RESEARCH
Original Research

Within- and Between-Individual Variation in Nutrient Intake in Children and Adolescents

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ARTICLE INFORMATION

Article history:
Accepted 7 March 2014

Keywords:
Diet recall
Nutrient intake
Diet assessment
Children
National Health and Nutrition Examination Survey (NHANES)

Supplementary materials:
Tables 1, 4, 5, 9, and 10 available online at www.andjrnl.org

2212-2672/$36.00
http://dx.doi.org/10.1016/j.jand.2014.03.016

ABSTRACT

Background Little is known regarding the number of 24-hour recalls required to rank-order children and adolescents on usual intake for diet–disease studies.

Objective To determine the within- to between-individual variance ratios and number of 24-hour recalls required to rank-order individuals on usual intake for select macro- and micronutrients in a large, multiracial/ethnic sample of children and adolescents.

Design Cross-sectional survey.

Participants/setting Children and adolescents ages 6 to 17 years participating in the 2007-2008 and 2009-2010 National Health and Nutrition Examination Survey (NHANES).

Main outcome measures Variance ratios for predefined sex, age (children age 6 to 11 years, adolescents age 12 to 17 years), and racial/ethnic groups (Mexican American/Hispanic, non-Hispanic black, and non-Hispanic white).

Statistical analysis Mixed-effects linear regression models were used to estimate within- and between-individual variance components for selected nutrients. The number of 24-hour recalls required to rank-order participants on usual intake (absolute values and energy-adjusted) was obtained from the nutrient variance ratios for various levels of accuracy.

Results Variance ratios were more than 1 for all nutrients examined. High values (variance ratio >3) were observed for protein, saturated and unsaturated fatty acids, cholesterol, and several micronutrients. Variance ratios for absolute nutrient intakes were similar for both sexes within age groups, but higher for children than for adolescents. A total of six to nine and three to six 24-hour recalls were typically sufficient to rank-order children and adolescents, respectively, on usual intake with an accuracy of r=0.8. Additional recalls were required to achieve the same accuracy for energy-adjusted nutrients. Variance ratios were similar for adolescents across racial/ethnic groups, but highly variable in children.

Conclusions A total of six to nine 24-hour recalls may represent a reasonable trade-off between accuracy and participant burden for rank-ordering nutrient intakes in children and adolescents. Additional research is required to determine whether this may be reduced using statistical modeling–based approaches and the number of recalls children and adolescents will reliably complete.

J Acad Nutr Diet. 2014;■:■-■.

ASSESSING NUTRITIONAL STATUS AND DIET–disease relationships in pediatric populations relies on adequate measurement of dietary intake.[1] Multiple 24-hour diet recalls are commonly used to measure nutrient intake in children and adolescents for purposes of dietary surveillance, but have been used to a lesser extent for diet–disease research. To date, limitations of the 24-hour recall for such studies have been the high cost, logistics, participant burden, and cognitive challenges associated with administering multiple recalls. The number of recalls required to properly rank-order individuals on usual intake for diet–disease or diet–health parameter studies depends on the day-to-day variability of the nutrient and desired level of precision,[2,3] and can be determined from the within- to between-individual variance ratio obtained from repeat administrations.[3-5] As the within- to between-individual variance ratio increases, denoting greater variation in nutrient intake within than between individuals, so does the number of 24-hour recalls required to rank-order individuals on usual intake.

Advantages of administering 24-hour recalls for diet disease or diet–health parameter studies include that recalls can be unannounced, administered across various time intervals, administered to diverse populations, and may be more highly correlated with recovery biomarkers than other dietary assessment instruments.[3,6] Recent technological advancements, such

as the development of an automated, self-administered 24-hour recall for use in children and adolescents (ASA24-Kids),[7,8] eliminates the cost associated with administering multiple recalls and may facilitate their increased use as the primary instrument for epidemiologic studies conducted in pediatric populations. Thus, to properly plan, conduct, and interpret such studies, nutrition professionals and researchers will require accurate and current information with respect to the within- to between-individual variance ratios for specific nutrients.

The within- to between-individual variance ratios for particular nutrients have been shown to vary across populations and to differ for sex and age groups in children[2,5,9]; however, few studies have specifically examined nutrient variance ratios for US children and adolescents.[10,11] Of those that have, analyses were conducted more than a decade ago and, therefore, may no longer adequately reflect current patterns of dietary intake. Numerous factors, including temporal changes in the US food supply, marketing and availability of processed foods, and the number of meals eaten away from the home represent elements with the potential to impact variance ratios for macro- and micronutrients. The extent, or even direction, of such changes on nutrient variance ratios cannot be easily anticipated, necessitating their empirical examination. Moreover, evidence regarding the extent to which nutrient variance ratios in children and adolescents may differ across racial or ethnic groups in the United States is lacking.

