Development and Evaluation of a Brief Questionnaire to Assess Habitual Beverage Intake (BEVQ-15): Sugar-Sweetened Beverages and Total Beverage Energy Intake

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ABSTRACT

Attention on beverage intake, specifically sugar-sweetened beverages (SSB), has increased in recent years (1). Energy-containing beverages do not provide the same satiety as solid foods, and intake of solid food is not spontaneously reduced when energy-containing beverages are consumed (2,3). This may contribute to positive energy balance (1). Conversely, a reduction in energy intake occurs by replacing SSB with water and may facilitate weight loss (4,5). A valid, reliable and sensitive assessment tool for quantifying beverage consumption and determining its influence on weight status could help advance research on this topic. Three studies were conducted to develop the BEVQ, a self-administered quantitative beverage intake questionnaire. First study (n=105): the 19-item BEVQ's validity was examined by comparing participant's beverage intake to the "gold standard" of dietary intake assessment, food intake records; reliability was assessed by comparing two BEVQ's, administered two weeks apart. The BEVQ demonstrated acceptable validity (R^2=0.53, water g; 0.46, 0.61 total beverage g, kcal; 0.49, 0.59 SSB g, kcal) as well as reliability (all correlations $P<0.001$) (6). Second study (n=1,596): the BEVQ underwent exploratory factor analyses (EFA) to identify the potential to reduce items. Three beverage items, which contributed <10% to total beverage intake g, kcal, were eliminated; EFA identified beer and light beer as a combined category. The refinement led to the 15-item BEVQ, which produced a lower readability score of 4.8 and shorter administration time (~2 min) (7). Third study (n=70): the ability of the BEVQ-15 to detect changes in beverage intake was evaluated by increasing participant water and fruit juice consumption and evaluating BEVQ-15 outcomes before and after the feeding period. Increases in water, juice and total beverage (g) were detected during the intervention period ($P<0.001$) (8). This rapid, valid, reliable and sensitive beverage intake assessment tool may determine the habitual intake of SSB and other beverages, and evaluate the effectiveness of clinical and public health interventions which aim to address national SSB recommendations. Future work is needed to evaluate the validity and reliability of the BEVQ-15 in children, as well as develop cost-effective noninvasive biomarkers that can objectively estimate intake of specific foods/dietary components (9).

References

1. de Graaf C. Why liquid energy results in overconsumption. *Proc Nutr Soc.* 2011;70(2):162-170.
2. DiMeglio DP, Mattes RD. Liquid versus solid carbohydrate: effects on food intake and body weight. *Int J Obes Relat Metab Disord.* 2000;24(6):794-800.
3. Mattes RD. Dietary compensation by humans for supplemental energy provided as ethanol or carbohydrate in fluids. *Physiol Behav.* 1996;59(1):179-187.
4. Dennis EA, Dengo AL, Comber DL, Flack KD, Savla J, Davy KP, Davy BM. Water consumption increases weight loss during a hypocaloric diet intervention in middle-aged and older adults. *Obesity.* 2009;18(2):300-307.
5. Stookey JD, Constant F, Gardner CD, Popkin BM. Replacing sweetened caloric beverages with drinking water is associated with lower energy intake. *Obesity.* 2007;15(12):3013-3022.
6. Hedrick V, Comber D, Estabrooks P, Savla J, Davy B. The beverage intake questionnaire: initial validity and reliability. *J Am Diet Assoc.* 2010;110:1227-1232.
7. Hedrick V, Savla J, Comber D, Flack K, Estabrooks P, Nsiah-Kumi P, Ortmeier S, Davy B. Development of a brief questionnaire to assess habitual beverage intake (BEVQ-15): sugar-sweetened beverages and total beverage energy intake. In Review.
8. Hedrick V, Comber DL, Ferguson K, Estabrooks P, Savla J, Dietrich A, Serrano E, Davy B. A rapid beverage intake questionnaire can detect changes in beverage intake. In Preparation.
9. Monsen E. *Research Successful Approaches*. 2nd ed: American Dietetic Association; 2003.

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Chapter 1: Introduction

Obesity has become a major public health issue in the United States (U.S.), with 68.3% of adults (20 years and older) overweight (Body Mass Index [BMI] 25-29.9 kg/m^2) or obese (BMI $\geq$ 30 kg/m^2) (1). Despite the risk of health consequences associated with a BMI >25, such as cardiovascular disease, hypertension, diabetes, some forms of cancer and overall mortality (2), and in addition to countless efforts to develop strategies to promote weight management, the prevalence of obesity has not decreased (3). Furthermore, increased sugar-sweetened beverage (SSB) intake, specifically soft drinks, has been theorized to be an underlying contributor to increased body weight and consequently an increased risk of diabetes, cardiovascular disease and hypertension (4-7). SSB include regular soft drinks, fruit drinks, tea or coffee sweetened with sugar, energy/sport drinks and other beverages containing added sugars. Per person, an average of 458 calories (kcal) from beverages is consumed daily (8), equating to 21.0% of total daily energy. Compared to recent decades, this represents an increase in energy intake from SSB of 222 calories per day (8). Although water is the most commonly consumed beverage in the United States (U.S.) (8), energy-containing soda is the number one contributor to total daily energy from all food and beverages at 7.1% (9). According to the American Heart Association, the majority of added sugars (~50%) in American's diets originate from SSB (10).

Energy-containing beverages may not provide the same satiety value as solid foods, and intake of solid food is not spontaneously reduced when energy-containing beverages are consumed (11,12). This may account for increased total daily energy intake and potentially over time, weight gain (13). Conversely, when SSB intake is replaced by water (14) or water

consumption is increased (15), self-reported energy intake appears to decrease, which may facilitate weight loss over time (15,16). With an emphasis on obesity prevention, the U.S. 2010 Dietary Guidelines recommended a consumption of less than 15% of total daily energy from solid fats and added sugars (current intake of approximately 33% of total energy intake) (17,18). The American Heart Association also suggested added sugar intake should be, based on the U.S. Department of Agriculture Food Guide, no more than 80 kcals per day for the average female and 150 kcals for the average male, depending on energy requirements and physical activity levels (10). As well, SSB should be replaced with non-caloric beverages such as water, or healthier alternatives such as milk (6,18). Despite multiple SSB and added sugar intake recommendations, a rapid (< 5 minutes) and valid beverage intake assessment tool does not exist for evaluation of these dietary intake behaviors, thus requiring collection of extensive longitudinal date in order to examine the impact of public health interventions targeting habitual beverage intake, as well as attaining direct evidence linking beverage consumption patterns with weight outcomes (19).

Common methods to assess beverage and food intake include food diaries and dietary recalls, however, these methods are not without limitations. They can be costly (time-wise), cause a high subject burden, provide only recent intake (i.e., not habitual intake patterns) and are not always feasible in large scale studies (20-22). Alternatively, food frequency questionnaires (FFQ) may be able to provide habitual dietary intake patterns with less associated cost, time and subject burden. However, FFQ must demonstrate acceptable validity, reliability (22) and an ability to detect changes in intake (23,24) in order to be an effective tool in determining dietary intake. The availability of a rapid (< 5 minutes), self-administered, valid (i.e., the tool is

measuring intended items accurately), reliable and reproducible (i.e., the tool provides the same response over time) beverage intake assessment tool for determining habitual beverage intake in adults, including quantities and energy contribution, could greatly enhance nutrition research targeting beverage intake patterns; the questionnaire must also possess the ability to detect changes in beverage intake over time.

The purpose of the following investigations was to develop a rapid, self-administered beverage intake questionnaire (BEVQ) and evaluate its relative validity, test-retest and inter-item reliability and ability to detect changes in beverage intake. Relative validity is used to measure the degree of agreement between a test measure and a reference measure (e.g., BEVQ compared to food diaries and dietary recalls). Test-retest reliability measures the ability of a test to provide the same responses over time for an individual. Inter-item reliability, also known as internal consistency, measures the correlation between items within a single construct (25). The BEVQ is currently 1) the only known rapid beverage intake questionnaire, 2) the only questionnaire to use exploratory factor analysis to combine variables for the purpose of reducing the length of a quantitative FFQ, and 3) the only pre-validated questionnaire to utilize a feeding study-type design to evaluate the sensitivity to change of a questionnaire.

Regardless of efforts to create FFQ that are valid and reliable, the subjective nature of self-reported dietary intake methods is a limitation of reporting accurate intake (26). Biomarkers of dietary intake are able to objectively assess dietary intake/status and assist in overcoming the bias of self-reported dietary intake errors (27-29); biomarkers are also able to provide additional validity to newly developed questionnaires (30). According to the Institute of Medicine, the field

of nutritional biomarkers requires future research, including the need to improve dietary assessment methods (27). Additional research should include the development of biomarkers that are able to assess specific food/dietary component intake (e.g., ^{13}C for corn and cane sugar intake (31)) rather than individual nutrients (32), as well as developing biomarkers associated with low cost and invasiveness (27). To identify gaps in the literature pertaining to dietary biomarkers, the final chapter reviews current dietary biomarkers for macronutrients (carbohydrates, fats, proteins) and includes a novel review of biomarkers pertaining to specific foods and dietary components. Furthermore, the presented biomarkers were assessed for validity, reproducibility and sensitivity to change, as well as cost, biological sample used and invasiveness of the procedure. The availability of valid sensitive biomarkers that provide estimates of specific foods and dietary components could enhance nutritional research targeting compliance to national recommendations, such as the U.S. 2010 Dietary Guidelines and the American Heart Association, as well as determine significant associations between dietary intake and disease risks. Moreover, the development of specific biomarkers will aid in the improvement and expansion of valid FFQ that may be used by practitioners, as well as researchers assessing habitual beverage intake and possible influence on weight and health status.

References

1. Flegal K, Carroll M, Ogden C, Curtin L. Prevalence and trends in obesity among U.S. adults, 1999-2008. *J Am Med Assoc.* 2010;303(3):235-241.

2. Hensrud DD, Klein S. Extreme obesity: a new medical crisis in the United States. *Mayo Clin Proc.* 2006;81(10):S5-S10.

3. Hedley AA, Ogden CL, Johnson CL, Carroll MD, Curtin LR, Flegal KM. Prevalence of Overweight and Obesity Among US Children, Adolescents, and Adults, 1999-2002. *JAMA.* June 16, 2004 2004;291(23):2847-2850.

4. Brown I, Stamler J, Van Horn L, Robertson C, Chan Q, Dyer A, Huang C, Rodriguez B, Zhao L, Daviglus M, Ueshima H, Elliott P. Sugar-sweetened beverage, sugar intake of individuals, and their blood pressure: international study of macro/micronutrients and blood pressure. *Hypertension.* 2011;57(4):695-701.

5. de Koning L, Malik VS, Rimm EB, Willett WC, Hu FB. Sugar-sweetened and artificially sweetened beverage consumption and risk of type 2 diabetes in men. *Am J Clin Nutr.* 2011;93(6):1321-1327.

6. Malik V, Popkin B, Bray G, Despres J, Hu F. Sugar-sweetened beverages, obesity, type 2 diabetes mellitus, and cardiovascular disease risk. *Circulation.* 2010;121:1356-1364.

7. Vartanian L, Schwartz M, Brownell K. Effects of soft drink consumption on nutrition and health: a systematic review and meta-analysis. *Am J Public Health.* 2007;97(4):667-675.

8. Duffey K, Popkin B. Shifts in patterns and consumption of beverages between 1965 and 2002. *Obesity (Silver Spring).* 2007;15(11):2739-2747.

9. Block G. Foods contributing to energy intake in the U.S.: data from NHANES III and NHANES 1999-2000. *J Food Compos Anal.* 2004(17):439-447.

10. Johnson R, Appel L, Brands M, Howard B, Lefevre M, Lustig R, Sacks F, Steffen L, Wylie-Rosett J. Dietary sugars intake and cardiovascular health: a scientific statement from the American Heart Association. *Circulation.* 2009;120(11):1011-1020.

11. DiMeglio DP, Mattes RD. Liquid versus solid carbohydrate: effects on food intake and body weight. *Int J Obes Relat Metab Disord.* 2000;24(6):794-800.

12. Mattes R. Dietary compensation by humans for supplemental energy provided as ethanol or carbohydrate in fluids. *Physiol Behav.* 1996;59(1):179-187.

13. de Graaf C. Why liquid energy results in overconsumption. *Proc Nutr Soc.* 2011;70(2):162-170.

14. Stookey JD, Constant F, Gardner CD, Popkin BM. Replacing sweetened caloric beverages with drinking water is associated with lower energy intake. *Obesity.* 2007;15(12):3013-3022.

15. Dennis EA, Dengo AL, Comber DL, Flack KD, Savla J, Davy KP, Davy BM. Water consumption increases weight loss during a hypocaloric diet intervention in middle-aged and older adults. *Obesity.* 2009;18(2):300-307.

16. Davy B, Dennis EA, Dengo AL, Wilson K, Davy K. Water consumption reduces energy intake at a breakfast meal in obese older adults. *J Am Diet Assoc.* 2008;180:1236-1239.

17. U.S. Department of Health and Human Services, and U.S. Department of Agriculture (HHS, USDA). Dietary Guidelines for Americans, 7th Edition. Washington, DC: US Government Printing Office; 2010.

18. Van Horn L. Development of the 2010 U.S. dietary guidelines advisory committee report: perspectives from a registered dietitian. *J Am Diet Assoc.* 2010;110(11):1638-1645.

19. Allison DB, Mattes RD. Nutritively sweetened beverage consumption and obesity: the need for solid evidence on a fluid issue. *J Am Med Assoc.* 2009;301(3):318-320.

20. Marshall T, Eichenberger Gilmore J, Broffitt B, Levy S, Stumbo P. Relative validation of a beverage frequency questionnaire in children ages 6 months through 5 years using 3-day food and beverage diaries. *J Am Diet Assoc.* 2003;103(6):714-720.

21. Thomson C, Giuliano A, Rock C, Ritenbaugh C, Flatt S, Faerber S, Newman V, Caan B, Graver E, Hartz V, Whitacre R, Parker F, Pierce J, Marshall J. Measuring dietary change in a diet intervention trial: comparing food frequency questionnaire and dietary recalls. *Am J Epidemiol.* 2003;157(8):754-762.

22. Willett WC, Lenart E. *Nutritional Epidemiology*. 2nd ed: Oxford University Press; 1998.

23. Guyatt G, Walter S, Norman G. Measuring change over time: assessing the usefulness of evaluation instruments. *J Chronic Dis.* 1987(40):171-178.

24. Kristal A, Beresford S, Lazovich D. Assessing change in diet-intervention research. *Am J Clin Nutr.* 1994;59(1 Suppl):185S-189S.

25. Gleason P, Harris J, Sheean P, Boushey C, Bruemmer B. Publishing nutrition research: validity, reliability, and diagnostic test assessment in nutrition-related research. *J Am Diet Assoc.* 2010;110:409-419.

26. Thompson FE, Subar AF, Loria CM, Reedy JL, Baranowski T. Need for technological innovation in dietary assessment. *J Am Diet Assoc.* 2010;110(1):48-51.

27. Institute of Medicine of the National Academies. Dietary Reference Intakes: Research Synthesis Workshop Summary. Washington, DC: The National Academies Press; 2007.

28. Hardin DS. Validating dietary intake with biochemical markers. *J Am Diet Assoc.* 2009;109(10):1698-1699.

29. McCabe-Sellers B. Advancing the art and science of dietary assessment through technology. *J Am Diet Assoc.* 2010;110(1):52-54.

30. Bogers RP, van Assema P, Kester ADM, Westerterp KR, Dagnelie PC. Reproducibility, validity, and responsiveness to change of a short questionnaire for measuring fruit and vegetable intake. *Am J Epidemiol.* 2004;159(9):900-909.

31. Davy BM, Jahren AH, Hedrick VE, Comber DL. Association of δ13C in fingerstick blood with added-sugar and sugar-sweetened beverage intake. *J Am Diet Assoc.* 2011;111(6):874-878.

32. Monsen E. *Research: Successful Approaches*. 2nd ed: American Dietetic Association; 2003.

Chapter 2:

The Beverage Intake Questionnaire: Initial Validity and Reliability

Abstract

Consumption of energy-containing beverages may lead to weight gain, yet research investigating this issue is limited. An easily-administered beverage intake assessment tool could facilitate research on this topic. The purpose of this cross-sectional investigation was to determine the validity and reliability of a self-administered beverage intake questionnaire (BEVQ), which estimates mean daily intake of beverages consumed (g, kcals) across 19 beverage categories. Participants (n=105; aged 39±2 yrs) underwent assessments of height, weight, body mass index and dietary intake using 4-day food intake records (FIR) from June 2008-June 2009. The BEVQ was completed at two additional visits (BEVQ1, BEVQ2). Urine samples were collected to objectively determine total fluid intake and encourage accurate self-reporting. Relative validity was assessed by comparing BEVQ1 with FIR results; test-retest reliability was assessed by comparing BEVQ1 and BEVQ2. Analyses included descriptive statistics, bivariate correlations, paired sample *t* tests and independent sample *t* tests. Self-reported water and total beverage intake (g) were not different between the BEVQ1 and FIR (mean difference: 129±77 g [P=0.096] and 61±106 g [P=0.567], respectively). Total beverage and sugar-sweetened beverage (SSB) energy intake were significantly different, although mean differences were small (63 and 44 kcal, respectively). Daily consumption (g) of water (R^2=0.53), total beverages (R^2=0.46) and SSB (R^2=0.49) determined by the BEVQ1 were correlated with reported intake determined by the FIR, as was energy from total beverages (R^2=0.61) and SSB (R^2=0.59) (all P<0.001). Reliability was demonstrated, with correlations (P<0.001) detected

between BEVQ1 and BEVQ2 results. The BEVQ is a valid, reliable and rapid self-administered dietary assessment tool.

Introduction

Obesity has become an epidemic in the United States (1), with more than 66% of adults overweight (Body Mass Index [BMI] 25-29.9 kg/m^2) or obese (BMI $\geq$ 30 kg/m^2) (2). Despite efforts to identify strategies which effectively promote weight management, the prevalence of obesity has not declined (3). According to laboratory-based feedings studies (4), energy-containing beverages are less satiating than solid foods. Specifically, intake of solid food is not spontaneously reduced when energy-containing beverages are consumed (5,6), regardless of nutrient composition (e.g., low fat milk, soda or juice) (7,8). Thus, consumption of energy-containing beverages may increase energy intake and lead to weight gain (4).

Interventions targeting energy-containing beverage consumption could lead to weight loss for overweight and obese individuals. Self-reported energy intake declines when sugar-sweetened beverage (SSB) intake is replaced with water (9); premeal water consumption reduces subsequent meal energy intake and facilitates weight loss over time (10). Furthermore, a sugared beverage tax is being enforced to discourage SSB consumption in several U.S. states (11). A recent Scientific Statement from the American Heart Association highlighted the contribution of SSB to total added sugar intake and recommended added sugar intake guidelines (12). However, the need for direct evidence linking beverage consumption patterns with weight outcomes has been suggested (13).

Food diaries and recalls are commonly used to assess dietary intake; however these methods are resource-intensive, time-consuming, burdensome for participants, provide only recent intake data (i.e., not habitual intake patterns) and are not always feasible in large-scale

studies (14,15). There is currently no rapid (< 5 minutes) method for determining habitual beverage intake in adults, including quantities and energy contribution. A brief, self-administered, valid and reliable beverage intake assessment tool could enhance nutrition research targeting beverage intake patterns.

The purpose of this investigation was to test the validity and reliability of a newly developed self-administered beverage intake questionnaire (BEVQ) as compared to a "gold standard" of measuring dietary intake – food intake records (FIR), which have been used in numerous validation studies (16-21). Although their limitations are recognized (22), FIR are suitable for comparison to questionnaires to establish validity, and have the least correlated errors of the dietary intake methods available (15).

Methods

Subjects and Design. Healthy adults (n=105) aged ≥21 years were recruited for this cross-sectional investigation from a local university community between June 2008-June 2009. The Virginia Tech Institutional Review Board approved the study protocol. Participants provided written informed consent prior to enrollment, however they were not aware of the specific purpose of the study; they were informed that the study was evaluating a new food intake questionnaire.

Methods. Participation entailed three laboratory visits within a two-week period; visits were completed in one of two randomly assigned visit sequences. The three study visits included the completion of two BEVQ and one four-day FIR, as follows: Sequence 1: (visit 1) BEVQ1,

(visit 2) FIR, (visit 3) BEVQ2; Sequence 2: (visit 1) FIR, (visit 2) BEVQ1, (visit 3) BEVQ2. Completing the FIR before the BEVQ could heighten participant's awareness of their food and beverage intake, and falsely increase correlations between the FIR and BEVQ (15). Randomizing visit sequence provided a means to determine if randomization sequence influenced results. All visits were conducted between 12 pm – 5 pm to avoid the differences in urinary specific gravity (SG) measurements that may occur throughout the day.

For all participants, visit 1 included the following procedures: height, measured in meters without shoes using a wall mounted stadiometer; body weight, measured in light clothing without shoes, to the nearest 0.2 kg using a physician's balance scale (Seca; Hanover, Maryland); and BMI, calculated as weight (kg)/height (m^2). Participants provided information on demographic characteristics and health status (e.g., age, race/ethnicity, medical history, medications). Sequence 1 participants then completed a BEVQ (BEVQ1) and provided a urine sample to determine SG; sequence 2 participants received instructions for completing a four-day FIR, including the use of two-dimensional food models to assist with portion size determination. Urinary SG was determined using a handheld refractometer (ATAGO 4410 Digital Urine Specific Gravity Refractometer, Bellevue, Washington). The urine sample provided an objective indicator of total fluid intake, and also served to encourage the accuracy of participant's self-reported dietary intake (15). Food records were kept either from Sunday through Wednesday or Wednesday through Saturday, in order to capture both weekend and weekday dietary habits; FIR were reviewed for completeness upon return, and analyzed using nutritional analysis software (Nutrition Data Systems for Research [NDS-R] 2007, University of Minnesota, Minneapolis, MN).

At visit 2, sequence 1 participants were provided with instructions for completing the FIR identical to that for the initial visit of sequence 2 participants; sequence 2 participants completed a BEVQ (BEVQ1), provided a urine sample and returned the FIR. At visit 3, sequence 1 participants completed a BEVQ (BEVQ2), provided a urine sample and returned the FIR; sequence 2 participants completed a BEVQ (BEVQ2) and provided a urine sample. Participants were compensated $10 upon completion of all three study visits.

