inclusion of other breads as part of mixed dishes or perhaps additions to foods, such as croutons on salads, while the WFRQ is capturing entire foods and may represent phantom reporting. The reported amount of pasta consumed was higher on the WFRQ compared to the 24TR. However, only 5 of the 11 participants who reported pasta consumption on both the 24TR and the WFRQ reported serving amounts greater than one on the 24TR. This suggests the reporting amount differences are portion size recall issues or, possibly, coding differences of the WFRQ pasta items (i.e., manicotti, stuffed shells, lasagna) to the NCC food and nutrient database. Pasta is an amorphous food and it is likely difficult to quantify serving amounts, even with good portion size aids.

Dairy and Non-dairy: Total dairy consumption is part of the 2010 HEI and dairy foods are primary contributors to energy, protein, fat, potassium and sodium intake among 19-50 year old Americans. (Table 4.3).[50,172] Overall percentage of agreement of reduced fat/low/fat free milk consumption was low at 78% (κ=0.51). However, this combines the 'Reduced Fat Milk' and the 'Low fat/Fat free' milk subgroups which had even lower overall percentage agreement at 72% (κ=0.25) and 65% (κ=0.31), respectively. Specific categories of fat-type for milk consumed as a beverage or in cereal are included in the WFRQ. These are likely to be consumed as larger servings. Milk fat-type is not included when it is used as an additive such as in coffee or tea, thus there is likely discordant coding of milk fat-type from the WFRQ to the NCC food and nutrient database in this scenario. This is supported in that an average of 0.5 servings per person was reported only on the 24TR and 0.8 servings per person only on the WFRQ. This compares to an average of 1.8 servings and 1.6 servings when milk consumption is reported on both the 24TR and WFRQ. Adding milk fat-type categories to coffee and tea may improve food reporting agreement. Reported serving amounts of milk consumption are slightly greater with the 24TR. This could be due to reported milk consumption with cereals and the alignment of the WFRQ serving amount with the NCC food and nutrient database.

Reported cheese consumption also had low overall percentage agreement at 74% (κ=0.43). This is particularly driven by the increased 24TR reporting of full fat cheese. This may be cheese being captured in mixed foods such as sandwiches, salads, chili, Mexican foods, or as toppings on pasta. Reported serving size amounts support this as 8 participants who reported cheese consumption on the 24TR accounted to only 3.6 servings or 0.46 per person compared to 0.87 servings per person for those with cheese consumption captured on both the 24TR and the WFRQ. This does not appear to be the case where only the WFRQ captures cheese consumption because it is 0.75 servings per person. It is not entirely clear what is being reported on the WFRQ but not the 24TR, possibly foods such as grilled cheese sandwiches, cheese sticks, or bruschetta.

There are several yogurt subgroups based on fat content and sweeteners, however, there is not good agreement between the WFRQ and the 24TR for each of these subgroups. When all the subgroups are combined the overall percentage of agreement is 96% (κ=0.85). Even though the WFRQ includes categories for fat content and type of sweetener, these appear poorly recalled on the WFRQ. It is possible there is an order effect since ‘low fat’ yogurt and ‘artificially sweetened’ yogurt are the first categories listed and these accounted for 7 of the 9 reported yogurts consumed. When all yogurt subgroups are combined, the 24TR alone did not capture any additional yogurt consumption. This may be a food item where gathering the food detail is not viable. Larger serving amounts of yogurt were captured with the WFRQ and when examining individual level data, serving amounts were slightly, yet uniformly, higher with the WFRQ suggesting the coding of WFRQ servings to the NCC food and nutrient database may need to be modified. A similar issue is observed with reported consumption of frozen dairy desserts where agreement is good but reported amounts consumed were higher for the WFRQ compared to the 24TR.

Meat, Fish, Poultry, Eggs, Nuts, and Seeds: Meats are leading contributors to energy, protein, fats, vitamin E, potassium, sodium, and iron intake among U.S. adults (Table 4.3).[50] Meat and legumes are combined on the 2010 HEI as a measure of total protein foods.[172] The three primary issues with reporting meat consumption is the capture of fat content, discordant reporting for the four main meat groups, and discrepancies in reported serving amounts. The WFRQ did not uniformly have fat content categories for all meats, even within a given subgroup such as beef. Fat content questions were available for all cold cuts, sausage, bacon, ground beef, and steak. This might explain discordant capture within subgroups but these discrepancies remained when the subgroups were collapsed into the main meat groups. Mixed foods may be the primary culprit for capture of meat only on the 24TR as they are frequently used in chili, pastas, pizza, and Mexican foods.

The WFRQ does ask if pastas and pizza are meat-based but it does not ask about the specific type of meat. In the case of Mexican foods, beans are used as the default when coding to the NCC food and nutrient database as opposed to other meats like poultry. The use of meats in salads, sandwiches, and other mixed dishes is also likely captured by the 24TR and not the WFRQ. It may be useful to explore the addition of meat categories to common mixed food items on the WFRQ and to modify the coding of the WFRQ food item to the NCC food and nutrient database to use certain meats as a default.

This does not, however, explain why the WFRQ may be capturing meats while the 24TR does not, especially for cold cuts. For many of the discordant cases, the serving sizes are less than one which suggests these meats are included as part of mixed dishes. Additionally, some participants reported there was no clear WFRQ food item for sausages other than breakfast-type sausages, like summer sausages, which could also lead to discordant reporting. Finally, reported serving amounts are much greater on the WFRQ for poultry and cold cuts and sausages. Portion size recall may be an issue but it seems likely that the serving amount cross-walk between the WFRQ and the NCC food and nutrient database needs to be re-examined. For example, on the WFRQ, chicken consumption is reported by number of wings, legs, thighs, and breasts and linking these serving categories to the NCC food and nutrient database may need to be modified.

Eight participants reported egg consumption on both the 24TR and the WFRQ. Another 10 participants only reported consumption on the 24TR and in small serving amounts indicating this was the use of eggs as part of other mixed dishes or recipes. This additional 24TR reporting did lead to a large overall increase in reported serving amounts but it may be difficult to capture egg food additions on the WFRQ unless they are part of salads or ethnic foods.

For ‘nuts and seeds’ and ‘nuts and seeds butters’, the missed reporting contributes much to serving amounts. Where these are reported on both instruments, the reported servings are similar. For the 24TR, this could represent the inclusion of these in mixed foods such as salads or cakes. Peanut butter may be better captured on the WFRQ because it is a specific food detail item for various bread foods. There is good serving amount alignment for nut and seed butters since on average only one serving size per participant is reported whether when reported on both instruments or separately.

Fats (Butter, Margarine, Oil, Salad Dressing, etc.): Fats are significant contributors to energy, total fat, saturated fatty acids, monounsaturated fatty acids, and vitamin E intake in the U.S. (Table 4.3).[50] Fats are a challenging food group to capture because they are primarily used as food additions such as toppings, spreads, or in cooking preparation. Agreement between the 24TR and the WFRQ on reporting of total fats and amounts consumed is excellent but there is much lower agreement for the main fat subgroups of margarine, oil, shortening, butter, salad dressing, and cream. The WFRQ does include reporting categories for food additions with many food items ranging from vegetables to sandwiches to breakfast foods to Mexican foods but it does not distinguish between regular and reduced fat content. There are some WFRQ food items, like pastries and cookies, where fat content is distinguished but not fat type (i.e. margarine, butter, shortening, etc.). Almost 60% of study participants reported consumption of cakes, pastries, cookies, and similar sweets thus the choice of fat subgroup used when coding a WFRQ food item to the NCC food and nutrient database could be affecting the discrepant reporting between the 24TR and the WFRQ. These types of variations in capturing fat food subgroups are likely contributing to the lower agreement of fat food subgroups consumed, along with participant recall of these additions to their foods or as part of cooking preparation.

