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Repeatability and validity of a food frequency questionnaire in free-living older people in relation to cognitive function

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Abstract

Objectives: To determine the repeatability and validity of a self-administered, 175-item food frequency questionnaire (FFQ) in free-living older people and to assess whether these are influenced by cognitive function.

Participants and setting: 189 free-living people aged 64-80y were recruited from participants in a previous study.

Design: To assess repeatability, 102 (52M, 50F) participants completed the FFQ on two occasions three months apart. To assess validity, another 87 participants (44 M, 43 F) completed the FFQ and a four-day weighed diet record three months later. 25 nutrients were studied.

Results: For repeatability, Spearman rank correlation coefficients were above 0.35 ($p<0.05$) for all nutrients. Cohen's weighted Kappa was above 0.4 for all nutrients except starch, riboflavin, retinol, β-carotene, and calcium. There were no substantial differences in correlation coefficients between sub-groups divided by short-term memory test score. There was no clear pattern for correlation coefficients in sub-groups divided by executive function test score. For validity, the Spearman rank correlation coefficients were above 0.2 ($p<0.05$) for all nutrients except fat, mono-unsaturated fatty acids, niacin equivalents and vitamin D, and Cohen's weighted kappa was above 0.4 for alcohol and was above 0.2 for 13 other nutrients. Participants in the lowest-score groups of short-term memory and executive function had the lowest median Spearman correlation coefficient.

Conclusions: The FFQ had reasonable repeatability and validity in ranking nutrient intakes in this population though the results varied between nutrients. Poor short-term memory or executive function may affect FFQ validity in ranking nutrient intakes.

Key words: Food frequency questionnaires, Repeatability, Validity, Older people, Cognitive ability

Introduction

Food frequency questionnaires (FFQs) have many practical advantages for assessing nutrient intake in epidemiological studies investigating diet-disease relationships but it is necessary to assess the repeatability and validity of each FFQ in the study population [1]. Nutrient intake assessment in older people presents particular challenges because of changes in appetite and varying degrees of cognitive decline. In young adults there is evidence that age and sex are associated with the validity of FFQ but there is no consistency in the direction of significant associations [2]. In an older population in which validity of a FFQ was assessed in 232 people aged 68-99 years using three 24 hour dietary recalls, cognitive ability was found to have no significant impact on validity [3].

The Scottish Collaborative Group FFQ (SCG FFQ) has been applied in a range of epidemiological studies in Scotland. The validity of the most recent versions was assessed in young adults using four-day weighed diet records (4-d WR) [4] and in children using four-day non-weighed diet records [5] with both versions showing reasonable validity. The aim of the present study was to determine the repeatability and validity of SCG FFQ version 7.0 in older people and to explore whether there was any association between cognitive ability and repeatability or validity.

Methods

Study design and participants

From 910 free-living healthy people aged 65 years old or over who had participated in the MAVIS study of the effect of multivitamin and multimineral supplements on morbidity from infections in older people [6], 712 people aged 65 to 80 having no terminal illness or dementia (screened by one of the researchers, ACM) were posted a copy of the SCG FFQ v.7.0 in August 2004 (FFQ1). 317 (44.5%) participants posted back completed FFQs. Those not willing to take part in the present study (n 54) and who returned the FFQ with more than ten items left blank and could not be contacted by telephone (n 19) were excluded. The remaining 244 people agreed to take part in either the repeatability study or the validity study or both.

As part of the MAVIS study, short-term memory was assessed by digit span forward test [7] and executive function was assessed by verbal fluency test (generating words by given initial letters) [8] at baseline in 2002.

One hundred and twelve participants who agreed to take part in the repeatability study were randomly selected and were posted a second copy of SCG FFQ v.7.0 (FFQ2) three months later. A further 93 participants who agreed to take part in the validity study were randomly selected to carry out a 4d-WR. The remaining 39 of the 244 people who were eligible for the present study were not contacted because of reaching sufficient sample size. For 4d-WR, one author (XJ) visited the participants at home to give a demonstration of how to keep a weighed diet record. Each participant was given a set of digital kitchen scales with capacity of 10kg and precision of 2g, a food diary and a stamped addressed envelope for posting back the scales and completed diary. Four consecutive days including either Saturday, Sunday or both were randomly selected and agreed by the participant as weighing days. Grampian Research Ethics Committee approved the study protocol.

