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VALIDATION OF NUTRIENT INTAKE ESTIMATES DERIVED USING A SEMI-QUANTITATIVE FFQ AGAINST 3 DAY DIET RECORDS IN THE BALTIMORE LONGITUDINAL STUDY OF AGING

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Abstract

Objective: To examine the relative validity of a multicultural FFQ used to derive nutrient intake estimates in a community dwelling cohort of younger and older men and women compared with those derived from 3 day (3d) diet records during the same time-frame.

Design: Cross-sectional analyses.

Setting: The Baltimore Longitudinal Study of Aging (BLSA) conducted in the Baltimore, MD and District of Columbia areas.

Participants: A subset (n=468, aged 26 to 95 years (y), 47% female, 65% non-Hispanic white) from the BLSA, with complete data for nutrient estimates from a FFQ and 3d diet records.

Measurements: Pearson's correlation coefficients (energy adjusted and de-attenuated) for intakes of energy and 26 nutrients estimated from the FFQ and the mean of 3d diet records were calculated in a cross-sectional analysis. Rankings of individuals based on FFQ for various nutrient intakes were compared to corresponding rankings based on the average of the 3d diet records. Bland Altman plots were examined for a visual representation of agreement between both assessment methods. All analyses were stratified by sex and age (above and below 65 y).

Results: Median nutrient intake estimates tended to be higher from the FFQ compared to average 3d diet records. Energy adjusted and de-attenuated correlations between FFQ intake estimates and records ranged from 0.23 (sodium intake in men) to 0.81 (alcohol intake in women). The FFQ

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Ethical Standards: This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the Institutional Review Board at the National Institutes of Health. Written informed consent was obtained from all participants.

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classified more than 70 percent of participants in either the same or adjacent quartile categories for all nutrients examined. Bland Altman plots demonstrated good agreement between the assessment methods for most nutrients.

Conclusions: This FFQ provides reasonably valid estimates of dietary intakes of younger and older participants of the BLSA.

Keywords

Food frequency questionnaire; diet records; validation; Baltimore Longitudinal Study of Aging

Introduction

The United States (U.S.) population is rapidly aging, with the age group over 65 years (y) being the fastest growing segment. It is estimated that by 2030, 1 in 5 Americans will be over the age of 65 y (1). As average lifespan increases, the prevention of chronic disease and subsequent development of disability continues to be a top public health priority. The Baltimore Longitudinal Study of Aging (BLSA) is a long-standing observational study aimed at understanding the processes of aging and pathogenesis of various age-related outcomes. Since the early years of the study, diet was recognized as an important factor that contributes to the health trajectory (2, 3). Dietary assessment began in 1961, using 7 day diet records, which were later reduced to 3 day (3d) records. Due to the high participant burden of these records, and declining compliance, the study began using an FFQ in 2005, and gradually phased out the collection of dietary data via diet records, with a period of overlap (between 2005-2008), where both were collected.

There are various methods of assessing dietary intake and each one has both advantages and disadvantages. One of the main advantages of the FFQ is the relative ease of implementation in large cohort studies. Compared to diet records, a single administration of a FFQ allows for assessment of usual dietary intakes over a longer period of time and is less burdensome with respect to time as well as cost (4). Whether the FFQ conveys nutrient intake information that is valid and well correlated with that collected by dietary record requires validation (5). The BLSA study population has a large percentage of older persons, with a mean age of over 65 y. Validation of the FFQ is particularly important in this population, in light of the challenges of capturing dietary habits of older individuals (6).

The objective of this study was to compare the nutrient intakes assessed by FFQ with those derived from 3d diet records at a time when both evaluations were obtained from the same individuals. Our overall hypothesis was that nutrient intakes from the FFQ would be comparable to those from the 3d diet records for men and women, as well as those older and younger than 65 y.

Methods

Subjects and Setting

The participants for the present cross-sectional analyses were a subset of the BLSA cohort. The BLSA is a population based study aimed to evaluate contributors of healthy aging in the

older population residing predominantly in the Baltimore- Washington DC area (2). Starting in 1958, participants were examined every one to four years, depending on their age. Currently there are approximately 1100 active participants in the BLSA study.

Data from a subset (n=468) of the BLSA participants who had visits between 2005 and 2008, and who completed both 3d diet records and the FFQ were included in the present analyses. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the Institutional Review Board at the National Institutes of Health. Written informed consent was obtained from all participants.

Diet Records

Dietary intakes were assessed using 3d diet records; details regarding dietary data collection methods have been published previously (7, 8). Briefly, trained dietitians instructed study participants to complete diet records, to be completed at home, including 2 weekdays and 1 weekend day. These were then brought by participants to the study center during their visits for review and processing. Dietary data were entered into the University of Minnesota Nutrient Data System for Research (NDSR) program at the Jean Mayer U.S. Department of Agriculture Human Nutrition Research Center on Aging at Tufts University. Any questions about the diet records during data entry were resolved by contacting participants by telephone. The NDSR program and the USDA National Nutrient Database for Standard Reference (9) were used to derive nutrient intakes.