Reported serving amounts are similar between the two instruments when reported on both instruments except for oil, where the WFRQ captures 15% more servings of oil consumption. The differential capture of fat food subgroups is, however, a concern for assessing total amounts consumed as this contributes to lower energy, fats, and vitamin E correlations between the 24TR and the WFRQ. Some differences in amounts consumed may be due to coding of serving size from the WFRQ to the NCC food and nutrient database. For example, reported WFRQ serving amounts for oil are consistently higher than with the 24TR, especially when uniquely captured on each instrument. In this case, the WFRQ captures 1.75 servings/person while the 24TR only captures 0.86 servings/person. This is similarly observed for reporting of butter and animal fats while the opposite may be occurring for shortening. Yet, this alone will not sufficiently address the increased serving amounts attributable to missed reporting such as with margarine, shortening, and salad dressing. Adding more food addition or food preparation categories to the WFRQ may be warranted but a more detailed examination specifically linking the 24TR reporting to food items would be required to identify where best to make these changes on the WFRQ and this is beyond the scope of our current analysis. Even this will not, however, fully solve the challenge of recalling foods used as additions or incorporated as part of other mixed dishes.

Sweets (Candy, Honey, Sugar, Sweet Sauces, etc): Sweets mainly comprise of sugar, sugar additions (i.e. syrup, honey, jam, etc) and candies. In the U.S., they are leading contributors to energy and fat intake (Table 4.3).[50] As with fats, sugar and sugar additions are typically used as additions or part of cooking preparation. The WFRQ does include food detail items to capture the consumption of these Sweets subgroups but like fats this varies by food items throughout the WFRQ. Given that differential reporting is fairly equal between the 24TR and the WFRQ for these two Sweets subgroups, it is most likely that recall is driving the discrepant reporting and adding food detail to more WFRQ food items is not likely to solve this. The difference in reported serving size amounts for sugar is of greater concern because this leads to an overall 46% higher reported sugar consumption with the 24TR and could affect energy and fat intake correlations. Where sugar is captured as an additive on the WFRQ, there is no serving amount associated with the item. This suggests that the serving amount cross-walk from the WFRQ to the NCC food and nutrient database may need to be increased to better reflect the amounts participants are actually adding to their foods.

Reported serving amounts is also a concern with chocolate and non-chocolate candies as reported amounts are 33% and 100% greater with the WFRQ compared to the 24TR. But, unlike sugar and sugar additions, the WFRQ does include serving amount categories for candies. This could be a combination of portion size estimation by the participant or needing to revisit the coding of the WFRQ serving amount to the NCC food and nutrient database. Improving portion size estimation would require finding better portion size aids, whether written or visual. A closer look at the relationship between the WFRQ serving amount which is reported in ounces compared to the NCC food and nutrient database serving amount reported in grams may also explain the difference.

Beverages (Coffee, Tea, Alcoholic, Soft Drinks, Fruit Drinks, Water, etc): Soft drink and alcohol consumption are leading contributors to energy in take among 19-50 years U.S. adults (Table 4.3). These, along with slid fats, are also key constituents of the 'Empty Calories' component of the 2010 HEI.[172] Tea is a leading food for potassium intake and fruit drinks for vitamin C intake. Reporting of beverage consumption is very good between the 24TR and the WFRQ, with the exception of serving amounts for soft drinks and reporting of alcohol consumption. The WFRQ captures 48% more soft drink consumption than the 24TR. The WFRQ has extensive categories for reporting soft drink serving sizes that include reporting by glass, can, bottle, and small, medium, and large sizes from soda fountains. It is possible the WFRQ serving amount cross-walk to the NCC food and nutrient database for these categories is overestimated yet for several participants, the differences in serving amounts ranged from 1 to 6 serving sizes more on the WFRQ versus the 24TR. This suggests that it is more likely a difference in actual reporting, with the WFRQ capturing more soda consumption. It is difficult to assess whether this additional reporting is based on true consumption or due to 'phantom' reporting because there are more options available for reporting and suggests any changes to the WFRQ is premature until this can be examined in greater detail.

The discordance with reporting alcohol beverage consumption is odd as people usually do not forget consuming beer, wine, or a hard liquor drink. This could be non-systematic social desirability reporting bias. Another possibility is phantom reporting, similar to what was theorized for consumption of citrus juice, where a person often has a beer or glass of wine as part of their habitual diet and thus report consumption as a daily event. However, upon further examination of individual reporting for wine, the reported serving amounts are small when captured by the 24TR only suggesting this may be wine used as part of cooking or other recipes. There is no place on the WFRQ that captures this type of food detail and, given its limited reporting and impact on energy and nutrient intake, there is no need to add this level of detail to the WFRQ.

Miscellaneous (Pickled Foods, Gravy, Sauces, and Condiments): Sauces and condiments, along with soup broths, are leading foods contributing to sodium intake among U.S. adults (Table 4.3). Sauces and condiments, soup broth, and sugar substitutes are all foods used as additions with other foods or part of mixed dishes. It is not surprising to see such discrepancies of capture between the 24TR and the WFRQ, especially for sauces and condiments since food detail to capture their consumption is limited on the WFRQ. Tartar sauce is asked with the fish food items but catsup and mustard are not included with food items such as hot dogs or hamburgers. Catsup is asked as a stand-alone item on the WFRQ but this may not be working well. The inclusion of this food detail on the WFRQ may reduce these discrepancies. This could also be done for common sauces used with specific food items. Soup broth consumption is also missed on the WFRQ. Reported serving amounts captured only on the 24TR are small suggesting the use of soup broth as part of other dishes. This level of food detail may be difficult to capture because there is not a clear link with other food items already on the WFRQ. Food detail on artificial sweeteners is included for WFRQ food items but, as an additive, recall of these may be poor.

The discrepancy in reported consumption of pickled foods may partially be due to the WFRQ combining cucumbers and pickles as a single item. This might account for some participants who only reported consumption of pickled foods on the 24TR and splitting this food item may help. Olives and pickles are used as food additions in salads, pizza, hamburgers, and other foods and this level of food detail is not included on the WFRQ.

Olives are a separate WFRQ food item. Reported amounts of pickled foods consumed is much higher on the WFRQ compared to the 24TR, where these are captured on both instruments. This could be due to misaligned coding of WFRQ olive serving amounts to the NCC food and nutrient database or inadequate serving amount categories on the WFRQ and needs to be reassessed.

Recommendations to Improve the WFRQ

A few themes emerge when examining the reporting of foods and food amounts for each of the nine main food groups. Many of the discrepancies in reported food consumption are related to foods used as additions, including cooking preparation, or in distinguishing between food types such as fat type or sweets type. For several foods, our results suggest this is systematic, with the 24TR usually capturing this type of intake. In many cases, adjustments could be done to include this level of food detail with WFRQ food items where they are most commonly used. Including a list of items included in salads is an example. For others, like adding wine to a recipe, are not as amenable to adding on the WFRQ. Decisions to add WFRQ food items need to be deliberate and balanced between the additional user burden and the gain in improved habitual energy and nutrient intake estimates and correlations. Our analysis did not get to this level of detail and it is likely a larger sample size would be required to do this well. Recall of foods included as part of mixed dishes or as additions has been a consistent concern in dietary assessment.

Frequently the WFRQ captures foods not picked up by the 24TR and it is not clear why this is the case. This also occurs with some foods only reported on the 24TR, although some of this is due to the food items not being included on the WFRQ, such as non-breakfast sausages, or combined on the WFRQ, such as cucumbers and pickles. It is possible that participants report foods they usually eat instead of those actually consumed the prior day and this may particularly affect foods consumed at breakfast such as citrus juice, cereals, or pastries. However, we are not able to elucidate this with certainty. In the best case scenario, this type of recall is non-systematic and non-differential thus having less effect on overall energy and nutrient intake estimates, although still lowering correlations.

Of greater concern is recall of consumed serving amounts. This is most pronounced for total reported serving amounts of grains, meats, sweets, and beverages where the foods are reported on both the 24TR and the WFRQ. In some cases this may represent the classic problem of estimating portion sizes for amorphous foods or additions such as cereals, grain and flour mixes, cold cuts on sandwiches, or use of sugars. In others it could be poor recall of how many bread slices or rolls were consumed or how many sodas or candy bars were eaten. Trying to improve portion size aids on the WFRQ, such as better portion size descriptions or the inclusion of visual aids like diagrams or photos, may help with participant recall.[141] Again, these additions need to be balanced with user acceptability and burden.

