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Concurrent and construct validity of Mediterranean diet scores as assessed by an FFQ

Alejandra A Benítez-Arciniega[1,2,3], Michelle A Mendez[4,5], Jose M Baena-Díez[6], Maria-Asunción Rovira Martori[1,3], Cristina Soler[7], Jaume Marrugat[3,5,7], Maria-Isabel Covas[1,2,3], Hector Sanz[7], Alba Llopis[1] and Helmut Schröder[1,2,3,]*, on behalf of the REGICOR and HERMES investigators†

[1]Cardiovascular Risk and Nutrition Research Group (CARIN-ULEC), IMIM-Hospital del Mar Barcelona, Biomedical Research Park (Parc de Recerca Biomèdica de Barcelona – PRBB), c/Doctor Aiguader 88, 08003 Barcelona, Spain: [2]CIBER Physiopathology of Obesity and Nutrition (CIBEROBN), Instituto de Salud Carlos III, Madrid, Spain: [3]Program of Research in Inflammatory and Cardiovascular Disorders, IMIM-Hospital del Mar, Barcelona, Spain: [4]Center for Research in Environmental Epidemiology (CREAL), Biomedical Research Park (Parc de Recerca Biomèdica de Barcelona – PRBB), Barcelona, Spain: [5]CIBER Epidemiology and Public Health (CIBERESP), Instituto de Salud Carlos III, Madrid, Spain: [6]Centro de Salud La Marina, IDIAP Jordi Gol, Barcelona, Spain: [7]Cardiovascular Epidemiology and Genetics Research Group (EGEC-ULEC), IMIM-Hospital del Mar, Barcelona, Spain

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Abstract

Objective: The aim of the present study was to assess the concurrent and construct validity of two diet-quality indices, a modified Mediterranean diet score (mMDS) and a Mediterranean-like diet score (MLDS) additionally incorporating unhealthy food choices, as determined by an FFQ.

Design: A validation study assessing FFQ intake estimates compared with ten or more unannounced 24 h recalls. Pearson's correlation coefficients, intraclass correlation coefficients (ICC), Bland–Altman plots and the limits of agreement method were used to assess the between-method agreement of scores. Construct validity was shown using associations between nutrient intakes derived from multiple 24 h recalls and the mMDS and MLDS derived from the FFQ.

Setting: Gerona, Spain.

Subjects: A total of 107 consecutively selected participants from a population-based cross-sectional survey.

Results: Pearson's correlations for the energy-adjusted mMDS and MLDS compared with multiple recalls were 0·48 and 0·62, respectively. The average FFQ energy-adjusted mMDS and MLDS were 102 % and 98 % of the recall-based mMDS and MLDS estimates, respectively. The FFQ under- and overestimated dietary recall estimates of the energy-adjusted MLDS by 28 % and 25 %, respectively, with slightly wider boundaries for the mMDS (31 % and 34 %). The ICC, which assesses absolute agreement, was similar to Pearson's correlations (mMDS = 0·48 and MLDS = 0·61). The mean differences between methods were similar across the range of average ratings for both scores, indicating the absence of bias. The FFQ-derived mMDS and MLDS correlated in the anticipated directions with intakes of eleven (73·3 %) and thirteen of fifteen nutrients (86·7 %), respectively.

Conclusions: The FFQ provides valid estimates of diet quality as assessed by the mMDS and MLDS.

Keywords
Validation
Diet quality
Mediterranean diet scores
Construct validity

Dietary scores are composite constructs of dietary components used to estimate overall dietary quality[1–3]. These predefined combinations of foods and/or nutrients provide single operative variables and are considered valuable tools for the analysis of associations between diet quality and health outcomes. Index summary scores, such as the Healthy Eating Index, Diet Quality Index or the Mediterranean diet score (MDS), are based on interpretation of current dietary guidance and on dietary recommendations[4,5]. The traditional MDS was proposed by Trichopoulou *et al.*[6] in 1995 as a tool to assess the degree of adherence to the traditional Mediterranean diet. Assessing adherence to the Mediterranean diet has

† A full roster of REGICOR investigators and collaborators can be found at www.REGICOR.org/regicor.inv

*Corresponding author: Email hschroeder@imim.es

received increasing attention during recent years because of the beneficial effect of this dietary pattern on various aspects of human health[5–9].

Large epidemiological studies have relied primarily on the FFQ approach to estimate habitual individual dietary intake[10]. However, concerns have been raised recently about the ability of participants to provide valid reports of dietary behaviour using these tools, particularly given the demonstration of disparities in diet–disease associations derived from an FFQ compared with alternative instruments[11,12]. Therefore, assessments of the validity of data derived from an FFQ, or the degree to which the instrument really measures what it attempts to measure, are essential.