Development and Scoring of the Beverage Intake Questionnaire (BEVQ). The BEVQ was developed to estimate mean daily intake of water, SSB and total beverages (grams [g], calories [kcals]) across 19 beverage categories plus one open-ended section for "other" beverages not listed (Figure 1). This tool is a quantitative food frequency questionnaire (FFQ); the frequency of food items consumed and amounts consumed are assessed (22). Beverage categories were grouped by energy and macronutrient content using published food composition tables (23) and nutritional analysis software (NDS-R 2007, University of Minnesota, Minneapolis, MN). Common beverage portion sizes (e.g., 12 fl oz can of soft drinks, 20 fl oz bottles of juice/water/soft drinks), and common cup sizes (e.g., juice glasses [(4-6 fl oz] and cups [8 fl oz]) were utilized to assess amounts consumed. Due to the desire to develop a brief, single-page BEVQ, the most commonly consumed beverage units were included. To score the BEVQ, frequency ("how often") is converted to the unit of times per day, then multiplied by the amount consumed ("how much each time") to provide average daily beverage consumption in fl oz. Energy and grams (per fl oz) for each beverage category were determined using food composition tables (25). Total energy and grams of each beverage were determined by multiplying the number of fl oz per day by the energy and grams per fl oz of each category. To

quantify total SSB consumption, beverage categories containing added sugars were summed (sweetened juice beverages/drinks, regular soft drinks, sweet tea, sweetened coffee, energy drinks, mixed alcoholic drinks, meal replacement beverages). During pilot testing of the BEVQ, average administration time was determined to be ~3.5 minutes (range: 2 min 12 sec – 4 min 26 sec).

Data Analysis. Statistical analyses were performed using SPSS statistical analysis software (v. 12.0 for Windows, 2003, SPSS Inc., Chicago, IL). Descriptive statistics (mean$\pm$standard error of the mean [SEM]; frequencies) are reported for demographic characteristics and average total consumption of beverages and beverage categories (g, kcal). Paired sample *t* tests were used to compare the energy intake (kcal) and the g consumed of specific beverages across dietary assessment tools. To assess relative validity, the BEVQ1 responses were compared to FIR responses, and to assess test-retest reliability, BEVQ1 responses were compared to BEVQ2. Independent sample *t* tests were used to assess potential differences in the randomization sequence. Associations among variables (beverage intake variables, SG) were assessed using correlational analyses (Spearman's R^2). The alpha level was set *a priori* at $P \leq 0.05$.

Results and Discussion

One hundred and five individuals (45 males; 60 females) completed all study visits. Participants were primarily Caucasian (85% of sample), with remaining participants self-identified as Asian (8%), African American (4%) or "other" (4%). Mean age of participants was 39$\pm$2 yrs (range: 21-93 yrs), which was distributed across the adult age range as follows: 21-39 yrs, 60%; 40-59 yrs, 23%; $\geq$ 60 yrs, 17%. BMI was widely distributed (mean = 25.6$\pm$0.6 kg/m^2;

range 16.2-62.5 kg/m^2), although participants were primarily of "normal" BMI status (BMI <18.5 kg/m^2, 2%; 18.5-24.9 kg/m^2, 53%; 25.0-29.9 kg/m^2, 30%; >30.0 kg/m^2, 15%). Of 72 participants who provided information on their educational level, most reported being college-educated (n=67).

Results from the relative validity and test-retest reliability assessment of the BEVQ are presented in Table 1. Of the 21 beverage variables assessed (grams and energy for 19 individual beverage categories, plus SSB and total beverages), responses on the two assessment tools (BEVQ1, FIR) were significantly correlated (all P<0.001) with two exceptions: sweetened coffee and mixed alcoholic drinks. Responses between the BEVQ1 and FIR were not different for intake (g) of water, juice drinks, vegetable juice, milk (all types), soft drinks (regular and diet), light beer, liquor, mixed alcoholic drinks, wine and total beverage intake. Differences in beverage energy content between assessment tools were < 35 kcal across all categories, although this difference was significant for 100% fruit juice, sweet tea, sweetened coffee, beer, meal replacement and energy drinks. Significant mean differences were detected in total beverage and sweetened beverage energy intake determined using the two tools, although this difference was minimal (63 and 44 kcal, respectively). These two variables were, however, each significantly correlated between the tools. Reliability was acceptable (R^2=0.45-0.87; all P<0.001), as FFQ considered reliable typically report correlations ranging 0.5-0.7 (15,24). Significant correlations were detected between all variables, although the correlation for energy drinks was lower than that for other beverage categories. No significant differences were found between BEVQ responses based on the two study sessions (BEVQ1, BEVQ2), or between the two visit sequences (data not shown). Urinary SG measurements were not significantly different across

visits (1.0146±0.0008 vs. 1.0146±0.0008 SG; mean difference: -0.000019±0.007 SG). As would be expected for a possible biomarker of total fluid intake, SG was negatively correlated with grams of total daily beverage consumption (BEVQ) at time one and time two (R^2=-0.202 and R^2=-0.238; P<0.05, respectively). SG was also negatively correlated with BEVQ water intake (g) at time one (R^2=-0.236, P<0.05) and time two (R^2=-0.319, P<0.01). Thus, the BEVQ appears to be a valid, reliable and easily-administered questionnaire for assessing beverage intake in adults.

Beverage consumption is a timely topic in the weight management field (11,13) and particularly for SSB, there are broad public health implications (12). This tool may be useful for researchers and clinicians interested in assessing habitual beverage consumption patterns, particularly in large-scale investigations where lengthier, resource-intensive dietary intake assessment techniques are not feasible. Among dietetic practitioners, this tool could be utilized as a rapid method to assess beverage consumption as part of a Nutrition Assessment in the Nutrition Care Process, and potentially in Nutrition Monitoring and Evaluation.

The present findings are consistent with others using more extensive dietary intake assessment methods, reporting a mean beverage energy intake of 458 kcal per day (25). Water is the most consumed beverage in the U.S., followed by coffee, soft drinks, whole milk, fruit juices and alcohol (25). The present findings are consistent with this pattern, with the exception of whole milk. In the general population, the majority of beverage energy (~50%) comes from SSB, such as regular soft drinks, fruit drinks, sweet tea and energy drinks (25,26). In this sample, SSB contribute ~40% of total beverage energy. Furthermore, Block (27) reported that

energy-containing soft drinks are the greatest contributor to total daily energy intake (i.e., all food and beverages) at 7.1%, while beer was also among the top contributors (2.6% of total energy). In this sample, soft drinks were the fifth highest contributor of energy from beverages, preceded by fat-free milk (greatest contributor of energy), fruit juice, reduced-fat milk and sweet tea. These differences may be attributed to the demographics of our sample, as age, weight status, educational level and socioeconomic status may influence beverage consumption (28).

After completing this initial evaluation of the BEVQ, several limitations were determined. Questions from participants during completion of the BEVQ suggested some refining may be needed, for example the BEVQ does not include a category for hot cocoa and participants were uncertain how to report sports drink intake. Beverage category descriptions may also need modification, for example, "coffee with cream and/or sugar" may be misinterpreted as coffee with cream. Participants were uncertain as to whether milk in cereal and coffee should be included in their responses. To address this issue, future versions will include additional respondent instructions such as to only report consumption of liquids when consumed as beverages. It is possible that the BEVQ underestimates certain beverage categories due to the upper limits on quantities (60 fl oz per day), for example, water intake. However, estimated BEVQ mean daily water intake is similar to that reported by National Health and Nutrition Examination Surveys (NHANES) (29) and the present findings did not indicate a ceiling effect. A final limitation is the use of a self-reported FIR for validation, as underreporting errors are common (22). However, FIR are recommended for validation of FFQ due to a reduced likelihood of correlated errors (15), when direct measurement of food intake is not feasible. Future work will determine if reducing the length of the tool is possible without impacting

results, if the tool is sensitive to changes in beverage intake and if the tool may be used in low-literacy populations. Due to the primarily Caucasian composition of this sample, future studies including larger numbers of minorities are warranted to determine if the BEVQ is a valid tool across ethnic/racial groups.

Conclusion

An easily-administered, valid and reliable beverage intake questionnaire may be desirable for practitioners, as well as for researchers assessing habitual beverage intake and possible influence on weight and health status. This tool may also be useful for large-scale studies, and for interventions targeting changes in beverage intake, particularly in light of data indicating that increasing water consumption and reducing energy-containing beverage consumption facilitates weight loss (10).

Figure 1: Beverage Intake Questionnaire (BEVQ-19)

Beverage Questionnaire-19

Instructions:
In the past month, please indicate your response for each beverage type by marking an "X" in the bubble for "how often" and "how much each time"

1) Indicate how often you drank the following beverages, for example, you drank 5 glasses of water per week, therefore mark 4-6 times per week

2) Indicate the approximate amount of beverage you drank each time, for example, you drank 1 cup of water 2 times per day, therefore mark 1 cup under "how much each time"

Subject ID _____

Date _____

	HOW OFTEN (MARK ONE)							HOW MUCH EACH TIME (MARK ONE)				
Type of Beverage	**Never or less than 1 time per week (go to next beverage)**	**1 time per week**	**2-3 times per week**	**4-6 times per week**	**1 time per day**	**2+ times per day**	**3+ times per day**	**Less than 6 fl oz (3/4 cup)**	**8 fl oz (1 cup)**	**12 fl oz (1 1/2 cups)**	**16 fl oz (2 cups)**	**More than 20 fl oz (2 1/2 cups)**
Water	O	O	O	O	O	O	O	O	O	O	O	O
100% Fruit Juice	O	O	O	O	O	O	O	O	O	O	O	O
Sweetened Juice Beverage/Drink (fruit ades, lemonade, punch, Sunny Delight)	O	O	O	O	O	O	O	O	O	O	O	O
100% Vegetable Juice (V8, etc.)	O	O	O	O	O	O	O	O	O	O	O	O
Whole Milk	O	O	O	O	O	O	O	O	O	O	O	O
Reduced Fat Milk (2%)	O	O	O	O	O	O	O	O	O	O	O	O
Low Fat/Fat Free Milk (Skim, 1%, Buttermilk, Soymilk)	O	O	O	O	O	O	O	O	O	O	O	O
Soft Drinks, Regular	O	O	O	O	O	O	O	O	O	O	O	O
Diet Soft Drinks/Artificially Sweetened Drinks (Crystal Light)	O	O	O	O	O	O	O	O	O	O	O	O
Sweetened Tea	O	O	O	O	O	O	O	O	O	O	O	O
Coffee, with cream and/or sugar (includes non-dairy creamer)	O	O	O	O	O	O	O	O	O	O	O	O
Tea or Coffee, black, with/ without artificial sweetener (no cream or sugar)	O	O	O	O	O	O	O	O	O	O	O	O
Non-alcoholic or Light Beer	O	O	O	O	O	O	O	O	O	O	O	O
Beer, Ales, Wine Coolers	O	O	O	O	O	O	O	O	O	O	O	O
Hard Liquor (shots, rum, tequila, etc.)	O	O	O	O	O	O	O	O	O	O	O	O
Mixed Alcoholic Drinks (daiquiris, margaritas, etc.)	O	O	O	O	O	O	O	O	O	O	O	O
Wine (red or white)	O	O	O	O	O	O	O	O	O	O	O	O
Meal Replacement Shakes/Protein Drinks (Slimfast, shakes, etc.)	O	O	O	O	O	O	O	O	O	O	O	O
Energy Drinks (Red Bull, Rockstar, Full Throttle, etc.)	O	O	O	O	O	O	O	O	O	O	O	O
Other (list):	O	O	O	O	O	O	O	O	O	O	O	O
Other (list):	O	O	O	O	O	O	O	O	O	O	O	O

Virginia Polytechnic Institute and State University, 2008

Table 1. Validity and Test-Retest Reliability of a Beverage Intake Questionnaire (BEVQ): Comparison to a Four-Day Food Intake Record (FIR) and Results of Two BEVQ Administrations

		Validity[†]			**Reliability**[††]
Beverage Category	**BEVQ1**[a]	**FIR**[a] **(Difference with BEVQ1)**[b]	**Correlations**[c] **(R^2)**	**BEVQ2**[a] **(Difference with BEVQ1)**[b]	**Correlations**[c] **(R^2)**
Water, g	881±51	1010±90 (-129±77)	0.686***	840±53 (41±42)	0.677***
100% Fruit Juice					
g	86±13	55±9 (31±12*)	0.367***	99±15 (-13±13)	0.722***
kcal	51±8	32±5 (19±7**)	0.403***	57±8 (-6±7)	0.754***
Juice Drinks					
g	52±19	70±21 (-18±27)	0.375***	43±11 (9±12)	0.693***
kcal	24±9	27±5 (-2±9)	0.401***	20±5 (4±6)	0.691***
Vegetable Juice					
g	8±4	6±2 (3±3)	0.526***	2±1 (-1±3)	0.451***
kcal	2±1	1±1 (1±1)	0.527***	10±4 (-1±1)	0.451***

Whole Milk					
g	14±6	15±4 (-1±6)	0.353***	15±5 (-1±4)	0.762***
kcal	11±4	16±6 (-6±7)	0.346***	11±4 (-1±3)	0.755***
Reduced Fat Milk					
g	60±16	35±8 (25±15)	0.276**	54±19 (6±13)	0.648***
kcal	36±10	22±8 (15±9)	0.272**	33±12 (3±8)	0.645***
Fat Free Milk					
g	185±29	146±18 (40±24)	0.705***	172±25 (14±24)	0.747***
kcal	70±11	55±7 (15±9)	0.707***	64±10 (5±9)	0.748***
Regular Soft Drinks					
g	69±18	72±16 (-3±13)	0.600***	71±23 (-3±12)	0.733***
kcal	29±8	32±7 (-3±6)	0.616***	32±10 (-3±5)	0.750***
Diet Soft Drinks					
g	120±30	121±25 (-1±16)	0.808***	132±30 (-11±12)	0.838***
kcal	1±1	1±1 (-1±1)	0.810***	1±1 (-1±1)	0.839***

Sweet Tea					
g	92±28	44±17 (48±20*)	0.391***	81±25 (11±11)	0.696***
kcal	29±9	15±6 (15±7*)	0.416***	26±8 (3±3)	0.695***
Sweetened Coffee					
g	98±18	7±4 (91±17***)	0.106	112±21 (-14±10)	0.873***
kcal	27±5	2±1 (25±5***)	0.106	31±6 (-4±3)	0.874***
Regular Coffee/Tea					
g	189±33	284±31 (-95±29**)	0.550***	174±35 (16±28)	0.787***
kcal	3±1	3±1 (-1±1)	0.542***	2±1 (1±1)	0.783***
Light Beer					
g	32±12	15±9 (16±14)	0.437***	33±11 (-1±5)	0.811***
kcal	7±3	3±2 (4±3)	0.441***	7±2 (-1±1)	0.816***
Beer					
g	43±10	115±25 (-72±20**)	0.488***	23±4 (-7±6)	0.729***
kcal	20±4	54±12 (-33±10**)	0.497***	54±12 (-3±3)	0.734***

Liquor					
g	9±3	7±3 (3±2)	0.491***	11±3 (-2±3)	0.789***
kcal	21±6	16±6 (6±4)	0.487***	27±7 (-5±6)	0.787***
Mixed Alcoholic Drinks					
g	8±4	2±2 (6±4)	-0.35	9±4 (-1±1)	0.765***
kcal	11±5	3±3 (8±6)	-0.35	12±6 (-1±2)	0.765***
Wine					
g	31±8	31±9 (1±4)	0.712***	31±9 (-1±3)	0.828***
kcal	22±6	22±7 (1±1)	0.713***	22±6 (-1±2)	0.834***
Meal Replacement Drinks					
g	23±9	9±5 (14±6*)	0.571***	17±7 (6±5)	0.777***
kcal	15±6	6±3 (9±4*)	0.571***	11±4 (4±3)	0.777***
Energy Drinks					
g	16±8	35±10 (-19±9*)	0.420***	12±7 (4±4)	0.265**
kcal	7±4	16±5 (-8±4*)	0.420***	5±3 (2±2)	0.265**

Total Sugar-Sweetened Beverages					
g	357±47	237±38 (119±44**)	0.409***	344±49 (12±19)	0.830***
kcal	143±20	100±15 (44±17*)	0.459***	137±20 (6±8)	0.818***
Total Beverage					
g	2017±94	2077±109 (-61±106)	0.456***	1965±96 (52±69)	0.635***
kcal	387±34	324±26 (63±27*)	0.405***	388±33 (-1±17)	0.739***

[†]Relative Validity was assessed by comparing BEVQ1 with FIR results.

[††]Test-retest Reliability was assessed by comparing BEVQ1 and BEVQ2.

[a]Values expressed as Mean±Standard Error of the Mean (SEM).

[b]Mean differences according to a paired sample *t* test; slight differences may be noted from the preceding columns due to rounding, as whole numbers are presented in the table.

[c]Spearman's correlation.

*P<0.05.

**P<0.01.

***P<0.001.

References

1. Hensrud DD, Klein S. Extreme obesity: a new medical crisis in the United States. *Mayo Clinic Proc.* 2006;81:S5-S10.
2. Ogden C, Carroll M, Curtin L, McDowell M, Tabak C, Flegal K. Prevalence of overweight and obesity in the United States, 1999-2004. *J Am Med Assoc.* 2006;295(295):1549-1555.
3. Hedley A, Ogden C, Johnson C, Carroll M, Curtin L, Flegal K. Prevalence of overweight and obesity among U.S. children, adolescents, and adults, 1999-2002. *J Am Med Assoc.* 2004;291(291):2847-2850.
4. Dennis E, Flack K, Davy BM. Beverage consumption and adult weight management: a review. *Eat Behav.* 2009;10(4):237-246.
5. DiMeglio D, Mattes R. Liquid versus solid carbohydrate: effects on food intake and body weight. *Int J Obes Relat Metab Disord.* 2000;27(27):794.
6. Mattes R. Dietary compensation by humans for supplemental energy provided as ethanol or carbohydrate in fluids. *Physiol Behav.* 1996;59(1):179-187.
7. Almiron-Roig E, Drewnowski A. Hunger, thirst, and energy intakes following consumption of caloric beverages. *Physiol Behav.* 2003;79(4-5):767-773.
8. DellaValle DM, Roe LS, Rolls BJ. Does the consumption of caloric and non-caloric beverages with a meal affect energy intake? *Appetite.* 2005;44(2):187-193.
9. Stookey JD, Constant F, Gardner CD, Popkin BM. Replacing sweetened caloric beverages with drinking water is associated with lower energy intake. *Obesity.* 2007;15(12):3013-3022.

10. Dennis EA, Dengo AL, Comber DL, Flack KD, Savla J, Davy KP, Davy BM. Water consumption increases weight loss during a hypocaloric diet intervention in middle-aged and older adults. *Obesity.* 2009;18(2):300-307.

11. Brownell K, Frieden T. Ounces of prevention: the public policy case for taxes on sugared beverages. *N Engl J Med.* 2009;360(18):1805-1808.

12. Johnson R, Appel L, Brands M, Howard B, Lefevre M, Lustig R, Sacks F, Steffen L, Wylie-Rosett J. Dietary sugars intake and cardiovascular health: a scientific statement from the American Heart Association. *Circulation.* 2009;120(11):1011-1020.

13. Allison DB, Mattes R. Nutritively sweetened beverage consumption and obesity: the need for solid evidence on a fluid issue. *J Am Med Assoc.* 2009;301(301):318-320.

14. Thomson C, Giuliano A, Rock C, Ritenbaugh C, Flatt S, Faerber S, Newman V, Caan B, Graver E, Hartz V, Whitacre R, Parker F, Pierce J, Marshall J. Measuring dietary change in a diet intervention trial: comparing food frequency questionnaire and dietary recalls. *Am J Epidemiol.* 2003;157(157):754-762.

15. Willett W, Lenart E. *Nutritional Epidemiology*. 2nd ed: Oxford University Press; 1998.

16. Block G. A review of validations of dietary assessment methods. *Am J Epidemiol.* 1982(115):492-505.

17. Block G, Woods M, Potosky A, Clifford C. Validation of a self-administered diet history questionnaire using multiple diet records. *J Clin Epidemiol.* 1990;43(12):1327-1335.

18. Cade J, Thompson R, Burley V, Warm D. Development, validation and utilisation of food-frequency questionnaires-a review. *Public Health Nutr.* 2002;5(04):567-587.

19. Cade JE, Burley VJ, Warm DL, Thompson RL, Margetts BM. Food-frequency questionnaires: a review of their design, validation and utilisation. *Nutr Res Rev.* 2004;17(01):5-22.

20. Marshall T, Eichenberger Gilmore J, Broffitt B, Levy S, Stumbo P. Relative validation of a beverage frequency questionnaire in children ages 6 months through 5 years using 3-day food and beverage diaries. *J Am Diet Assoc.* 2003;103(103):714-720.

21. Matthys C, Pynaert I, De Keyzer W, De Henauw S. Validity and reproducibility of an adolescent web-based food frequency questionnaire. *J Am Diet Assoc.* 2007;107(4):605-610.

22. Monsen E. *Research: Successful Approaches*. 2nd ed: American Dietetic Association; 2003.

23. Pennington J, Bowes ADP, Church HN. *Bowes & Church's Food Values of Portions Commonly Used*. 17th ed: Lippincott Williams & Wilkins; 1998.

24. Willett W. Future directions in the development of food-frequency questionnaires. *Am J Clin Nutr.* 1994:171S-174S.

25. Duffey KJ, Popkin BM. Shifts in patterns and consumption of beverages between 1965 and 2002. *Obesity.* 2007;15(11):2739-2747.

26. Popkin BM, Armstrong LE, Bray GM, Caballero B, Frei B, Willett WC. A new proposed guidance system for beverage consumption in the United States. *Am J Clin Nutr.* 2006;83(3):529-542.

27. Block G. Foods contributing to energy intake in the U.S.: data from NHANES III and NHANES 1999-2000. *J of Food Compos Anal.* 2004(17):439-447.

28. Rehm C, Matte T, Van Wye G, Young C, Frieden T. Demographic and behavioral factors associated with daily sugar-sweetened soda consumption in New York City adults. *J Urban Health.* 2008;85(85):375-385.

29. Kant AK, Graubard BI, Atchison EA. Intakes of plain water, moisture in foods and beverages, and total water in the adult U.S. population--nutritional, meal pattern, and body weight correlates: National Health and Nutrition Examination Surveys 1999-2006. *Am J Clin Nutr.* 2009;90(3):655-663.

Chapter 3:

Development of a Brief Questionnaire to Assess Habitual Beverage Intake (BEVQ-15): Sugar-Sweetened Beverages and Total Beverage Energy Intake

Abstract

Energy-containing beverages, specifically sugar-sweetened beverages (SSB), may contribute to weight gain and obesity development. Yet, no rapid assessment tools are available which quantify habitual beverage intake (grams, energy) in adults. The objective of this investigation is to determine the factorial validity of a newly developed beverage intake questionnaire (BEVQ) and identify the potential to reduce items. Participants from varying economic and educational backgrounds (n=1,596; age 43$\pm$12 yrs; BMI 31.5$\pm$0.2 kg/m^2) completed a 19-item BEVQ (BEVQ-19). Beverages that contributed <10% to total beverage, or SSB, energy and grams were identified for potential removal. Factor analyses identified beverage categories that could potentially be combined. Regression analyses compared BEVQ-19 outcomes with the reduced version's (BEVQ-15) variables. Inter-item reliability was assessed using Cronbach's Alpha. Following BEVQ-15 development, a subsequent study (n=70; age 37$\pm$2 yrs; BMI 24.5$\pm$0.4 kg/m^2) evaluated the relative validity of the BEVQ-15 through comparison of three 24-hour dietary recalls' (FIR) beverage intake. Three beverage items were identified for elimination (vegetable juice, meal replacement drinks and mixed alcoholic drinks); beer and light beer were combined into one category. Regression models using BEVQ-15 variables explained 91-99% of variance in the four major outcomes of the BEVQ-19 (all P<0.001). Cronbach's Alpha ranged 0.97-0.99 for all outcomes. In the follow-up study, BEVQ-15 and FIR variables were significantly correlated with the exception of whole milk; BEVQ-15

SSB (R^2=0.69) and total beverage energy (R^2=0.59) were more highly correlated with FIR than previously reported for the BEVQ-19. The BEVQ-15 produced a lower readability score of 4.8, which is appropriate for individuals with a fourth grade education or greater. The BEVQ-19 can be reduced to a 15-item questionnaire. This brief dietary assessment tool will enable researchers and practitioners to rapidly (administration time of ~2 min) assess habitual beverage intake, and to determine possible associations of beverage consumption with health-related outcomes, such as weight status.

