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Original Research

Development and Validation of a Comprehensive Semi-Quantitative Food Frequency Questionnaire that Includes FODMAP Intake and Glycemic Index

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ABSTRACT

Background Fermentable, short chain carbohydrates (FODMAPs) have been identified as triggers for functional gastrointestinal symptoms. In addition, excess FODMAP consumption has been implicated in the onset of Crohn's disease, and animal studies suggest that a low glycemic index diet can impair absorption of fructose, a major dietary FODMAP. Such hypotheses cannot be tested without the ability to quantify FODMAP ingestion with a validated dietary assessment tool.

Objective To assess the validity and reproducibility of a 297-item comprehensive, semi-quantitative food frequency questionnaire (FFQ) in estimating intake of macro- and micronutrients, FODMAPs, and glycemic index/load.

Subjects/setting One hundred healthy participants were recruited to complete the FFQ on two occasions, plus four 1-week food diaries kept during a 12-month period. Participants exhibiting major dietary change during the study period or low energy reporting on the FFQ were excluded.

Main outcome measures Validation and reproducibility of the semi-quantitative FFQ by comparison with the mean of four 1-week food diaries.

Statistical analyses performed Validation was assessed using Wilcoxon signed rank test, Spearman's correlation, Bland-Altman, and weighted κ statistics. Reproducibility was examined using Shrout-Fleiss intraclass correlation coefficient.

Results Seventy-two participants fulfilled inclusion and exclusion criteria. Demographics of the participants were comparable with 2006 Australian Census data. Consistent with other reported FFQs, the FFQ overestimated nutrient intake by a mean 140% (range=95% to 249%). However, based on the other analyses performed, it demonstrated validity for intake of sugars, fiber, alcohol, glycemic index, glucose, FODMAPs, calcium, folate, phosphate, potassium, iron, and magnesium; moderate validation for energy, total fat, saturated fat, carbohydrates, sodium, thiamin, sucrose, and retinol; poor validation for protein, mono/polyunsaturated fat, starch, glycemic load, niacin, and zinc. Riboflavin intake was not validated. Intraclass correlation coefficients for reproducibility ranged from 0.352 to 0.928.

Conclusions The FFQ was validated for assessment of a wide range of nutrients, including the new class of carbohydrates, FODMAPs, and glycemic index. This provides a useful tool for dietary research, particularly in the area of gastroenterological disorders.

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Dietary, poorly absorbed, short chain carbohydrates (fermentable oligo-, di-, mono-saccharides, and polyols [FODMAPs]) have been highlighted as triggers for gastrointestinal symptoms in irritable bowel syndrome (1-7), Crohn's disease, and ulcerative colitis (8). The main dietary sources of FODMAPs include fructose in excess of glucose, in honey, apples, and pears; fructans in wheat, rye, onion, and garlic; galactans in cabbage and legumes; lactose in milk and milk products; and polyols, including sorbitol and mannitol in stone fruits, mushrooms and used as artificial sweeteners. Dietary restriction of FODMAPs has been shown to reduce symptoms of bloating, gas, and diarrhea, with placebo-controlled rechallenge confirming the role of FODMAPs in symptom induction. Although the intestinal response to FODMAPs can be the most important single factor in the induction of symptoms, the actual level of FODMAP intake by those with functional symptoms is of pathogenic relevance. In addition, these carbohydrates have been implicated in the onset of Crohn's disease in genetically susceptible individuals, with delivery of poorly absorbed carbohydrates theoretically increasing intestinal permeability and mucosal injury (9). In order to examine such theories, as well other relationships between specific dietary sugars and disease, knowledge of the level of intake of FODMAPs is of great importance in the relevant populations. It is challenging, however, to measure and quantify usual dietary intake in epidemiologic studies, particularly when

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dietary assessment tools validated to measure FODMAP consumption do not exist.

Nutrition surveys are used widely in medical research to determine dietary trends and associations. Assessments can be made using a variety of methods, including 24-hour food recall, weighed food records, and food frequency questionnaires (FFQs). In order to gain exposure to an individual's usual dietary habits, sacrificing precise measurements for information relating to a longer time frame can be more beneficial (10). Such data can be acquired from the use of FFQs.