Food frequency questionnaires

The SCG FFQ v.7.0 consists of 175 foods and drinks grouped into 19 categories followed by four sections with questions on type and amount of oil and spread used, consumption of other foods or drinks not listed in the FFQ, dietary supplements used, and any comments on diet. For each food or drink in the main list, a common measure for indicating portion was given and a photograph illustrating some of these measures was given on the cover page of the FFQ for reference.

Participants were asked to recall their typical diet over the last 2-3 months. Unlike the version of the SCG FFQ used in younger adults, a single response was used to describe the consumption of each food as rarely or never, 1-3 per month, 1 per week, 2-3 per week, 4-6 per week, 1 per day, 2-3 per day, 4-6 per day, or 7+ per day. A sample page of the FFQ is available at http://www.abdn.ac.uk/deom/ffq/.

The completion of FFQs was checked soon after return. Participants who left more than ten answers blank were contacted by telephone for details. Nutrients from foods listed in the section on 'other foods not listed in the FFQ' were added to the lines with foods having similar nutrient composition. Oil and spreads were coded based on the fatty acid composition. Nutrient intake was calculated using an in-house programme based on *McCance & Widdowson's The Composition of Foods (fifth edition)* [9] and related supplements [10-18].

Weighed food records

The completion of weighed records was checked soon after return. Participants who did not give enough details of foods were contacted by telephone. People were excluded from analysis if substantial details of foods were not given. WINDIETs (Robert Gordon University, Aberdeen, UK) which is also based on *McCance & Widdowson's The Composition of Foods (fifth edition)* and related supplements was used to calculate the nutrients from weighed food records. A second researcher (LCAC) checked the coding of ten randomly selected weighed diet records. Inconsistent coding was discussed and the coding of the rest of the diaries was amended accordingly.

Statistical methods

Student independent *t* test was used to compare the baseline characteristic differences between people completed present study and those not.

The same statistical methods were used for repeatability and validity. Standardised operating procedures for the FFQ were used. Outliers (<2.5% or >97.5% based on FFQ1 energy intake) were excluded from analysis.

To assess the agreement of absolute nutrient intakes, the mean differences in absolute nutrient intakes between two measurements as percentage of averages were calculated as described by Bland & Altman [19].

To assess the agreement in ranking nutrient intakes, nutrients were energy adjusted using the residual method [20] for men and women combined, and Spearman rank correlation coefficients, cross-classification (percentage correctly classified and percentage grossly misclassified into quartiles) and Cohen's weighted kappa (linear weighting) as a summary of cross-classification were calculated. To assess the effect of cognitive function on repeatability and validity in ranking nutrient intakes, medians and ranges of Spearman rank correlation coefficients for groups divided by third of digit span forward test scores and verbal fluency test scores were identified and compared.

SPSS 14.0 (Chicago, IL, USA) was used for all the analyses except Cohen's weighted kappa for which STATA 8.0 (College Station, TX, USA) was used. We adopted Cohen's weighted kappa greater than 0.20 as minimum levels of acceptable agreement [21]. The repeatability and validity of nutrient intakes from dietary supplements was not assessed.

Results

One hundred and two out of 112 participants posted back FFQ2 with all having reasonable quality of completion. Eighty seven out of 93 participants completed the 4d-WR with reasonable quality (the other six did not complete all four days or had substantial details of food not given). Compared with people who did not respond (n 523), those who completed the present study (n 189) were significantly younger (69.7 vs. 71.4 years old, p <0.001) and less likely to have heart disorders (21.2% vs. 28.7%, p 0.045); there were no statistically significant difference in sex (p 0.690), BMI (p 0.680), hypertension (p 0.715), cancer (0.216), diabetes (0.122), stroke (p 0.609), number of medicine taking (0.053), or short-term memory (p 0.064) and executive function (0.077).