Semi-quantitative FFQ

The self-administered, semi-quantitative FFQ queried participants on their general eating patterns for the previous year. Based originally on a modification of the original Block-National Cancer Institute FFQ, the food list, weightings of food items within FFQ food line, portion sizes and recipe assumptions were updated and adjusted for a general U.S. population. Changes included the addition of foods and recipes from large ethnic minority groups, updating and expansion of portion size options, addition of relevant questions on food preparation and improvements in question flow. Versions of this questionnaire have previously been validated in a Puerto Rican population living in Massachusetts (10, 11). FFQs were checked for completeness, scanned (Opscan 6 National Computer Systems, St. Paul, MN) and data transferred to electronic files at Tufts University, Boston MA. The University of Minnesota NDSR software and the USDA National Nutrient Database for Standard Reference (9) were used to calculate the food and nutrient intake profiles.

Assessment of covariates

Information on covariates including age, smoking status, education and anthropometric parameters were assessed during the medical examination and interview that occurred during the participant’s clinical visit. Height, weight and waist circumference were assessed using standardized procedures (12, 13) and Body Mass Index (BMI) was calculated as weight (in kilograms) divided by height (in meters) squared.

Statistical Analysis

As has been previously done, we excluded participants who reported energy intakes < 600 kcal/d or >4000 kcal/d on the FFQ or the mean of the three 24-hour dietary records (n=32), resulting in an analytical sample size of 468.

Descriptive analyses were used to assess the demographics of the study population. Median intakes of 26 macro- and micro-nutrients were calculated. Because nutrient estimates were not normally distributed, they were log transformed before analyses. Except for energy, nutrients derived from the FFQ and the 3d diet records were adjusted for energy intake from the same instrument using residual analyses (14).

To examine the relative validity of the FFQ, we computed Pearson correlations between nutrient intakes as assessed by the FFQ and the mean of the 3d diet records. As day to day within person variation in dietary intakes for the estimates from the diet records can attenuate the correlations between the mean of the diet records and FFQ, we calculated de-attenuated correlation coefficients. These were derived by calculating the intra- to inter person variance for the nutrient intakes as estimated by the 3d diet records and using these in the formula expressed below:

$$r_t = r_O \sqrt{\left(1 + \text{intra}_X / \text{inter}_X / n_X\right)}$$

where ro is the observed correlation coefficient between the nutrient intakes, as determined from the mean of the three diet records and the FFQ; intrax is the intra subject variation; interx is the inter subject component of variance for each nutrient; and nx is the number of days of diet records which, in the present study, was 3 days (15). Lastly, we examined cross classification tables for various nutrients to assess the extent of misclassification by reporting the percentage of participants that were classified in the same or within one quartile as well as opposite or discordant quartiles (indicating gross misclassification). To obtain a visual comparison of the agreement using the FFQ and the mean of the 3d diet records, Bland-Altman plots were examined (16). The differences in the intake estimates between the FFQ and the mean of the 3d diet records were plotted against the mean of estimates obtained from the FFQ and mean of the 3d diet records. The overall mean difference and the limits of agreements (95% Confidence Limits) were used to determine the agreement between both the assessment methods. All analyses were conducted using SAS (version 9.3, 2012, SAS Institute, Cary, NC). Alpha for all analyses was set at the 0.05 level.

Results

There were 468 BLSA participants with both FFQ and 3d diet records collected at the same time. Ages ranged from 26 to 95 y. The men in this sample were slightly older (71.0 vs 65.8 y), taller (175 vs 163 cm), had larger waist circumference (98.5 vs 85.7 cm) and were heavier (83.8 vs 70.4 kg) than the women (Table 1). There were no differences in BMI, race, percent smokers or level of education by sex. Waist circumference was greater in older individuals, but none of the other variables differed by age group. Of note, the prevalence of

smokers was low, and the level of education was high--56.3% of men and 47.2% of women had more than 16 y of education.

In general, the median estimates of 26 macro and micronutrient intakes were higher for the FFQ compared to 3d diet records (Tables 2 and 3). Nutrients for which the estimates were ≥ 15% different for the FFQ than for the records included total protein and selenium (for women), alcohol, vitamin A, alpha- and beta-carotene, vitamin B12, copper and sodium (for all groups), total dietary fiber (for men and those ≥65 y), vitamin E, calcium, zinc and phosphorous (for women and those <65 y), animal protein, vitamin B6, vitamin K, iron, magnesium and manganese (for those <65 y).

Energy adjusted correlations between diet records and FFQ ranged from 0.27-0.65 (sodium-alcohol) in the total sample, 0.20-0.69 (sodium-alcohol) for men, 0.27-0.62 (vitamin B 12-alcohol) for women, 0.26-0.64 (sodium-alcohol) for participants under 65 y of age and. 0.26-0.66 (zinc-alcohol) for those over 65 y of age. On average, correlations between estimates from the 3d diet records and FFQ were higher for macronutrients (Table 4) than micronutrients (Table 5). For macronutrients, the average energy adjusted and de-attenuated correlations were 0.57, men had higher average correlations than women (0.58 vs. 0.54), and the younger participants had higher correlations than the older (0.63 vs. 0.52). For micronutrients, the average energy adjusted and de-attenuated correlations were 0.51, men had higher average correlations than women (0.54 vs. 0.48), with almost no difference between average correlations for the younger and older participants.