Introduction

Consumption of energy-containing beverages, particularly sugar-sweetened beverages (SSB), may lead to weight gain and obesity (1-4). The National Health and Nutrition Examination Survey (NHANES) has not revealed a decline in obesity prevalence when comparing results from 1999-2006 to 2007-2008; 68.3% of all adults (20 years and older) were found to be overweight (Body Mass Index [BMI] 25-29.9 kg/m^2) or obese (BMI $\geq$ 30 kg/m^2) in 2007-2008 (5). Increased body weight and energy intake, along with poor health outcomes such as increased risk of type 2 diabetes, cardiovascular disease and hypertension, have been associated with high intakes of SSB, specifically soft drinks (6-9).

A recent Scientific Statement from the American Heart Association showed that the majority of added sugars (~50%) in American's diets come from SSB (10). Guidelines suggest that no more than one half of discretionary energy, based on the United States Department of Agriculture Food Guide, should be consumed from added sugars (10). This represents an added sugar intake level of no more than 80 calories (kcals) per day for the average female and 150 kcals per day for the average male, depending on energy requirements and physical activity energy expenditure (10).

The 2010 U.S. Dietary Guidelines emphasize obesity prevention, with a recommendation to consume less than 15% of total energy from solid fats and added sugars (which currently comprise approximately 33% of total energy intake) (11,12). It is suggested that SSB be replaced with non-caloric beverages such as water, or healthier alternatives such as milk (9,12). To determine the habitual intake of SSB and other beverages, as well as to evaluate the

effectiveness of clinical and public health interventions which aim to address the Dietary Guidelines and the American Heart Association's SSB recommendations, a valid, reliable and rapidly administered beverage intake assessment tool is needed.

The most common methods to assess dietary intake are food diaries and recalls, which are resource-intensive (e.g., time, cost) for researchers and burdensome for respondents, and they are limited by only providing information on recent dietary intake (13-15). Therefore, it may be difficult to determine habitual intake, as well as changes in food or beverage consumption with these dietary assessment methods. Alternatively, food frequency questionnaires (FFQ) are an acceptable method for assessing habitual dietary intake, without the added costs typically incurred by dietary recalls (16-18). The availability of a brief, self-administered quantitative beverage intake questionnaire could greatly enhance research targeting habitual beverage intake patterns in adults, particularly one that may be used with lower-literacy populations.

The purpose of this investigation is to refine a valid and reliable 19-item beverage intake questionnaire (BEVQ-19) (19) by determining the factorial validity of the BEVQ, evaluating the potential to reduce the length of this tool and reducing the reading level to be suitable across various populations. To our knowledge, only one investigation has focused on the variable reduction of a quantitative dietary questionnaire (20), and no studies have used exploratory factor analysis (EFA) to combine variables for the purpose of reducing the length of a quantitative dietary assessment tool. Exploratory factor analysis has been used in quantitative research to identify common dietary patterns (21), which proves useful for combining dietary variables that share similar nutritional characteristics within a questionnaire. Thus, our objective is to develop

and evaluate a reduced version of the BEVQ-19 that can be used to accurately and rapidly assess habitual beverage intake across a wide variety of adult populations.

Methods

Subjects and Design. One thousand five hundred and ninety six participants aged $\geq$ 18 years completed the BEVQ-19 as part of their baseline assessments in three separate investigations between June 2008-December 2009. The Virginia Tech Institutional Review Board approved the study protocols and all participants provided written informed consent. As part of these investigations, healthy adults underwent objective assessments of height and weight, and BMI was calculated. Information on self-reported gender, age, race/ethnicity, education and income was also collected, and all participants completed the BEVQ-19. All BEVQ were self-administered, without regard for education or income levels. Following development of the reduced BEVQ, adult participants (n=70) were recruited for a subsequent investigation from August-December 2010 to evaluate validity of the shortened tool. Quality assurance included checking data sets for missing data, examining variable ranges for data entry errors, as well as randomly selecting participant data to double check entry accuracy.

Beverage Intake Questionnaire. The BEVQ-19 is a quantitative 19-item FFQ (19), in that it measures frequency of beverage items, as well as amounts consumed; semi-quantitative FFQ only measure frequency of food item intake (22). The frequency of food item consumption, which is the principal determinant of total intake, provides the most accurate picture of overall consumption (16). In contrast, food intake records (FIR) provide only recent dietary intake. The BEVQ-19 estimates habitual mean daily intake of water, total beverages and SSB (kcals, grams

[g] consumed) across 19 beverage categories plus one open-ended section for "other" beverages not listed: water, regular soft drinks, diet soft drinks, juice, juice drinks, vegetable juice, whole milk, reduced fat milk, low fat/skim milk, sweet tea, coffee/tea with cream and/or sugar, black coffee/tea, light beer, regular beer, liquor, mixed alcoholic drinks, wine, meal replacement drinks and energy drinks. The SSB category is comprised of regular soft drinks, juice drinks, sweet tea, coffee/tea with cream and/or sugar, mixed alcoholic drinks, meal replacement drinks and energy drinks. Rationale for developing the current beverage categories has been previously described (19). Respondents are asked to indicate "how often" and "how much" of a beverage they consumed in the past month. Responses for the "how often" category range from "never or less than 1 time per week" up to "3+ times per day"; "how much" ranges from "less than 6 fl oz (¾ cup)" up to "more than 20 fl oz (2 ½ cups)." Beverage intake responses are able to range from 0 fl oz to 60 fl oz (e.g., 3 times per day, 20 fl oz each time) per day. Responses given for the "other beverage" category were scored in the appropriate beverage category at the investigator's discretion.

Development and Evaluation of the Reduced Beverage Intake Questionnaire. The initial step for developing the reduced BEVQ was to first examine cumulative frequencies to identify beverage categories that contributed <10% to total beverage energy and grams, or SSB energy and grams (i.e., not in the top 90% of kcal or gram consumption) from the BEVQ-19 data. To ensure that beverage categories consumed more among certain population segments were not eliminated, age-, gender-, race-, BMI-, education- and income-specific groups were individually assessed to determine if the same beverage categories were consistently contributing <10% to total beverage and SSB energy and grams. Next, EFA were performed on the remaining beverages to see if it

was possible to combine items into categories that were logical from a nutritional perspective (e.g., regular and light beer) and to attest to the stability of the factor structure.

Validity of the reduced BEVQ was evaluated in the follow-up investigation. Participants (n=70) completed the self-administered reduced BEVQ and three 24-hour dietary recalls (FIR) within the same week; FIR consisted of two weekdays and 1 weekend day. Recalls were analyzed using nutritional analysis software (Nutrition Data Systems for Research [NDS-R] 2009, University of Minnesota, Minneapolis, MN). Relative validity was assessed by comparing beverage intake (g, kcal) assessed using the reduced BEVQ with the mean FIR beverage intake for each beverage category.

Data Analysis. Statistical analyses were performed using statistical analysis software (SPSS v. 12.0 for Windows, 2003, SPSS Inc., Chicago, IL). Descriptive statistics (mean$\pm$standard error of the mean [SEM]) are reported for demographic characteristics and mean total consumption of beverages and beverage categories (g, kcal). To identify beverage categories for potential removal from the BEVQ-19, first descending cumulative frequencies were used to determine the consumption level of each beverage category (e.g., percent of beverage kcals and grams). Next, a random half of the sample was used to conduct factor analyses to further refine the instrument by determining if beverage categories could be combined. Factor analyses were also used to provide evidence of a stable factor structure. The second half of the sample was used to cross-validate these findings. Lastly, independent sample *t* tests were used to assess the relative validity of the reduced BEVQ as compared to the BEVQ-19 outcomes (mean daily total beverage energy and grams, and mean daily SSB energy and grams). To perform this two-group

comparison, data from 50% (randomly selected) of the sample using the reduced BEVQ was compared to outcomes in the remaining 50% of the sample using the BEVQ-19 data. Dividing the sample into halves creates variability and non-dependence in the data, versus comparing each participant's original consumption to the newly calculated reduced consumption (23) Stepwise multiple linear regression was used to examine the model fit and percent of variance explained by the reduced BEVQ compared to the BEVQ-19. Reliability analyses for differences among the reduced BEVQ and BEVQ-19 outcomes were assessed using Cronbach's Alpha to evaluate internal consistency/inter-item reliability, and Pearson's correlations to assess test-retest reliability.

To assess the relative validity of the reduced BEVQ in the follow-up investigation, paired sample *t* tests were used to compare the energy and g consumed of specific beverages determined by the reduced BEVQ with the mean FIR beverage intake for each beverage category. Associations among beverage intake variables determined by the two intake assessment tools were evaluated using correlational analyses (Spearman's R^2). The alpha level was set *a priori* at $P \leq 0.05$.

Results

Demographics. Participants with complete BEVQ-19 data were included (n=1,596) in the analysis to develop the reduced BEVQ. The percentage of unreported data for the following demographic characteristics was as follows: gender, 2% of the sample; race/ethnicity, 2%; education, 2%; income, 9%; age, 3%; BMI, 0.5%. Participants were primarily female (75% of sample) and Caucasian (65%) from varying economic and educational backgrounds (Table 2).

Age ranged 18-93 yrs (mean 43±12 yrs) and BMI ranged 16-63 kg/m^2 (mean 31.5±0.2 kg/m^2). A large percentage of the sample was overweight/obese (84%), which may be attributed to much of the sample being recruited from rural health-disparate areas (24), and among individuals interested in weight management interventions.

Identification of "Low Consumption" Beverage Categories. Using descending cumulative frequencies for the four beverage outcomes (total and SSB energy and grams), four beverage categories consistently contributed <10% to total energy and grams and were thus identified for potential removal: energy drinks, vegetable juice, mixed alcoholic drinks and meal replacement drinks. Only beverage categories which contributed <10% to *both* total energy and total grams were considered for deletion. Upon further investigation of consumption patterns across specific demographic groups (age, gender, race, BMI, education and income) energy drinks were within the top 90% of consumed beverages for adults ≤35 years old. It is also possible that energy drinks were underreported in the initial validation and reliability assessment (19), as the phrase "sport drinks" was not included as an example in the energy drinks category. Therefore, the energy drink category was not removed from the reduced BEVQ. The remaining three "low consumption" beverage categories were removed (vegetable juice, mixed alcoholic drinks and meal replacement drinks) in the reduced version of the BEVQ.

Factor Analysis. Using EFA and the remaining 16 beverage categories, scree plots revealed six factors with eigenvalues ≥1 for both total energy and grams. Using principal axis factoring (PAF) as the extraction method, the Varimax-rotated 6-factor solution extracted one possible factor that could be combined into one category: beer and light beer (Table 3). Factor loadings

for beer (g, kcal=0.846, 0.854) and light beer (g, kcal=0.620, 0.613) were acceptable, e.g., $\geq$0.3 (25). Beverages with absolute factor loadings of <0.3 were suppressed and not reported. The six factors for total energy explained 60% of variance, and the six total gram factors explained 51% of variance, which is comparable to other validation studies using EFA (26-28). As a result of the removal of consistent "low consumption" beverage categories and the EFA, the 15-item BEVQ (BEVQ-15) was produced (Figure 2). The EFA was conducted on a randomly selected 50% of the sample and cross-validated on the other half of the sample.

To evaluate the model fit in the successive reduction of the BEVQ-19 to the BEVQ-15, multiple linear regression models were utilized. The values presented represent the results of the EFA and are correlations of four different models with each of the four primary BEVQ-19 outcomes. Model 1 compares the BEVQ-19 to a questionnaire with the beer and light beer categories combined into one category (total beverage g, kcal R^2=1.00, R^2=0.999, respectively; P<0.01). Model 2 represents the omission of the vegetable juice category from the BEVQ (with beer categories combined) (total beverage g, kcal R^2=0.995, R^2=0.998, respectively; P<0.001). No results are available for SSB in the first and second models due to beer, light beer and vegetable juice not impacting SSB energy or gram outcomes (i.e., none of these beverage categories are SSB). Model 3 has the beer and light beer categories combined, and omits vegetable juice and mixed alcoholic drinks (total beverage g, kcal R^2=0.994, R^2=0.981; SSB g, kcal R^2=0.996, R^2=0.955, respectively; all P<0.001); Model 4 has vegetable juice, mixed alcoholic drinks and meal replacement drinks omitted, as well as beer and light beer categories combined, to give the BEVQ-15 (total beverage g, kcal R^2=0.988, R^2=0.964; SSB g, kcal R^2=0.978, R^2=0.912, respectively; all P<0.001). Trivial reductions in R^2 values were noted with

each successive reduction of the BEVQ variables, and all correlations of the BEVQ-15 with the original BEVQ-19 outcomes were significant (Model 4).

Assessment of Reliability and Internal Consistency. Test-retest Pearson bivariate correlations between the BEVQ-19 and BEVQ-15 outcomes were significant between total beverage g and kcal (R^2=0.99 and 0.98, respectively; $P \leq 0.01$) and SSB g and kcal (R^2=0.99 and 0.96, respectively; $P \leq 0.01$). Absolute differences in outcomes between the 19- and 15-item BEVQ were minimal (total beverage intake, 39 g and 26 kcal; SSB intake, 24 g and 22 kcal).

Internal consistency for the BEVQ-15 was assessed by Cronbach's Alpha (29). All beverage outcomes were acceptable (e.g., ≥ 0.7) (30) as follows: total beverage intake (g, kcal=0.997, 0.991), SSB intake (g, kcal=0.994, 0.977).

Validity Testing. To evaluate the relative validity of the reduced version of the BEVQ (BEVQ-15), major outcomes were first compared with the full version (BEVQ-19). There were no significant differences between total beverage grams and SSB grams for the BEVQ-19 and BEVQ-15 (mean differences, 38 ± 49 g and 27 ± 29 g, respectively, $P>0.05$) (Figure 3a). There was no significant difference in total beverage energy between the BEVQ-19 and BEVQ-15 (mean difference, 28 ± 19 kcal, $P>0.05$), but there was a significant difference, although minimal, between the BEVQ-19 and BEVQ-15 SSB energy (mean difference, 27 ± 12 kcal, P=0.026) (Figure 3b).

Evaluation of Successive Reduction. Participants in the follow-up investigation to assess the relative validity of the BEVQ-15 were primarily younger adults (mean age 37±2 yrs) with a mean BMI of 24.5±0.4 kg/m^2. The sample was 60% female and 79% Caucasian. As presented in Table 4, responses between the BEVQ-15 and FIR were not significantly different for beverage intake (g) excluding 100% fruit juice, reduced fat milk, fat free milk and black coffee/tea (all < 58 g difference). Absolute differences in beverage energy between assessment tools were < 36 kcal across all categories, although this difference was significant for 100% fruit juice, reduced fat milk, fat free milk and black coffee/tea. Of the 17 beverage variables assessed (grams and energy for 15 individual beverage categories, plus SSB and total beverages), responses using the two assessment tools (BEVQ-15, FIR) were significantly correlated, with the exception of whole milk. The highest correlations were found (in descending order) between beer, diet soft drinks, wine, regular coffee/tea and total SSB (range: R^2=0.76-0.69, P<0.001).

Readability and Administration Time. Using the Flesch-Kinkaid method (31) a readability score of 4.8 was produced, which indicates the BEVQ-15 is appropriate for individuals with a fourth grade education or greater. The original 19-item BEVQ produced a higher score of 6.9. During pilot testing of the BEVQ-15, average administration time was determined to be 2 min 15 sec (range: 40 sec – 4 min 26 sec). The BEVQ-19 took an average of 3 min 30 sec to complete (19).

Discussion

To examine the validity and reproducibility of a 15-item reduced version of a newly developed beverage intake questionnaire, four major beverage intake outcomes (mean daily beverage energy and grams, mean daily SSB energy and grams) were compared between the

BEVQ-19, BEVQ-15 and FIR. Using multiple statistical procedures to assess the validity and reliability of the BEVQ-15, it was determined that the reduced tool possesses the ability to provide accurate and reliable information comparable to that of the full-length version (BEVQ-19). In addition, the new tool offers the advantages of a lower reading level, and a more rapid administration time. The lower reading level and shorter administration time of the BEVQ-15 is significant when assessing the habitual beverage intake of low-literacy populations, who may be at an increased risk for health disparities and poor dietary intake patterns (32).

In the initial validity and reliability study (19), which compared BEVQ-19 to FIR outcomes, mean differences between total beverage and SSB energy and SSB grams were significantly different. However, in this examination of the BEVQ-15 and FIR (Table 4), SSB and total beverage energy were not significantly different, and correlations between the two tools were higher for these variables (R^2~0.6-0.7) than that previously reported for the longer-length BEVQ. Correlations of the BEVQ-15 major outcomes with FIR outcomes were significant, with the exception of whole milk. The multiple linear regression models suggest minimal differences in outcomes of the BEVQ-15 as compared to the BEVQ-19.

Several modifications were made to the instructions based on participant feedback from a previous study utilizing the BEVQ-19 (19); modifications included adding instructions to 1) not record beverages used in cooking or other preparations, and to 2) count milk added to tea and coffee in the "tea/coffee with cream" beverage category, not in the milk categories. Additionally, the phrase "sports drinks" was added to the "energy drinks" category, and every other beverage category was shaded to improve response accuracy. Also, fluid ounces and cups

were both listed for the "how much" category to provide multiple measuring methods. Although three beverage categories have been removed (vegetable juice, mixed alcoholic drinks and meal replacement drinks), respondents still have use of the "other beverage" category to record consumption of such beverages. Researchers and health professionals can score these individual items in the appropriate category at their discretion using published food composition tables (19).

Dietary Patterns. Upon further investigation of the newly created factors from the EFA, several dietary patterns, beyond the association of the beer and light beer categories, emerged: intake of water was negatively associated with regular soft drink intake (g); regular soft drinks, juice drinks and energy drinks (kcal) were all positively associated; and juice and whole milk intake (kcal) demonstrated high positive factor loadings (Table 3). However, these patterns did not provide information on beverage categories which could be logically combined, from a nutritional perspective. According to the 2010 U.S. Dietary Guidelines (11), 36% of added sugar intake comes from regular soft drinks, energy and sports drinks; combined with the negative association of water intake to soft drink intake displayed by the BEVQ-15, it is likely water intake is being replaced by SSB in many American's diets. The BEVQ-15 may be a useful tool for determining adherence to the 2010 U.S. Dietary Guidelines and American Heart Association recommendations for SSB intake, and potentially for evaluating interventions which target changes in beverage intake patterns.

Strengths and Limitations. The ability to accurately assess the validity and reliability of a dietary questionnaire relies on having a large sample size (15) and utilizing multiple statistical methods, which has been achieved in this investigation. An important component of relative validity

testing is comparing results of a questionnaire to a "gold standard," in this case the FIR (15,22), which was conducted following development of the reduced-length BEVQ.

The BEVQ is a quantitative questionnaire which bases its dietary outcomes on actual self-reported amounts (fluid ounces) of beverages. In comparison, semi-quantitative questionnaires only report the frequency of items consumed, often based on standard serving sizes. Quantitative questionnaires may provide more accurate outcomes because respondents are able to choose actual amounts consumed versus a standard portion size (22). Therefore, the BEVQ-15 is able to produce information on amounts (grams, kcal) consumed for individual beverage categories, as well as SSB and total beverages. Researchers and practitioners can quickly score the BEVQ-15, and provide immediate feedback regarding an individual's habitual beverage intake. This may be useful for comparing SSB intake to the recommended added sugar intake guidelines put forth by the American Heart Association (10). The consumption of added sugars, specifically SSB, has been associated with greater energy intake, higher body weight, lower intake of essential nutrients, hypertension and dyslipidemia (6,10,33). Thus, the ability to rapidly identify individuals with excessive SSB consumption, who may be at increased risk for these health conditions, may be of great clinical significance.

Although this examination possesses several important strengths, it is not without some limitations that should be acknowledged. First, the initial data set contained a high percentage of women (75%); however, the follow-up study comparing the BEVQ-15 to FIR had a lower proportion of women to men (60 and 40%, respectively). Second, future work is necessary to assess the ability to detect changes in beverage intake with the BEVQ-15, in order to determine if this tool could be used for dietary interventions which aim to reduce beverage energy or SSB

intake. Finally, as with any self-reported dietary intake assessment, the data is subjective (FIR, BEVQ), and accurate comparisons of the BEVQ to the FIR depends on the participant's recollection of their habitual beverage consumption (22). Future validation studies should include objective measures of dietary intake, for example biomarkers of SSB intake (34).

Conclusion

The 15-item BEVQ demonstrates acceptable validity and reliability as compared to the original 19-item BEVQ. Thus, the BEVQ-19 can be reduced to a shortened 15-item questionnaire, which is capable of examining the habitual beverage intake of adults including those with lower literacy levels. The validity and reliability of the BEVQ-15 makes it useful for large-scale investigations, as well as for use by practitioners. This low-resource tool will enable researchers and practitioners to rapidly assess beverage intake, and to determine possible associations of beverage consumption with health-related outcomes, such as weight status. Future work is necessary to evaluate the ability of the BEVQ-15 to detect changes in beverage intake.

Figure 2: The Brief 15-Item Beverage Intake Questionnaire (BEVQ-15)

Beverage Questionnaire (BEVQ-15)

Instructions:
In the past month, please indicate your response for each beverage type by marking an "X" in the bubble for "how often" and "how much each time".

Participant ID _____

Date _____

1. Indicate how often you drank the following beverages, for example, if you drank 5 glasses of water per week, mark 4-6 times per week.
2. Indicate the approximate amount of beverage you drank each time, for example, if you drank 1 cup of water each time, mark 1 cup under "how much each time".
3. Do not count beverages used in cooking or other preparations, such as milk in cereal.
4. Count milk added to tea and coffee in the *tea/coffee with cream beverage category* **NOT** in the milk categories.