Repeatability

In the 102 people who completed both FFQ1 and FFQ2, extreme energy intakes based on FFQ1 were excluded first (n 5). They were the lowest two (3600 kJ or 860 kcal, F; 4141 kJ or 989 kcal, F) and the highest three (13763 kJ or 3287 kcal, M; 14705 kJ or 3512 kcal, M; 20027 kJ or 4783 kcal, M). The mean age of the 97 remaining participants (50M, 47F) included in the analysis was 69.6 years (SD 3.7), the mean BMI was 27.8 (SD 3.8), mean digit span forward score was 11.6 (SD 2.2), and mean verbal fluency score was 35.4 (SD 11.8).

For agreement in absolute nutrient intakes between FFQ1 and FFQ2, the mean differences of absolute nutrient intakes as the percentage of averages were all less than 20% except alcohol in women (21%, 95% CI -4%, 46%). The variance of nutrient intakes from the FFQs was similar in men and women (***Table 1***).

For agreement in ranking nutrient intakes, the Spearman rank correlation coefficients between FFQ1 and FFQ2 for all 25 nutrients were 0.35 or greater (p<0.05) in men and women separately or combined. When men and women were combined, Cohen's weighted kappa was 0.40 or greater for all nutrients except for starch (*k* 0.39), riboflavin (*k* 0.39), retinol (*k* 0.29), β-carotene (*k* 0.32) and calcium (*k* 0.24). These five nutrients also had 40% or less correct cross-classification into quartiles (***Table 2***).

Figure 1 presents the median (range) of the Spearman rank correlation coefficients for groups divided by third of digit span forward test scores and verbal fluency test scores. The number of men and women in each group was similar. The median (range) coefficients for low-, medium- and high- digit span forward test score group were 0.62 (0.06, 0.84), 0.64 (0.34, 0.89) and 0.71 (0.41, 0.90) respectively which were not substantially different. The median (range) coefficients for low-, medium- and high- verbal fluency test score group were 0.64 (0.33, 0.87), 0.75 (0.47, 0.88) and 0.55 (0.11, 0.82) respectively.

Validity

In the 87 people who completed FFQ1 and 4d-WRs, extreme energy intakes based on FFQ1 were excluded first (n 4). They were the lowest two (3978 kJ or 950 kcal, M; 4409 kJ or 1053 kcal, F) and the highest two (31356 kJ or 7489 kcal, M; 31629 kJ or 7554 kcal, F). The mean age of the 83 remaining participants included in the analysis was 69.7 (SD 4.0) years, mean BMI was 28.1 (SD 3.7), mean digit span forward score was 11.5 (SD 2.2), and mean verbal fluency score was 33.5 (SD 12.0).

Energy intakes from 4d-WRs ranged from 3308 kJ (790 kcal, F) to 13842 kJ (3306 kcal, M). ***Table 3*** shows the means of absolute nutrient intakes from FFQ1 and 4d-WRs for validity assessment together with those from UK National Diet and Nutrition Survey (NDNS) of free-living older people aged 65 year and over which also used 4d-WR [22]. The energy and nutrient intakes from 4d-WR of the participants were slightly higher than those from NDNS. In men, the mean differences of absolute nutrient intakes between FFQ1 and 4d-WR as the percentage of averages ranged from -13% (protein, 95% CI -24%, -4%) to 32% (vitamin D, 95% CI 9%, 55%). In women, the mean differences ranged from 14% (fat, 95% CI 5%, 26%) to 71% (alcohol, 95% CI 36%, 107%) with vitamin B12, retinol and alcohol more than 40%. In women all the nutrients from FFQs were higher than those from 4d-WR.

For agreement in ranking nutrient intakes between FFQ and 4d-WR, Spearman correlation coefficients were over 0.3 ($p<0.05$) for 12 nutrients in men and for 17 nutrients in women (***Table 4***). When men and women were combined, the Spearman rank correlation coefficients were over 0.2 ($p<0.05$) for all 25 nutrients except fat, mono-unsaturated fatty acids, niacin equivalents and vitamin D. Cohen's weighted kappa was greater than 0.4 for alcohol only and was more than 0.2 for 13 other nutrients.