Data from dietary assessment in epidemiological studies are used most effectively in ranking individuals on usual intake. For all nutrients, more than 70% of individuals were classified within the same or adjacent quartile; with the lowest concordance, of 68.2%, for vitamin B12 and the highest concordance, of 90.3%, for alcohol both in men. The percentage of participants misclassified in extreme ranks was < 9% for all nutrients, with the highest discordance, at 8.7%, for vitamin K in women, and the lowest discordance, at 0.6%, for calcium in younger participants (Tables 6 and 7). On average, for the macronutrients, 80% of the participants were classified within a quartile with only 4 % being misclassified in extreme ranks. Differences by sex were small; however, there was a higher degree of misclassified in extreme ranks for those participants who were older as compared to those who were younger (4.4 vs. 3.7). For the micronutrients, there were no differences by age; however, there was a higher degree of misclassified in extreme ranks for men as compared to women (5.3 vs. 4.5).

Bland Altman plots for macro- and micro-nutrients showed no trend in the differences between the measurements using the FFQ and recalls over the various intake ranges for the total group, nor for the sex and age subgroups, indicating no systematic bias between estimation of intakes using both the FFQ and the recalls across the range of mean intake values. While this was true for almost all nutrients, for representative purposes we present these plots for energy, protein, vitamin B6 and phosphorous (Figure 1, Panels A-D).

Discussion

Estimates of macro- and micronutrient intake assessed using a FFQ were validated against data from 3d diet records in a long-standing study of aging adults. High quality dietary assessment is an important goal in epidemiological studies in order to uncover the role of diet in health and disease. In the BLSA, dietary data have been used to understand correlations between nutrient intake and health trajectories (7, 17, 18). As the study changes from 3d records to an FFQ, validation is particularly important to ensure continuity in the dietary data that have been collected since the early 1960s. Our results indicate that the FFQ provides valid estimates for most macro- and micro-nutrients, overall and by sex and age group. We also conducted analysis by race and found similar results (data not shown).

A comparison of nutrient estimates from BLSA with those from the general population, as assessed by the National Health and Nutrition Examination Survey (NHANES, 2005-2006 and 2007-2008) (19), show several differences, suggesting that BLSA participants follow a more healthful diet than the general population. The macronutrient composition of the diet was comparable at ~50%, 35%, and 15% of energy from carbohydrate, fat, and protein respectively. However, BLSA participants reported average total energy intakes approximately 300 kcal/d lower than the general U.S. population. At the same time, however, intakes of dietary fiber were approximately 4 g/d higher than those reported in NHANES. In addition, the majority of the micronutrient intakes were higher in the BLSA compared to the national average. The largest differences were observed for alpha carotene, beta carotene, vitamin C, and vitamin K, where estimated intake in the BLSA was > 15% above that in NHANES. The greatest difference was observed for beta- carotene, where intakes were > 50% higher in the BLSA than in NHANES. The higher estimation of both macro- and micronutrients by FFQ, compared to diet records, as observed in this study, has been reported by several populations (20-22). Under-reporting in the food records may reflect the participants desire to present a “healthier” diet during the days they recorded their diet, and it is known that food records may contribute to “under-eating” during the observation period (23, 24). Despite this, the correlational comparison between the FFQ and the 3d diet records show that intake rankings from the FFQ were valid for all macro- and micronutrients examined. For all sub-groups, alcohol showed the highest correlation while sodium, zinc and vitamin B12 showed the lowest correlations. Energy adjusted correlations ranged from 0.20-0.69 and de-attenuated correlations ranged from 0.23-0.81 for sodium and alcohol intakes for men. These ranges are comparable to previous studies of adults (20-22, 25-27). In the BLSA, correlations for sodium were low across all demographic groups. These correlations are slightly lower than previous reports; for example in postmenopausal women, where correlations were 0.33 and male health professionals were as high as 0.6 (25, 27), suggesting that sodium intake was not well captured by either the FFQ or the diet records in this population. Sodium intake is notoriously difficult to estimate using various dietary assessment methods, due to uncertainties of content in processed foods and poor estimation of amounts added in cooking and at the table (28, 29). Interestingly, the high correlation for alcohol was also reported in a Finnish population where the highest correlation was estimated at 0.7 for men (26). This may be expected, as alcohol intake tends to be a recurrent within person pattern.

Overall, there were few differences in the correlations between men and women or between older and younger participants, confirming the general validity of FFQ for this population. However there were some key differences. Correlations for monounsaturated fatty acids (MUFA), total fat, vitamin B12, vitamin B6 and vitamin E were more than 40% higher for women than for men, while correlations for sodium, total protein and animal protein were higher in men than in women. This may reflect differences in reporting patterns of animal-based foods between the sexes. While correlations for most nutrients tended to be better in younger adults, the largest differences (>40%) relative to older adults, were observed for polyunsaturated fatty acids, MUFA, animal protein, total protein, and zinc.

Most epidemiological investigations rely on self-report of dietary information and are dependent on the cognitive status of the cohort. While there have been several investigations examining the validity of FFQs in older cohorts (30-34), few amongst these have specifically examined the role of cognition status on observed associations. Among those that have, Morris et al. (35) using multiple recalls and Arsenault et al. (36) using nutrient biomarkers demonstrated no differences in validation results across cognition status, while Jia et al. (37) reported weaker associations among those with poorer cognition status. In our study, correlations tended to be better in younger relative to older participants. In the BLSA, the Blessed Information Memory-Concentration (IMC) test was used as an initial screening for cognitive function for in all participants. Further cognitive assessment was performed using the Mini-Mental State Examination (MMSE). Twenty five of the 468 subjects had IMC error score of greater than 4, indicating possible cognitive impairment. Of these, four subjects had missing MMSE scores but did have IMC score within the normal range in subsequent visits. The average (SD) MMSE score for the remaining 21 subjects was 25.0(6.2). Of these, 5 subjects had an MMSE score less than 24. Sensitivity analysis excluding these 5 subjects did not change the results (data not shown) and therefore we have presented the analysis which includes all participants. It is important to note that reporting dietary intakes on a FFQ relies on generic rather than episodic memory (15) which is known to decline with age (38).