	HOW OFTEN (MARK ONE)							HOW MUCH EACH TIME (MARK ONE)				
Type of Beverage	**Never or less than 1 time per week (go to next beverage)**	**1 time per week**	**2-3 times per week**	**4-6 times per week**	**1 time per day**	**2+ times per day**	**3+ times per day**	**Less than 6 fl oz (3/4 cup)**	**8 fl oz (1 cup)**	**12 fl oz (1 1/2 cups)**	**16 fl oz (2 cups)**	**More than 20 fl oz (2 1/2 cups)**
Water	o	o	o	o	o	o	o	o	o	o	o	o
100% Fruit Juice	o	o	o	o	o	o	o	o	o	o	o	o
Sweetened Juice Beverage/ Drink (fruit ades, lemonade, punch, Sunny Delight)	o	o	o	o	o	o	o	o	o	o	o	o
Whole Milk	o	o	o	o	o	o	o	o	o	o	o	o
Reduced Fat Milk (2%)	o	o	o	o	o	o	o	o	o	o	o	o
Low Fat/Fat Free Milk (Skim, 1%, Buttermilk, Soymilk)	o	o	o	o	o	o	o	o	o	o	o	o
Soft Drinks, Regular	o	o	o	o	o	o	o	o	o	o	o	o
Diet Soft Drinks/Artificially Sweetened Drinks (Crystal Light)	o	o	o	o	o	o	o	o	o	o	o	o
Sweetened Tea	o	o	o	o	o	o	o	o	o	o	o	o
Tea or Coffee, with cream and/or sugar (includes non-dairy creamer)	o	o	o	o	o	o	o	o	o	o	o	o
Tea or Coffee, black, with/ without artificial sweetener (no cream or sugar)	o	o	o	o	o	o	o	o	o	o	o	o
Beer, Ales, Wine Coolers, Non-alcoholic or Light Beer	o	o	o	o	o	o	o	o	o	o	o	o
Hard Liquor (shots, rum, tequila, etc.)	o	o	o	o	o	o	o	o	o	o	o	o
Wine (red or white)	o	o	o	o	o	o	o	o	o	o	o	o
Energy & Sports Drinks (Red Bull, Rockstar, Gatorade, Powerade, etc.)	o	o	o	o	o	o	o	o	o	o	o	o
Other (list):	o	o	o	o	o	o	o	o	o	o	o	o

Figure 3a: Comparison of BEVQ-19 and BEVQ-15: Total Beverage and Sugar-Sweetened Beverage (SSB) Grams

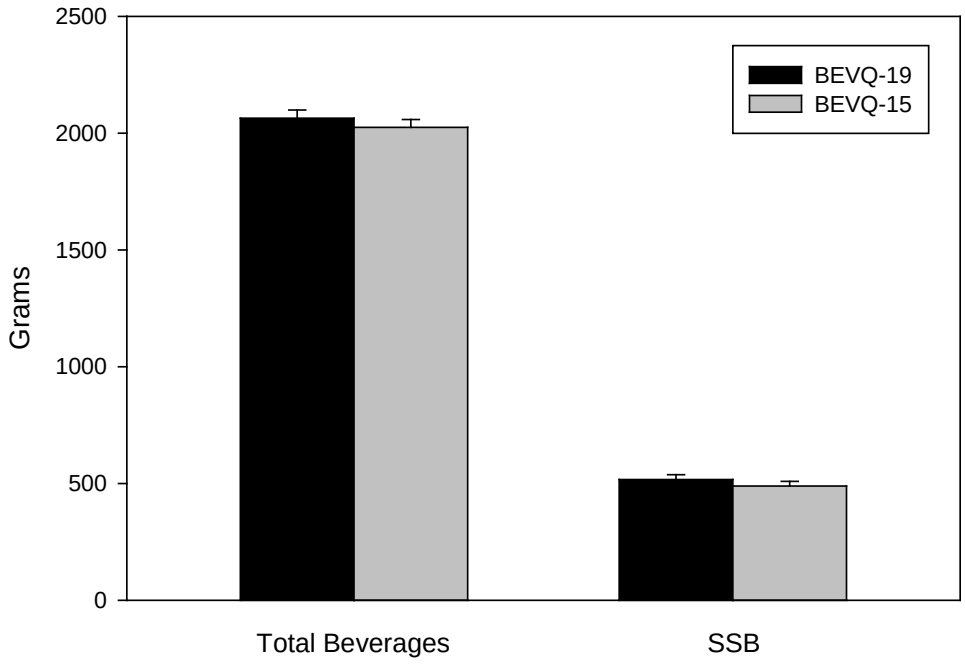
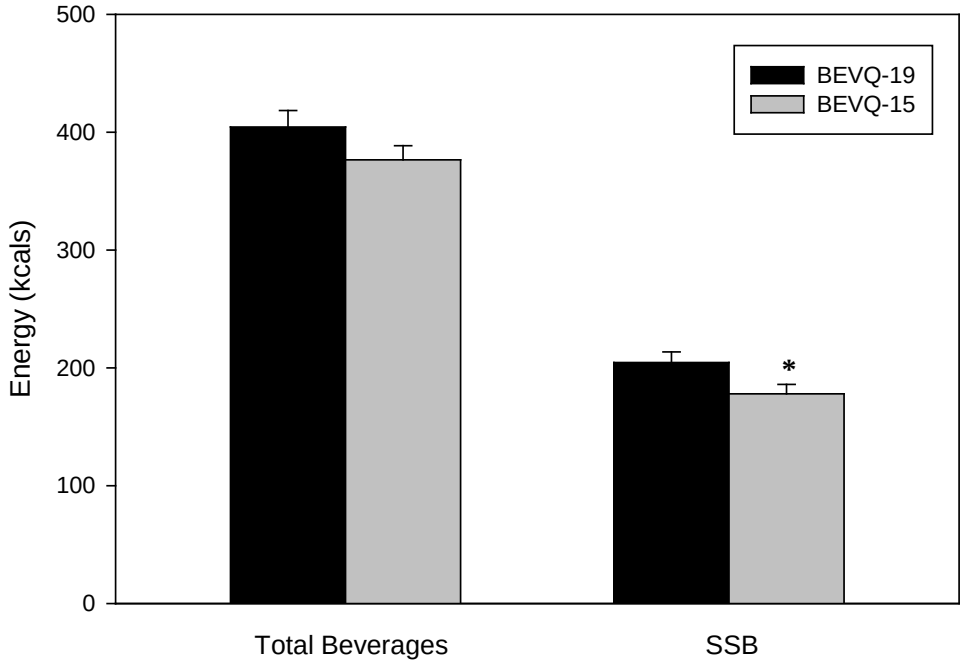


Figure 3b: Comparison of BEVQ-19 and BEVQ-15: Total Beverage and Sugar-Sweetened Beverage (SSB) Energy



*Significantly different from BEVQ-19 (P=0.026).

Table 2. Participant Demographic Characteristics: Development of a Brief Beverage Intake Questionnaire

Total number of participants, n*	1,596
Male, n (%)	365 (23)
Female, n (%)	1,195 (75)
Age, n (%)	
18-39 y	625 (39)
40-59 y	818 (51)
≥60 y	116 (7)
Mean Age, yrs**	43±12
Race/Ethnicity, n (%)	
Caucasian	1,039 (65)
African American	338 (21)
American Indian/Alaskan Native	83 (5)
Hispanic	52 (3)
Asian	23 (1)
Other	31 (2)
BMI Status, n (%)	
Underweight (<18.5 kg/m^2)	7 (1)
Normal Weight (18.5-24.9 kg/m^2)	235 (15)
Overweight (25-29.9 kg/m^2)	515 (32)
Obese (≥30 kg/m^2)	828 (52)
Mean BMI (kg/m^2)**	31.5±0.2

Education Level, n (%)	
Did not complete high school	62 (4)
High school graduate	221 (14)
Some college	466 (29)
College graduate	481 (30)
Post college work	334 (21)
Household Income Level, n (%)	
≤ $14,999	78 (5)
$15,000 - $29,999	170 (11)
$30,000 - $49,999	317 (20)
$50,000 - $99,999	537 (34)
≥$100,000	356 (22)

*Slight differences from the total may be due to non-reported data.

**Values are expressed as Mean ± Standard Error of the Mean (SEM).

Table 3. Exploratory Factor Analysis: Mean Daily Total Beverage Grams and Energy

Mean Daily Total Beverage Grams						
Beverage Category*	Factors					
	1	2	3	4	5	6
Beer, g	0.846					
Light Beer, g	0.620					
Juice, g		0.688				
Juice Drinks, g		0.439				
Whole Milk, g		0.348				
Energy Drinks, g			0.632			
Regular Soft Drinks, g				0.495		
Water, g				-0.391		
Sweetened Coffee, g					0.466	
Sweet Tea, g						0.400
Mean Daily Total Beverage Energy						
Beverage Category	Factors					
	1	2	3	4	5	6
Beer, kcal	0.854					
Light Beer, kcal	0.613					
Juice, kcal		0.773				
Whole Milk, kcal		0.310				
Energy Drinks, kcal			0.473			
Juice Drinks, kcal		0.320	0.466			
Regular Soft Drinks, kcal			0.371			
Fat Free Milk, kcal				-0.403		
Sweetened Coffee, kcal					0.422	
Sweet Tea, kcal						0.381

*Beverage categories with factor loadings <0.3 were suppressed.

Table 4. Validity of a Reduced Beverage Intake Questionnaire (BEVQ-15): Comparison of BEVQ-15 with Mean Beverage Intake from Three 24-Hour Food Intake Recalls (FIR)

Beverage Category	**BEVQ-15[a]**	**FIR[a] (Difference from BEVQ-15)[b]**	**Correlations[c] (R^2)**
Water, g	722±51	781±60 (-59±58)	0.469***
100% Fruit Juice			
g	90±14	55±12 (35±16*)	0.415***
kcal	51±8	31±7 (20±9*)	0.415***
Juice Drinks			
g	39±12	55±13 (-16±18)	0.270*
kcal	18±6	26±6 (-8±8)	0.269*
Whole Milk			
g	23±11	6±4 (17±11)	0.129
kcal	17±8	4±3 (13±9)	0.129
Reduced Fat Milk			
g	45±12	16±6 (28±11*)	0.267*
kcal	27±7	10±4 (17±7*)	0.267*
Fat Free Milk			
g	76±16	44±13 (32±14*)	0.305**
kcal	28±6	17±5 (12±5*)	0.305**
Regular Soft Drinks			
g	63±19	81±20 (-18±14)	0.585***
kcal	27±8	36±9 (-8±6)	0.589***

Diet Soft Drinks			
g	137±33	143±38 (-7±30)	0.759***
kcal	3±2	1±1 (2±2)	0.713***
Sweet Tea			
g	86±35	79±32 (7±33)	0.394***
kcal	28±11	25±10 (2±11)	0.394***
Sweetened Coffee			
g	157±28	137±24 (20±23)	0.653***
kcal	42±7	38±7 (4±6)	0.646***
Regular Coffee/Tea			
g	107±25	165±33 (-58±22**)	0.695***
kcal	1±1	2±1 (-1±1**)	0.695***
Beer			
g	89±17	194±68 (-105±58)	0.758***
kcal	31±6	67±24 (-36±20)	0.758***
Liquor			
g	18±5	14±5 (4±5)	0.522***
kcal	43±11	34±11 (8±12)	0.522***
Wine			
g	27±7	34±8 (-7±5)	0.746***
kcal	19±5	24±6 (-5±4)	0.746***

Energy Drinks			
g	41±13	40±17 (1±13)	0.598***
kcal	18±6	18±8 (1±6)	0.599***
Total Sugar-Sweetened Beverages			
g	382±56	392±46 (-10±46)	0.673***
kcal	135±21	143±17 (8±17)	0.688***
Total Beverage			
g	1688±106	1847±107 (-159±85)	0.510***
kcal	350±39	335±39 (15±26)	0.558***

[a]Values expressed as Mean±Standard Error of the Mean (SEM).

[b]Mean differences according to a paired sample *t* test; slight differences may be noted from the preceding columns due to rounding, as whole numbers are presented in the table.

[c]Spearman's correlation.

*P<0.05.

**P<0.01.

***P<0.001.

References

1. Almiron-Roig E, Drewnowski A. Hunger, thirst, and energy intakes following consumption of caloric beverages. *Physiol Behav.* 2003;79(4-5):767-773.
2. DellaValle DM, Roe LS, Rolls BJ. Does the consumption of caloric and non-caloric beverages with a meal affect energy intake? *Appetite.* 2005;44(2):187-193.
3. DiMeglio D, Mattes R. Liquid versus solid carbohydrate: effects on food intake and body weight. *Int J Obes.* 2000;24(6):794-800.
4. Mattes R. Dietary compensation by humans for supplemental energy provided as ethanol or carbohydrate in fluids. *Physiol Behav.* 1996;59(1):179-187.
5. Flegal K, Carroll M, Ogden C, Curtin L. Prevalence and trends in obesity among U.S. adults, 1999-2008. *J Am Med Assoc.* 2010;303(3):235-241.
6. Vartanian L, Schwartz M, Brownell K. Effects of soft drink consumption on nutrition and health: a systematic review and meta-analysis. *Am J Public Health.* 2007;97(4):667-675.
7. Brown I, Stamler J, Van Horn L, Robertson C, Chan Q, Dyer A, Huang C, Rodriguez B, Zhao L, Daviglus M, Ueshima H, Elliott P. Sugar-sweetened beverage, sugar intake of individuals, and their blood pressure: international study of macro/micronutrients and blood pressure. *Hypertension.* 2011;57(4):695-701.
8. de Koning L, Malik VS, Rimm EB, Willett WC, Hu FB. Sugar-sweetened and artificially sweetened beverage consumption and risk of type 2 diabetes in men. *Am J Clin Nutr.* 2011;93(6):1321-1327.
9. Malik V, Popkin B, Bray G, Despres J, Hu F. Sugar-sweetened beverages, obesity, type 2 diabetes mellitus, and cardiovascular disease risk. *Circulation.* 2010;121:1356-1364.

10. Johnson R, Appel L, Brands M, Howard B, Lefevre M, Lustig R, Sacks F, Steffen L, Wylie-Rosett J. Dietary sugars intake and cardiovascular health: a scientific statement from the American Heart Association. *Circulation.* 2009;120(11):1011-1020.

11. U.S. Department of Health and Human Services, and U.S. Department of Agriculture (HHS, USDA). Dietary Guidelines for Americans, 7th Edition. Washington, DC: U.S. Government Printing Office; 2010.

12. Van Horn L. Development of the 2010 U.S. dietary guidelines advisory committee report: perspectives from a registered dietitian. *J Am Diet Assoc.* 2010;110(11):1638-1645.

13. Marshall T, Eichenberger Gilmore J, Broffitt B, Levy S, Stumbo P. Relative validation of a beverage frequency questionnaire in children ages 6 months through 5 years using 3-day food and beverage diaries. *J Am Diet Assoc.* 2003;103(6):714-720.

14. Thomson C, Giuliano A, Rock C, Ritenbaugh C, Flatt S, Faerber S, Newman V, Caan B, Graver E, Hartz V, Whitacre R, Parker F, Pierce J, Marshall J. Measuring dietary change in a diet intervention trial: comparing food frequency questionnaire and dietary recalls. *Am J Epidemiol.* 2003;157(8):754-762.

15. Willett W, Lenart E. *Nutritional Epidemiology*. 2nd ed: Oxford University Press; 1998.

16. Heady J. Diets of bank clerks: development of a method of classifying the diets of individuals for use in epidemiologic studies. *J R Stat Soc.* 1961;124:336-361.

17. Kristal A, Beresford S, Lazovich D. Assessing change in diet-intervention research. *Am J Clin Nutr.* 1994;59(1 Suppl):185S-189S.

18. Willett W. Future directions in the development of food-frequency questionnaires. *Am J Clin Nutr.* 1994:171S-174S.

19. Hedrick V, Comber D, Estabrooks P, Savla J, Davy B. The beverage intake questionnaire: initial validity and reliability. *J Am Diet Assoc.* 2010;110:1227-1232.

20. Block G, Hartman A, Naughton D. A reduced dietary questionnaire: development and validation. *Epidemiology.* 1990;1(1):58-64.

21. Schulze M, Hoffmann K, Kroke A, Boeing H. An approach to construct simplified measures of dietary patterns from exploratory factor analysis. *Br J Nutr.* 2003;89(3):409-419.

22. Monsen E. *Research: Successful Approaches*. 2nd ed: American Dietetic Association; 2003.

23. Kenny D, Judd C. Consequences of violating the independence assumption in analysis of variance. *Psychol Bull.* 1986;99:422-431.

24. U.S. Department of Health and Human Services, Office of Disease Prevention and Health Promotion. Healthy People 2020: About Healthy People. Accessed July 5, 2011.

25. Pedhazur E, Pedhazur-Schmelkin L. *Measurement, Design, and Analysis: An Integrated Approach*. New York, New York: Psychology Press; 1991.

26. Arnow B, Kenardy J, Agras W. The emotional eating scale: the development of a measure to assess coping with negative affect by eating. *Int J Eat Disord.* 1995;18(1):79-90.

27. Folkman S, Lazarus R, Dunkel-Schetter C, DeLongis A, Gruen R. Dynamics of a stressful encounter: cognitive appraisal, coping, and encounter outcomes. *J Pers Soc Psychol.* 1986;50(5):992-1003.

28. Ozier A, Kendrick O, Knol L, Leeper J, Perko M, Burnham J. The eating and appraisal due to emotions and stress (EADES) questionnaire: development and validation. *J Am Diet Assoc.* 2007;107(4):619-628.

29. Cronbach L. Coefficient alpha and the internal structure of tests. *Psychometrika.* 1951(16):297-334.

30. Nunnally J, Bernstein I. *Psychometric Theory*. 3rd ed. New York, New York: McGraw-Hill; 1994.

31. Flesch R. A new readability yardstick. *J Appl Psychol.* 1948;32(3):221-233.

32. Kant A, Graubard B. Secular trends in the association of socio-economic position with self-reported dietary attributes and biomarkers in the U.S. population: National Health and Nutrition Examination Survey (NHANES) 1971-1975 to NHANES 1999-2002. *Public Health Nutr.* 2007;10(2):158-167.

33. Welsh J, Sharma A, Abramson J, Vaccarino V, Gillespie C, Vos M. Caloric sweetener consumption and dyslipidemia among U.S. adults. *J Am Med Assoc.* 2010;303(15):1490-1497.

34. Davy BM, Jahren AH, Hedrick VE, Comber DL. Association of $\delta^{13}C$ in fingerstick blood with added-sugar and sugar-sweetened beverage intake. *J Am Diet Assoc.* 2011;111(6):874-878.

Chapter 4:

A Rapid Beverage Intake Questionnaire Can Detect Changes in Beverage Intake

Abstract

Attention on beverage intake, specifically sugar-sweetened beverages (SSB), has increased in recent years. Energy-containing beverages do not provide the same satiety as solid foods, and intake of solid food is not spontaneously reduced when energy-containing beverages are consumed. This may contribute to positive energy balance. Conversely, a reduction in energy intake occurs by replacing SSB with water and may facilitate weight loss. A valid, reliable and sensitive assessment tool for quantifying beverage consumption and determining its influence on weight status could help to advance research on this topic. The valid and reliable beverage questionnaire (BEVQ-15) estimates mean daily intake of water, SSB and total beverages (g, kcal) across multiple beverage categories. The objective of this investigation is to determine the ability of the BEVQ-15 to detect changes in beverage intake over time. Participants (n=70; age=37$\pm$2 yrs; BMI=24.5$\pm$0.4 kg/m^2) underwent two, randomly assigned, 30-day periods (Intervention, increased water and fruit juice consumption; Control, increased solid fruit consumption), with a 30-day washout phase between feeding periods. The BEVQ-15 was administered at the beginning and end of each period. Reliability was assessed by Pearson's correlations, paired sample *t* tests and Cronbach's Alpha. Paired sample *t* tests and repeated measures ANOVA were used to evaluate sensitivity to change. Sixty-nine participants from varying economic backgrounds completed all study sessions. Reliability was acceptable for all beverages (range: R^2=0.52-0.95, P<0.001), other than energy drinks. Increases in water (g), juice (kcal, g) and total beverage (g) were detected during the intervention period (P<0.001); no

changes were detected in the control period. The BEVQ-15 demonstrates the ability to detect changes in beverage intake over time. This brief (~ 2 min), self-administered, valid, reliable and sensitive beverage intake assessment tool may be used by researchers and practitioners who evaluate and intervene upon beverage intake patterns in adults.

Introduction

Obesity has become a major public health issue in the United States (U.S.), with 68.3% of adults (20 years and older) overweight (Body Mass Index [BMI] 25-29.9 kg/m^2) or obese (BMI $\geq$ 30 kg/m^2) (1). A BMI > 25 is associated with health conditions such as hypertension, diabetes, cardiovascular disease, some forms of cancer, sleep apnea and overall mortality (2). Increased body weight, as well as an increased risk of type 2 diabetes, cardiovascular disease and hypertension, has been associated with sugar-sweetened beverage (SSB) intake, specifically soft drinks (3-6). Attention has been directed at intake of energy (calorie) containing beverages and developing strategies to facilitate weight loss through changes in beverage intake (7).

A shift in beverage intake pattern has occurred over the last 40 years that may have, in part, contributed to rising obesity rates (8). Total daily energy consumed from beverages has increased from 11.8% (1965) to 21.0% (2002) (8). Per person, this increase equates to 222 calories (kcal) per day (e.g., potentially a weight gain of 23 pounds per year if solid food energy intake is not equally decreased). Average daily energy intake from beverages is approximately 458 kcals per person. Water remains the most consumed beverage in the U.S., followed by coffee, soda, whole-fat milk, fruit juices and alcohol (8). However, according to a recent Scientific Statement from the American Heart Association, the majority of added sugars in American's diets (~50%) come from SSB, such as regular soft drinks, fruit drinks, sweet tea and energy drinks (9). A major pattern that has emerged with increased consumption of SSB is decreased milk consumption, attributed to both increased SSB portion size and more servings per day of SSB, and a reduction of portion size and servings of milk (10). This pattern leads to increased energy intake with minimal nutritional value. Furthermore, Block (11) reported that

energy-containing soda is the number one contributor to total daily energy (from all food and beverages) at 7.1%; while beer provided the second highest amount of total daily energy from all food and beverages at 2.6%.

Because energy-containing beverages may not provide the same satiety value as solid foods, intake of solid food is not spontaneously reduced when energy-containing beverages are consumed (12,13), regardless of nutrient composition (low fat milk, soda or juice) (14,15). Thus, consumption of energy-containing beverages may increase total daily energy intake (7). In contrast, a reduction in self-reported energy intake has been demonstrated by replacing SSB with water (16), and with increasing water intake (17). Therefore, it appears that high intakes of SSB increase energy intake and may contribute to positive energy balance, while replacing energy-containing beverages with water may reduce energy intake and facilitate weight loss. The 2010 U.S. Dietary Guidelines, which highlights the importance of obesity prevention, recommends decreasing the consumption of solid fats and added sugars from a current intake of 33% to less than 15% of total energy intake (18,19). To achieve this goal, it is advised that SSB be replaced with non-caloric beverages such as water or healthier alternatives such as milk (5,19). A valid, reliable and rapidly administered beverage intake assessment tool, which is capable of determining the sensitivity to change of habitual beverage consumption, is needed to determine the effectiveness of clinical and public health interventions targeting the SSB recommendations set forth by the U.S. Dietary Guidelines and the American Heart Association.

Food diaries/dietary recalls are commonly used to assess beverage and food intake; however, these methods can be costly, time consuming, cause a high respondent burden, provide

only recent intake information (i.e., not habitual intake patterns) and are not always feasible in large scale studies (20-22). A brief food frequency questionnaire (FFQ) can be as sensitive as multiple food intake records when measuring changes in dietary intake over time (23). However, FFQ must be valid (i.e., the intended items are measured accurately), reliable and reproducible (i.e., the questionnaire provides the same responses over time) (22) and sensitive to change (i.e., detect changes in consumption over time) (23,24). Yet, the issue of sensitivity to change of FFQ, has not been considered or studied extensively (23,24).