Lastly, an area that needs greater exploration, and may be a first step to improving WFRQ energy and nutrient estimates, is the aligning of WFRQ foods and serving amounts with the NCC food and nutrient database. Reconsidering the coding of Mexican foods as bean-based is one example. Reported serving amounts were consistently higher on the 24TR for refined grains (e.g. 'grain, flour, dry mixes', 'loaf-type bread and rolls', cereals, and 'cakes, cookies, and pies'), poultry, cold cuts and sausages, and sugars. The opposite was found for candies and soft drinks. Re-examining the serving amount cross-walk will include looking at amounts used for food additions but also at how portion categories were categorized on the WFRQ such as was done with chicken (e.g. legs, thighs, wings, breasts).

Limitations

Understanding our results requires a blend of quantitative and qualitative interpretation. Much of this is due to our limited convenience sample size of 46 mostly middle-age, educated women from the Minneapolis-St. Paul metropolitan areas who reported their intake during the Fall season. We want to make sure that proposed WFRQ modifications are robust enough to be valid in the general adult population, thus our examination of leading foods contributing to US intake of energy and nutrients. The small sample size, however, limits our interpretation for leading foods that were not frequently consumed by our sample, especially food subgroups such as fish, fried commercial foods, popcorn, alcohol, fruit drinks, pork, nuts and seeds butter, and others. This is a particular problem when trying to understand discrepant reporting or when one or two reported serving amounts are outliers. There is some concern that conducting the WFRQ prior to the 24TR on the same day may trigger similar reporting on the 24TR. We believed that the intensity of the 24TR would 'wash-out' any such effect. Interestingly, we found many instances where a food was reported only on the WFRQ which suggests it did not influence reporting on the 24TR or that the 24TR multi-pass interviewer method improved a participants' actual recall (i.e., eliminated phantom reporting/foods). Although we did not test for this, there is some concern that repeated administration of the dietary recall instrument, such as food records, leads to reporting fatigue. This may be occurring with the WFRQ since it would have been the 3rd or 4th administration but the time of the same day 24TR. This could have resulted in less than optimal reporting of foods consumed on the WFRQ. Conversely, could it be that this might increase habitual reporting of food consumption, or phantom reporting? Finally, in identifying potential causes, and plausible solutions, we need to be careful because it is not be entirely clear which dietary assessment method provides a closer reflection of the 'truth'. We used the 24TR as the 'truth'. But food items such as soft drinks, candies, and popcorn hint that the WFRQ may better capture these foods and food amounts. But, given the thoroughness and intensity of the multi-pass TR and results from previous studies, the 24TR overall is likely to more accurate and precise than the WFRQ.

Conclusion

While not definitive, our analyses provides some concrete next steps to improve the WFRQ such as examining more closely the aligning of WFRQ foods and food amounts to the NCC food and nutrient database, considering the addition of more food detail items, and identifying suitable portion size aids to include on the WFRQ. Once the above recommendations have been addressed, then other concerns about overall WFRQ design could be addressed, such as anchors such as meal times or how the sections and foods within sections are ordered. We modeled the WFRQ after the NCI-DHQ, accepting all the cognitive and usability testing that had been performed during its development. However, we changed the recall time frame and moved to the web medium. These modifications may require significant redesign of the WFRQ to make it easier to use and potentially more valid at capturing habitual dietary intake. This type of redesign has already been attempted with the Energetics study of a 24-hour recall web dietary assessment although it is not yet clear whether this tool is superior to the simpler WFRQ.[131,133,134] Additional usability concerns, such as designing for tablets and Smartphones, should also be considered. In the end, however, future web dietary assessment methods to examine habitual dietary intake in large free living populations will need to weigh the trade-offs between improved precision, accuracy and burden to the participant and research team.

Table 4.1: Mean nutrient intake estimates of the web food report questionnaire (WFRQ) and the 24-hour telephone recalls (24TR) collected on the same day and Spearman correlations between the methods (n=46).

	24-hour Telephone Recalls (mean ± SD)	**Web Food Report Questionnaire (mean ± SD)**	**24TR vs WFRQ† *r***
Total Energy (kcal)	1967 ± 608	2011 ± 653	0.54
Macronutrients			
Carbohydrate (g)	265.4 ± 87.2	267.4 ± 95.8	0.54
Protein (g)	72.8 ± 24.1	76.2 ± 31.7	0.37
Total Dietary Fiber (g)	20.1 ± 9.3	20.5 ± 10.5	0.40
Total Fat (g)	71.4 ± 33.4	73.8 ± 35.3	0.49
Saturated Fat Acids (g)	23.1 ± 11.9	24.4 ± 11.5	0.49
Monounsaturated FAs (g)	26.8 ± 14.2	26.2 ± 13.2	0.48
Polyunsaturated FA's (g)	15.7 ± 8.5	16.6 ± 12.7	0.62
Cholesterol (mg)	219.7 ± 162.2	206.8 ± 144.4	0.62
Trans-Fats (g)	3.9 ± 2.8	4.2 ± 3.9	0.58
Omega-3 (g)	1.5 ± 0.8	1.5 ± 1.4	0.71
Alcohol (g)	2.2 ± 6.8	2.1 ± 5.4	0.36
Caffeine (mg)	135.9 ± 125.2	143.6 ± 142.4	0.85
Micronutrients			
Vitamin A (mcg) [Retinol]	502.0 ± 307.1	428.2 ± 297.3*	0.62
Vitamin C (mg)	96.2 ± 69.1	90.9 ± 67.9	0.41
Vitamin D (mcg)	4.7 ± 3.7	4.8 ± 4.4	0.66
Vitamin E (mg)	10.2 ± 7.3	9.8 ± 6.7	0.23^{ns}
Beta-carotene (mg)	4315 ± 4383	4603 ± 6101	0.76
Potassium (mg)	2827 ± 962	2773 ± 999	0.44
Calcium (mg)	1064 ± 751	958 ± 461	0.68
Sodium (mg)	3131 ± 1296	3283 ± 1070	0.35
Folate (g)	520 ± 395	497 ± 298	0.37
Iron (g)	17.2 ± 11.5	16.9 ± 8.4	0.34

* $p \leq 0.05$ – mean intake significantly different between the 24TR and WFRQ.
† All correlations are significant at $p \leq 0.02$ unless indicated otherwise 'ns'.

Table 4.2a: **Fruit** Food Group and Subgroups: Agreement between the 24-hour telephone recall (24TR) and the Web Food Report Questionnaire (WFRQ) on food and serving size reporting (n = 46). Shaded rows represent aggregated food subgroups.

Food Group & Subgroup†	24TR / WFRQ				% Agree	Cohen's Kappa	Total 24TR Servings (a)*	Total WFRQ Servings (a)*	Difference in servings (24TR-WFRQ) (a)*
	a = Yes/Yes	b = No/Yes	c = Yes/No	d = No/No					
Total Fruit (HEI)	38	2	3	3	89	0.48	96.0 (92.9)	97.0 (94.7)	-1.0 (-1.8)
Total Fruit Juice	11	3	9	23	74	0.45	20.9	18.0	2.9
Citrus Juice	7	4	9	26	72	0.33	16.2 (8.9)	13.5 (10.5)	2.7 (-1.6)
Fruit Juice excluding Citrus Juice	3	0	2	41	96	0.73	4.7	4.5	0.2
Citrus Fruit	4	0	0	42	100	1.00	5.4	7.0	-1.6
Fruit excluding Citrus Fruit	29	6	2	9	83	0.59	68.4 (67.0)	71.1 (63.3)	-2.6 (3.7)
Avocado and Similar	1	0	0	45	100	1.0	1.3	1.0	0.3

† Fried fruits (i.e., fried bananas or fried apples) and fruit-based savory snacks (i.e., apple or banana chips) were not captured by either the 24TR or the WFRQ and are not included in the table. They are included in the 'Total Fruit' calculations.