Unlike records, dietary data obtained from FFQ is generally used to rank individuals in the population based on their usual intakes (39). The percentage of participants that were classified into the same vs extreme quartiles was comparable to results reported by other cohorts of older adults (20-22). These diet records and FFQ classified over ~70% of participants either in the same or adjacent quintiles for all nutrients. It is noteworthy that most were correctly classified for sodium, where the correlations between the food records and FFQ were lowest. At the same time, the percentages of participants classified in extreme quartiles were low, at < 8% for most nutrients.

As is common with validation studies, a significant limitation is that generalizability to other populations is limited. The BLSA cohort includes predominantly non-Hispanic white, older, highly educated and motivated participants. However, this questionnaire has been previously validated in low income and Hispanic populations (10, 11, 40). Therefore, these results add to the evidence supporting its use more broadly.

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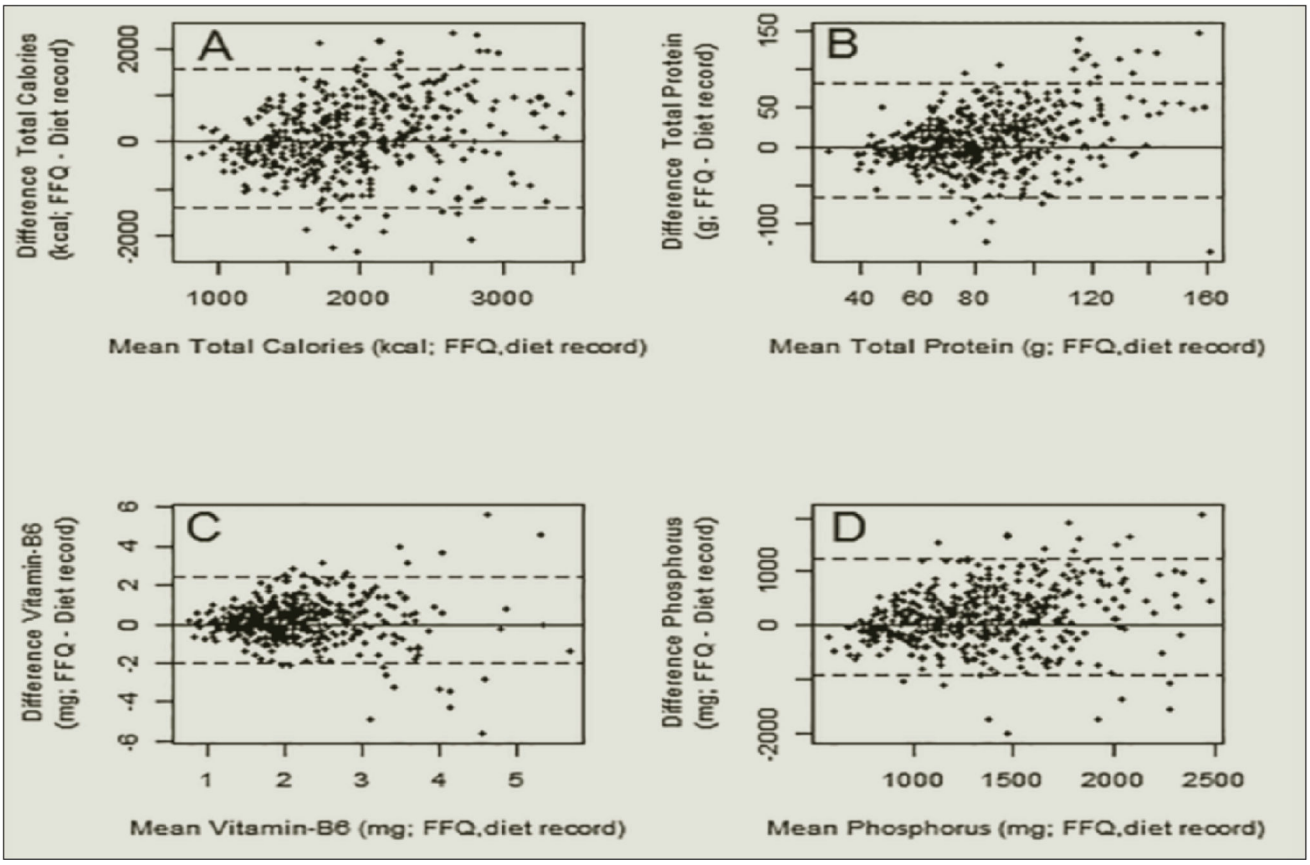

Figure 1.