Validation studies involve comparison of responses to the new tool (FFQ) with those achieved with a "gold standard" of measuring dietary intake. A true gold standard does not exist and, therefore, the majority of FFQ validation studies use 24-hour recalls, food diaries, or weighed food records. Each of these has its own limitations, particularly as they all provide just a "snapshot" of an individual's dietary intake unless completed daily for a 12-month period, which is obviously not appealing to recruited subjects. In practice, the majority of studies implements food diaries or weighed food records for comparison with the FFQs, each kept for 3 to 7 days at quarterly intervals over a year to capture seasonal variation.

The analytical techniques to quantify levels of FODMAPs in food have been developed, allowing the compilation of FODMAP composition tables of Australian foods (11,12). These data can now be used for the design and validation of an FFQ able to assess FODMAP consumption. Accordingly, this study aimed to design and assess the validity and reproducibility of an FFQ able to measure FODMAP intake. In addition, it was decided that creating a comprehensive FFQ able to measure FODMAPs while also assessing intake of macro- and micronutrients would provide a dietary assessment tool with multiple uses. Responses to this comprehensive FFQ were compared with data captured by four 1-week food records kept during a 12-month period to gain information on seasonal variation.

METHODS

A 297-item comprehensive FFQ was designed to assess macronutrient and micronutrient intake, FODMAPs, fiber, starch, glycemic index, and glycemic load. The questionnaire was based on the Harvard FFQ (13), with sections divided into individual food groups. The FFQ included initial questions on vitamin/mineral supplementation, and then covered all food groups. Food lists were considerably expanded compared with existing FFQs because of the variability of FODMAP intake between similar foods (eg, peaches and nectarines). Foods were listed as typical serving sizes obtained from NUTTAB 2006, a reference database for Food Standards Australia, New Zealand (http://www.foodstandards.gov.au/monitoringandsurveillance/nuttab2006/ onlineversionintroduction/onlineversion.cfm) in order to provide semi-quantitative assessment.

The food record format allowed for entry of foods and fluids consumed at breakfast, morning tea, lunch, afternoon tea, dinner, supper, as well as supplement use. It also included prompts for subjects to note metric quantities of each food and specific ingredients in a recipe so that all the foods consumed could be entered for analysis.

Subject Recruitment

One hundred English-speaking volunteers were recruited from a variety of sources to ensure people from different social, ethnic, and educational backgrounds were included. Advertisement began at Box Hill Hospital, with additional participants recruited through flyers and word of mouth. Registered dietitians were excluded in this validation study as it was thought they may affect the outcomes with their advanced skills in completing such questionnaires and food records.

Additional exclusion criteria were to be applied on the results of data collection and analysis. Any participant who admitted to major changes in their diet during the study period or changes to existing medical conditions that impact on diet (such as newly diagnosed diabetes or change in activity of inflammatory bowel disease) were excluded because they are likely to impact on validation of the FFQ. In addition, the ratio of energy intake (EI) compared with estimated basal metabolic rate using Schofield Equation (basal metabolic rate [BMR]) was used to determine whether subjects substantially underestimated intake. A cut-off in EI/BMR (14) of <1.06 for the food diaries and <1.35 for the FFQ based on 95% confidence intervals was applied because this identifies low energy reporters and, therefore, results that are not representative of usual intake.

All subjects were asked to complete the FFQ first. At that time, they were also provided with a 7-day food record to complete, which requested meal and beverage details including metric measure estimates of serving sizes, ingredients, and recipes. Three months later, the second 7-day food record was sent to the subjects for completion. A total of four 7-day food records were completed, each 3 months apart. When the final food record was returned, subjects were then sent the FFQ to repeat for reproducibility analysis.

All participants gave written informed consent prior to enrollment in the study. The protocol was approved by the Eastern Health Research and Ethics Committee, Box Hill, Victoria, Australia.

Survey Food Composition Database Development

Compilation of the food composition database (Figure) was undertaken using a combination method (15). FODMAP data for the majority of foods were taken directly from our laboratory with close control of sampling and analysis. Indirect data were retrieved from NUTTAB 2006 to obtain macro- and micronutrient nutritional analysis of the foods. All foods within the FFQs were added to the database. Once food diaries were entered for analysis, the additional most commonly consumed foods were added to the database. Data were a combination of original (from our laboratory), imputed (analytical values obtained from recipe calculation), or borrowed from existing databases. Where several food choices were available on NUTTAB 2006, the online database was cross-referenced to examine the food choices in more detail and choose the most appropriate. FoodWorks Professional Edition (version 4.00.1194, Xyris Software [Australia] Pty Ltd; www.xyris.com.au, Brisbane, Queensland, Australia) was used as the software to hold the database.