Therefore, the purpose of this study was to determine the within- to between-individual variance ratios for select macro- and micronutrients among children and adolescents participating in the 2007-2008 and 2009-2010 National Health and Nutrition Examination Survey (NHANES) and to calculate the number of 24-hour recalls required to rank-order individuals on usual intake at various levels of accuracy. In addition, we calculated the expected correlation between the average of three 24-hour recalls and usual nutrient intake and examined the consistency in the within- to between-individual variance ratios across specific racial/ethnic groups including Mexican Americans/Hispanics, non-Hispanic blacks, and non-Hispanic whites.

METHODS

Study Design

The NHANES is a complex, stratified, multistage probability survey of noninstitutionalized US civilians used to monitor the health and nutritional status of the country.[12] Since 1999, NHANES has been administered as a continuous survey conducted in 2-year cycles. NHANES participants complete a comprehensive in-home interview followed by a physical exam at a mobile exam center. All components of the NHANES are approved by the National Center for Health Statistics Ethics Review Board. Parental informed consent is obtained for all participants younger than 18 years of age and child assent for those ages 7 to 17 years. Data from the 2007-2008 and 2009-2010 cycles were used for the present analysis. Unweighted examination response rates for the 2007-2008 and 2009-2010 NHANES were 74.5% and 77.3%, respectively.[13] Children and adolescents ages 6 to 17 years who completed two valid[14] 24-hour recalls were eligible for this analysis (n=3,473).

Dietary Assessment

Two nonconsecutive 24-hour recalls were conducted as part of the dietary interview component of the 2007-2008 and 2009-2010 NHANES. An automated, five-step, multiple pass method was used to enhance detail and limit omissions with three-dimensional measuring guides provided to assist in portion size estimation. The first recall was conducted in the mobile exam center. The second recall was scheduled during the mobile exam and conducted 3 to 10 days later via telephone. Diet recalls for participants 6 to 11 years of age were conducted with the assistance of a parent or adult care provider. Nutrient values for the 2007-2008 and 2009-2010 NHANES cycles were calculated using the US Department of Agriculture Food and Nutrient Database for Dietary Studies (FNDDS) versions 4.1 and 5.0, respectively. The addition of new food codes and modifications to the database for version 5.0 are not expected to have materially altered nutrient intake estimates between cycles.

Statistical Analysis

Mixed-effects linear regression models were used to estimate the within-individual (S^2_w) and between-individual (S^2_b) variance components for the selected nutrients. The within- to between-individual variance ratio was calculated as S^2_w/S^2_b. Fixed-effect terms for recall sequence (Day 1 vs Day 2), day of the week (weekday vs weekend), and season (November 1-April 30 vs May 1-October 31) were included in all models. Individuals were nested within locations (masked variance pseudo primary sampling unit and masked variance pseudo strata) using a random effect to account for the cluster, stratified sampling design.[15-17] For race/ethnic-specific models, hierarchal clustering by location was ignored because it improved model convergence and had no material impact on the variance ratios estimated within sex and age groups (Table 1, available online at www.andjrnl.org). All analyses were conducted on the unweighted NHANES sample because sampling weights to account for the probability of selection of primary sampling units are not provided as part of the public use data files. Therefore, the analyses do not provide nationally representative estimates. However, because of the oversampling of specific racial/ethnic groups, the unweighted NHANES sample constitutes a unique multiracial/ethnic population, allowing us to assess similarities and differences in the variance ratios for dietary nutrients across the groups represented in the survey.

All analyses were performed separately for boys and girls and by predefined age groups. Age cutpoints were chosen to correspond with the NHANES dietary interview protocol for conducting an assisted (children age 6 to 11 years) or self-report (adolescents age 12 to 17 years) 24-hour recall. Analyses further stratified by race/ethnicity examined whether the variance ratios differed for select subpopulations. A Box-Cox power transformation was applied to all nutrients before analysis to better meet model assumptions. Analyses also examined whether the variance ratios differed for energy-adjusted nutrient intakes and for intakes calculated from foods+supplements. Energy-adjustment was conducted using the residual method on the transformed variables.[18] To calculate the number of days required to obtain a given correlation (r) between observed and