(A-D) Bland-Altman plots of the difference between nutrient intakes from the mean of 3d diet records and FFQ against the mean of the two for the Baltimore Longitudinal Study of Aging validation study participants. Dotted lines (-------) represent 95% limits of agreement

Table 1

Demographic characteristics of the Baltimore Longitudinal Study of Aging validation study participants[a,b]

Characteristics	All (n=468)	Men (n=207)	Women (n=261)	<65 y (n=293)	≥65 y (n=175)
Age (y)	68.1 (13.3)	71.0 (12.0)	65.8 (13.9)*	54.5 (9.6)	76.2 (7.3)
BMI (kg/m2)	26.9 (4.79)	27.2 (4.11)	26.6 (5.25)	27.1 (5.07)	26.7 (4.61)
Height (cm)	168 (9.35)	175 (7.60)	162 (6.27)*	168 (8.47)	168 (9.84)
Weight (kg)	76.3 (16.2)	83.8 (15.0)	70.4 (14.7)*	77.3 (17.4)	75.6 (15.5)
Waist circumference (cm)	91.2 (12.4)	98.5 (10.2)	85.7 (10.9)*	89.6 (12.0)	92.2 (12.5)**
Smoking status (% current smokers)	3.86	4.41	3.44	5.71	2.75
Race (%)					
- White	64.5	71.7	58.9	65.1	58.9
- Black	21.4	14.6	26.6	24.0	26.6
- Other	14.1	13.7	14.4	10.9	14.4
Education (%)					
- High school (≤12 y)	8.33	8.29	8.37	7.43	8.87
- Some College (13-15 y)	13.5	10.7	15.6	12.6	14.0
- College (16 y)	26.9	24.4	28.9	30.3	24.9
- Professional (≥17 y)	51.3	56.6	47.1	49.7	52.2

a. Variables reported as percentage or means (SD) as appropriate

b. For variables expressed on a continuous scale, generalized linear models were used to examine differences across categories. For categorical variables, homogeneity across strata tested with χ^2 test

* Difference between sex groups P<0.05

** Difference between age groups P<0.05

Table 2

Median (Inter-Quartile Range) for daily dietary macronutrient intakes of the Baltimore Longitudinal Study of Aging validation study participants as measured by the mean of the 3d diet records and FFQ

Nutrient	All		Men		Women		<65y		≥65y	
	Diet record	FFQ	Diet record	FFQ	Diet record	FFQ	Diet record	FFQ	Diet record	FFQ
Total energy (kcal)	1839 (730)	1874 (983)	2037 (766)	2087 (1078)	1659 (612)	1762 (862)	1826 (723)	1984 (1062)	1829 (730)	1805 (950)
Total Carbohydrate, g	217 (92)	216 (120)	247 (103)	233 (134)	202 (71.2)	202 (95.7)	208 (92.3)	227 (123)	221 (93.2)	210 (110)
Total Fat, g	68.4 (35.7)	69.7 (40.1)	74.8 (41.5)	73.3 (45.9)	63.8 (34.2)	66.0 (34.7)	71.7 (36.5)	77.1 (42.1)	66.8 (34.5)	66.0 (37.1)
Total Protein, g	75.5 (32.7)	81.5 (43.4)	83.2 (33.4)	85.2 (49.8)	67.6 (27.7)	79.6 (36.4) *	77.6 (33.3)	86.5 (38.7)	74.5 (30.6)	78.3 (43.3)
Vegetable Protein, g	24.6 (13.4)	25.7 (14.9)	27.8 (14.2)	28.8 (16.1)	22.8 (11.0)	23.7 (13.1)	24.5 (14.6)	28.7 (16.6)	24.7 (12.6)	24.9 (14.7)
Animal Protein, g	49.6 (26.7)	54.4 (33.1)	52.5 (28.0)	57.4 (40.5)	46.3 (25.4)	53.4 (29.0)	50.3 (29.7)	59.6 (30.2) *	49.4 (25.1)	51.6 (33.8)
Alcohol, g	0.00 (10.9)	2.58 (12.2) *	0.47 (16.1)	4.42 (17.9) *	0.14 (7.32)	2.12 (10.2) *	0.35 (12.2)	3.03 (13.5) *	0.17 (8.38)	2.10 (12.0) *
Cholesterol, mg	229 (170)	253 (183)	256 (178)	255 (215)	216 (173)	253 (167)	232 (175)	263 (177)	224 (168.7)	244 (183)
Total Saturated Fatty Acids, g	21.3 (13)	22.1 (14.4)	23.6 (13.3)	23.3 (16.2)	19.1 (13.0)	21.2 (13.6)	22.0 (14.0)	24.1 (14.6)	21.1 (12.9)	21.1 (14.3)
Total Monounsaturated Fatty Acids, g	26.4 (14.8)	25.7 (15.7)	29.1 (16.2)	28.0 (18.0)	24.4 (13.5)	24.8 (13.6)	27.6 (14.8)	28.8 (16.4)	25.7 (14.3)	24.2 (14.5)
Total Polyunsaturated Fatty Acids, g	14.0 (8.70)	15.1 (9.99)	15.1 (8.61)	15.9 (11.1)	13.1 (8.75)	14.3 (8.37)	14.6 (8.70)	16.7 (11.4)	13.7 (8.35)	14.2 (8.67)
Total Sugars, g	38.6 (28.6)	33.1 (25.1)	46.4 (33.1)	33.3 (28.1)	35.6 (22.5)	33.1 (24.4)	38.3 (29.6)	34.8 (23.5)	38.8 (28.2)	31.5 (25.7)
Total Dietary Fiber, g	18.9 (10.9)	20.5 (11.5) *	20.6 (3.30)	21.4 (11.8) *	18.2 (9.28)	19.6 (11.3)	18.3 (10.2)	20.9 (12.2)	19.3 (11.0)	20.4 (11.1) *