Figure 2 presents the median (range) of the Spearman correlation coefficients for the 25 nutrients for groups divided by third of digit span forward test scores and verbal fluency test scores. Fewer men were in the highest group of verbal fluency test score than women (11 vs 18). The median (range) coefficients for low-, medium- and high- digit span forward test score group were 0.22 (-0.20, 0.62), 0.36 (0.03, 0.75) and 0.45 (-0.01, 0.70) respectively which suggested a positive association. The median (range) coefficients for low-, medium- and high- verbal fluency test score group were 0.28 (-0.44, 0.62), 0.39 (-0.08, 0.71) and 0.35 (0.19, 0.78) respectively. This suggested that the low-score group had the lowest validity, but there was little difference between the medium and high score groups.

Discussion

We found in free-living older people, the SCG FFQ v.7.0 had reasonable repeatability in ranking most nutrient intakes and reasonable validity compared to the 4d-WR. Poor short-term memory and executive function was associated with low FFQ validity in this population, but there was no clear pattern of association with repeatability.

We also found the absolute nutrient intakes from FFQ tended to be higher than those from 4d-WR in women but these differences were not seen in men. There is evidence that people tend to reduce their food intakes when doing weighed food records, and hence under-estimate their nutrient intakes [20]. The differences between the sexes may therefore be due to men and women in this study having a different extent of under-estimation for nutrient intakes from weighed food records.

In the 712 people who were posted FFQ1, less than half responded (317, 44.5%) and posted back the completed FFQ. One of the reasons of the low response rate may be due to a 175-item FFQ was too long to complete especially for older people. This was confirmed by the necessity of contacting a certain number of participants who did not fully complete the questionnaire. Other reasons could include illness of the participant or spouse or change of address after completing the previous study.

There are a limited number of studies which have assessed FFQ validity in older people. In the study by Nes *et al* [23], the repeatability and validity of a FFQ was assessed in 38 free-living women aged 67 to 80 years old in Norway. Comparing the results of SCG FFQ v.7.0 in women with those from this FFQ, the repeatability results were similar but the validity of SCG FFQ v.7.0 was lower for most nutrients. This may be due to Nes *et al* using more than ten non-consecutive weighing days, which may give a better correlation with 'usual' intake than intakes estimated from shorter period consecutive weighing days [24]. Another possible reason is that Nes *et al*'s FFQ had options for defining portion sizes for each meal. A review of FFQ design and validation suggested that the validity of a FFQ could be improved if the participants were able to define their own portion sizes [25]. In the study by Smith *et al* [26], the validity of a FFQ that had no options for defining portion sizes was assessed using more than ten non-consecutive weighing days in 79 free-living men and women aged 65 to 80 years old. Compared with this FFQ, validity of SCG FFQ v.7.0 was slightly lower for fat, fatty acids, sugar, retinol, β-carotene and zinc. This again may due to better capture of habitual intakes by using a longer period of weighed diet records.

The association between cognitive function and validity in the present study is not consistent with the findings by Morris *et al* [3]. Morris *et al.* found no clear difference in coefficients for log-transformed energy adjusted nutrient intakes across participants divided by tertile of global cognitive ability. This may be due to different cognitive domains tested between the two studies. Morris *et al* used the summary of short-term memory assessed by East Boston Test, processing speed assessed by Symbol Digit Modalities test and global cognitive ability assessed by Mini-Mental State Examination. The cognitive domains assessed in the present study were short-term memory and executive function. Digit span forward is a test of attention and immediate memory involving a relatively familiar task which may be performed relatively well even in advanced cognitive decline, while verbal fluency tests speed of processing and information retrieval which are sensitive to the difficulty in generating words characteristic of Alzheimer's disease [27]. The two tests were selected for the MAVIS study as they could be carried out by telephone at follow-up. Future studies should include a wider range of tests of different cognitive domains such as attention and long-term memory which may relate to the quality of food diary and FFQ completion.

One limitation of the present study in assessing the effect of cognitive ability is that the cognitive ability of the participants was assessed at the baseline of the MAVIS study [6] which the FFQs were completed in 2004, so cognitive decline could have deteriorated in some participants during the two-year gap. Moreover, although the sample size of this study is large enough for assessing repeatability and validity of a FFQ [24], the sample size was small when participants were split into tertiles for assessing the effect of cognitive ability.

One of the factors that might affect the generalisability of the results from this study is that the participants were in reasonable health. People with severe cognitive impairment and dementia were excluded from the study because of difficulties in cooperation. Therefore, the results of this study apply to free-living healthy people but could differ for those whose cognitive function is severely impaired or for very old people (>80y).