Most FFQ validation studies have focused on comparing intake estimates using the instrument with those obtained using a reference method to determine whether it reasonably ranks subjects on the basis of their reported intakes of individual nutrients and/or food groups. However, it is impossible to determine from these data whether the FFQ accurately ranks participants against a composite score composed of multiple nutrients and/or foods, such as the MDS. We are not aware of studies assessing the validity of the MDS across dietary assessment methods. The objective of the present study was to estimate the concurrent and construct validity of two variants of MDS assessment in a subpopulation of a representative Spanish population compared with a series of ten or more unannounced 24 h recalls.

Methods

Subjects

Participants were selected from a population-based cross-sectional survey conducted in Spain in 2005 (REGICOR study)[13]; 150 men and women were selected consecutively. Forty-three participants with incomplete records were excluded; complete dietary data from an FFQ and from at least ten completed 24 h recalls were available for 107 individuals. Participants with complete data did not differ from the initial validation sample with respect to variables potentially related to diet quality, including age, gender and BMI (not shown). The project was approved by the local ethics committee (Comités Éticos de Investigación Clínica – Instituto Municipal de Asistencia Sanitaria, Barcelona, Spain).

Dietary assessment

FFQ

Food consumption was estimated using a validated[14] FFQ administered by a trained interviewer. In a 166-item food list including alcoholic and non-alcoholic beverages (typical foods in north-eastern Spain), participants indicated their usual consumption and chose from ten frequency categories, ranging from never or <1 time/month to ≥6 times/d. Food items were listed under fourteen food groups: milk and dairy products, cereals and grain products, vegetables, legumes, sausages, oils and fats, eggs, meat and fish, fast food, canned products, fruit, nuts, sweets and desserts, and others (salt and sugar), as well as alcoholic and non-alcoholic beverages.

Multiple 24 h recalls

Twelve unannounced 24 h dietary recalls were collected by telephone over a 12-month period by a trained interviewer. At least ten completed recalls were required for inclusion in the analysis. Dietary recalls were conducted on non-consecutive days, including at least five weekdays and one weekend day. Food intake data recorded during the 24 h recalls were grouped into the food-based dietary components of the FFQ for analysis.

Calculation of dietary quality scores

The modified Mediterranean diet score. The modified MDS (mMDS) was calculated according to the tertile distribution of food consumption, with the exception of red wine[15,16]. For cereals, fruit, vegetables, legumes, fish, olive oil and nuts, the lowest tertile was coded as 1, medium as 2 and the highest as 3. For meat (including poultry and sausages) and dairy products, the score was inverted, with the highest tertile coded as 1 and the lowest as 3. Moderate red wine consumption (up to 20 g) was included as a favourable component in the MDS, with a score of 3. Exceeding this upper limit or reporting no red wine consumption was coded as 0. The resulting score ranged from 10 to 30.

The Mediterranean-like dietary score. The Mediterranean-like dietary score (MLDS) was constructed by adding three food groups to the ten components of the mMDS: sugar-sweetened carbonated beverages and added sugars; pastries; and fast food. These food groups were scored inversely. In addition, we omitted high-fat dairy products as a negative component and instead included low-fat dairy products as a beneficial food group. We also excluded poultry and rabbit from the meat and sausage food group. The resulting scores ranged from 13 to 39.

Other variables

Measurements of demographic, socio-economic and lifestyle variables including smoking habits and alcohol consumption were obtained through structured standard questionnaires administered by trained personnel.

Statistical analyses

Differences in continuous variables were compared by the Student t test or the Mann–Whitney U test (for non-normally distributed variables). Categorical variables were tested using the χ^2 goodness-of-fit test.

Spearman's correlation coefficients and cross-classification were used to assess the capability of the FFQ to rank participants according to their food group intake or on the basis of scores obtained on the Mediterranean diet indices. Estimated intakes of individual food groups were also compared across instruments. Cross-classification was carried out using contingency tables of tertile distribution of the FFQ compared with the 24 h recall-derived mMDS and MLDS. The proportion of participants correctly categorized (same tertile) and grossly misclassified (opposite tertiles) was calculated.

The mMDS and MLDS were normally distributed. Therefore, relative agreement of the mMDS and MLDS was assessed by calculating Pearson's product–moment correlation coefficients to compare the 24 h recall scores (reference method) with the participants' scores on the FFQ (test method).