* The FFQ value is >15% different than the value of the median values for the average of the 3d diet records

Table 3

Median (Inter-Quartile Range) for daily dietary micronutrient intakes of the Baltimore Longitudinal Study of Aging validation study participants as measured by the mean of the 3d diet records and FFQ

Nutrient	All		Men		Women		< 65 y		≥65 y	
	Diet record	FFQ	Diet record	FFQ	Diet record	FFQ	Diet record	FFQ	Diet record	FFQ
Total Vitamin A Activity, IU	7404 (7004)	10295 (6913) *	7304 (6888)	9462 (7600) *	7533 (7011)	10549 (6757) *	6755 (7166)	10941 (6489) *	7793 (7833)	9944 (6962) *
Alpha-Carotene, ug	402 (930)	542 (637) *	422 (950)	521 (648) *	354 (916)	550 (623) *	361 (865)	567 (740) *	411 (978)	518 (573) *
Beta-Carotene Equivalents, ug	3403 (4132)	5138 (3897) *	3356 (3977)	4666 (4008) *	3520 (4280)	5470 (3792) *	3162 (4261)	5513 (3539) *	3562 (4516)	4925 (4016) *
Vitamin B-6, mg	1.87 (0.97)	2.11 (1.18)	2.12 (1.12)	2.21 (1.24)	1.74 (0.89)	2.01 (1.02)	1.89 (1.03)	2.24 (1.22) *	1.87 (0.95)	1.99 (1.06)
Vitamin B-12, ug	5.02 (4.31)	8.31 (5.87) *	5.79 (4.66)	8.84 (5.82) *	4.34 (3.89)	7.69 (5.77) *	5.03 (4.65)	9.07 (6.05) *	4.99 (4.21)	7.99 (5.44) *
Total Folate, ug	419 (220)	425 (241)	445 (238)	451 (268)	390 (213)	411 (215)	406 (233)	468 (256)	421 (214)	397 (224)
Vitamin E, mg	7.44 (5.21)	9.10 (6.14) *	7.80 (5.47)	9.15 (6.90)	7.24 (5.22)	9.08 (5.73) *	7.92 (5.64)	10.7 (6.57) *	7.22 (4.79)	8.38 (5.51)
Vitamin C, mg	104 (87.1)	103 (76.9)	104 (91.5)	102 (71.9)	103 (82.7)	105 (82.4)	98.4 (92.0)	103 (82.8)	108 (81.5)	103 (74.6)
Vitamin D, ug	4.68 (4.76)	4.61 (3.22)	5.00 (5.46)	4.69 (2.93)	4.47 (3.99)	4.51 (3.34)	4.28 (5.33)	4.83 (3.26)	4.82 (4.47)	4.51 (3.14)
Vitamin K, ug	120 (139)	133 (116)	100 (111)	108 (106)	135 (163)	148 (119)	129 (141)	153 (125) *	113 (141)	126 (109)
Calcium, mg	761 (409)	921 (533) *	812 (432)	924 (535)	724 (400)	918 (521) *	766 (395)	976 (479) *	755 (418)	854 (559)
Copper, mg	1.30 (0.63)	1.62 (0.84) *	1.39 (0.64)	1.68 (0.95) *	1.24 (0.56)	1.55 (0.75) *	1.29 (0.65)	1.67 (0.93) *	1.30 (0.58)	1.58 (0.83) *
Iron, mg	14.59 (7.71)	16.0 (9.29)	16.74 (9.55)	17.3 (10.5)	13.1 (6.52)	15.2 (7.69)	13.8 (8.14)	17.6 (10.2) *	14.96 (7.49)	15.2 (8.67)
Potassium, mg	2845 (1211)	3091 (1504)	3109 (1284)	3203 (1563)	2706 (1110)	2991 (1429)	2752 (1270)	3148 (1420)	2909 (1169)	3034 (1542)
Sodium, mg	3041 (1390)	4002 (2234) *	3386 (1498)	4445 (2515) *	2918 (1344)	3871 (1908) *	3150 (1403)	4487 (2284) *	2972 (1394)	3747 (2031) *
Magnesium, mg	307 (149)	340 (164)	340 (153)	360 (185)	290 (129)	324 (161)	298 (140)	355 (156) *	310 (151)	331 (171)
Manganese, mg	3.71 (2.25)	4.03 (2.49)	4.05 (2.51)	4.40 (2.44)	3.45 (1.95)	3.82 (2.17)	3.51 (2.16)	4.36 (2.50) *	3.88 (2.34)	3.87 (2.39)
Selenium, ug	105 (50.4)	117 (66.3)	119 (55.8)	127 (73.4)	93.7 (41.4)	110 (55.3) *	110 (54.1)	122 (68.0)	102 (49.0)	113 (67.5)
Zinc, mg	10.3 (5.30)	12.3 (6.79) *	11.5 (5.43)	13.0 (7.86)	9.44 (4.35)	11.7 (5.44) *	10.7 (4.82)	13.5 (6.61) *	10.2 (5.61)	11.6 (6.60)
Phosphorus, mg	1211 (501)	1352 (699)	1341 (528)	1459 (743)	1101 (483)	1320 (665) *	1173 (493)	1430 (643) *	1219 (506)	1320 (723)