Conclusion

In free-living older people, SCG FFQ v.7.0 had reasonable repeatability and validity for most nutrients. Poor short-term memory or executive function may adversely affect the validity of a FFQ. The results apply to free-living older people aged 65 to 80 years old but could differ for those with more cognitive function impairment or for very old people.

Competing interests

No competing interests.

Authors' contributions:

XJ recruited the participants, undertook data collection, coded the weighed diet records, conducted the statistical analysis and drafted the manuscript. LCAC provided the advice on coding the diet records and coded randomly selected records to guarantee the data quality. LSA contributed statistical support. ACM contributed to participant recruitment. GMcN supervised the design, conduct and completion of the study and commented on the drafts of the manuscript. All authors read and approved the final draft of the manuscript.

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Table 1 Summary of nutrient intakes for repeatability, mean (SD)

	Men, n 50			Women, n 47		
	FFQ1	**FFQ2**	**Difference[1] (95% CI)**	**FFQ1**	**FFQ2**	**Difference[1] (95% CI)**
Energy (kJ)	8315 (2067)	7735 (2363)	9 (2, 15)	7966 (2301)	7566 (2503)	6 (-1, 14)
Energy (kcal)	1986 (494)	1847 (564)	9 (2, 15)	1903 (550)	1807 (598)	6 (-1, 14)
Fat (g)	76.1 (22.9)	71.9 (27.8)	8 (0, 16)	73.0 (27.3)	67.4 (28.3)	10 (2, 18)
SFA (g)	31.4 (12.7)	30.2 (15.5)	7 (-2, 17)	30.0 (12.6)	27.3 (12.4)	9 (-1, 19)
Cholesterol (mg)	289 (94)	279 (118)	6 (-3, 14)	278 (117)	266 (146)	8 (-2, 17)
MUFA (g)	25.1 (7.3)	23.6 (8.9)	8 (0, 17)	23.9 (10.1)	21.7 (9.7)	11 (2, 19)
PUFA (g)	11.7 (4.3)	10.6 (3.9)	10 (2, 18)	11.7 (4.5)	10.9 (4.8)	10 (1, 19)
Alcohol (g)	11.4 (18.0)	10.3 (12.4)	10 (-9, 29)	5.04 (9.94)	3.29 (6.15)	21 (-4, 46)
Protein (g)	75.2 (16.6)	71.3 (21.2)	7 (0, 14)	77.2 (24.7)	74.8 (27.3)	4 (-3, 16)
Dietary fibre (g)	15.0 (5.7)	14.1 (5.17)	6 (-2, 13)	16.2 (6.3)	16.9 (8.5)	1 (-9, 10)
Starch (g)	137 (48)	121 (46)	13 (4, 21)	120 (47)	115 (42)	4 (-5, 13)
Sugar (g)	105 (41)	100 (35)	4 (-3, 11.)	115 (38)	114 (44)	3 (-7, 13)
Thiamine (mg)	1.61 (0.52)	1.50 (0.49)	7 (0, 15)	1.55 (0.47)	1.54 (0.56)	3 (-5, 12)
Niacin equivalents (mg)	34.6 (8.4)	32.6 (9.5)	7 (0, 14)	34.8 (10.3)	33.8 (12.7)	5 (-3, 13)
Riboflavin (mg)	1.96 (0.60)	1.91 (0.71)	5 (-3, 12)	1.93 (0.60)	1.99 (0.97)	2 (-7, 11)
Vitamin B6 (mg)	2.11 (0.69)	1.97 (0.62)	6 (0, 13)	2.07 (0.65)	2.12 (0.92)	2 (-7, 10)
Vitamin B12 (μg)	6.23 (2.58)	6.22 (3.07)	3 (-7, 13)	6.88 (5.62)	6.74 (4.71)	1 (-10, 13)
Folate (μg)	280 (82)	261 (86)	7 (1, 14)	267 (75)	273 (112)	2 (-6, 9)
Retinol (μg)	555 (423)	547 (398)	5 (-8, 18)	492 (347)	700 (1116)	-5 (-21, 10)
β-carotene equivalents (μg)	2382 (1439)	2246 (1277)	6 (-8, 20)	3074 (2040)	3260 (3339)	3 (-13, 19)
Vitamin C (mg)	88.8 (45.5)	84.2 (41.4)	4 (-5, 12.)	107 (50)	113 (60)	-2 (-13, 9)
Vitamin D (μg)	3.71 (1.69)	3.75 (2.29)	4 (-8, 15)	4.42 (5.40)	3.65 (2.05)	7 (-5, 19)
Vitamin E (mg)	7.96 (3.89)	7.48 (3.53)	5 (-4, 14)	8.84 (3.39)	8.66 (4.15)	7 (-5, 19)
Iron (mg)	12.1 (3.1)	11.5 (3.7)	6 (0, 12)	12.2 (4.0)	11.8 (5.5)	6 (-4, 15)
Calcium (mg)	1038 (311)	995 (397)	7 (-2, 16)	1007 (310)	1023 (408)	1 (-9, 11)
Zinc (mg)	8.78 (2.17)	8.41 (2.87)	6 (-2, 14)	8.94 (2.81)	8.79 (3.43)	4 (-4, 11)
Selenium (μg)	45.1 (13.5)	41.8 (13.1)	8 (1, 15)	49.0 (24.6)	47.2 (20.2)	3 (-5, 10)