* Values in parenthesis represent serving size amounts where both the 24TR and the WFRQ capture the food group as indicated by 'a = Yes/Yes' in Column 2.

Table 4.2b: **Vegetable** Food Group and Subgroups: Agreement between the 24-hour telephone recall (24TR) and the Web Food Report Questionnaire (WFRQ) on food and serving size reporting (n = 46). Shaded rows represent aggregated food subgroups.

Food Group & Subgroup	24TR / WFRQ				% Agree	Cohen's Kappa	Total 24TR Servings (a)*	Total WFRQ Servings (a)*	Difference in Servings (24TR – WFRQ) (a)*
	a = Yes/Yes	b = No/Yes	c = Yes/No	d = No/No					
Total Vegetables (HEI)	40	1	2	3	93	0.63	162.0 (150.9)	148.2 (146.6)	13.8 (4.3)
Dark Green Vegetables	15	5	4	22	80	0.60	25.0 (20.1)	28.2 (23.0)	-3.2 (-2.8)
Deep-Yellow Vegetables	12	1	8	25	80	0.59	14.6 (12.4)	15.2 (13.8)	-0.5 (-1.4)
Tomatoes	22	6	9	9	67	0.29	29.0 (21.0)	21.0 (17.0)	8.0 (4.0)
Total Potatoes & Starchy Vegetables	24	3	6	13	80	0.59	32.7 (24.8)	30.4 (28.8)	2.3 (-4.0)
White Potatoes	7	0	5	34	89	0.67	15.3 (10.0)	8.5 (8.5)	6.8 (1.5)
Fried Potatoes	3	0	1	42	98	0.85	4.8 (2.4)	2.5 (2.5)	2.3 (-0.1)
Other Starchy Vegetables	17	4	5	20	80	0.61	12.5 (12.4)	19.4 (17.8)	-6.9 (-5.4)
Legumes (Cooked Dried Beans)	7	7	2	30	80	0.49	8.5 (7.0)	14.3 (8.1)	-5.8 (-1.1)
Other Vegetables	32	2	7	5	80	0.41	46.6 (39.8)	36.6 (35.9)	10.0 (3.9)
Fried Vegetables	0	0	1	45	98	--	0.5	0	0.5
Vegetable Juice	1	1	0	44	98	0.66	5	2.5	2.5

* Values in parenthesis represent serving size amounts where both the 24TR and the WFRQ capture the food group as indicated by 'a = Yes/Yes' in Column 2.

Table 4.2c: **Grains (Bread, Cereal, Pasta, Rice)** Food Group and Subgroups: Agreement between the 24-hour telephone recall (24TR) and the Web Food Report Questionnaire (WFRQ) on food and serving size reporting (n = 46). Shaded rows represent aggregated food subgroups.

Food Group & Subgroup†	24TR / WFRQ				% Agree	Cohen's Kappa	Total 24TR Servings (a)*	Total WFRQ Servings (a)*	Difference in Servings (24TR – WFRQ) (a)*
	a = Yes/Yes	b = No/Yes	c = Yes/No	d = No/No					
Total Grains	46	0	0	0	100	1.0	342.8	294.6	48.2
Total Whole Grains (HEI)	29	1	6	10	85	0.64	121.0 (113.5)	89.2 (85.4)	31.8 (28.1)
Total Refined Grains (HEI)	39	2	4	1	87	0.18	206.7 (203.9)	189.7 (182.7)	16.9 (21.2)
Total Grain, Flour, Mixes	19	3	9	15	74	0.48	55.5 (44.5)	33.7 (29.8)	21.8 (14.7)
Grain, Flour, Dry Mixes – Whole Grain	7	1	2	36	93	0.78	13.3 (10.7)	11.0 (10.0)	2.3 (0.7)
Grain, Flour, Dry Mixes – Refined Grain	13	3	12	18	67	0.36	42.2 (30.7)	22.7 (18.8)	19.5 (11.9)
Total Loaf-type Bread & Plain Rolls	27	3	6	10	80	0.55	88.6 (70.6)	62.4 (49.8)	20.8 (20.8)
Loaf-type Bread and Plain Rolls – Whole Grain & Some Whole Grain	9	3	3	31	87	0.66	27.2 (18.2)	22.5 (18.0)	4.7 (0.2)
Loaf-type Bread & Plain Rolls – Whole Grain	4	3	5	34	83	0.40	19.2	10.5	8.7
Loaf-type Bread & Plain Rolls – Some Whole Grain	2	4	2	38	87	0.33	8.0	12.0	-3.9
Loaf-type Bread and Plain Rolls – Refined Grain	17	2	8	19	78	0.57	61.4 (52.4)	39.9 (31.8)	21.5 (20.6)
Total Other Breads	12	3	5	26	83	0.62	36.8 (33.9)	38.1 (34.3)	-1.3 (-0.4)
Other Breads – Whole Grain	1	0	3	42	93	0.39	3.8	0.4	3.4
Other Breads – Some Whole Grain	0	0	1	45	98	---	1.0	0	1.0
Other Breads – Refined Grain	12	3	3	28	87	0.70	32.0	37.7	-5.7
Total Crackers	7	3	2	34	89	0.67	9.2 (8.3)	10.3 (7.1)	-1.1 (1.2)
Crackers – Whole Grain	0	0	2	44	96	---	2.7	0	2.7

Table 4.2c (continued): **Grains (Bread, Cereal, Pasta, Rice)** Food Group and Subgroups: Agreement between the 24-hour telephone recall (24TR) and the Web Food Report Questionnaire (WFRQ) on food and serving size reporting (n = 46). Shaded rows represent aggregated food subgroups.

Crackers – Some Whole Grain	0	0	1	45	98	---	1.1	0	1.1
Crackers – Refined Grain	5	5	0	36	89	0.61	5.4	10.3	-4.9
Pasta – Refined Grain	11	4	4	27	83	0.60	23.9 (22.6)	37.2 (30.7)	-13.3 (-8.1)
Total Cereals	14	1	4	27	89	0.76	62.5 (55.3)	46.1 (42.3)	16.4 (13.0)
Total Ready-to-Eat Unsweetened Cereals	3	2	5	36	85	0.38	15.5	10.9	4.6
Ready-to-eat Cereal – Unsweetened, Whole Grain	3	1	5	37	87	0.43	15 (7.7)	10.1 (7.1)	5.4 (0.6)
Ready-to-eat Cereal – Unsweetened, Some Whole Grain	0	1	0	45	98	---	0.5	0.8	-0.8
Total Ready-to-Eat Presweetened Cereals	8	2	3	33	89	0.69	47.0	35.2	11.8
Ready-to-eat Cereal – Presweetened, Whole Grain	7	2	3	34	89	0.67	46.0 (36.0)	34.0 (26.0)	12.0 (10.0)
Ready-to-eat Cereal – Presweetened, Some Whole Grain	1	0	0	45	100	1.0	1.1	1.2	-0.2
Total Cakes, Cookies, Pies, etc.	17	3	7	19	78	0.57	39.7 (29.9)	25.4 (22.9)	14.2 (7.0)
Cakes, Cookies, Pies, etc – Some Whole Grain	0	0	4	42	91	---	2.2	0	2.2
Cakes, Cookies, Pies, etc – Refined Grain	16	3	6	21	80	0.61	37.5	25.4	12.1
Total Snack Bars	2	0	3	41	93	0.54	5.7	5.5	0.2
Snack Bars – Whole Grain	0	0	4	42	91		3.9	0	3.9
Snack Bars – Some Whole Grain	0	1	2	43	93	-0.03	1.8	1.6	0.2

Table 4.2c (continued): **Grains (Bread, Cereal, Pasta, Rice)** Food Group and Subgroups: Agreement between the 24-hour telephone recall (24TR) and the Web Food Report Questionnaire (WFRQ) on food and serving size reporting (n = 46). Shaded rows represent aggregated food subgroups.