* The FFQ value is >15% different than the value of the median values for the average of the 3d diet records

Table 4

Pearson's correlations for macronutrient intakes between the estimates from the FFQ and the mean of 3d diet records for the participants in the Baltimore Longitudinal Study of Aging validation study

Nutrient	All		Men		Women		< 65 y		≥65 y	
	Energy adjusted	De-attenuated	Energy adjusted	De-attenuated	Energy adjusted	De-attenuated	Energy adjusted	De-attenuated	Energy adjusted	De-attenuated
Total Carbohydrate	0.56	0.62	0.63	0.71	0.49	0.55	0.61	0.69	0.49	0.55
Total Fat	0.46	0.55	0.55	0.66	0.37	0.44	0.54	0.65	0.40	0.47
Total Protein	0.37	0.45	0.25	0.31	0.45	0.56	0.47	0.57	0.28	0.35
Vegetable Protein	0.56	0.64	0.61	0.71	0.49	0.57	0.52	0.61	0.57	0.65
Animal Protein	0.41	0.50	0.28	0.33	0.50	0.60	0.52	0.63	0.32	0.38
Alcohol	0.65	0.77	0.69	0.81	0.62	0.73	0.64	0.80	0.66	0.75
Cholesterol	0.52	0.64	0.49	0.61	0.53	0.65	0.51	0.62	0.52	0.64
Total Saturated Fatty Acids	0.48	0.57	0.52	0.62	0.43	0.51	0.50	0.61	0.47	0.55
Total Monounsaturated Fatty Acids	0.39	0.48	0.51	0.62	0.29	0.35	0.47	0.58	0.33	0.40
Total Polyunsaturated Fatty Acids	0.34	0.41	0.29	0.35	0.37	0.45	0.45	0.55	0.27	0.33
Total Sugars	0.53	0.60	0.54	0.61	0.50	0.57	0.55	0.62	0.50	0.56
Total Dietary Fiber	0.53	0.60	0.59	0.66	0.47	0.53	0.59	0.67	0.50	0.56
Average correlations	0.48	0.57	0.50	0.58	0.46	0.54	0.53	0.63	0.44	0.52

Table 5

Pearson's correlations for micronutrient intakes between the estimates from the FFQ and the mean of 3d diet records for the participants in the Baltimore Longitudinal Study of Aging validation study

Nutrient	All		Men		Women		< 65 y		≥65 y	
	Energy adjusted	De-attenuated	Energy adjusted	De-attenuated	Energy adjusted	De-attenuated	Energy adjusted	De-attenuated	Energy adjusted	De-attenuated
Total Vitamin A Activity	0.34	0.45	0.34	0.44	0.34	0.45	0.33	0.45	0.35	0.46
Alpha-Carotene	0.37	0.50	0.38	0.51	0.38	0.51	0.35	0.52	0.38	0.49
Beta-Carotene Equivalents	0.37	0.51	0.36	0.51	0.36	0.51	0.38	0.57	0.37	0.50
Vitamin B-6	0.42	0.50	0.52	0.62	0.36	0.43	0.38	0.46	0.45	0.53
Vitamin B-12	0.35	0.45	0.43	0.56	0.27	0.35	0.31	0.44	0.36	0.45
Total Folate	0.46	0.55	0.53	0.64	0.39	0.46	0.41	0.50	0.49	0.57
Vitamin E	0.36	0.42	0.42	0.48	0.30	0.34	0.36	0.42	0.36	0.41
Vitamin C	0.46	0.56	0.48	0.58	0.44	0.53	0.48	0.61	0.45	0.53
Vitamin D	0.45	0.56	0.48	0.59	0.44	0.54	0.43	0.52	0.45	0.57
Vitamin E	0.36	0.41	0.41	0.47	0.30	0.35	0.37	0.43	0.35	0.40
Vitamin K	0.38	0.52	0.31	0.43	0.35	0.49	0.33	0.50	0.40	0.53
Calcium	0.56	0.65	0.57	0.66	0.52	0.61	0.57	0.65	0.54	0.64
Copper	0.42	0.49	0.46	0.54	0.37	0.44	0.39	0.47	0.43	0.50
Iron	0.40	0.47	0.43	0.51	0.36	0.43	0.44	0.51	0.38	0.45
Potassium	0.50	0.57	0.56	0.63	0.47	0.53	0.53	0.60	0.48	0.54
Sodium	0.27	0.32	0.20	0.23	0.33	0.39	0.26	0.31	0.27	0.32
Magnesium	0.60	0.67	0.64	0.72	0.59	0.66	0.59	0.67	0.60	0.67
Manganese	0.59	0.68	0.68	0.77	0.52	0.59	0.53	0.61	0.63	0.71
Selenium	0.36	0.47	0.31	0.40	0.39	0.49	0.42	0.56	0.33	0.41
Zinc	0.31	0.39	0.25	0.32	0.36	0.45	0.41	0.50	0.26	0.33
Phosphorus	0.52	0.60	0.56	0.65	0.50	0.59	0.54	0.63	0.49	0.57
Average correlations	0.42	0.51	0.44	0.54	0.40	0.48	0.42	0.52	0.42	0.50

