RESEARCH
Original Research

Reproducibility and Intermethod Reliability of a Calcium Food Frequency Questionnaire for Use in Hispanic, Non-Hispanic Black, and Non-Hispanic White Youth

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ABSTRACT

Background A dietary assessment instrument designed for use in a nationally representative pediatric population was required to examine associations between calcium intake and bone mineral accrual in a large, multicenter study.

Objective To determine the reproducibility and intermethod reliability of a youth calcium food frequency questionnaire (FFQ) in a multiracial/ethnic sample of children and adolescents.

Design Reproducibility (n=69) and intermethod reliability (n=393) studies were conducted by administering repeat FFQs and three unannounced 24-hour dietary recalls to stratified random samples of individuals participating in the Bone Mineral Density in Childhood Study.

Participants/setting Children and adolescents ages 5 to 21 years.

Main outcome measures Calcium intake estimated from the FFQ and 24-hour dietary recalls.

Statistical analysis Reproducibility was assessed by the intraclass correlation coefficient (ICC). Intermethod reliability was assessed by deattenuated Pearson correlations between the FFQ and 24-hour recalls. Attenuation factors and calibration corrected effect estimates for bone density were calculated to determine the potential influence of measurement error on associations with health outcomes.

Results The ICC (0.61) for repeat administrations and deattenuated Pearson correlation between the FFQ and 24-hour recalls (r=0.60) for all subjects indicated reproducibility and intermethod reliability (Pearson r=0.50 to 0.74 across sex and age groups). Attenuation factors were ≤0.50 for all sex and age groups and lower for non-Hispanic blacks (λ=0.20) and Hispanics (λ=0.26) than for non-Hispanic whites (λ=0.42).

Conclusions The Bone Mineral Density in Childhood Study calcium FFQ appears to provide a useful tool for assessing calcium intake in children and adolescents drawn from multiracial/ethnic populations and/or spanning a wide age range. However, similar to other FFQs, attenuation factors were substantially <1, indicating the potential for appreciable measurement error bias. Calibration correction should be performed and racial/ethnic differences in performance considered when analyzing and interpreting findings based on this instrument.

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FOOD FREQUENCY QUESTIONNAIRES (FFQS) HAVE been used extensively to obtain information on usual intake of foods and nutrients, including calcium, and to examine estimates of calcium intake in relation to health outcomes.[1-6] Advantages of FFQs for measuring dietary calcium intake, especially in large studies, include low cost, ease of administration, and focus on usual consumption of calcium-containing foods and supplements. Despite these strengths, nutrient intakes estimated from FFQs are subject to measurement error due to the limited number of food items queried, reliance on generic memory, potential reporting biases, and inaccuracies in food and nutrient databases. To properly interpret findings from a newly developed FFQ, reproducibility (intramethod reliability) and validation studies

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must be conducted. Ideally, the extent of error is determined from objective measures of true dietary intake; however, such measures are rare and confined to a select few recovery biomarkers.[7] Therefore, intermethod reliability studies are generally conducted that compare the performance of the new instrument with an accepted method. These studies are often referred to as relative validation studies, although an accurate measure of dietary intake is required to determine validity; therefore, the term *intermethod reliability* is preferable.[8] Multiple, unannounced 24-hour dietary recalls or dietary records are commonly used to assess intermethod reliability under the assumption that these methods provide an unbiased measure of dietary intake for a single day.[9-12] Regression calibration provides a means to correct for measurement error in the primary instrument (ie, the FFQ) and to obtain relatively unbiased measures of association between a food or nutrient and health outcome when the assumptions for proper reference instrument are met.[10,13,14]