The rapid, valid and reliable BEVQ-15 can determine the habitual beverage intake patterns of adults, including those with lower literacy levels (25,26). Currently, the BEVQ-15 is the only known validated beverage intake assessment tool for adults. However, it is not known if the BEVQ-15 can detect changes in beverage intake over time. Without the availability of a questionnaire that is sensitive to changes in beverage consumption patterns, extensive longitudinal data must be collected to examine habitual beverage intake; consequently, it is challenging to overcome weaknesses in the current body of literature on this topic (27). To our knowledge, no prior investigations using feeding studies to evaluate the sensitivity to change of a validated dietary questionnaire have been conducted. The limited available literature pertaining to the sensitivity to change of dietary questionnaires focuses on comparing changes between multiple tools (i.e., which tool produces a higher index of change) (21,23,28,29). A brief, self-administered, valid, reliable and sensitive beverage intake tool could enhance nutrition intervention research targeting habitual beverage intake patterns in adults. Thus, our objective is to determine the ability of the BEVQ-15 to detect changes in total beverage consumption, as well as specific beverage categories (water, 100% fruit juice).

Methods

Subjects and Design. Healthy adults (n = 70) aged ≥21 years were recruited from a university community between August and December 2010. The Virginia Tech Institutional Review Board approved the study protocol. Participants provided written informed consent before enrollment; however, they were not aware of the specific purpose of the study. They were informed that the purpose of the study was to evaluate a dietary questionnaire.

Methods. This study utilized a randomized, within-subject crossover design, to examine the sensitivity to change of the BEVQ-15. Figure 4 depicts the overall design and study procedures. Participants completed two 30-day periods: 1) increased water and fruit juice consumption (intervention), and 2) increased whole fruit consumption (control), in a randomly assigned sequence, with a 30-day washout period between feeding periods. Condition two served to mask the emphasis on beverage intake. To keep participants naïve to the specific study purpose, several dietary intake assessment methods were utilized: a fruit and vegetable screener (FVS) (Appendix B) (30), BEVQ-15 and 24-hour dietary recalls. The FVS measures servings of fruits, vegetables and juice (30). The number of servings is converted into a score of 0-5, with 0 being equivalent to < one serving per week and 5 being > 2 servings per day. The rationale for choosing 30-day periods for each condition is primarily based on the time frame measured by the BEVQ-15 and FVS (i.e., intake within the last month), which is consistent to methods suggested in an extensive review on the development of FFQ (31).

Suggested beverage consumption guidelines for the items manipulated (water, 100% fruit juice) recommend a daily intake of 50 fl oz of water and eight fl oz of 100% fruit juice (32);

therefore, in order to not greatly exceed recommended amounts, individuals consuming more than 48 fl oz of water and 16 fl oz of fruit juice per day were excluded from the study. In an effort to increase beverage consumption, without greatly increasing energy intake, water and fruit juice were selected for the intervention phase rather than SSB. To monitor for weight gain, weekly weight checks were performed throughout the study. Since carbohydrate containing items were provided, individuals with diabetes (determined by reported health history) were excluded from the study. Participants with food allergies/intolerances to beverage items were also excluded.

Initial/Screening Visit. Screening and initial visit measurements are present in Figure 4; assessments included height, measured in meters without shoes using a wall mounted stadiometer; body weight, measured in light clothing without shoes, to the nearest 0.1 kg using a digital scale (Scale-Tronix, Inc., Model 5002, Wheaton, IL); and BMI, calculated as kg/m^2. Self-reported information was collected on demographic characteristics and health status (e.g., age, gender, race/ethnicity, income, education and medical history). Participants also provided a urine sample, which was used to measure urinary specific gravity (SG), an objective indicator of total fluid intake (hydration status and compliance). The urine sample functioned as a "bogus pipeline," which may enhance validity of participant's responses by leading them to believe an objective measure of their intake was being examined (22). Biomarkers also serve to establish the validity of new questionnaires, as well as testing the sensitivity to change during intervention studies (33). SG was determined using a handheld refractometer (ATAGO 4410 Digital Urine Specific Gravity Refractometer, Bellevue, WA).

An in-person 24-hour dietary recall was collected and instructions for completing two additional 24-hour recalls via the telephone were provided, along with pictures of food models to determine portion size. Baseline dietary intake was established by calculating the total food and beverage intake from the 24-hour recalls using nutritional analysis software (Nutrition Data System for Research, 2009, University of Minnesota, Minneapolis [NDS-R]). Participants were then randomly assigned to one of two 30-day feeding period sequences.

Feeding and Washout Periods. After completion of initial measurements, participants underwent the first 30-day feeding period. Individuals assigned to sequence 1 were instructed to consume two 8 fl oz bottles of *Deer Park* water (Nestlé Waters North America Inc., Stamford, CT) and two 4.23 fl oz boxes of *Juicy Juice* 100% juice (assorted flavors) (Nestlé, Glendale, CA) per day, in addition to their usual intake. Participants in sequence 2 were instructed to consume two servings of fruit (apples, oranges or 4 oz canned fruit in juice) per day, in addition to their usual intake. Water, juice and fruit were provided to participants during their weekly visits. In order to assess dietary compliance, daily tracking sheets for water, juice and fruit intake were provided (Appendices C,D), and participants were instructed to bring them to the weekly visits.

At the end of the first feeding period, participants completed the BEVQ-15 and FVS questionnaires, provided a urine sample and were instructed to return to their usual dietary habits for a 30-day washout period. During this time, no food or beverages were provided; however, participants still completed weekly weight checks. At the end of the washout period, SG, BEVQ and FVS were assessed, and instructions for completing the second feeding period were given.

An exit interview asking the participants what they believed to be the purpose of the study was conducted on the final visit. The specific aims of the study were revealed to participants and $45 compensation was provided.

Data Analysis. Statistical analyses were performed using SPSS statistical analysis software (version 19.0 for Windows, 2010, International Business Machines Corporation, Pittsburgh, PA). Descriptive statistics (mean$\pm$standard error of the mean [SEM] and frequencies) are reported for demographic characteristics and mean total consumption of beverages and beverage categories (g, kcal). To assess test-retest reliability of the BEVQ-15, Pearson's correlations and paired sample *t* tests compared BEVQ at visit 1 responses to BEVQ at visit 2; Cronbach's Alpha was used to evaluate internal consistency. To assess the BEVQ-15's sensitivity to change, as well as the FVS, paired sample *t* tests were used to compare mean differences between pre and post intervention beverage variables; condition by time differences were assessed by Repeated Measures Analysis of Variance (RM-ANOVA). Finally, RM-ANOVA was used to evaluate possible sequence effects, and paired sample *t* tests were used to determine the effectiveness of the crossover study design. The alpha level was set *a priori* at $P \leq 0.05$. Quality assurance included checking data for missing data, examining variable ranges for data entry errors, as well as randomly selecting participant data to double check entry accuracy.

Results

Demographics. Participants were split with regard to gender (60% female) and were primarily Caucasian (79%) from varying economic backgrounds (Table 5). Age ranged 21-82 yrs (mean = 37$\pm$2 yrs) and BMI ranged 17.7-33.2 kg/m^2 (mean = 24.5$\pm$0.4 kg/m^2). Baseline dietary intake

from the 24-hour dietary recalls (average of three days) and BEVQ-15 is presented in Table 5, including total dietary kcals and added sugar intake, water, juice, total SSB and beverage intake (kcal, g). Table 5 (Participant Demographics) reflect n = 70, while subsequent results only include participants who completed all study visits (n = 69).

Reliability of the BEVQ-15. The BEVQ-15 was originally developed as a 19-item questionnaire (BEVQ-19), which was shown to have acceptable validity and reliability (25). The BEVQ-19 underwent further testing and analyses to determine the factorial validity of the items and identify potential items to remove; it was subsequently reduced to the BEVQ-15, which demonstrated acceptable validity, reduced administration time (2 min 15 sec) and a lower literacy level (4.8 using the Flesch-Kinkaid method) (26). Test-retest Pearson bivariate correlations between the visit 1 and 2 BEVQ responses for the fifteen beverage items and four beverage outcomes (g, kcal) were all significant (range: R^2=0.52-0.95, P<0.001) with the exception of energy drink kcals and g (R^2=0.22, P=0.08); however, the absolute difference was minimal (mean difference = 4$\pm$7 kcal, 9$\pm$16 g). Absolute differences in outcomes between the visit 1 and 2 BEVQ were minimal (data not shown). Cronbach's Alpha ranged 0.71-0.94 for all outcomes.

Sensitivity to Change of the BEVQ-15. The ability of the BEVQ-15 to detect significant changes in beverage intake was assessed through several measures. The effectiveness of the study's crossover design was evaluated (i.e., comparing visits 2 and 10 BEVQ-15's [BEVQ2, BEVQ10]). The BEVQ2 and BEVQ10 were considered baseline measurements (administered before the start of each feeding period). No significant differences were found between BEVQ2

and BEVQ10 water, juice and total beverage outcomes; thus, the washout period served its purpose in returning participants to baseline beverage intake status. In addition, no significant differences between sequences were found for water (g) and juice (g, kcal). Mean differences between baseline and day 30, as well as between the intervention and control feeding periods for water, juice and total beverages are displayed in Table 6. Significant differences in intake of all beverage variables during the intervention phase were detected (all $P \leq 0.001$); and significant differences over time between feeding conditions were noted (all $P \leq 0.001$), with the exception of total beverage kcals (mean difference = 66 ± 65 kcal). No significant differences were found from baseline to day 30 during the control feeding period for any of the manipulated beverage variables. Daily tracking sheets indicated high reported compliance to increased water and fruit juice consumption (mean percent = 94.3 ± 0.9, 94 ± 0.9, respectively).

Sensitivity to Change of the FVS. Although the major aim of this study was to evaluate the sensitivity to change of the BEVQ-15, whole fruit was provided during the control feeding period to keep participants naïve to the exact purpose of the study (i.e., beverage intake changes). Given that, to our knowledge, the sensitivity to detect changes in fruit intake has not been evaluated with the FVS, additional evaluation of this tool was included. There was a significant increase in fruit score during the control phase (mean score = 2.5 ± 0.2, 4.8 ± 0.1, baseline, day 30; mean difference = 2.3 ± 0.2, $P<0.001$), which indicates that participants increased their fruit intake from approximately 2-6 servings per week to 1-2 servings per day. A significant difference over time between the feeding conditions ($P \leq 0.0001$) in fruit intake was detected (mean difference in score = 2.1 ± 0.3). During the intervention (i.e., beverage period) the fruit score did not change

(P=0.117). Daily tracking sheets indicated high reported compliance to the fruit intake instructions during this period (mean percent = 88.7±1.6).

Beverage Intake Patterns. Although participants were instructed to maintain current dietary habits with the exception of the specified diet instructions, determining possible shifts in beverage intake patterns (specifically in SSB intake due to the increased intake of water) was of interest. When comparing pre to post intervention beverage variables (excluding water and juice) no significant changes were noted in other beverages or total SSB intake (SSB [post-pre] mean difference = -22±16 kcal, -44±39 g).

No significant changes were found in urinary SG (mean pre = 1.0155, mean post = 1.0156; mean difference = 0.00013±0.001 SG) or weight status (mean difference = 0.3±0.2 kg) across the intervention phase.

Discussion

To determine if a brief, valid and reliable beverage intake questionnaire can detect changes in beverage intake, beverage intake was manipulated and self-reported beverage intake was compared before and after a 30-day intervention period. This investigation determined that the BEVQ-15 can detect changes in beverage intake, both total and within individual beverage categories. Furthermore, no significant differences were detected in non-manipulated beverage variables. The reliability of the BEVQ-15 was also demonstrated. In fact, several beverage variables demonstrated higher Pearson correlations when compared to the initial reliability testing of the longer version, BEVQ-19 (25).

The BEVQ-15 is the only known validated, reliable and rapid (~ 2 min) beverage intake questionnaire that is able to detect changes in beverage intake in adults, as well as low literacy populations. With approximately 50% of all added sugar intake coming from SSB, the BEVQ-15 could provide greater opportunities to assess the impact of clinical and public health interventions targeting SSB intake, as well as, the development of strategies which improve beverage choices. Insufficient clinical evidence linking SSB intake to adverse health conditions, such as obesity, hypertension, diabetes and cardiovascular health, can be associated with the current lack of a beverage intake assessment tool (27). Furthermore, the influence of the American Heart Association and U.S. 2010 Dietary Guidelines recommendations for beverage intake could be assessed for impact on public health issues, and researchers and practitioners can rapidly assess individual's habitual beverage patterns (water, SSB, milk).

Strengths and Limitations. Strengths of this investigation include: a randomized cross-over design, blinding participants to the study's purpose to reduce potential for bias in self-reported measures, a semi-controlled feeding approach, in combination with objective biomarkers of fluid intake, which may have contributed to the high compliance rate. Participant retention was also very high, with attrition <0.01% of sample, and the sample was fairly diverse (age, gender, BMI). Finally, FFQ are not often evaluated for their ability to detect changes in dietary intake (23,24), and no other investigations have examined the sensitivity to change in validated FFQ using a semi-controlled feeding design.

As in any investigation of free-living individuals, there is limited monitoring of dietary intake outside of the laboratory. In effort to overcome this limitation, urinary specific gravity

samples were obtained, weekly visits that provided necessary beverages and fruits were conducted and beverage and fruit daily tracking sheets were recorded.

Conclusion

The BEVQ-15 was developed to rapidly assess water intake, total beverage intake, as well as SSB intake, across multiple populations, including those with low-literacy levels. The BEVQ-15 demonstrates an acceptable ability to detect changes in beverage intake over time. Thus, the BEVQ-15 can be used to assess changes in beverage intake in intervention studies which target changes in beverage intake behaviors; furthermore, the BEVQ-15 may help determine possible relationships between beverage consumption and health-related outcomes, such as those related to diabetes, hypertension and obesity. Future work is needed to evaluate the validity and reliability of the BEVQ-15 in children.

Figure 4: Study Procedures: A Beverage Intake Questionnaire Can Detect Changes in Beverage Intake

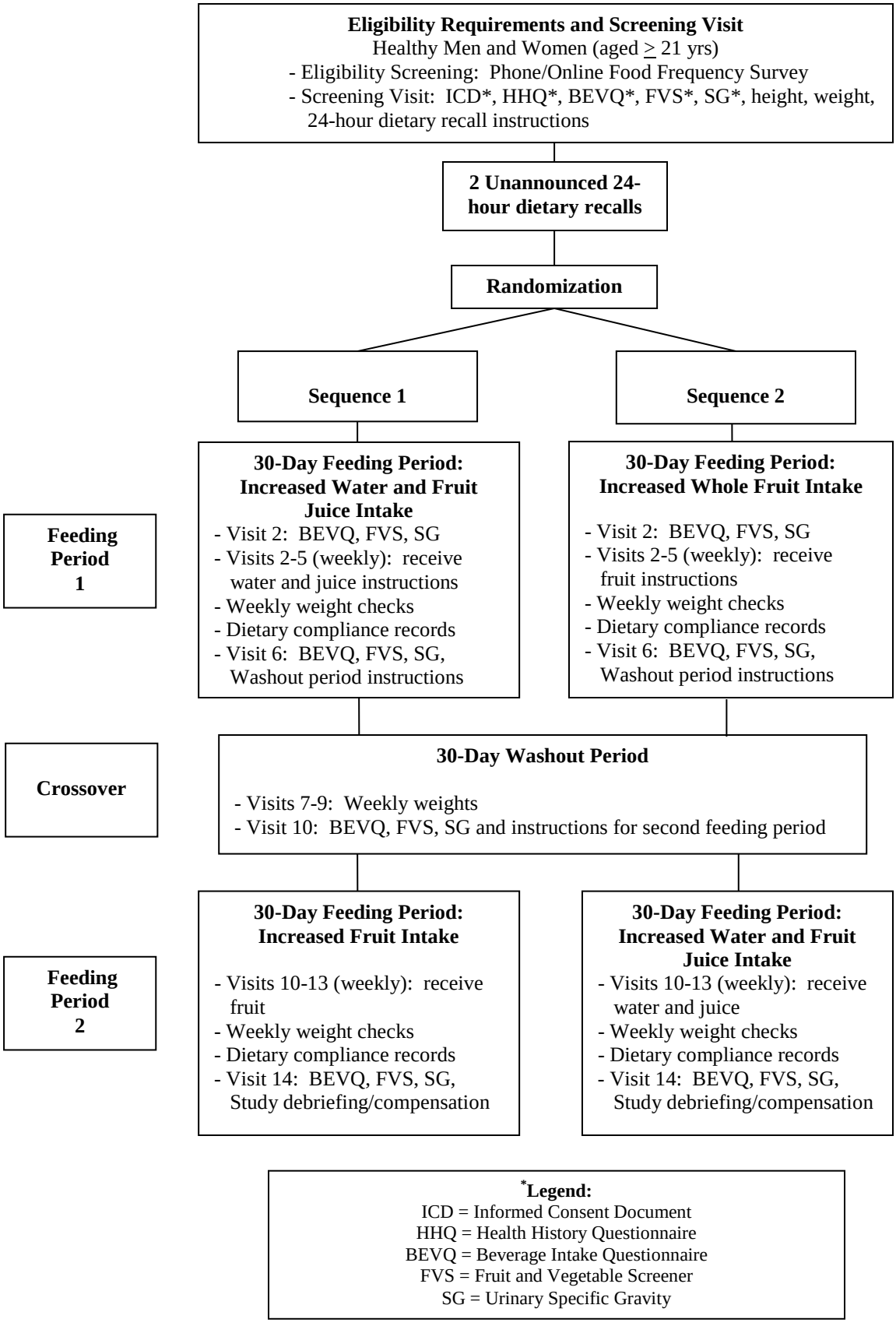


Table 5: Participant Demographic Characteristics: The Ability of a Beverage Intake Questionnaire (BEVQ-15) to Detect Changes in Beverage Intake

Total number of participants, n	70
Male, n (%)	28 (40)
Female, n (%)	42 (60)
Age, n (%)	
21-39 y	46 (66)
40-59 y	16 (23)
$\geq$60 y	8 (11)
Mean Age (yrs)*	37$\pm$2
Race/Ethnicity, n (%)	
Caucasian	55 (79)
African American	9 (13)
American Indian/Alaskan Native	0 (0)
Hispanic	1 (1)
Asian	4 (6)
Other	1 (1)

BMI Status, n (%)	
Underweight (<18.5 kg/m^2)	3 (4)
Normal Weight (18.5-24.9 kg/m^2)	33 (47)
Overweight (25-29.9 kg/m^2)	31 (44)
Obese ($\geq$30 kg/m^2)	3 (4)
Mean BMI (kg/m^2)*	24.5$\pm$0.4
Education Level, n (%)	
Did not complete high school	0 (0)
High school graduate	1 (1)
Some college	11 (16)
College graduate	22 (32)
Post college work	36 (52)
Household Income Level, n (%)	
$\leq$ $14,999	10 (14)
$15,000 - $29,999	17 (24)
$30,000 - $49,999	13 (19)
$50,000 - $99,999	16 (23)
$\geq$$100,000	14 (20)
Dietary Intake from 24-Hour Dietary Recalls*	
Total Food/Beverage Energy (kcals)	2,072$\pm$82
Total Food/Beverage Added Sugars (g)	66$\pm$4

Beverage Intake from BEVQ-15[*, **]	
Water (g)	722±51
Fruit Juice Energy (kcals)	51±8
Fruit Juice (g)	90±14
Total SSB Energy (kcals)	135±21
Total SSB (g)	382±56
Total Beverage Energy (kcals)	350±39
Total Beverage (g)	1,688±106

[*]Values are expressed as Mean±Standard Error of the Mean (SEM).

[**]BEVQ-15, 15-Item Beverage Intake Questionnaire. SSB (sugar-sweetened beverages) includes the following beverages: regular soft drinks, sweet tea, coffee with cream and/or sugar, juice drinks and energy drinks.

Table 6: Ability of the Beverage Intake Questionnaire (BEVQ-15) to Detect Changes in Beverage Intake: Differences in Water, Juice and Total Beverage Intake During Intervention and Control Feeding Conditions

Beverage Variable[a]	**Baseline**	**Day 30**	**Change**[b]
Water (g)			
Intervention	719±55	905±45	186±42*
Control	755±84	645±49	110±71
Sensitivity to Change			296±78*
Juice (g)			
Intervention	100±14	410±33	310±33*
Control	101±16	106±15	5±14
Sensitivity to Change			305±38**
Juice (kcal)			
Intervention	62±9	235±19	173±21**
Control	55±9	61±9	6±8
Sensitivity to Change			167±23**
Total Beverage (g)			
Intervention	1,700±109	2,158±97	458±85*
Control	1,794±137	1,740±129	55±115
Sensitivity to Change			513±133*

Total Beverage (kcal)			
Intervention	360±40	505±37	145±35*
Control	356±39	435±66	79±49
Sensitivity to Change			66±65

[a]Expressed as Mean±Standard Error of the Mean (SEM).

[b]Mean difference within condition over time, according to a paired sample *t* test. Slight differences may be noted from the preceding rows due to rounding; whole numbers are present in the Table. Condition by time difference assessed by Repeated Measures Analysis of Variance (ANOVA).

*P<0.001.

**P<0.0001.

References

1. Flegal K, Carroll M, Ogden C, Curtin L. Prevalence and trends in obesity among U.S. adults, 1999-2008. *J Am Med Assoc.* 2010;303(3):235-241.
2. Hensrud DD, Klein S. Extreme obesity: a new medical crisis in the United States. *Mayo Clin Proc.* 2006;81(10):S5-S10.
3. Brown I, Stamler J, Van Horn L, Robertson C, Chan Q, Dyer A, Huang C, Rodriguez B, Zhao L, Daviglus M, Ueshima H, Elliott P. Sugar-sweetened beverage, sugar intake of individuals, and their blood pressure: international study of macro/micronutrients and blood pressure. *Hypertension.* 2011;57(4):695-701.
4. de Koning L, Malik VS, Rimm EB, Willett WC, Hu FB. Sugar-sweetened and artificially sweetened beverage consumption and risk of type 2 diabetes in men. *Am J Clin Nutr.* 2011;93(6):1321-1327.
5. Malik V, Popkin B, Bray G, Despres J, Hu F. Sugar-sweetened beverages, obesity, type 2 diabetes mellitus, and cardiovascular disease risk. *Circulation.* 2010;121:1356-1364.
6. Vartanian L, Schwartz M, Brownell K. Effects of soft drink consumption on nutrition and health: a systematic review and meta-analysis. *Am J Public Health.* 2007;97(4):667-675.
7. de Graaf C. Why liquid energy results in overconsumption. *Proc Nutr Soc.* 2011;70(2):162-170.
8. Duffey KJ, Popkin BM. Shifts in patterns and consumption of beverages between 1965 and 2002. *Obesity.* 2007;15(11):2739-2747.
9. Johnson R, Appel L, Brands M, Howard B, Lefevre M, Lustig R, Sacks F, Steffen L, Wylie-Rosett J. Dietary sugars intake and cardiovascular health: a scientific statement from the American Heart Association. *Circulation.* 2009;120(11):1011-1020.