FFQ: food frequency questionnaire; MUFA: mono-unsaturated fatty acids; PUFA: poly-unsaturated fatty acids; SFA: saturated fatty acids
[1](FFQ1 - FFQ2) /(FFQ1+FFQ2)/2 ×100%

Table 2 Correlation between repeated FFQ for energy-adjusted nutrient intakes for repeatability

	Spearman correlation coefficient			**Cross classification[1]**		**Weighted kappa[1,2]**
	Men, n 50	**Women, n 47**	**All, n 97**	**All, n 97**		**All , n 97**
				Correct%	**Opposite%**	
Fat	0.62**	0.64**	0.66**	47	4	0.49
SFA	0.72**	0.59**	0.66**	45	2	0.47
Cholesterol	0.77**	0.47**	0.64**	50	3	0.47
MUFA	0.64**	0.62**	0.66**	56	2	0.50
PUFA	0.69**	0.57**	0.65**	46	2	0.45
Alcohol	0.86**	0.81**	0.87**	63	0	0.69
Protein	0.48**	0.63**	0.60**	51	3	0.49
Dietary fibre	0.75**	0.62**	0.71**	55	2	0.52
Starch	0.51**	0.62**	0.58**	40	3	0.39
Sugar	0.80**	0.58**	0.73**	57	0	0.59
Thiamine	0.69**	0.55**	0.63**	52	2	0.50
Niacin equivalents	0.64**	0.62**	0.64**	42	0	0.40
Riboflavin	0.57**	0.58**	0.58**	38	2	0.39
Vitamin B6	0.65**	0.59**	0.65**	57	2	0.54
Vitamin B12	0.76**	0.66**	0.72**	53	0	0.54
Folate	0.64**	0.74**	0.71**	46	2	0.49
Retinol	0.59**	0.35*	0.48**	38	4	0.29
β-carotene equivalents	0.37**	0.53**	0.49**	36	3	0.32
Vitamin C	0.80**	0.70**	0.79**	64	1	0.65
Vitamin D	0.73**	0.76**	0.74**	51	0	0.54
Vitamin E	0.73**	0.45**	0.62**	46	1	0.44
Iron	0.59**	0.46**	0.55**	42	4	0.44
Calcium	0.45**	0.37**	0.42**	33	5	0.24
Zinc	0.50**	0.61**	0.57**	41	1	0.42
Selenium	0.70**	0.83**	0.83**	54	0	0.60

FFQ: food frequency questionnaire; MUFA: mono-unsaturated fatty acids; PUFA: poly-unsaturated fatty acids; SFA: saturated fatty acids
*p<0.05, **p<0.01
[1]Participants were divided into quartiles according to energy-adjusted nutrient intake
[2]Linear weighting

Table 3 Summary of nutrient intakes for validity, mean (SD)