Snack Bars – Refined Grain	0	1	0	45	98	---	0	3.9	-3.9
Total Chips	10	2	1	33	93	0.83	17.0 (16.8)	24.8 (20.1)	-7.8 (-3.3)
Snack Chips – Whole Grain (GRW0900)	8	1	1	36	96	0.86	12.7 (12.5)	12.1 (11.6)	0.6 (0.9)
Snack Chips – Refined Grain	2	2	0	42	96	0.65	4.2	12.7	-8.4
Total Popcorn	3	0	0	43	100	1.0	3.9	11.1	-7.2
Popcorn	2	1	0	43	98	0.79	3.1	11.1	-8.0
Flavored Popcorn	0	0	1	45	98	---	0.8	0	0.8

† Ten food subgroups not captured by either the 24TR or the WFRQ are not included in the table. They are included in the 'Total Grains' and 'Total Whole Grains' calculations.

* Values in parenthesis represent serving size amounts where both the 24TR and the WFRQ capture the food group as indicated by 'a = Yes/Yes' in Column 2.

Table 4.2d: **Dairy and Nondairy Alternatives** Food Group and Subgroups: Agreement between the 24-hour telephone recall (24TR) and the Web Food Report Questionnaire (WFRQ) on food and serving size reporting (n = 46). Shaded rows represent aggregated food subgroups.

Food Group & Subgroup†	24TR / WFRQ				% Agree	Cohen's Kappa	Total 24TR Servings (a)*	Total WFRQ Servings (a)*	Difference in Servings (24TR – WFRQ) (a)*
	a = Yes/Yes	b = No/Yes	c = Yes/No	d = No/No					
Total Dairy (HEI)	42	1	2	1	93	0.37	100.6 (98.4)	96.9 (96.3)	3.7 (2.0)
Total Milk	27	3	6	10	80	0.55	50.2 (46.9)	45.2 (42.2)	5.0 (4.7)
Milk-Whole	1	0	0	45	100	-	0.3	0.5	-0.2
Milk – Reduced Fat & Low Fat/ Fat Free	26	4	6	10	78	0.51	49.4 (46.6)	44.7 (41.7)	4.7 (4.9)
Milk-Reduced Fat	5	8	5	28	72	0.25	6.9	14.6	-7.7
Milk-Low Fat Fat Free	16	5	11	14	65	0.31	42.5	30.1	-1.6
Milk-Nondairy	2	0	0	44	100	-	2.0	1.5	0.5
Artificially Sweetened Flav Milk Beverage Powder w/Non-Fat Dry Milk	1	0	0	45	100	-	2.5	2.5	0
Total Cheese	24	4	8	10	74	0.43	24.4 (20.8)	22.3 (19.3)	2.1 (1.5)
Cheese – Full Fat	20	5	11	10	65	0.28	18.0	17.1	1.0
Cheese – Reduced Fat	6	1	3	36	91	0.70	6.3	4.7	1.6
Cheese – Low Fat / Fat Free	0	2	0	44	96	-	0.0	0.6	-0.6
Total Yogurt Dairy	7	2	0	37	96	0.85	4.8 (4.8)	7.8 (6.3)	-3.1 (-1.6)
Yogurt – Sweetened Whole Milk	0	0	1	45	98	-	0.3	0.0	0.3
Yogurt – Sweetened Low Fat	0	2	1	43	93	-	0.7	1.0	-0.3
Yogurt – Sweetened Fat Free	0	0	3	43	93	-	2.1	0.0	2.1
Yogurt – Art Sweetened Whole Milk	0	0	1	45	98	-	0.7	0.0	0.7
Yogurt – Art Sweetened Low Fat	0	7	0	39	85	-	0.0	6.8	-6.8

Table 4.2d (continued): **Dairy and Nondairy Alternatives** Food Group and Subgroups: Agreement between the 24-hour telephone recall (24TR) and the Web Food Report Questionnaire (WFRQ) on food and serving size reporting (n = 46). Shaded rows represent aggregated food subgroups.

Yogurt – Art Sweetened Fat Free	0	0	2	44	96	-	1.0	0.0	1.1
Frozen Dairy Dessert	7	0	2	37	96	0.85	15.0 (10.9)	15.0 (15.0)	0.0 (-4.1)
Pudding & Other Dairy Dessert	0	0	1	45	98	-	0.9	0.0	0.9
Dairy-based Sweetened Meat Replacement	0	0	2	44	96	-	1.3	0.0	1.3
Dairy-based Art Sweetened Meat Replacement	0	2	0	44	96	-	0	2.5	-2.5

† Nine food subgroups not captured by either the 24TR or the WFRQ are not included in the table. In general these were Ready-to-drink flavored milks, nondairy foods (i.e. cheese, yogurt, frozen dessert), and infant formula. They are included in the 'Total Milk' calculations.

* Values in parenthesis represent serving size amounts where both the 24TR and the WFRQ capture the food group as indicated by 'a = Yes/Yes' in Column 2.

Table 4.2e: **Meat, Fish, Poultry, Eggs, Nuts, and Seeds** Food Group and Subgroups: Agreement between the 24-hour telephone recall (24TR) and the Web Food Report Questionnaire (WFRQ) on food and serving size reporting (n = 46). Shaded rows represent aggregated food subgroups.

Food Group & Subgroup†	24TR / WFRQ				% Agree	Cohen's Kappa	Total 24TR Servings (a)*	Total WFRQ Servings (a)*	Difference in Servings (24TR – WFRQ) (a)*
	a = Yes/Yes	b = No/Yes	c = Yes/No	d = No/No					
Meat & Legumes (HEI)	45	1	0	0	98	-	197.1 (197.1)	231.6 (230.1)	-34.6 (-33.1)
Total Beef	13	6	6	21	74	0.46	49.0 (39.2)	52.5 (43)	-3.5 (-3.8)
Beef	9	4	8	25	74	0.41	37.8	36.5	1.4
Lean Beef	2	4	3	37	85	0.28	11.2	16.1	-4.9
Total Pork	3	3	4	36	85	0.37	10.0	9.1	0.9
Fresh Pork	0	2	1	43	93	-	1.1	4.2	-3.1
Lean Fresh Pork	0	1	1	44	96	-	3.8	0.0	3.8
Cured Pork	0	4	3	39	85	-	0.8	4.9	-4.2
Lean Cured Pork	0	0	2	44	96	-	4.3	0	4.3
Total Poultry	16	0	7	23	85	0.70	49.4 (41.6)	53.1 (53.1)	-3.8 (-11.5)
Poultry	1	2	1	42	93	0.79	7.3	12.5	-5.2
Lean Poultry	14	0	8	24	83	0.65	42.1	40.6	1.4
Lean Fish – Fresh & Smoked	2	0	2	42	96	-	3.4	15.4	-11.9
Shellfish	1	1	2	42	93	0.37	2.1	2.4	-0.4
Total Cold Cuts & Sausage	7	7	2	30	80	0.49	17.2 (13.0)	35.1 (26.3)	-17.9 (-13.2)
Cold Cuts & Sausage	2	3	2	39	89	0.39	5.8	4.6	1.2
Lean Cold Cuts & Sausage	5	5	1	35	87	0.55	11.4	30.5	-19.1
Eggs	8	0	10	28	78	0.49	15.7 (11.0)	10.9 (10.9)	4.8 (0.1)
Nuts & Seeds	9	3	6	28	80	0.53	30.7 (19.6)	25.6 (19.2)	6.5 (0.4)
Nut & Seed Butter	3	4	2	37	87	0.43	6.5 (4.0)	9.0 (3.5)	-2.5 (0.5)
Meat Alternatives	1	3	0	42	93	0.38	4.4	4.2	0.3

† Twelve food subgroups not captured by either the 24TR or the WFRQ are not included in the table. These include veal, lamb, game, commercial fried chicken, fresh fish (≥ 10% fat), commercial fried fish, commercial fried shellfish, organ meats, baby food mixtures, and egg substitutes. They are included in the 'Total Meat' calculations where appropriate.