10. Nielsen SJ, Popkin BM. Changes in beverage intake between 1977 and 2001. *Am J Prev Med.* 2004;27(3):205-210.

11. Block G. Foods contributing to energy intake in the U.S.: data from NHANES III and NHANES 1999-2000. *J Food Compos Anal.* 2004(17):439-447.

12. DiMeglio DP, Mattes RD. Liquid versus solid carbohydrate: effects on food intake and body weight. *Int J Obes Relat Metab Disord.* 2000;24(6):794-800.

13. Mattes R. Dietary compensation by humans for supplemental energy provided as ethanol or carbohydrate in fluids. *Physiol Behav.* 1996;59(1):179-187.

14. Almiron-Roig E, Drewnowski A. Hunger, thirst, and energy intakes following consumption of caloric beverages. *Physiol Behav.* 2003;79(4-5):767-773.

15. DellaValle DM, Roe LS, Rolls BJ. Does the consumption of caloric and non-caloric beverages with a meal affect energy intake? *Appetite.* 2005;44(2):187-193.

16. Stookey JD, Constant F, Gardner CD, Popkin BM. Replacing sweetened caloric beverages with drinking water is associated with lower energy intake. *Obesity.* 2007;15(12):3013-3022.

17. Dennis EA, Dengo AL, Comber DL, Flack KD, Savla J, Davy KP, Davy BM. Water consumption increases weight loss during a hypocaloric diet intervention in middle-aged and older adults. *Obesity.* 2009;18(2):300-307.

18. U.S. Department of Health and Human Services, and U.S. Department of Agriculture (HHS, USDA). Dietary Guidelines for Americans, 7th Edition. Washington, DC: U.S. Government Printing Office; 2010.

19. Van Horn L. Development of the 2010 U.S. dietary guidelines advisory committee report: perspectives from a registered dietitian. *J Am Diet Assoc.* 2010;110(11):1638-1645.

20. Marshall T, Eichenberger Gilmore J, Broffitt B, Levy S, Stumbo P. Relative validation of a beverage frequency questionnaire in children ages 6 months through 5 years using 3-day food and beverage diaries. *J Am Diet Assoc.* 2003;103(6):714-720.

21. Thomson C, Giuliano A, Rock C, Ritenbaugh C, Flatt S, Faerber S, Newman V, Caan B, Graver E, Hartz V, Whitacre R, Parker F, Pierce J, Marshall J. Measuring dietary change in a diet intervention trial: comparing food frequency questionnaire and dietary recalls. *Am J Epidemiol.* 2003;157(8):754-762.

22. Willett W, Lenart E. *Nutritional Epidemiology*. 2nd ed: Oxford University Press; 1998.

23. Kristal A, Beresford S, Lazovich D. Assessing change in diet-intervention research. *Am J Clin Nutr.* 1994;59(1 Suppl):185S-189S.

24. Guyatt G, Walter S, Norman G. Measuring change over time: assessing the usefulness of evaluation instruments. *J Chronic Dis.* 1987(40):171-178.

25. Hedrick V, Comber D, Estabrooks P, Savla J, Davy B. The beverage intake questionnaire: initial validity and reliability. *J Am Diet Assoc.* 2010;110:1227-1232.

26. Hedrick V, Savla J, Comber D, Flack K, Estabrooks P, Nsiah-Kumi P, Ortmeier S, Davy B. Development of a brief questionnaire to assess habitual beverage intake (BEVQ-15): sugar-sweetened beverages and total beverage energy intake. In Review.

27. Allison DB, Mattes RD. Nutritively sweetened beverage consumption and obesity: the need for solid evidence on a fluid issue. *J Am Med Assoc.* 2009;301(3):318-320.

28. Osler M, Heitmann BL. The validity of a short food frequency questionnaire and its ability to measure changes in food intake: a longitudinal study. *Int J Epidemiol.* 1996;25(5):1023-1029.

29. Peterson KE, Hebert JR, Hurley TG, Resnicow K, Thompson FE, Greene GW, Shaikh AR, Yaroch AL, Williams GC, Salkeld J, Toobert DJ, Domas A, Elliot DL, Hardin J, Nebeling L. Accuracy and precision of two short screeners to assess change in fruit and vegetable consumption among diverse populations participating in health promotion intervention trials. *J Nutr.* 2008;138(1):218-225.

30. Block G, Gillespie C, Rosenbaum EH, Jenson C. A rapid food screener to assess fat and fruit and vegetable intake. *Am J Prev Med.* 2000;18(4):284-288.

31. Cade J, Thompson R, Burley V, Warm D. Development, validation and utilisation of food-frequency questionnaires - a review. *Public Health Nutr.* 2002;5(04):567-587.

32. Popkin BM, Armstrong LE, Bray GM, Caballero B, Frei B, Willett WC. A new proposed guidance system for beverage consumption in the United States. *Am J Clin Nutr.* 2006;83(3):529-542.

33. Bogers RP, van Assema P, Kester ADM, Westerterp KR, Dagnelie PC. Reproducibility, validity, and responsiveness to change of a short questionnaire for measuring fruit and vegetable intake. *Am J Epidemiol.* 2004;159(9):900-909.

Chapter 5:

Dietary Biomarkers: Advances, Limitations and Future Directions

Abstract

The subjective nature of self-reported dietary intake assessment methods presents numerous challenges to obtaining accurate dietary intake and nutritional status. This limitation can be overcome by the use of dietary biomarkers, which are able to objectively assess dietary consumption without the bias of self-reported dietary intake errors. Although biomarkers provide independent data, they can have many confounding factors to their validity, such as genetics, age and health status. The purpose of this review is to provide an update to the current literature regarding available dietary biomarkers, as well as a novel review on biomarkers of specific foods and dietary components. The evaluation of macronutrient and specific food biomarkers revealed many areas which lacked sufficient research. Many biomarkers discussed were determined to be potential biomarkers, which needed additional research to validate. Further research is required to produce sensitive, specific, cost-effective and noninvasive biomarkers. As the profession of dietetics and health continues to trend towards individualized nutrition, developing biomarkers that measure intake of specific foods, rather than nutrients, will become a primary focus. The emerging field of metabolomics may help to overcome this knowledge gap by identifying metabolites of a specific food within the metabolome. However, advances in food metabolome databases are necessary before significant advances in metabolomics for dietary biomarkers occur. The availability of biomarkers that estimate intake of specific foods and dietary components could greatly enhance nutritional research targeting compliance to national recommendations as well as direct associations with outcomes of chronic

disease. More research is necessary to further refine existing biomarkers by accounting for many confounding factors, establishing new indicators of specific food intake and developing techniques that are cost-effective, noninvasive, rapid and accurate measures of nutritional status.

Introduction

Collecting dietary intake data is associated with many challenges, which are primarily related to the subjective nature of data collection tools, such as food frequency questionnaires (FFQ), multiple-day food records and 24-hour dietary recalls. People are not always able to recall all foods consumed or the specific components of the food (e.g., whole vs. skim milk), have difficulty determining accurate portion sizes and typically underreport dietary intake (1-4). Each method has strengths and limitations; however, food records and dietary recalls typically are costly (resource-intensive), time consuming, cause a high burden on respondents, provide only recent intake information (i.e., not habitual intake patterns) and are not always feasible in large scale investigations or studies examining low income and low literacy populations (4-6). A FFQ may provide a glimpse into a population's habitual dietary intake over time, whereas food records and dietary recalls assess days/weeks, which may be more precise but not representative of typical intake over time (4). Thus, using self-reported dietary intake methods to measure dietary intake is a commonly cited research limitation (3). However, biomarkers of food or nutrient intake are able to objectively assess dietary intake/status without the bias of self-reported dietary intake errors (7-9). Biomarkers may also assist in overcoming the challenge of intra-individual variability of one's diet (2). The Institute of Medicine has recognized the lack of nutritional biomarkers as a knowledge gap requiring future research, including: 1) the need for biomarkers that can predict functional outcomes and chronic diseases, and 2) the need to improve dietary assessment and planning methods (7). Dietary biomarkers are not without limitations; cost and degree of invasiveness are factors to consider (3); therefore, the need for non-invasive, inexpensive and specific dietary markers is clear (7).

Dietary biomarkers are typically used 1) for their ability to more accurately assess nutritional intake/status versus traditional dietary intake methods (FFQ, diet recall), 2) to validate self-reported intake measures, 3) to provide intake of dietary items when inadequate food-composition databases are present, and 4) to provide a more accurate measure of dietary intake to predict nutritional-disease risk as well as the overall population's nutritional status (10). Biomarkers can be categorized into short-term (reflecting intake over past hours/days), medium-term (reflecting intake over weeks/months) and long-term markers (reflecting intake over months/years), with the type of sample used being a main determinant of time (e.g., blood, hair, adipose tissue) (10).

Although it has been established that dietary biomarkers generally provide a more proximal measure of dietary intake, certain factors, which may not present in traditional dietary assessment methods, may possibly skew biomarker measures of dietary intake. Factors that may alter the response of biomarkers include genetic variability, lifestyle/physiologic factors (e.g., smoking), dietary factors (e.g., nutrient-nutrient interaction), biological sample and analytical methodology (11). Limited research is available which evaluates the impact of these factors. As a result, it is imperative to assess a biomarker's validity, reproducibility, ability to detect changes over time and robustness across diverse populations, as well as strengths and limitations to ensure it is evaluated using the proper techniques.

As the profession of dietetics and health continues to trend towards individualized nutrition (9,12), developing biomarkers that measure intake of specific foods, rather than nutrients, will become a primary focus (2). The emerging field of metabolomics in human

nutrition may help advance the discovery of novel biomarkers for specific dietary intake and consequently health status (13). Metabolomics is the identification of small molecule metabolites and nutrients available in bio-fluids (blood, saliva, urine, etc.) that makes up the metabolome (14,15). The metabolites are the products of metabolism of medicines, foods, toxins, etc. (15,16). Metabolomics has been used to identify dietary intake patterns by identifying the molecules that vary between different diets (14), which can be useful in determining potential diet-disease risk markers (17), as well as the potential to discover novel biomarkers for specific foods (18). The availability of biomarkers that provide estimates of specific foods and dietary components intake could greatly enhance nutritional research targeting compliance to national recommendations, such as the U.S. 2010 Dietary Guidelines and the American Heart Association. The purpose of this review is to present and evaluate available literature regarding current dietary biomarkers for macronutrient dietary component/foods (carbohydrates, fats, proteins), as well as food/nutrients which cannot be categorized with macronutrients (e.g., caffeine). Furthermore, it will include a novel review on biomarkers for specific foods/dietary components (e.g., ^{13}C for corn and cane sugars (19)). This review aims to provide a critical examination of the available methods for measuring traditional macronutrient intake/status that have been updated or modified in the past ten years and assess validity, reproducibility and sensitivity of proposed/accepted biomarkers. To our knowledge, no review regarding biomarkers for intake of specific foods and dietary components has been conducted.

Methods

A literature search was conducted in February 2011. Stage 1 consisted of an electronic search of the keywords “dietary biomarkers” using PubMed (MEDLINE database). The review

was limited to clinical trials, meta-analysis, randomized controlled trials and reviews published within the past 10 years (Feb. 2001-Feb. 2011). This search identified 1,203 articles. Stage 2 involved a review of article title and abstract; to be included in the review, the focus of the article had to be intake biomarkers of macronutrients or specific foods/dietary component intake. Examples of excluded articles include: biomarkers of disease-risk/health status; biomarkers associated with weight loss, physical activity, dietary supplements or medicines; biomarkers of oxidative stress; and biomarkers of dietary item function rather than biomarker of intake (e.g., effect of fiber on colon health). Stage 2 identified 72 articles. At Stage 3, full texts of papers were downloaded and assessed further for exclusion/inclusion criteria, as listed above.

Results

Twenty-six articles were identified for inclusion. Biomarkers were categorized under their respective macronutrient, as well as an additional category for specific dietary components that did not fall into the macronutrient category (e.g., caffeine). Research findings are summarized within the text in the following order: macronutrients (carbohydrates, fats and proteins) and specific foods/dietary components. Recent literature related to biomarkers for dietary macronutrients (carbohydrate, fat and protein containing foods) is summarized in Table 7.

Carbohydrates

The American Heart Association and the U.S. 2010 Dietary Guidelines both provide recommendations for added sugar intake, as it is theorized that added sugars in the diet, specifically sugar-sweetened beverages (SSB), have contributed to the rise in obesity prevalence

(20-22). Yet, significant evidence is needed to link SSB and added sugar to obesity and other co-morbidities such as hypertension, diabetes and cardiovascular disease (23-25). Thus, valid reliable biomarkers of sugar intake are needed to further confirm recommendations. Additionally, the U.S. 2010 Dietary Guidelines suggest one half of grains consumed should be whole grains (26), as whole grain products are important for heart health (27,28). However, the general population may have difficulty in distinguishing whole grains from refined products. Thus, a valid biomarker of whole grain intake would provide insight into the health of one's dietary patterns (28).

Cane Sugar and High Fructose Corn Syrup. Carbon stable isotope abundance of ^{13}C is a novel biomarker for cane sugar and high fructose corn syrup (HFCS). Cane sugar and HFCS are derived from C_4 plants (includes molasses, brown and powdered cane sugar), making their intake measureable through ^{13}C isotope measures (29). Cook et al. (30) used ^{13}C from blood glucose to determine its potential as a biomarker for cane sugar/HFCS; unfortunately, fasting glucose ^{13}C levels were inadequate indicators of intake as gluconeogenesis caused ^{13}C dilution. However, random plasma ^{13}C measurements showed high correlations with consumption of cane sugar/HFCS from the previous meal (R^2=0.90) and serum ^{13}C levels were shown to be correlated with SSB intake (R^2=0.18) in older adults (31). Davy et al. (19) used fingerstick blood to measure the ^{13}C isotope content. The results were comparable to ^{13}C venipuncture samples (31) and correlations with added sugars (calories [kcals] and grams [g], R^2=0.37) and total SSB (kcal and g, R^2=0.35, 0.28) were noted.

Although moderate correlations were found for serum ^{13}C to added sugars and SSB, there are limitations that require further research before ^{13}C isotopes are considered a valid biomarker of cane sugar and HFCS. While high correlations were found for random plasma glucose ^{13}C measures to cane sugar and HFCS, this only reflects extremely recent intake, as in the previous meal. Fingerstick serum ^{13}C measures appear to be the better choice (possibly reflects a longer intake period and is less invasive) for a cane sugar/HFCS intake biomarker; however, further research needs to be conducted to determine the intake period reflected in the measurement.

Beet sugar and maple syrup, which only account for a small fraction of added sugars in the diet, are not captured by ^{13}C measures as they are C_3 plants, as well, honey is not included (29). Thus, biomarkers for sugar intake that rely on ^{13}C isotopes are only able to capture part of the general population's intake; even so, this does reflect a large portion of the consumed added sugars. Another major difficulty of using ^{13}C isotopes is that corn is also a C_4 plant; thus corn, corn derivatives and animals that consumed corn are reflected in the measurement. ^{13}C was shown to be correlated with whole corn intake and animal protein intake (R^2=0.15, 0.28, respectively) (31). A second isotope, ^{15}N, may be able to account and correct for animal protein intake (32). Overall, ^{13}C measures have shown promise as they can distinguish low from high sugar consumers (19), and have demonstrated significant correlations between SSB, added sugars and cane sugar/HFCS. Further research is needed to refine this biomarker and establish the intake period reflected by the measurement.

Sugar. Urinary sucrose and fructose have been investigated as possible biomarkers of sugar intake. Urinary sucrose, fructose and combined sucrose/fructose are associated with sugar intake

(R^2=0.86, 0.80, 0.89, respectively), and are reproducible (R^2=0.44, 0.81, 0.67, respectively) (33). Urinary sucrose and fructose concentrations did not significantly differ between normal and obese BMI individuals when using a sugar controlled diet (34). Kuhnle et al. (35) examined two analytical methods of determining urinary sucrose, gas chromatography mass spectrometry (GC-MS) and liquid chromatography mass spectrometry (LC-MS). GC-MS is able to identify more compounds than LC-MS, but the sample preparation for GC-MS is more labor-intensive and the analysis takes longer to run as it is examining more compounds than LC-MS.

Urinary sucrose and fructose are able to detect a dose-response in sugar intake (33), classify an individual as a high or low sugar consumer and are suitable for normal and obese BMI classes (34). As well, both the LC-MS and GC-MS analytic methods predicted urinary sucrose as a suitable biomarker of sugar intake (35). However, a major limitation of urinary sucrose and fructose is the capability to only reflect short term intake. Further research is needed to develop a biomarker of total sugar intake that is reflective over a longer period of time (i.e., habitual intake).

Whole Grain Wheat and Rye. Several studies have examined plasma alkylresorcinol (AR) concentrations as a possible whole grain wheat/rye biomarker. Total plasma AR was shown to increase with whole grain intake and decrease with refined bread intake after one week (36). Plasma AR demonstrated high reproducibility (R^2=0.85) (37) and was significantly correlated with whole grain intake (R^2=0.58) (28), (R^2=0.94) (36). Red blood cell (RBC) AR increases and decreases with whole grain ingestion. As plasma AR was correlated with whole grain intake, it was compared to RBC AR and found to be significantly correlated (R^2=0.85) (36). However,

AR may be retained in RBC membranes during low AR intake (36). Investigation of enterolactone (ENL), the main end-product of whole grains, revealed its poor function as a biomarker of whole grain intake, as it is a non-specific biomarker that has many dietary sources and varies greatly between genders (36). AR homolog C17:0/C21:0 ratios have the potential to differentiate between types of whole grain intake, specifically wheat and rye (28,36,37).

3,5-dihydroxybenzoic acid (DHBA) and 3-(3,5-dihydroxyphenyl)-propanoic acid (DHPPA) are two metabolites of AR that are excreted through urine. Recovery was shown to decrease with high AR doses; it could be that a 24-hour urine collection was not enough time to recover the high dose. DHBA and DHPPA were able to demonstrate a higher dose-response effect than plasma AR at low intake levels (38).

Total plasma AR appears to be a possible short term (half-life approximately four hours) biomarker of whole grain intake. However, AR may accumulate over periods of high intake, thus, over-estimating intake at high levels and under-estimating at low levels (28,37,38). RBC AR may be a longer term indicator of whole grain intake than plasma AR, as they retain AR. Further research is needed to assess effects of various other whole grains on the AR homolog C17:0/C21:0 ratio, in addition to determining the time period being reflected.

Fats

The current lack of a valid total fat dietary biomarker has hindered research targeting direct relationships of fat intake to cardiovascular disease, as dietary fat intake assessment has largely relied on subjective data (4,39). The composition of fatty acid intake is reflected in

measurements of blood cholesterol (e.g., LDL, HDL). However, actual intake of specific fatty acids (mono-unsaturated [MUFA], poly-unsaturated [PUFA] and saturated fatty acids [SFA]), which may be indicators of specific diseases and disease risks, is difficult to capture (4,40). Additionally, intake of omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), have been linked with a decrease in cardiovascular disease; however, current methods of determining true intake have proven to be costly and time consuming (41). Thus, research is needed to develop biomarkers that are cost-effective and able to detect dietary fat/fatty acid intake.

Total Fat. Dietary biomarkers that represent total fat intake have demonstrated conflicting results. A study utilizing fatty acid concentrations of MUFA, PUFA and SFA in RBC were revealed as inadequate for possible biomarkers of total fat intake, especially SFA. Also, EPA, DHA and oleic acid may provide short term biomarkers of relative intake but not total fat intake (42). In contrast, another study investigated the possibility of using a combination of fatty acids to create a biomarker of total fat intake. Using three different biological samples, RBC, plasma phospholipids (PL) and cholesterol esters (CE), to measure fatty acid status, three prediction models were produced that had high sensitivity and specificity (all >90%) in discerning between low fat/high fat intakes (39). *Trans*-fats were a common indicator of total fat intake for all models, but it may be less useful as a biomarker as *trans*-fats are being removed from many foods. RBC markers may be a useful long term marker, as the RBC turnover is approximately 120 days; RBC also showed smaller changes in fatty acid composition compared to PL and CE measures (39). Thus, utilizing a combination of various fatty acids may prove to be a biomarker of total fat intake.

Fatty Acids. Several studies examining biomarkers of relative fatty acid intakes have produced favorable outcomes. PUFA, measured in adipose tissue, showed strong correlations with respective dietary intake (R^2=0.15-0.58), specifically linoleic and alpha-linolenic acids (40). Another study deemed n-6 PUFA and n-3 PUFA in PL as long term biomarkers of relative intake (R^2=0.16, 0.29, respectively) (43). A study comparing pre- to post-menopausal women indicated a significant correlation between RBC and PUFA in post-menopausal women (R^2=0.39), but not pre-menopausal (R^2=0.17) (44). Significant correlations between RBC MUFA and relative intake (R^2=0.40-0.48) (44) were found. Also, plasma MUFA *cis*18:1n-9 was found to be a long term biomarker for total MUFA (R^2=0.22) (43). Oleic acid in RBC was found to be a valid biomarker of intake (R^2=0.45-0.47) (44). RBC SFA were found to be inadequate biomarkers of SFA intake (44); however, serum SFA 15:0 showed a correlation to total SFA dietary intake (R^2=0.19) (43). *Trans*-fatty acids were also shown to correlate significantly with dietary intake (R^2=0.43) (40).

Adipose and plasma levels of PUFA are the best indicators of relative intake; RBC levels need further research as correlations differed between population groups. RBC and plasma MUFA are valid measures of MUFA intake, while RBC SFA is not a valid indicator of intake. Serum SFA measures show potential as biomarkers, but *trans*-fatty acid biomarkers may not be as useful due to reductions in the food supply.

Essential Fatty Acids. Alpha-linolenic and linoleic acid are two essential fatty acids (EFA). Significant tissue-dietary correlations of alpha-linolenic and linoleic acid, respectively, in

adipose tissue (R^2=0.51, 0.52), fasting blood (R^2=0.38, 0.43) and fasting plasma levels (R^2=0.39, 0.41) have been reported (45). Others (44) have noted a significant correlation between RBC linoleic acid and relative dietary intake (R^2=0.23 pre-menopausal, 0.39 post-menopausal), but not for RBC alpha-linolenic acid. Fasting blood is comparable in results to plasma and adipose tissue, less expensive and less invasive than adipose tissue sampling. Thus, whole blood measures appear to be the ideal indicator of long-term linoleic acid intake, and possibly alpha-linolenic acid; further research is necessary (45).

Eicosapentaenoic Acid and Docosahexaenoic Acid. EPA and DHA are omega-3 fatty acids primarily obtained from fish consumption (41). Levels of plasma EPA and DHA, when compared to their relative dietary intake, produce significant correlations (EPA, R^2=0.57 males, 0.60 females; DHA, R^2=0.57 males, 0.30 females) (46). The stable isotope ^{15}N is associated with fish intake; thus, levels of EPA and DHA ^{15}N were assessed in blood and hair samples. Dietary EPA and DHA were correlated with blood ^{15}N levels (R^2=0.47, 0.46, respectively) (41). Hair ^{15}N was correlated with dietary EPA and DHA (R^2=0.83, 0.84, respectively) (47).