	Men			NDNS	Women			NDNS
	FFQ n 42	4-d WR n 42	Difference[1] (95% CI)	4d-WR N 632	FFQ n 41	4-d WR n 41	Difference[1] (95% CI)	4d-WR n 643
Energy (kJ)	8053 (2260)	8367 (1957)	-5 (-13, 4)	7993 (1950)	8442 (2654)	6850 (1821)	19 (11, 28)	5954 (1410)
Energy (kcal)	1923 (540)	1998 (467)	-5 (-13, 4)	1909 (465)	2016 (634)	1636 (435)	19 (11, 28)	1422 (337)
Fat (g)	29.9 (21.3)	74.4 (24.9)	0 (-11, 11)	74.7 (23.6)	72.3 (25.2)	63.0 (24.2)	14 (2, 26)	58.0 (18.3)
SFA (g)	29.6 (11.9)	28.8 (13.3)	6 (-8, 26)	30.6 (11.4)	30.0 (13.4)	21.4 (8.5)	31 (17, 44)	24.7 (9.5)
Cholesterol (mg)	265 (86)	302 (204)	-5 (-19, 9)	293 (120)	261 (113)	220 (116)	18 (3, 32)	222 (92)
MUFA (g)	24.6 (8.0)	23.0 (7.9)	8 (-5, 22)	-	23.2 (7.9)	19.1 (8.8)	21 (8, 35)	-
PUFA (g)	11.4 (3.8)	9.81 (3.27)	15 (0, 29)	-	12.1 (4.8)	8.5 (4.1)	36 (23, 48)	-
Alcohol (g)	7.51 (8.07)	9.13 (13.3)	12 (-24, 47)	21.5 (22.3)	5.83 (11.8)	4.85 (10.6)	71 (36, 107)	8.6 (7.8)
Protein (g)	73.4 (5.7)	83.5 (22.3)	-13 (-22, -4)	71.5 (17.0)	79.0 (27.7)	66.5 (18.1)	14 (5, 23)	56.0 (13.4)
Dietary fibre (g)	15.4 (5.7)	15.0 (6.3)	3 (-7, 14)	13.5 (5.8)	17.8 (6.4)	12.6 (4.3)	33 (22, 44)	11.0 (4.7)
Starch (g)	128 (50)	142 (44)	-11 (-21, -2)	129 (38)	137 (57)	110 (28)	18 (8, 27)	96 (26)
Sugar (g)	114 (41)	101 (37)	10 (-3, 23)	103 (43)	125 (40)	91.0 (34.2)	32 (22, 43)	79 (34)
Thiamine (mg)	1.62 (0.71)	1.67 (0.66)	-3 (-12, 7)	1.49 (0.46)	1.78 (0.75)	1.39 (0.37)	19 (9, 30)	1.19 (0.35)
Niacin equivalents (mg)	35.2 (1.4)	39.1 (12.3)	-11 (-21, -1)	32.0 (8.4)	37.1 (1.2)	30.6 (7.9)	16 (7, 25)	24.8 (6.9)
Riboflavin (mg)	2.01 (0.84)	1.86 (0.70)	6 (-4, 16)	1.74 (0.70)	2.23 (1.09)	1.57 (0.48)	29 (17, 41)	1.43 (0.57)
Vitamin B6 (mg)	2.15 (0.97)	2.17 (0.81)	-2 (-14, 9)	2.1 (0.7)	2.39 (0.94)	1.76 (0.49)	26 (16, 36)	1.6 (0.5)
Vitamin B12 (µg)	6.31 (3.06)	5.48 (3.07)	17 (0, 35)	6.1 (6.2)	7.02 (4.50)	4.04 (2.27)	46 (28, 63)	4.5 (4.4)
Folate (µg)	281 (121)	275 (120)	3 (-7, 13)	270 (95)	314 (131)	221 (56)	30 (20, 41)	207 (75)
Retinol (µg)	534 (448)	438 (367)	19 (-5, 42)	847 (1701)	804 (1093)	477 (895)	47 (22, 72)	699 (1366)
β-carotene equivalents (µg)	2437 (1223)	3059 (2986)	6 (-17, 30)	1951 (1478)	3258 (3199)	2981 (3494)	27 (3, 51)	1618 (1425)
Vitamin C (mg)	99.6 (50.8)	83.6 (51.3)	22 (7, 38)	66.9 (42.1)	125 (53)	87.3 (45.2)	38 (22, 53)	60.7 (41.7)
Vitamin D (µg)	3.90 (1.92)	3.13 (2.49)	32 (9, 55)	4.07 (3.22)	3.89 (2.06)	2.53 (2.01)	49 (29, 68)	2.92 (2.41)
Vitamin E (mg)	7.88 (3.46)	6.99 (2.77)	11 (-4, 25)	9.0 (5.0)	9.39 (4.23)	6.53 (2.75)	35 (23, 46)	6.8 (3.9)
Iron (mg)	12.1 (4.7)	13.4 (5.3)	-9 (-20, 2)	11.0 (3.6)	12.9 (5.6)	10.3 (3.1)	18 (7, 30)	8.6 (2.9)
Calcium (mg)	1052 (384)	923 (369)	13 (3, 23)	836 (285)	1118 (501)	773 (230)	31 (21, 42)	690 (246)
Zinc (mg)	8.70 (2.92)	9.01 (3.47)	-12 (-24, -1)	8.9 (2.8)	9.39 (3.64)	7.49 (2.02)	19 (8, 30)	7.0 (2.4)
Selenium (µg)	44.1 (14.5)	44.9 (18.1)	0 (-13, 13)	-	47.9 (17.4)	40.5 (20.0)	18 (6, 31)	-