± The 'Meat and Legumes' food group includes all meat food subgroups and legumes from Table 4.2b.

* Values in parenthesis represent serving size amounts where both the 24TR and the WFRQ capture the food group as indicated by 'a = Yes/Yes' in Column 2.

Table 4.2f: Fats **(Butter, Margarine, Oil, Salad Dressing, etc.)** Food Group and Subgroups Agreement between the 24-hour telephone recall (24TR) and the Web Food Report Questionnaire (WFRQ) on food and serving size reporting (n = 46). Shaded rows are aggregated subgroups.

Food Group & Subgroup†	24TR / WFRQ				% Agree	Cohen's Kappa	Total 24TR Servings (a)*	Total WFRQ Servings (a)*	Difference in Servings (24TR – WFRQ (a)*)
	a = Yes/Yes	b = No/Yes	c = Yes/No	d = No/No					
Total Fats	42	2	1	1	93	0.37	171.4 (170.2)	179.6 (178.3)	-8.2 (-8.1)
Total Margarine	8	2	9	27	76	0.44	25.0 (12.4)	14.1 (11.4)	10.8 (1.0)
Margarine - Regular	4	5	8	29	72	0.20	14.8	14.1	0.7
Margarine – Red Fat	0	0	3	43	93	-	10.2	0.0	10.2
Oil	19	4	8	15	72	0.48	62.6 (55.7)	70.9 (63.9)	-8.3 (-8.1)
Shortening	3	10	5	28	67	0.09	11.9	10.4	1.5
Total Butter & Animal Fatst	7	5	11	23	65	0.22	25.2 (16.4)	24.1 (13.1)	1.1 (3.3)
Butter & Animal Regular	7	5	10	24	67	0.25	24.2 (16.4)	24.1 (13.1)	0.1 (3.3)
Butter & Animal Red Fats	0	0	1	45	98	-	1	0	1
Total Salad Dressing	14	6	4	22	78	0.55	18.4 (16.4)	21.6 (16.3)	-3.2 (0.0)
Salad Dressing – Regular	9	3	5	29	83	0.57	14.2	13.3	1.0
Salad Dressing – Red Fat etc	3	6	2	35	83	0.34	4.1	8.3	-4.2
Vegetable-based Savory Snack	4	2	0	40	96	0.78	3.9	6.0	-2.1
Total Creams	5	7	4	30	76	0.33	8.9 (5.2)	20.0 (4.6)	-11.1 (0.6)
Cream	5	5	2	34	85	0.50	7.4	16.5	-9.1
Cream – Red Fat	0	2	1	43	93	-	0.5	3.5	-3.0
Cream – Low Fat / Fat Free	0	0	1	45	98	-	1.0	0	1.0
Cream – Non-dairy	3	1	2	40	93	0.63	15.6	12.5	3.1

† One food subgroup, meat-based savory snack, was not captured by either the 24TR or the WFRQ and is not included in the table. It is included in the 'Total Fats' calculation.

* Values in parenthesis represent serving size amounts where both the 24TR and the WFRQ capture the food group as indicated by 'a = Yes/Yes' in Column 2.

Table 4.2g: **Sweets (Candy, Honey, Sugar, Sweet Sauces, etc)** Food Group and Subgroups: Agreement between the 24-hour telephone recall (24TR) and the Web Food Report Questionnaire (WFRQ) on food and serving size reporting (n = 46).

Food Group & Subgroup†	24TR / WFRQ				% Agree	Cohen's Kappa	Total 24TR Servings (a)*	Total WFRQ Servings (a)*	Difference in Servings (24TR – WFRQ) (a)*
	a = Yes/Yes	b = No/Yes	c = Yes/No	d = No/No					
Sugar	13	4	5	24	80	0.59	32.7 (24.5)	17.6 (14.9)	15.0 (9.6)
Syrup, Honey, Jam, Jelly, Preserves	10	3	4	29	85	0.63	10.8 (7.9)	10.3 (9.4)	0.5 (-1.4)
Sauces, Sweet – Regular	0	0	0	46	100	-	-	-	-
Sauces, Sweet – Red Fat, Calories, Fat Free	0	0	2	44	96	-	0.8	0	0.8
Chocolate Candy	13	1	3	29	91	0.80	15.2 (13.1)	20.2 (19.5)	-5.0 (-6.4)
Non-chocolate Candy	3	2	2	39	91	0.55	9.2 (8.3)	18.4 (14.2)	-9.3 (-5.9)
Sweetened Flavored Milk Beverage Powder w/o Non-fat Dry Milk	0	2	0	44	96	-	0	2	-2

† The Frosting or Glaze food subgroup was not captured by either the 24TR or the WFRQ and is not included in the table. It is included in the 'Total Fats' calculation.

* Values in parenthesis represent serving size amounts where both the 24TR and the WFRQ capture the food group as indicated by 'a = Yes/Yes' in Column 2.

Table 4.2h: **Beverages (Coffee, Tea, Alcoholic, Soft Drinks, Fruit Drinks, Water, etc)** Food Group and Subgroups: Agreement between the 24-hour telephone recall (24TR) and the Web Food Report Questionnaire (WFRQ) on food and serving size reporting (n = 46). Shaded rows represent aggregated food subgroups.

Food Group & Subgroup†	24TR / WFRQ				% Agree	Cohen's Kappa	Total 24TR Servings (a)*	Total WFRQ Servings (a)*	Difference in Servings (24TR – WFRQ) (a)*
	a = Yes/Yes	b = No/Yes	c = Yes/No	d = No/No					
All Soft Drinks	18	2	1	25	93	0.87	46.5 (45.0)	68.6 (62.6)	-22.1 (-17.6)
Sweetened Soft Drinks	6	2	0	38	96	0.83	10.6 (10.6)	27.0 (22.5)	-16.4 (-11.9)
Art Sweet Soft Drinks	13	1	1	31	96	0.90	35.9 (34.3)	41.6 (40.1)	-5.7 (-5.7)
Fruit Drinks	4	1	1	44	97	0.78	5.4	6.5	-1.1
Sweetened Fruit Drinks	3	1	0	42	98	0.85	3.1	5.5	-2.4
Art Sweet Fruit Drinks	1	0	1	44	98	0.66	2.2	1.0	1.2
All Tea	10	0	0	36	100	1.0	21.8	20.6	1.1
Sweetened Tea	0	0	1	45	98	-	2.2	0.0	1.2
Art. Sweet	0	0	2	44	96	-	2.8	0.0	2.8
Unsweetened Tea	9	2	0	35	96	0.87	16.8	20.6	-3.9
All Coffee	18	1	3	24	91	0.87	46.1 (43.1)	50 (46.5)	-3.9 (-3.4)
Sweetened Coffee	0	0	1	45	98	-	0.8	0	0.8
Unsweetened Coffee	18	1	2	25	93	0.87	45.3	50	-4.7
Unsweetened Water	38	0	7	1	85	0.19	197.0 (174.1)	137.0 (137)	60.0 (37.1)
Nondairy Sweetened Meal Replace	0	1	1	44	96	-	1	2.5	-1.5
Non-alcoholic Beer	0	0	0	46	100	-	-	-	-
Non-alcoholic Light Beer	0	0	0	46	100	-	-	-	-
Beer and Ales	1	1	1	43	93	0.48	2	2	0
Cordial & Liqueur	0	0	0	46	100	-	-	-	-
Distilled Liquor	0	0	0	46	100	-	-	-	-
Wine	3	2	3	38	89	0.48	4.8	4.4	0.4

† Eleven food subgroups not captured by either the 24TR or the WFRQ were excluded from the table. These included coffee substitutes, sweetened waters, and sweetened nondairy meal replacement

Table 4.2i: **Miscellaneous (Pickled Foods, Gravy, Sauces, Condiments)** Food Group and Subgroups: Agreement between the 24-hour telephone recall (24TR) and the Web Food Report Questionnaire (WFRQ) on food and serving size reporting (n = 46). Shaded rows represent aggregated food subgroups.