Plasma EPA and DHA may be useful dietary biomarkers of their respective intake; further research is required to determine the time-period of intake reflected. Blood and hair ^{15}N both provide accurate biomarkers of EPA and DHA intake. The turnover of EPA and DHA differ, thus RBC ^{15}N levels may be providing indicators for two different time periods (41). Hair ^{15}N is able to reflect the previous two months of intake (47). Plasma EPA and DHA, RBC and hair ^{15}N all show potential as biomarkers of EPA and DHA intake; yet, further research is needed to determine dose-response as well as intake periods being measured.

Olive Oil. Lower incidences of cardiovascular disease have been associated with diets where olive oil is a major contributor to fat intake (48). Tyrosol and hydroxytyrosol are two phenolic compounds derived from olive oil intake. Tyrosol shows a strong dose-response effect in 24-hour urine samples, as well as similar recovery for a single dose and a week of sustained doses (16.9%, 19.4%, respectively). Hydroxytyrosol had a recovery of 78.5% after a single dose and 121.5% recovery after a week of sustained intake. This reveals that hydroxytyrosol probably accumulates as the recovery was higher than the intake of olive oil; additionally, hydroxytyrosol can also be derived from other sources, including endogenous sources (48). Although further research is needed, tyrosol shows potential of being a valid biomarker of olive oil intake.

Proteins

A dietary biomarker of protein intake may be useful for determining nutritional status (over/under nourished). In addition, animal protein intake has been linked to increased risk of cancer, obesity, diabetes and the metabolic syndrome (49). However, research determining the long term effects of dietary protein intake is lacking due to the absence of a valid biomarker.

Total Protein. Urinary nitrogen is a valid method of assessing total protein intake, though, several limitations exist. A comparison of a 28 day feeding study with multiple 24-hour urine nitrogen outputs produced a correlation of 0.99. When the time period is reduced to a single observation, the correlation is reduced to 0.50, but improves to an acceptable correlation of 0.95 with 18 days (50). To obtain the most accurate measurements, individuals should maintain a constant daily intake and be in nitrogen balance. Urinary nitrogen is shown to underestimate at

high protein intake levels and overestimate at low intake levels, yet it is considered an adequate biomarker of protein intake. It is suggested that multiple 24-hour urine samples are needed to fully establish protein status (50).

Animal Protein. As discussed previously, isotopes ^{13}C and ^{15}N are demonstrated to be possible dietary biomarkers for added sugars and fatty acids (19,29-32,41,47). These isotopes have also been evaluated for their potential to measure animal protein intake via ^{15}N and ^{13}C hair, yet baseline measurements showed minimal correlations with dietary intake (R^2=0.17, 0.44, respectively). A decrease in both isotopes with decreased protein intake has been reported, but not a significant increase with increased protein intake after four weeks. Thus, hair ^{15}N and ^{13}C do not appear to be valid short term dietary biomarkers of protein intake, but further research is needed to determine if they could be valid longer term biomarkers (49).

Various Foods/Dietary Components

Table 8 contains a summary of the various food/dietary component biomarker studies that could not be categorized within a macronutrient category, as follows: caffeine, citrus, cocoa, garlic and wine.

Caffeine. Caffeine intake is especially difficult to assess via questionnaires and dietary recalls, as caffeine concentrations can vary greatly among different dietary items and may not be present in many nutritional software databases. However, due to the potentially harmful side effects of high caffeine intake, it may be important to develop acceptable intake levels and an appropriate biomarker that can capture consumption (51). Caffeine (137X) is broken down into four known

metabolites in the urine, 17X, 17U, 1X, AFMU. Caffeine, in its un-metabolized form, and AFMU are greatly influenced by inter-individual differences (e.g., genetic variability) and are not acceptable indicators of caffeine intake. Although 17X is minimally influenced by genetic variability and shows significant correlation with caffeine intake (R^2=0.58), it requires more research before it is considered a valid biomarker of intake. 17U and 1X are both minimally influenced by inter-individual differences, show high correlations with intake (R^2=0.87, 0.78, respectively) and may be acceptable biomarkers of caffeine consumption (51).

Citrus. Total fruit and vegetable intake is typically difficult to objectively quantify due to most biomarkers measuring the effect of fruit and vegetables on health markers (e.g., reduction of oxidative biomarkers (52)) or intake of non-specific nutrients, such as Vitamin C (which is found/added in many dietary items) (4). However, proline betaine was identified through nutrimetabolomic metabolic profiling as a possible marker of citrus consumption, which may be able to identify true intake of citrus fruits. Proline betaine was shown to be sensitive (86.3%), specific (90.6%) and significantly correlated with citrus consumption (R^2=0.40). A limitation of proline betaine is its rapid urinary excretion, (i.e., 24 hours after intake) (18).

Cocoa. Cocoa is a major source of certain phytochemicals (phenolic compounds), which have been shown to improve cardiovascular health and antioxidant status (53). A study utilizing metabolomic metabolic profiling identified twenty-seven cocoa urinary metabolites that occurred over the 24-hour period following intake (53). Additional research on the various identified cocoa metabolites should be conducted in order to develop a valid biomarker of cocoa intake.

Garlic. It has been hypothesized that garlic may provide chemo-preventive effects; thus, the development of a specific biomarker of garlic intake may enhance research targeting cancer prevention, as well as prevention of other chronic disease (54). S-allyl-mercapturic acid (ALMA) has been identified as a urinary metabolite of dietary garlic intake. In a research investigation, the presence of ALMA was detected in the majority of garlic consumers (fifteen out of sixteen), while only two control subjects out of fourteen had detectable levels of ALMA. Therefore, ALMA appears to differentiate garlic consumers from non-consumers. However, ALMA is a short term biomarker of garlic intake as the half-life is approximately six hours, and ALMA may increase with other sources; it is not specific to garlic intake (54).

Wine. Resveratrol, a phenolic compound found in wine, has been shown to be negatively correlated with cardiovascular disease (55). A biomarker for wine intake may prove to be useful, as people may not always accurately report alcoholic beverage consumption due to social undesirability (2). Metabolites of resveratrol have been discovered in urine and plasma, and total resveratrol metabolites (TRM) were analyzed to determine exposure and responsiveness of wine intake. Plasma TRM have an extremely short half-life of approximately two hours, and only reflect very recent intake. Urinary TRM, however, may differentiate between wine drinkers and non-drinkers with high sensitivity and specificity (73%, 93%, respectively). TRM also show a strong dose-response effect. A limitation of TRM is that it only reflects intake of regular consumers and may prove less useful in intermittent consumers of wine (55).

Conclusions and Future Directions

Biomarkers of dietary exposure should be valid, reproducible, able to detect changes in intake over time and be suitable for the general population. Yet, many of the dietary biomarkers reviewed appeared inadequate at meeting all of the aforementioned criteria (see Tables 7,8). The majority of reviewed studies only examined the validity of a biomarker (seventeen studies); three studies evaluated reproducibility and five studies demonstrated the biomarker's ability to be sensitive to changes in respective dietary intake. The best biomarkers available show validity, reproducibility and sensitivity; this review identified two biomarkers that met all three criteria: combined urinary sucrose and fructose for a sugar biomarker (33) and total plasma alkylresorcinol for a whole grain biomarker (28, 37). Additionally, fingerstick ^{13}C measurements demonstrated validity and reproducibility for cane sugar/HFCS intake (19), and urinary proline betaine demonstrated validity and sensitivity for citrus consumption (18).

There are multiple factors that warrant investigation before many of these biomarkers can be more widely utilized in nutrition research. Genetics, age, type of specimen, time of year, confounding dietary sources, etc. all play a pivotal role in the complexity of dietary biomarkers. This literature review indicated more research was needed for many macronutrient biomarkers, as well as novel indicators of specific foods/dietary components intake which could not be categorized within macronutrients. Furthermore, only a handful of biomarkers demonstrated cost-effectiveness and non-invasiveness (e.g., fingerstick vs. venipuncture). Emphasis should be placed on developing biomarkers based on hair, fingernail and fingerstick samples that require only minimal invasiveness and subject burden (e.g., fasting). The practicality of the measure is also an important consideration, including the accessibility, collection, processing, storage and

analysis of the specimen (2). In order to advance research targeting public and clinical health initiatives, valid biomarkers that can be collected and assessed with these considerations are urgently needed (7).

Biomarkers are needed to provide objective measures of nutrient status, which is a commonly cited limitation of subjective dietary assessment methods. However, some dietary intake methods use biomarkers to validate the data being collected. As noted by The Institute of Medicine, the need to expand upon dietary assessment methods is critical (7). Biomarkers that will allow for the assessment of specific consumption of items which could be deemed socially undesirable, such as sugar-sweetened beverages or high fat/saturated fat foods, without confounds of human subjective nature need to be developed (10). Future research pertaining to biomarkers should emphasize the development of biomarkers for evaluating adherence to national recommendations for specific food groups such as the U.S. 2010 Dietary Guidelines (e.g., whole grains, fruits and vegetables, low fat/fat free dairy products, added sugar) (26).

More research is needed to refine existing biomarkers by accounting for confounding factors, establishing new indicators of specific food intake and developing techniques that are cost-effective, noninvasive, rapid and accurate measures of nutritional status. The emerging field of metabolomics in human nutrition, as well as the development of valid FFQ and the continued expansion of food metabolome databases will allow for the further identification of specific dietary components in food, produce more valid biomarkers of exposure to certain foods and possibly advance nutritional science research which aims to evaluate diet and disease relationships.

Table 7. Summary of Recent Biomarker Studies Related to Macronutrient Foods

Food/Dietary Component[a]	Reference	Biomarker[b] (Sample Size)	Biological Sample	Analytic Procedure[c]	Biomarker Class[d]	Validity[e, f]	Reproducibility[f]	Sensitivity[g]
Carbohydrates								
Cane Sugar/ HFCS	Cook et al. (2009)	^{13}C in blood glucose (5 young adults)	Plasma	GC-IRMS	Short term	0.90		
	Yeung et al. (2010)	^{13}C (186 older adults)	Serum (fasting)	CF-SIRMS		0.18		
	Davy et al. (2011)	^{13}C (60 adults)	Fingerstick	NA-SIMS	Medium term?	0.37	0.87	
Sugar	Tasevska et al. (2005)	Sucrose and Fructose (12 male adults; 13 adults)	Urine (24 hr)	Enzymatic	Short term	0.89	0.67	+
	Kuhnle et al. (2008)	Sucrose (7 adults)	Urine (24 hr)	GC-MS	Short term			
			Urine (24 hr)	LC-MS	Short term			
Whole-Grain Wheat/Rye	Linko-Parvinen et al. (2007)	Enterolactone (ENL) (15 adults)	Plasma (fasting)	TR-FIA	Short term			
		Total Alkylresorcinol (AR) concentration	Plasma (fasting)	GC-MS	Short term	0.94		
		Erythrocyte AR	RBC (fasting)	GC-MS	Medium term?	0.85		
	Landberg et al. (2008, 2009, 2009)	DHBA, DHPPA (15 adults)	Urine (24-hr)	HPLC	Short term			
		Total Alkylresorcinol (AR) concentration (30 adults; 17 males with prostate cancer)	Plasma (fasting)	GC-MS	Short term	0.58	0.85	+

Food/Dietary Component[a]	Reference	Biomarker[b] (Sample Size)	Biological Sample	Analytic Procedure[c]	Biomarker Class[d]	Validity[e, f]	Reproducibility[f]	Sensitivity[g]
Fats								
Total Fat	King et al. (2006)	PUFA, MUFA, SFA (66 postmenopausal females)	RBC (fasting)	1D-TLC	Long term?			+
			Plasma (fasting)	1D-TLC				+
Fatty Acids	Baylin et al. (2002)	PUFA (503 older Costa Rican adults)	Adipose tissue (fasting)	GLC		0.58		
		Trans-fatty acids	Adipose tissue (fasting)	GLC		0.43		
	Poppitt et al. (2005)	SFA, MUFA, PUFA (20 male adults)	RBC (fasting)	GC				
	Fuhrman et al. (2006)	Oleic acid (204 female adults, pre/post menopausal)	RBC (fasting)	GC	Medium term	0.45; 0.47*		
		Total PUFA	RBC (fasting)	GC	Medium term	0.17[h]; 0.39*		
		Total MUFA	RBC (fasting)	GC	Medium term	0.40; 0.48*		
		Total SFA	RBC (fasting)	GC		0.14[h]; 0.07*[h]		
	Thiebaut et al. (2009)	SFA, MUFA, PUFA (1,114 female adults)	Serum (fasting)	GC	Long term	0.16-0.29		

Food/Dietary Component[a]	Reference	Biomarker[b] (Sample Size)	Biological Sample	Analytic Procedure[c]	Biomarker Class[d]	Validity[e, f]	Reproducibility[f]	Sensitivity[g]
Essential Fatty Acids (EFA)	Baylin et al. (2005)	Alpha-linolenic acid and Linoleic acid (200 Costa Rican adults)	Adipose	GLC	Long term	0.51; 0.52**		
			Blood (fasting)	GLC	Long term	0.38; 0.43**		
			Plasma (fasting)	GLC	Long term	0.39; 0.41**		
	Fuhrman et al. (2006)	Linoleic acid (204 female adults, pre/post menopausal)	RBC (fasting)	GC	Medium term	0.23; 0.39*		
		Alpha-linolenic acid	RBC (fasting)	GC		0.14[h]; 0.07*[h]		
EPA, DHA	Kuriki et al. (2003)	EPA (15 male, 79 female Japanese dietitians)	Plasma (fasting)	GC		0.57; 0.60***		
		DHA	Plasma (fasting)	GC		0.57; 0.30***		
	O'Brien et al. (2009)	^{15}N - EPA (496 adult Yup'ik Eskimos)	Blood	CF-IRMS		0.47		
		^{15}N - DHA	Blood	CF-IRMS		0.46		
	Nash et al. (2009)	^{15}N - EPA (144 adult Yup'ik Eskimos)	Hair	CF-IRMS	Medium term	0.83		
		^{15}N - DHA	Hair	CF-IRMS	Medium term	0.84		
Olive oil	Miro-Casas et al. (2002)	Tyrosol (7 adults)	Urine (24-hr)	GC-MS	Short term			
		Hydroxytyrosol	Urine (24-hr)	GC-MS	Short term			

Food/Dietary Component[a]	Reference	Biomarker[b] (Sample Size)	Biological Sample	Analytic Procedure[c]	Biomarker Class[d]	Validity[e, f]	Reproducibility[f]	Sensitivity[g]
Proteins								
Protein	Bingham (2003)	Urine Nitrogen (8 adults)	Urine (24-hr)	Kjeldahl	Short term	0.99		
Animal Protein	Petzke and Lemke (2009)	^{13}C (14 young female adults)	Hair	GC/C/IRMS	Medium term-Long term?	0.44		
		^{15}N	Hair	GC/C/IRMS	Medium term-Long term?	0.17[h]		

[a]HFCS, High fructose corn syrup; EPA, Eicosapentaenoic Acid; DHA, Docosahexaenoic Acid.

[b]DHBA, 3,5-Dihydroxybenzoic Acid; DHPPA, 3-(3,5-Dihydroxyphenyl)-Propanoic Acid; PUFA, Poly-Unsaturated Fatty Acid; MUFA, Mono-Unsaturated Fatty Acid; SFA, Saturated Fatty Acid; RBC, Red Blood Cell.

[c]GC-IRMS, gas chromatography isotope ratio mass; CF-SIRMS, Continuous-flow stable isotope ratio mass spectrometry; NA-SIMS, Natural abundance stable isotope mass spectrometry; GC-MS, Gas chromatography-mass spectrometry; LC-MS, Liquid chromatography-mass spectrometry; TR-FIA, Time-resolved fluroimmunoassay; HPLC, High-performance liquid chromatography; 1D-TLC, One-dimensional thin-layer chromatography; GLC, Gas liquid chromatography; GC, Gas chromatography; CF-IRMS, Continuous-flow isotope ratio mass spectrometry; GC/C/IRMS, Gas chromatography/combustion/ isotope ratio mass spectrometry.

[d]Short term: hours/days; Medium term: weeks/months; Long term: months/years.

[e]Correlations of biomarkers as compared to an appropriate dietary assessment method; Significant ($P<0.05$) unless otherwise specified.

[f]Representative values from the literature.

[g]Biomarker is able to detect changes over time; + = sensitivity has been demonstrated.

[h]Correlation not significant.

[*]Values presented are pre, post menopausal, respectively.

[**]Values presented are alpha-linolenic, linoleic acid, respectively.

[***]Values presented are male, female, respectively.

Table 8. Summary of Recent Biomarker Studies on Various Food/Dietary Components

Food/Dietary Component	Reference	Biomarker (Sample Size)	Biological Sample	Analytic Procedure[a]	Biomarker Class[b]	Validity[c,d]	Reproducibility[d]	Sensitivity[e]
Foods/Dietary Components								
Caffeine	Crews et al. (2001)	Caffeine (137X) (8 adults)	Urine (24-hr)	HPLC	Short term			
		Caffeine Metabolite: 17X	Urine (24-hr)	HPLC	Short term	0.58*		
		Caffeine Metabolite: 17U	Urine (24-hr)	HPLC	Short term	0.87*		
		Caffeine Metabolite: 1X	Urine (24-hr)	HPLC	Short term	0.78*		
		Caffeine Metabolite: AFMU	Urine (24-hr)	HPLC	Short term			
Citrus	Heinzmann et al. (2010)	Proline Betaine (8 adults)	Urine (24-hr)	1H NMR	Short term	0.40		+
Cocoa	Llorach et al. (2009)	Urinary metabolome (10 adults)	Urine	HPLC-q-TOF	Short term			
Garlic	Verhagen et al. (2001)	S-allyl-mercapturic acid (ALMA) (101 male adults)	Urine (24-hr)	GC-MS	Short term			
Wine	Zamora-Ros et al. (2006)	Total resveratrol metabolites (TRMs) (20 adults)	Urine (fasting)	LC-MS/MS	Short term			+
		TRMs	Plasma (fasting)	LC-MS/MS	Short term			

[a]HPLC, High-performance liquid chromatography; 1H NMR, 1H Nuclear magnetic resonance spectroscopy; HPLC-q-TOF, High-performance liquid chromatography with time of flight mass spectrometry; GC-MS, Gas chromatography-mass spectrometry; LC-MS/MS, Liquid chromatography-tandem mass spectrometry.

[b]Short term: hours/days; Medium term: weeks/months; Long term: months/years.

[c]Significant correlations ($P<0.05$) of biomarkers as compared to an appropriate dietary assessment method.

[d]Representative values from the literature.

[e]Biomarker is able to detect changes in intake over time.

*Significance not reported.

References

1. Frobisher C, Maxwell SM. The estimation of food portion sizes: a comparison between using descriptions of portion sizes and a photographic food atlas by children and adults. *J Hum Nutr Diet.* 2003;16(3):181-188.
2. Monsen E. *Research: Successful Approaches*. 2nd ed: American Dietetic Association; 2003.
3. Thompson FE, Subar AF, Loria CM, Reedy JL, Baranowski T. Need for technological innovation in dietary assessment. *J Am Diet Assoc.* 2010;110(1):48-51.
4. Willett W, Lenart E. *Nutritional Epidemiology*. 2nd ed: Oxford University Press; 1998.
5. Marshall T, Eichenberger Gilmore J, Broffitt B, Levy S, Stumbo P. Relative validation of a beverage frequency questionnaire in children ages 6 months through 5 years using 3-day food and beverage diaries. *J Am Diet Assoc.* 2003;103(6):714-720.
6. Thomson C, Giuliano A, Rock C, Ritenbaugh C, Flatt S, Faerber S, Newman V, Caan B, Graver E, Hartz V, Whitacre R, Parker F, Pierce J, Marshall J. Measuring dietary change in a diet intervention trial: comparing food frequency questionnaire and dietary recalls. *Am J Epidemiol.* 2003;157(8):754-762.
7. Institute of Medicine of the National Academies. Dietary Reference Intakes: Research Synthesis Workshop Summary. Washington, DC: The National Academies Press; 2007.
8. Hardin DS. Validating dietary intake with biochemical markers. *J Am Diet Assoc*. 2009;109(10):1698-1699.
9. McCabe-Sellers B. Advancing the art and science of dietary assessment through technology. *J Am Diet Assoc.* 2010;110(1):52-54.

10. Potischman N. Biologic and methodologic issues for nutritional biomarkers. *J Nutr.* 2003;133(3):875S-880S.

11. Jenab M, Slimani N, Bictash M, Ferrari P, Bingham S. Biomarkers in nutritional epidemiology: applications, needs and new horizons. *Hum Genet.* 2009;125(5):507-525.

12. Brennan L. Session 2: Personalised nutrition. Metabolomic applications in nutritional research. *Proc Nutr Soc.* 2008;67(4):404-408.

13. Zivkovic A, German J. Metabolomics for assessment of nutritional status. *Curr Opin Clin Nutr Metab Care.* 2009;12(5):501-507.

14. Gibney MJ, Walsh M, Brennan L, Roche HM, German B, van Ommen B. Metabolomics in human nutrition: opportunities and challenges. *Am J Clin Nutr.* 2005;82(3):497-503.

15. Wishart DS, Tzur D, Knox C, Eisner R, Guo AC, Young N, Cheng D, Jewell K, Arndt D, Sawhney S, Fung C, Nikolai L, Lewis M, Coutouly M-A, Forsythe I, Tang P, Shrivastava S, Jeroncic K, Stothard P, Amegbey G, Block D, Hau DD, Wagner J, Miniaci J, Clements M, Gebremedhin M, Guo N, Zhang Y, Duggan GE, MacInnis GD, Weljie AM, Dowlatabadi R, Bamforth F, Clive D, Greiner R, Li L, Marrie T, Sykes BD, Vogel HJ, Querengesser L. HMDB: The Human Metabolome Database. *Nucleic Acids Res.* 2007;35(suppl 1):D521-D526.

16. Oresic M. Metabolomics, a novel tool for studies of nutrition, metabolism and lipid dysfunction. *Nutr Metab Cardiovas.* 2009;19(11):816-824.

17. O'Sullivan A, Gibney MJ, Brennan L. Dietary intake patterns are reflected in metabolomic profiles: potential role in dietary assessment studies. *Am J Clin Nutr.* 2011;93(2):314-321.

18. Heinzmann SS, Brown IJ, Chan Q, Bictash M, Dumas M-E, Kochhar S, Stamler J, Holmes E, Elliott P, Nicholson JK. Metabolic profiling strategy for discovery of nutritional biomarkers: proline betaine as a marker of citrus consumption. *Am J Clin Nutr.* 2010;92(2):436-443.

19. Davy BM, Jahren AH, Hedrick VE, Comber DL. Association of $\delta^{13}C$ in fingerstick blood with added-sugar and sugar-sweetened beverage intake. *J Am Diet Assoc.* 2011;111(6):874-878.

20. Elliott SS, Keim NL, Stern JS, Teff K, Havel PJ. Fructose, weight gain, and the insulin resistance syndrome. *Am J Clin Nutr.* 2002;76(5):911-922.