Table 6

Quantification of macronutrient intakes of the Baltimore Longitudinal Study of Aging validation study participants, in percentages, into quartiles: Comparing the FFQ and the mean of the 3d diet records

Nutrient	All		Men		Women		<65 y		≥65 y	
	Same or adjacent quartile	Opposite quartile	Same or adjacent quartile	Opposite quartile	Same or adjacent quartile	Opposite quartile	Same or adjacent quartile	Opposite quartile	Same or adjacent quartile	Opposite quartile
Total Carbohydrate	84.6	4.3	84.5	1.4	82.4	5.4	81.2	4.1	89.1	3.4
Total Fat	79.1	3.8	85.5	3.4	74.7	4.2	76.1	4.8	84.0	2.9
Total Protein	74.1	4.7	70.0	6.8	80.1	3.8	71.0	6.1	78.3	3.4
Vegetable Protein	82.3	2.8	86.5	1.4	80.5	3.1	82.9	2.7	82.3	2.3
Animal Protein	78.2	6.0	73.9	7.2	80.8	5.0	76.1	7.5	83.4	4.0
Alcohol	87.8	1.7	90.3	1.4	85.1	1.5	87.7	1.0	88.0	2.3
Cholesterol	81.4	3.2	80.2	2.9	82.4	3.1	81.6	3.1	80.6	4.0
Total Saturated Fatty Acids	81.2	3.8	84.5	3.9	78.5	3.8	79.5	4.1	82.3	4.0
Total Monounsaturated Fatty Acids	76.7	6.0	82.6	5.8	71.6	5.7	73.0	6.5	82.9	5.1
Total Polyunsaturated Fatty Acids	73.1	4.3	72.9	6.3	75.5	3.4	70.6	5.1	79.4	4.0
Total Sugars	83.5	4.3	86.5	4.3	81.6	5.0	81.6	4.1	82.9	4.6
Total Dietary Fiber	82.1	4.1	81.6	1.4	81.2	4.6	80.2	4.1	82.9	4.0
Average %	80.3	4.1	81.6	3.9	79.5	4.1	78.5	4.4	83.0	3.7

Table 7

Quantification of micronutrient intakes of the Baltimore Longitudinal Study of Aging validation study participants, in percentages, into quartiles: Comparing the FFQ and the mean of the 3d diet records

Nutrient	All		Men		Women		<65 y		≥65 y	
	Same or adjacent quartile	Opposite quartile	Same or adjacent quartile	Opposite quartile	Same or adjacent quartile	Opposite quartile	Same or adjacent quartile	Opposite quartile	Same or adjacent quartile	Opposite quartile
Total Vitamin A Activity	75.0	6.8	76.2	6.1	76.3	8.2	76.0	8.0	75.8	5.1
Alpha-Carotene	75.9	4.5	76.6	5.4	76.8	4.3	74.9	4.6	77.1	4.4
Beta-Carotene Equivalents	76.7	6.0	77.0	6.1	77.8	6.8	78.3	5.7	76.1	5.8
Vitamin B-6	76.5	5.8	71.6	7.7	83.1	4.3	73.7	6.9	77.1	4.4
Vitamin B-12	72.2	3.6	68.2	4.2	77.3	3.9	70.9	2.3	74.7	4.8
Total Folate	77.8	4.5	77.0	6.9	82.1	2.9	78.3	6.3	78.5	3.8
Vitamin E	76.9	7.3	73.6	7.7	79.2	4.8	76.0	6.9	78.5	6.5
Vitamin C	79.1	3.8	79.3	5.7	81.6	4.3	81.7	4.0	79.9	4.4
Vitamin D	79.9	3.6	78.9	4.2	80.7	3.4	81.1	4.6	81.2	3.1
Vitamin E	77.4	6.2	73.2	7.3	78.7	4.8	76.6	6.3	77.5	6.1
Vitamin K	76.5	4.9	75.5	4.6	73.9	8.7	73.1	5.7	77.1	4.1
Calcium	82.1	2.1	81.2	1.1	85.0	1.4	82.9	0.6	83.6	2.4
Copper	77.8	5.1	75.9	4.6	80.7	5.8	76.0	4.6	78.8	5.5
Iron	78.0	6.0	76.2	6.5	80.7	5.8	80.6	5.1	78.5	5.8
Potassium	82.3	4.3	78.9	3.4	82.1	3.9	84.0	3.4	80.5	4.1
Sodium	72.2	7.5	75.1	7.7	69.1	7.7	75.4	7.4	74.1	7.8
Magnesium	85.5	3.2	84.7	3.4	85.0	1.0	86.3	2.9	86.7	3.8
Manganese	85.0	1.9	81.2	3.1	88.4	1.4	81.7	3.4	86.3	1.4
Selenium	73.3	4.3	76.2	4.6	72.5	3.9	76.0	4.0	73.7	4.4
Zinc	73.5	6.8	75.9	7.7	69.6	4.8	76.6	8.0	73.0	7.2
Phosphorus	82.9	4.1	80.1	3.1	83.1	2.4	82.9	2.3	82.6	5.1
Average %	77.9	4.9	76.8	5.3	79.2	4.5	78.2	4.9	78.6	4.8