4dWR: four day weighed food record; FFQ: food frequency questionnaire; MUFA: mono-unsaturated fatty acids; NDNS: National Diet and Nutrients Survey; PUFA: poly-unsaturated fatty acids; SFA: saturated fatty acids
- Not reported
[1](FFQ1 – 4dWR) /(FFQ1+4dWR)/2 ×100%

Table 4 Correlation between FFQ and four-day weighed food record for energy-adjusted nutrient intakes for validity

	Spearman correlation coefficient			**Cross classification[1]**		**Weighted kappa[1,2,3]**
	Men, n 42	**Women, n 41**	**All, n 83**	**All, n 83**		**All , n 83**
				Correct%	**Opposite%**	
Fat	0.29	0.16	0.20	30	8	0.15
SFA	0.29	0.50**	0.35**	30	5	0.21
Cholesterol	0.40**	0.32*	0.36**	35	5	0.26
MUFA	0.13	0.26	0.17	26	8	0.11
PUFA	0.19	0.31*	0.25*	35	7	0.19
Alcohol	0.78**	0.61**	0.70**	53	1	0.50
Protein	0.34*	0.26	0.30**	40	10	0.26
Dietary fibre	0.51**	0.51**	0.49**	42	4	0.34
Starch	0.31*	0.61**	0.42**	33	2	0.23
Sugar	0.24	0.36*	0.33**	32	8	0.19
Thiamine	0.47**	0.25	0.39**	40	6	0.30
Niacin equivalents	0.29	0.07	0.18	20	13	-
Riboflavin	0.54**	0.44**	0.50**	41	2	0.32
Vitamin B6	0.34*	0.27	0.29**	28	5	0.21
Vitamin B12	0.21	0.40*	0.31**	32	4	0.19
Folate	0.51**	0.24	0.40**	41	5	0.26
Retinol	0.23	0.29	0.26*	29	8	0.17
β-carotene equivalents	0.21	0.45**	0.33**	35	8	0.24
Vitamin C	0.58**	0.38*	0.52**	39	5	0.32
Vitamin D	0.06	0.34*	0.18	23	5	-
Vitamin E	0.09	0.34*	0.22*	36	7	0.15
Iron	0.46**	0.36*	0.41**	43	5	0.32
Calcium	0.58**	0.38*	0.48**	32	4	0.24
Zinc	0.08	0.47**	0.22*	26	10	0.09
Selenium	0.03	0.37*	0.24*	36	8	0.17

FFQ: food frequency questionnaire; MUFA: mono-unsaturated fatty acids; PUFA: poly-unsaturated fatty acids; SFA: saturated fatty acids
*$p<0.05$, **$p<0.01$
- Kappa was not calculated because observed concordance is smaller than mean-chance concordance.
[1]Participants were divided into quartiles according to energy-adjusted nutrient intake
[2]Linear weighting
[3]95%CI

Figure 1 Median (range) of Spearman correlation coefficients for 25 nutrients for repeatability (above) and validity (below), by third of cognitive function