The Bone Mineral Density in Childhood Study (BMDCS) was a large, national cohort of US children and adolescents designed to develop reference data for bone mass and density and to investigate the determinants of bone accretion.[15,16] To examine associations between calcium intake and bone mineral accrual in this cohort, a dietary assessment instrument designed for use in a nationally representative pediatric population was required. Therefore, an FFQ developed from dietary data collected as part of the third National Health and Nutrition Examination Study (NHANES III) and tailored for pediatric use was designed by NutritionQuest and used as the primary instrument to assess calcium intake. The purpose of this study was to examine the reproducibility and intermethod reliability of the BMDCS calcium FFQ for estimating usual dietary calcium intake in representative subsets of children and adolescents participating in the BMDCS. In addition, regression calibration was performed to assess potential measurement error bias when using the BMDCS calcium FFQ and to obtain correction factors that may be used to inform future studies. An example is provided investigating the impact of measurement error when estimating associations of calcium intake with bone mineral content (BMC) and areal bone mineral density (aBMD) at the spine to highlight the extent to which measurement error may influence effect estimates (ie, regression coefficients) and whether calibration correction may provide results more in line with calcium supplementation trials.[17-19]

MATERIALS AND METHODS

Study Population

The BMDCS comprised approximately 2,000 participants recruited from five clinical centers in the United States: Children's Hospital of Los Angeles (Los Angeles, CA), Cincinnati Children's Hospital Medical Center (Cincinnati, OH), Creighton University (Omaha, NE), Children's Hospital of Philadelphia (Philadelphia, PA), and Columbia University (New York, NY). The initial cohort consisted of a multiracial/ethnic sample of girls aged 6 to15 years and boys aged 6 to 16 years who were enrolled between July 2002 and November 2003 and followed annually for 6 years.[15] A second recruitment period, including individuals aged 5 and 19 years, occurred between August 2006 and November 2007 to increase the number of younger and older participants.[16] Healthy, normally developing children and adolescents were enrolled in the study. Participant recruitment and enrollment criteria have been described previously.[15,16] Informed consent was obtained from participants aged 18 years or older. Informed consent was obtained from the participant's parent or guardian and assent obtained from the participant for those younger than age 18 years. The study protocol was approved by the institutional review boards of all five centers.

Two substudies were conducted (reproducibility and intermethod reliability), each using a stratified, random sample of BMDCS participants aged 5 to 21 years of age at enrollment into the substudies. The goal of the reproducibility substudy was to assess the test–retest performance of the FFQ. Recruitment of participants (n=69) occurred from 2006 to 2007 by randomly selecting participants within strata defined by sex, age ($\leq$13 years and $>$13 years), and center. The first FFQ (FFQ_1) was administered during the visit. The questionnaire was completed by study participants older than age 13 years and by the parent and child together for those aged $\leq$13 years. The second FFQ (FFQ_2) was mailed to participants 1 to 2 weeks after the study visit and returned within 1 month. Visual aids, including pictures with glasses and bowls and lines indicating volumes, were provided to aid participants in assessing food quantity.

The goal of the intermethod reliability substudy was to assess the accuracy of the FFQ in relation to three unannounced, interviewer-administered 24-hour dietary recalls. Recruitment of participants (n=430) occurred from 2006 to 2009. Participants were randomly selected within strata defined by sex, age ($\leq$13 years and $>$13 years), and center. The sampling frame provided a subsample generally representative of the BMDCS cohort. The FFQ was administered during a clinical visit occurring from 2006 to 2009. The three unannounced 24-hour recalls were conducted via telephone by a study registered dietitian nutritionist (RDN) within 1 month of completing the FFQ. Visual aids, including pictures with glasses and bowls and lines indicating volumes, were provided to assist in portion size estimation. The FFQ and 24-hour recalls were completed by study participants older than age 13 years and by the parent and child together for those aged 13 years or younger. A total of 393 participants completed all three recalls and were included in our analyses. Compensation of $10 was provided for participation in a substudy.

Development of the FFQ

The BMDCS FFQ was designed to measure food items contributing calcium to the diets of children and adolescents during the previous 7 days. The FFQ was developed by NutritionQuest in accordance with procedures for the Block dietary questionnaires and screeners.[20-22] The initial list of calcium-containing foods was obtained from 24-hour recalls collected as part of NHANES III.[23] Individual food items were then aggregated into categories based on similarities in food type, nutrient content, and culinary use, and rank-ordered on contribution to total calcium intake. The minimum set of food categories that could capture $\geq$90% of calcium intake in each of nine prespecified age-race/ethnicity groups (ie, 6 to 10 years, 11 to 13 years, and 14 to 19 years; and Hispanic, non-Hispanic black, and non-Hispanic white) were included on