21. Popkin BM, Barclay D, Nielsen S. Water and food consumption patterns of U.S. adults from 1999 to 2001. *Obes Res.* 2005;13:2146-2152.

22. Stookey JD, Constant F, Gardner CD, Popkin BM. Replacing sweetened caloric beverages with drinking water is associated with lower energy intake. *Obesity.* 2007;15(12):3013-3022.

23. Allison DB, Mattes RD. Nutritively sweetened beverage consumption and obesity. *J Am Med Assoc.* 2009;301(3):318-320.

24. Brownell KD, Farley T, Willett WC, Popkin BM, Chaloupka FJ, Thompson JW, Ludwig DS. The public health and economic benefits of taxing sugar-sweetened beverages. *New Engl J Med.* 2009;361(16):1599-1605.

25. Van Baak MA, Astrup A. Consumption of sugars and body weight. *Obes Rev.* 2009;10:9-23.

26. U.S. Department of Health and Human Services, and U.S. Department of Agriculture (HHS, USDA). Dietary Guidelines for Americans, 7th Edition. Washington, DC: U.S. Government Printing Office; 2010.

27. Flight I, Clifton P. Cereal grains and legumes in the prevention of coronary heart disease and stroke: a review of the literature. *Eur J Clin Nutr.* 2006;60(10):1145-1159.

28. Landberg R, Kamal-Eldin A, Andersson A, Vessby B, Aman P. Alkylresorcinols as biomarkers of whole-grain wheat and rye intake: plasma concentration and intake estimated from dietary records. *Am J Clin Nutr.* 2008;87(4):832-838.

29. Jahren AH, Saudek C, Yeung EH, Kao WL, Kraft RA, Caballero B. An isotopic method for quantifying sweeteners derived from corn and sugar cane. *Am J Clin Nutr.* 2006;84(6):1380-1384.

30. Cook CM, Alvig AL, Liu YQ, Schoeller DA. The natural ^{13}C abundance of plasma glucose is a useful biomarker of recent dietary caloric sweetener intake. *J Nutr.* 2010;140(2):333-337.

31. Yeung EH, Saudek CD, Jahren AH, Kao WHL, Islas M, Kraft R, Coresh J, Anderson CAM. Evaluation of a novel isotope biomarker for dietary consumption of sweets. *Am J Epidemiol.* 2010;172(9):1045-1052.

32. Kraft RA, Jahren AH, Saudek CD. Clinical-scale investigation of stable isotopes in human blood: $\delta^{13}C$ and $\delta^{15}N$ from 406 patients at the Johns Hopkins Medical Institutions. *Rapid Commun Mass Sp.* 2008;22(22):3683-3692.

33. Tasevska N, Runswick SA, McTaggart A, Bingham SA. Urinary sucrose and fructose as biomarkers for sugar consumption. *Cancer Epidem Biomar.* 2005;14(5):1287-1294.

34. Joosen AMCP, Kuhnle GGC, Runswick SA, Bingham SA. Urinary sucrose and fructose as biomarkers of sugar consumption: comparison of normal weight and obese volunteers. *Int J Obes.* 2008;32(11):1736-1740.

35. Kuhnle GGC, Joosen AMCP, Wood TR, Runswick SA, Griffin JL, Bingham SA. Detection and quantification of sucrose as dietary biomarker using gas chromatography and liquid chromatography with mass spectrometry. *Rapid Commun Mass Sp.* 2008;22(3):279-282.

36. Linko-Parvinen A-M, Landberg R, Tikkanen MJ, Adlercreutz H, Peñalvo JL. Alkylresorcinols from whole-grain wheat and rye are transported in human plasma lipoproteins. *J Nutr.* 2007;137(5):1137-1142.

37. Landberg R, Kamal-Eldin A, Andersson S-O, Johansson J-E, Zhang J-X, Hallmans G, Åman P. Reproducibility of plasma alkylresorcinols during a 6-week rye intervention study in men with prostate cancer. *J Nutr.* 2009;139(5):975-980.

38. Landberg R, Åman P, Friberg LE, Vessby B, Adlercreutz H, Kamal-Eldin A. Dose response of whole-grain biomarkers: alkylresorcinols in human plasma and their metabolites in urine in relation to intake. *Am J Clin Nutr.* 2009;89(1):290-296.

39. King IB, Lemaitre RN, Kestin M. Effect of a low-fat diet on fatty acid composition in red cells, plasma phospholipids, and cholesterol esters: investigation of a biomarker of total fat intake. *Am J Clin Nutr.* 2006;83(2):227-236.

40. Baylin A, Kabagambe EK, Siles X, Campos H. Adipose tissue biomarkers of fatty acid intake. *Am J Clin Nutr.* 2002;76(4):750-757.

41. O'Brien DM, Kristal AR, Jeannet MA, Wilkinson MJ, Bersamin A, Luick B. Red blood cell $\delta^{15}N$: a novel biomarker of dietary eicosapentaenoic acid and docosahexaenoic acid intake. *Am J Clin Nutr.* 2009;89(3):913-919.

42. Poppitt S, Kilmartin P, Butler P, Keogh G. Assessment of erythrocyte phospholipid fatty acid composition as a biomarker for dietary MUFA, PUFA or saturated fatty acid intake in a controlled cross-over intervention trial. *Lipids Health Dis.* 2005;4(1):30.

43. Thiébaut ACM, Rotival M, Gauthier E, Lenoir GM, Boutron-Ruault M-C, Joulin V, Clavel-Chapelon F, Chajès V. Correlation between serum phospholipid fatty acids and dietary intakes assessed a few years earlier. *Nutr Cancer.* 2009;61(4):500-509.

44. Fuhrman B, Barba M, Krogh V, Micheli A, Pala V, Lauria R, Chajes V, Riboli E, Sieri S, Berrino F, Muti P. Erythrocyte membrane phospholipid composition as a biomarker of dietary fat. *Ann Nutr Metab.* 2006;50(2):95-102.

45. Baylin A, Kim MK, Donovan-Palmer A, Siles X, Dougherty L, Tocco P, Campos H. Fasting whole blood as a biomarker of essential fatty acid intake in epidemiologic studies: comparison with adipose tissue and plasma. *Am J Epidemiol.* 2005;162(4):373-381.

46. Kuriki K, Nagaya T, Tokudome Y, Imaeda N, Fujiwara N, Sato J, Goto C, Ikeda M, Maki S, Tajima K, Tokudome S. Plasma concentrations of (n-3) highly unsaturated fatty acids are good biomarkers of relative dietary fatty acid intakes: a cross-sectional study. *J Nutr.* 2003;133(11):3643-3650.

47. Nash SH, Kristal AR, Boyer BB, King IB, Metzgar JS, O'Brien DM. Relation between stable isotope ratios in human red blood cells and hair: implications for using the

nitrogen isotope ratio of hair as a biomarker of eicosapentaenoic acid and docosahexaenoic acid. *Am J Clin Nutr.* 2009;90(6):1642-1647.

48. Miro-Casas E, Covas MI, Fito M, Farre-Albadalejo M, Marrugat J, de la Torre R. Tyrosol and hydroxytyrosol are absorbed from moderate and sustained doses of virgin olive oil in humans. *Eur J Clin Nutr.* 2003;57(1):186-190.

49. Petzke KJ, Lemke S. Hair protein and amino acid ^{13}C and ^{15}N abundances take more than 4 weeks to clearly prove influences of animal protein intake in young women with a habitual daily protein consumption of more than 1 g per kg body weight. *Rapid Commun Mass Sp.* 2009;23(16):2411-2420.

50. Bingham SA. Urine nitrogen as a biomarker for the validation of dietary protein intake. *J Nutr.* 2003;133(3):921S-924S.

51. Crews H, Olivier L, Wilson L. Urinary biomarkers for assessing dietary exposure to caffeine. *Food Addit Contam.* 2001;18(12):1075-1087.

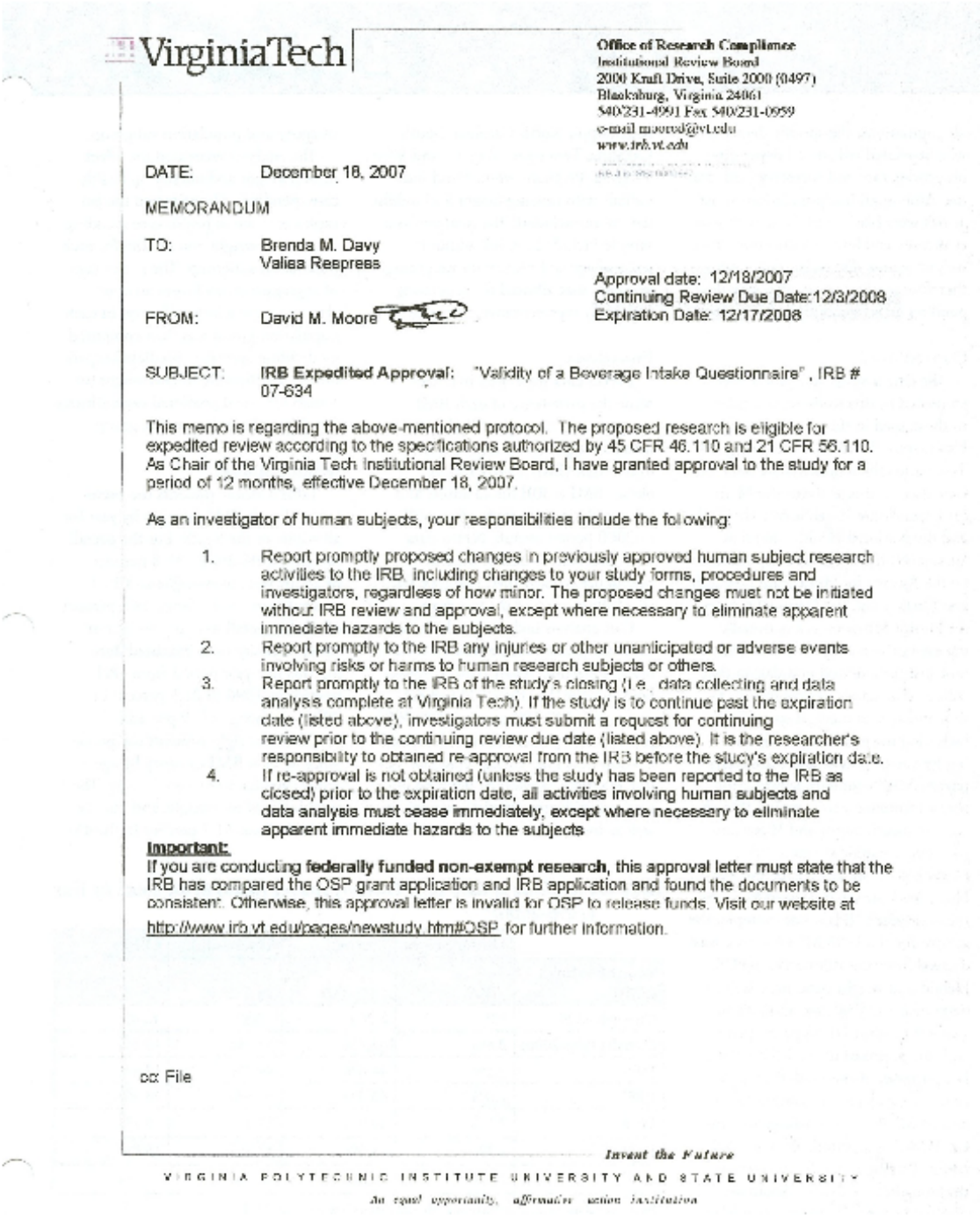
52. Thompson HJ, Heimendinger J, Diker A, O'Neill C, Haegele A, Meinecke B, Wolfe P, Sedlacek S, Zhu Z, Jiang W. Dietary botanical diversity affects the reduction of oxidative biomarkers in women due to high vegetable and fruit intake. *J Nutr.* 2006;136(8):2207-2212.

53. Llorach R, Urpi-Sarda M, Jauregui O, Monagas M, Andres-Lacueva C. An LC-MS-based metabolomics approach for exploring urinary metabolome modifications after cocoa consumption. *J Proteome Res.* 2009;8(11):5060-5068.

54. Verhagen H, Hageman GJ, Rauma A-L, Versluis-de Haan G, van Herwijnen MHM, de Groot J, Törrönen R, Mykkänen H. Biomonitoring the intake of garlic via urinary excretion of allyl mercapturic acid. *Brit J Nutr.* 2001;86(SupplementS1):S111-S114.

55. Zamora-Ros R, Urpi-Sarda M, Lamuela-Raventos RM, Estruch R, Vazquez-Agell M, Serrano-Martinez M, Jaeger W, Andres-Lacueva C. Diagnostic performance of urinary resveratrol metabolites as a biomarker of moderate wine consumption. *Clin Chem.* 2006;52(7):1373-1380.

Appendix A: Institutional Review Board Approval



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DATE: December 18, 2007

MEMORANDUM

TO: Brenda M. Davy
Valisa Respress

Approval date: 12/18/2007
Continuing Review Due Date:12/3/2008
Expiration Date: 12/17/2008

FROM: David M. Moore

SUBJECT: **IRB Expedited Approval:** "Validity of a Beverage Intake Questionnaire", IRB # 07-634

This memo is regarding the above-mentioned protocol. The proposed research is eligible for expedited review according to the specifications authorized by 45 CFR 46.110 and 21 CFR 56.110. As Chair of the Virginia Tech Institutional Review Board, I have granted approval to the study for a period of 12 months, effective December 18, 2007.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in previously approved human subject research activities to the IRB, including changes to your study forms, procedures and investigators, regardless of how minor. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.
2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.
3. Report promptly to the IRB of the study's closing (i.e., data collecting and data analysis complete at Virginia Tech). If the study is to continue past the expiration date (listed above), investigators must submit a request for continuing review prior to the continuing review due date (listed above). It is the researcher's responsibility to obtained re-approval from the IRB before the study's expiration date.
4. If re-approval is not obtained (unless the study has been reported to the IRB as closed) prior to the expiration date, all activities involving human subjects and data analysis must cease immediately, except where necessary to eliminate apparent immediate hazards to the subjects.

Important:
If you are conducting **federally funded non-exempt research**, this approval letter must state that the IRB has compared the OSP grant application and IRB application and found the documents to be consistent. Otherwise, this approval letter is invalid for OSP to release funds. Visit our website at http://www.irb.vt.edu/pages/newstudy.htm#OSP for further information.

cc: File

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FWA00000572(expires 1/20/2010)
IRB # is IRB00000667

DATE: May 16, 2008

MEMORANDUM

TO: Brenda M. Davy
Valisa Respress

Approval date: 12/18/2007
Continuing Review Due Date:12/3/2008
Expiration Date: 12/17/2008

FROM: David M. Moore

SUBJECT: **IRB Amendment 1 Approval:** "Validity of a Beverage Intake Questionnaire" , IRB # 07-634

This memo is regarding the above referenced protocol which was previously granted approval by the IRB on December 18, 2007. You subsequently requested permission to amend your IRB application. Since the requested amendment is nonsubstantive in nature, I, as Chair of the Virginia Tech Institutional Review Board, have granted approval for requested protocol amendment, effective as of May 16, 2008. The anniversary date will remain the same as the original approval date.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in previously approved human subject research activities to the IRB, including changes to your study forms, procedures and investigators, regardless of how minor. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.
2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.
3. Report promptly to the IRB of the study's closing (i.e., data collecting and data analysis complete at Virginia Tech). If the study is to continue past the expiration date (listed above), investigators must submit a request for continuing review prior to the continuing review due date (listed above). It is the researcher's responsibility to obtain re-approval from the IRB before the study's expiration date.
4. If re-approval is not obtained (unless the study has been reported to the IRB as closed) prior to the expiration date, all activities involving human subjects and data analysis must cease immediately, except where necessary to eliminate apparent immediate hazards to the subjects.

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FWA00000572(expires 1/20/2010)
IRB # is IRB00000667

DATE: September 30, 2009

MEMORANDUM

TO: Brenda M. Davy
Valisa Respress

Approval date: 9/29/2009
Continuing Review Due Date:9/14/2010
Expiration Date: 9/28/2010

FROM: David M. Moore

SUBJECT: **IRB Expedited Approval:** "Evaluation of a Dietary Questionnaire" , IRB # 09-731

This memo is regarding the above-mentioned protocol. The proposed research is eligible for expedited review according to the specifications authorized by 45 CFR 46.110 and 21 CFR 56.110. As Chair of the Virginia Tech Institutional Review Board, I have granted approval to the study for a period of 12 months, effective September 29, 2009.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in previously approved human subject research activities to the IRB, including changes to your study forms, procedures and investigators, regardless of how minor. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.
2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.
3. Report promptly to the IRB of the study's closing (i.e., data collecting and data analysis complete at Virginia Tech). If the study is to continue past the expiration date (listed above), investigators must submit a request for continuing review prior to the continuing review due date (listed above). It is the researcher's responsibility to obtain re-approval from the IRB before the study's expiration date.
4. If re-approval is not obtained (unless the study has been reported to the IRB as closed) prior to the expiration date, all activities involving human subjects and data analysis must cease immediately, except where necessary to eliminate apparent immediate hazards to the subjects.

Important:
If you are conducting **federally funded non-exempt research**, please send the applicable OSP/grant proposal to the IRB office, once available. OSP funds may not be released until the IRB has compared and found consistent the proposal and related IRB applicaton.

cc: File

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MEMORANDUM

DATE: May 27, 2010

TO: Brenda M. Davy, Valisa Respress

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires June 13, 2011)

PROTOCOL TITLE: Evaluation of a Dietary Questionnaire

IRB NUMBER: 09-731

Effective May 27, 2010, the Virginia Tech IRB Chair, Dr. David M. Moore, approved the amendment request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at http://www.irb.vt.edu/pages/responsibilities.htm (please review before the commencement of your research).

PROTOCOL INFORMATION:
Approved as: **Expedited, under 45 CFR 46.110 category(ies) 4, 7**
Protocol Approval Date: **9/29/2009**
Protocol Expiration Date: **9/28/2010**
Continuing Review Due Date*: **9/14/2010**
*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:
Per federally regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals / work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Date*	OSP Number	Sponsor	Grant Comparison Conducted?
5/27/2010	06057909	NIDDKD	yes on 5/27/2010

*Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.

cc: File

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MEMORANDUM

DATE: August 31, 2011

TO: Brenda M. Davy, Valisa Respress

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires May 31, 2014)

PROTOCOL TITLE: Evaluation of a Dietary Questionnaire

IRB NUMBER: 09-731

Effective September 29, 2011, the Virginia Tech IRB Chair, Dr. David M. Moore, approved the continuation request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at http://www.irb.vt.edu/pages/responsibilities.htm (please review before the commencement of your research).

PROTOCOL INFORMATION:
Approved as: **Expedited, under 45 CFR 46.110 category(ies) 4, 7**
Protocol Approval Date: **9/29/2011 (protocol's initial approval date: 9/29/2009)**
Protocol Expiration Date: **9/28/2012**
Continuing Review Due Date*: **9/14/2012**
*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:
Per federally regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals / work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Date*	OSP Number	Sponsor	Grant Comparison Conducted?
5/27/2010	06057909	NIDDKD	yes on 5/27/2010

*Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.

cc: File

Appendix B: Fruit and Vegetable Screener (FVS)

Subject ID: _____

Date: _____

Fruit-Vegetable Screener

Think about your eating habits over the past month or so. About how often do you eat each of the following foods? Remember breakfast, lunch, dinner, snacks and eating out. Mark one bubble for each food.

	(0)	(1)	(2)	(3)	(4)	(5)	Office use only
Fruits and Vegetables	Less than 1 per WEEK	Once a WEEK	2-3 times a WEEK	4-6 times a WEEK	Once a DAY	2+ a DAY	**SCORE**
Fruit juice, like orange, apple, grape, fresh, frozen or canned. (Not sodas or other drinks)	o	o	o	o	o	o	
How often do you eat any fruit, fresh or canned (not counting juice?)	o	o	o	o	o	o	
Vegetable juice, like tomato juice, V-8, carrot	o	o	o	o	o	o	
Green salad	o	o	o	o	o	o	
Potatoes, any kind, including baked, mashed or french fried	o	o	o	o	o	o	
Vegetable soup, or stew with vegetables	o	o	o	o	o	o	
Any other vegetables, including string beans, peas, corn, broccoli or any other kind	o	o	o	o	o	o	

Fruit Vegetable Score_____

Adapted from:

BLOCK DIETARY DATA SYSTEMS
www.nutritionquest.com

Appendix C: Daily Tracking Sheet for Water and Fruit Juice

Water and Fruit Juice Group - Instruction Sheet

Instructions:

Drink 2 bottles of *Deer Park* water and 2 boxes of *Juicy Juice* every day in addition to your normal beverage consumption. Please check off the boxes corresponding to water and juice each day after you have consumed one serving. We understand that occasionally you may not be able to consume 2 waters and 2 juices every day so we ask that you be honest when recording your consumption.

Day/Date	Day 1 Date:	Day 2 Date:	Day 3 Date:	Day 4 Date:	Day 5 Date:	Day 6 Date:	Day 7 Date:	Day 8 Date:
Water	☐	☐	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐	☐	☐
Juice	☐	☐	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐	☐	☐

Day/Date	Day 9 Date:	Day 10 Date:	Day 11 Date:	Day 12 Date:	Day 13 Date:	Day 14 Date:	Day 15 Date:	Day 16 Date:
Water	☐	☐	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐	☐	☐
Juice	☐	☐	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐	☐	☐

Day/Date	Day 17 Date:	Day 18 Date:	Day 19 Date:	Day 20 Date:	Day 21 Date:	Day 22 Date:	Day 23 Date:	Day 24 Date:
Water	☐	☐	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐	☐	☐
Juice	☐	☐	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐	☐	☐

Day/Date	Day 25 Date:	Day 26 Date	Day 27 Date:	Day 28 Date:	Day 29 Date:	Day 30 Date:
Water	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐
Juice	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐

Appendix D: Daily Tracking Sheet for Whole Fruit

Whole Fruit Group - Instruction Sheet

Instructions:

Eat 2 servings of fruit every day (whole or canned) in addition to your normal fruit consumption. Please check off the boxes after you have consumed one serving of fruit. We understand that occasionally you may not be able to consume 2 servings of fruit every day so we ask that you be honest when recording your consumption.

Day/Date	Day 1 Date:	Day 2 Date:	Day 3 Date:	Day 4 Date:	Day 5 Date:	Day 6 Date:	Day 7 Date:	Day 8 Date:
Fruit	☐	☐	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐	☐	☐

Day/Date	Day 9 Date:	Day 10 Date:	Day 11 Date:	Day 12 Date:	Day 13 Date:	Day 14 Date:	Day 15 Date:	Day 16 Date:
Fruit	☐	☐	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐	☐	☐

Day/Date	Day 17 Date:	Day 18 Date:	Day 19 Date:	Day 20 Date:	Day 21 Date:	Day 22 Date:	Day 23 Date:	Day 24 Date:
Fruit	☐	☐	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐	☐	☐

Day/Date	Day 25 Date:	Day 26 Date:	Day 27 Date:	Day 28 Date:	Day 29 Date:	Day 30 Date:
Fruit	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