Food Group & Subgroup†	24TR / WFRQ				% Agree	Cohen's Kappa	Total 24TR Servings (a)*	Total WFRQ Servings (a)*	Difference in Servings (24TR – WFRQ) (a)*
	a = Yes/Yes	b = No/Yes	c = Yes/No	d = No/No					
Gravy – Regular	0	0	0	46	100	-	-	-	-
Gravy – Red Fat/Fat Free	0	0	1	45	98	-	2.0	0.0	2.0
Sauces	3	0	18	25	61	0.15	33.9	2.6	31.3
Sauces & Condiments - Regular	0	1	1	44	96	-	5.4	7.0	-1.6
Sauces & Condiments – Red Fat	2	0	19	25	59	0.10	32.3	2.3	30.0
Pickled Foods	8	5	4	29	80	0.51	14.4 (8.9)	30.9 (21.0)	-16.6 (-12.1)
Misc. Dessert	0	0	1	45	98	-	0.5	0.0	0.5
Soup Broth	5	0	10	31	78	0.40	8.8 (3.5)	7.2 (7.2)	1.6 (-3.6)
Art Sweet Flav. Milk Powder w/ NoFat Milk	0	1	0	45	98	-	0.0	1.0	-1.0
Sugar Substitute	1	3	2	40	89	0.23	3.3	13	-9.7

† Non-grain flour, baby food desserts, and baby food mixtures are not captured by either the 24TR or the WFRQ and were excluded from the table.

* Values in parenthesis are serving size amounts where both the 24TR and the WFRQ capture the food group as indicated by 'a = Yes/Yes' in Column 2.

Table 4.3: 24TR and WFRQ agreement and serving size differential for select food groups and their ranked contribution to energy and nutrient intake among U.S. adults 19 – 50 years old from NHANES 2003-6.

	Agree (%)	κ	Serv. Δ*	Energy	Protein	Total Fat	SFA	MUFA	Fiber	Vitamin C	Vitamin E	Potassium	Sodium	Folate	Iron
Correlations†				0.54	0.37	0.49	0.49	0.49	0.40	0.41	0.23	0.44	0.35	0.37	0.34
FRUIT															
Fruit	89	0.48	- 6	26th	-	-	-	-	3rd	3rd	16th	7th	-	-	-
Fruit Juice	74	0.45	14	-	-	-	-	-	-	1st	-	6th	-	10th	-
VEGETABLES															
Potatoes	89	0.67	***44***	13th	-	14th	-	11th	5th	7th	-	3rd	-	-	-
Legumes	80	0.49	***-68***	-	-	-	-	-	2nd		-	11th	-	9th	11th
Dark Green	80	0.60	-13				-	-		6th	14th	-	-	15th	-
Other vegetables	80	0.41	***21***	-	-	-	-	-	7th	4th	-	10th	-	13th	-
Tomatoes	67	0.29	***28***	-	-	-	-	-	9th	5th	1st	4th	10th		10th
GRAINS															
Flour, bran; Rice,cooked grains	74	0.48	***39***	15th	-	-	-	-	11th	-	-	-	-	3rd 7th	6th 13th
Yeast breads, rolls	80	0.53	***30***	2nd	5th	-	19th	17th	1st	-	-	14th	2nd	2nd	2nd
Biscuits, pancakes, tortillas	83	0.62	-4	10th	10th	13th	-	13th	4th	-	-	-	6th	4th	5th
Cereal	89	0.76	***26***	-	-	-	-	-	10th	8th	8th	-	-	1st	1st
Pasta	83	0.60	***-56***	-	-	-	-	-	12th	-	-	-	-	6th	12th
Cakes, cookies, pastries, etc	78	0.57	***36***	1st	11th	4th	6th	3rd	8th	-	5th	16th	9th	5th	4th
Crackers, popcorn. chips	89 100 93	0.67 1.0 0.83	***-12*** ***-185*** ***-46***	8th	-	7th	10th	8th	6th	-	2nd	9th	8th	8th	8th
DAIRY															
Milk	78	0.51	9	11th	4th	11th	4th	14th	-	-	-	1st	14th	-	-
Cheese	74	0.43	9	6th	3rd	2nd	1st	5th	-	-	-	-	3rd	-	-
Milk desserts	96	0.85	0	20th	-	16th	9th	19th	-	-	-	-	-	-	-

Table 4.3 (continued): 24TR and WFRQ agreement and serving size differential for select food groups and their ranked contribution to energy and nutrient intake among U.S. adults 19 – 50 years old from NHANES 2003-6.

	Agree (%)	κ	Serv. Δ*	Energy	Protein	Total Fat	SFA	MUFA	Fiber	Vitamin C	Vitamin E	Potassium	Sodium	Folate	Iron
Correlations†				0.54	0.37	0.49	0.49	0.49	0.40	0.41	0.23	0.44	0.35	0.37	0.34
MEAT, NUTS, EGGS															
Beef	74	0.46	-7	5th	1st	3rd	2nd	2nd	-	-	11th	-	-		3rd
Poultry	85	0.70	-8	7th	2nd	8th	8th	6th	-	-	9th	8th	-		7th
Hot dogs, sausages, cold cuts	80	0.49	***-104***	14th	8th	6th	5th	4th	-	-		15th	4th		
Pork	85	0.37	9	18th	6th	12th	11th	12th	-	-		12th	7th		
Nuts/seeds, include butters	80 87	0.53 0.43	***21*** ***-38***	22nd	16th	10th	17th	10th	13th	-	3rd	-	-		
Eggs	78	0.49	***44***	-	9th	18th	16th	15th	-	-	10th	-	-		15th
FATS															
Oil, Shortening	72 67	0.48 0.09	-13 13	12th	-	1st	3rd	1st		-	6th				
Margarine & Butter	76 65	0.44 0.22	***43*** 4	21st	-	9th	7th	7th		-	7th		12th		
Salad dressing & mayonnaise	78	0.55	***-17***	16th	-	5th	12th	9th		-	4th				
SWEETS															
Sugar, Chocolate, Other candy	80 91 91	0.59 0.80 0.55	***46*** ***-33*** ***-101***	9th		17th	13th	16th	-	-	-	-	-		
BEVERAGES															
Soda, soft drinks	93	0.87	***-48***	3rd				-							9th
Tea, coffee	100 93	1.0 0.87	5 -10					-				2nd		12th	
Alcohol	87	0.50	6	4th				-				13th		11th	
Fruit drinks	87	0.78	***-20***					-		2nd					
MISCELLANEOUS															
Sauces & Condiments	0.61	0.15	***92***										5th		
Soup broths	78	0.40	***18***										11th		

*Serving Δ = % difference in reported total serving amounts between the 24TR and the WFRQ = [(Total 24TR – Total WFRQ)/(Total 24TR)] * 100
† Same day correlations between the 24TR and the WFRQ.

CHAPTER 5: SUMMARY

Diet-disease relationships are a complex interaction of biologic, behavioral, and environmental factors. Over the past 40 years there have been dynamic changes in dietary patterns in the United States and other developed countries, including those transitioning to developed status. Coupled with changes in physical activity behaviors, these have led to substantial increases in disability, premature mortality, and economic costs associated with obesity, diabetes, heart disease, cancer, and other chronic conditions.[1-5] Over the past few decades, the growth of population-based epidemiologic nutrition studies have increasingly clarified the role of diet in obesity and chronic disease and have been used to establish recommendations and policies for dietary practices.[1,6] At the crux of these essential studies and future studies is the ability to precisely and accurately estimate intake of foods, energy, nutrients, bioactive compounds, and additions and contaminants with tolerable measurement error. Ideally, dietary assessment methods would not only be precise and accurate but also efficient in time, expense, and usability, especially for large epidemiologic and clinical research studies needing to assess dietary behaviors in free living populations.

In practice, self-report dietary assessment methods are currently the most practical for implementing in large studies. Food frequency questionnaires remain the method of choice although self-report gold standards such as the multi-pass 24-hour telephone dietary recall and food diaries are also used. Unlike objective, yet expensive and burdensome, methods such as doubly labeled water and biomarkers, self-report methods are plagued with issues of misreporting and accompanying measurement error and bias (e.g. recall, social desirability, and reverse causality) that can affect research validity. Primary concerns include accurate recall of foods consumed, how often they were consumed, and in what amounts. Food frequencies questionnaires underestimate energy and nutrient intake by 30% or more compared to biomarkers.[13] The 24-hour telephone recall also underestimates energy and protein intake by 11% or more.[13] Establishing food energy and nutrient databases and then appropriately assigning foods and food amounts to these databases adds another level of potential error. While self-report methods will likely remain the most practical for assessing habitual dietary intake among free living populations, efforts to improve their validity and minimize participant and researcher burden need to continue.

As we identify opportunities to improve self-report dietary assessment, the emergence of efficient, affordable, and wide-spread use of the internet in nearly all segments of society coupled with rapidly developing technologies to maximize internet use have triggered exploration in developing dietary assessment tools that capitalize on the internet and, hopefully, improve estimates of habitual dietary intake. In August 2005, one of the most common paper-and-pencil FFQs, the NCI-DHQ, was modified for use on the internet. Since that time, several others have either modified existing FFQs to the internet, or have developed new internet dietary assessment tools, some following traditional FFQ formats and others developing hybrid 24-hour questionnaire – recall formats.

It is in this context that in 2007 we began developing the 24-hour Web Food Report Questionnaire (WFRQ) as no similar dietary assessment tool existed at that time. We developed the WFRQ based on principles espoused by Cade et al. to build off existing, well tested, and validated dietary assessment tools, choosing the NCI-DHQ which had been through substantial cognitive, usability, and validity testing.[77,100] Capitalizing on the strengths of web technology and using the 24-hour format, we used screening checklists and skip patterns to efficiently identify and query foods consumed the day before, increased the number of available food items from 124 to 248 by splitting some foods while also adding foods commonly consumed, incorporating more food detail (i.e., use of spreads on breads and rolls) and food type (i.e., fat content) selections, included finer portion amount categories, incorporated real-time data quality checks to assure accurate data input, and linking the WFRQ food items to the comprehensive, rigorous, and routinely updated Nutrition Coordination Centers' (NCC) food and nutrient database at the University of Minnesota.

Using a convenience sample of 51 middle-aged, mostly educated women, we conducted a comparative validation study of habitual dietary intake (3-day averages) captured with the WFRQ versus the 24TR. We also compared results from the NCI-DHQ with the 24TR. Among energy and 19 macro- and micronutrients, there were no differences in mean intake estimates between the WFRQ and the 24TR, with the exception of vitamin A. With the NCI-DHQ energy and 10 nutrient intake estimates (58% of comparisons) were significantly different from the 24TR. If adjusted for multiple comparisons there would be no significant differences with the 24TR and four significant differences with the NCI-DHQ when comparing with the 24TR. Correlations of the WFRQ and the NCI-DHQ with the 24TR ranged from 0.24 to 0.73 with the WFRQ and from 0.33 to 0.68 with the NCI-DHQ, similar to correlation ranges observed in the Eating and America's Table study that compared the NCI-DHQ to the 24TR.[77] In our study, 14 of 20 correlations were above 0.50 with the WFRQ while only 7 of 19 were above 0.50 with the NCI-DHQ. Assessing under-reporting of energy intake, we found that of the 51 study participants, 73% (n=37), 86% (n=44) and 86% (n=44) were individually classified as under-reporters on the 24TR, WFRQ, and NCI-DHQ, respectively, while overall mean energy intake estimates were under-reported by 15% for the 24TR, 19% for the WFRQ, and 25% for the NCI-DHQ. These amounts of energy intake under-reporting are similar to studies where the 24TR and the NCI-DHQ were compared against biomarkers. In the two largest studies, the 24TR was found to under-report energy intake by 11% - 20%.[13,164] The NCI-DHQ underreported energy intake by 30-38%.[13] Finally, on average, the WFRQ was completed in 10 minutes, much lower than reported times from the 24TR (20-30 minutes) or the NCI-DHQ (45-60 minutes).

Despite the promising results of the comparative validation study room for improvement remains. As mentioned earlier, key contributors to measurement error include recall of foods consumed, their frequency of consumption, and in what portions. Mapping of the WFRQ food items and portion categories to the NCC food and nutrient database may also introduce error. As part of our study validation design, we incorporated an administration of the WFRQ and the 24TR *for the same day*. This allowed us to make direct comparisons of reported foods and food amounts consumed among 46 participants and identify potential areas of future improvement of the WFRQ. The same day energy and nutrient intake estimates were similar between the 24TR and the WFRQ and correlations ranged from 0.23 to 0.85 with 12 of 23 below 0.50. Food reporting agreement was moderate to good (overall % agreement > 85%; κ > 0.40) for total fruit, total vegetables, whole grains, total milk, and the primary beverage food subgroups while food groups and subgroups within grains, meats, fats, and miscellaneous foods had poorer agreement. Discrepancies in reported food amounts were largest for grain subgroups (whole and refined), poultry, cold cuts and sausages, oils, sugar and candies, soft drinks, water, and pickled foods. More detailed examination of foods and food amounts consumed suggest that many foods commonly incorporated in mixed dishes or cooking preparation were captured with the 24TR and not the WFRQ. Identifying the appropriate food type, such as fat content or sweetener used, was also a problem. The addition of more food detail on the WFRQ may be merited. Differences in reported portion amounts may be the classic concern of accurately estimating food amounts, especially more amorphous foods, like mashed potatoes or French fries. Improvements in portion size aids to the WFRQ could be examined. Finally, there appears to be a fair amount of discrepant food and portion amounts that could be reduced by more refined mapping of the WFRQ food items and portion amount categories to the NCC food and nutrient database. Implementing a combination of the above recommendations may lead to better energy and nutrient intake estimates with the WFRQ.

Since 2007, a dietary assessment tool similar to the WFRQ but more intensive and comprehensive has been developed and validated. The DietDay is a multi-pass, web-based 24-hour self-administered recall. Like the WFRQ, it is based on a questionnaire format instead of being open-ended.[134] DietDay contains 9,349 foods and more than 7,000 food images in 61 modules. The food images are used to help estimate portion sizes. Recalls are anchored around the time of day: midnight to 11am, 11am to 5pm, and 5pm to midnight.[134] Validity and usability of the DietDay were assessed among 261 adults (131 African American, 130 White) comparing six DietDay assessments and the

NCI-DHQ to doubly-labeled water biomarkers.[133] The DietDay estimated energy intake was 9% lower compared to biomarkers while that of the NCI-DHQ was 27% lower.[133] Performance of the DietDay is mixed when comparing caretenoid intake with plasma concentration biomarkers.[131,134] Results from the Energetics study suggest the DietDay may perform better than the current WFRQ for capturing energy intake but it remains unclear how long it takes to complete the DietDay or how it performs capturing other nutrients and foods.

This ‘beta’ version of the WFRQ is promising for research use in large studies involving free living populations. WFRQ energy and nutrient intake estimates are generally similar to the 24TR and had better performance compared to the NCI-DHQ. Furthermore, the WFRQ had a user-friendly completion time of 10 minutes which equates to conducting 4-6 WFRQs per one NCI-DHQ (i.e., 45-60 minutes completion time). Key next steps for the WFRQ include a) identifying specific food items, detail, and portion size aids to include on the WFRQ, b) re-aligning the WFRQ foods and portion categories with the NCC food and nutrient database, c) automating energy and nutrient calculations and reporting directly from data collection, and d) conducting a more rigorous validation study of the improved WFRQ that would include doubly-labeled water, biomarkers, and a larger sample size. Additional future considerations might include examining web design issues to facilitate improved recall and user experience and exploring tailoring of the WFRQ for use on mobile platforms.

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