Two measures might be highly correlated; yet, there could be substantial differences in the two measurements across their range of values. For this reason we additionally analysed absolute agreement between two measurements by the intraclass correlation coefficient (ICC) and the Bland–Altman method[17]. The Bland–Altman analysis determines the average agreement between two methods by calculating the mean of their differences. The 95 % limits of agreement (LOA) provide an interval within which 95 % of these differences are expected to fall. Agreement between the MDS obtained from the FFQ and those obtained from 24 h recalls was depicted in Bland–Altman plots. A mean agreement of 100 % signified complete agreement between the methods. An LOA between 50 % and 200 % was considered reasonable[18].

A one-sample *t* test was used to determine the significance of differences between scores derived from the FFQ and those derived from 24 h recalls.

In addition, we analysed possible variations in the level of agreement between methods. Proportional bias indicates that the disparity between test and reference methods (i.e. the mean difference) varies significantly, depending on the magnitude of the mean ratings of dietary indices. For this purpose we performed linear regression analysis, with the mean instrument differences of the mMDS and MLDS constituting the dependent variable and the mean score for the corresponding mMDS and MLDS obtained by the test (FFQ) and reference methods (24 h recalls) constituting the independent variable.

Finally, to assess construct validity, general linear modelling was used to estimate associations between nutrient intakes (dependent variables) derived from 24 h recalls and from the tertile distribution of the mMDS and MLDS calculated from the FFQ (independent variable). Linear trends were tested by including the categorized variable (tertile distribution of the scores) as continuous in this model, and the *P* value for linear trend was calculated using polynomial contrast for continuous variables. The Statistical Package for the Social Sciences statistical software package version 13·0 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. Differences were considered significant if *P* was $<0·05$.

Results

With the exception of education, participants in the validation study did not differ significantly from the rest of the sample (Table 1). Spearman's correlation coefficients for food group intakes estimated from the FFQ and 24 h recalls ranged from 0·19 to 0·69, and were moderate on average (Table 2). We cross-classified food groups into tertiles to evaluate the ability of FFQ and 24 h recalls to rank participants on the basis of categories of intake. On average, 48·4 % of the individuals were grouped into the same tertile on both instruments (ranging from 33·6 % congruence for meat to 73·8 % for red wine). Mean gross misclassification (the percentage of individuals in opposite tertiles for the same food item using the two instruments) for food groups was 13·2 %, with fish being the most frequently misclassified food group (Table 2).

Pearson's correlation coefficients between the scores derived from the FFQ and 24 h recalls were moderate and good for the mMDS and MLDS, respectively (Table 3). Absolute agreement between the two MDS derived from the FFQ and 24 h recalls was determined by the ICC and LOA methods. The ICC was comparable to Pearson's correlations.

Mean agreement was calculated, and Bland–Altman's LOA method was used to determine, in absolute terms,

Table 1 Characteristics of the validation study participants and the REGICOR cohort study participants

	REGICOR cohort (*n* 6215)		Validation study (*n* 107)		
	Mean or median	SD 95% CI or P25 and P75	Mean or median	SD 95% CI or P25 and P75	*P*
Men (%)	52·5	51·3, 53·7	48·6	39·1, 58·1	0·423
Age (years)*	56·6	12·6	58·4	12·1	0·139
BMI (kg/m^2)*	27·3	4·5	27·6	4·2	0·509
Current smokers (%)	22·4	21·4, 23·4	16·1	8·9, 23·1	0·119
Alcohol intake (g/d)	3·1	0·0, 11·3	3·6	0·7, 11·3	0·446
LTPA (MET × min/d)	314	119, 402	327	159, 426	0·128
Education higher than primary school (%)	50·0	48·8, 51·3	62·6	53·1, 72·1	0·010

P25, 25th percentile; P75, 75th percentile; LTPA, leisure-time physical activity; MET, metabolic equivalent of task.
Categorical variables are presented as relative frequencies (95 % CI); continuous variables are presented as mean or median (SD or P25 and P75). Differences in continuous variables were compared using the Student *t* test or the Mann–Whitney *U* test. Categorical variables were tested using the χ^2 goodness-of-fit test.
*Data are presented as mean and SD.

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Table 2 Food intake, Spearman's correlation coefficients and agreement between food intake estimates between the FFQ and 24 h recalls

	FFQ			24 h recalls			Spearman's correlations*	Same tertile	Opposite tertile
	Median	P25	P75	Median	P25	P75		%	%
Vegetables (g/4·18 MJ)	231	148	326	78	55	110	0·55	56·1	10·2
Fruit (g/4·18 MJ)	119	66	184	170	83	234	0·28	41·1	12·1
Nuts (g/4·18 MJ)	4·7	1·6	9·9	1·1	0·0	3·7	0·36	46·7	15·9
Meat (g/4·18 MJ)	63	42	79	48	35	64	0·26	33·6	15·9
Fish (g/4·18 MJ)	34	22	47	25	14	36	0·19	39·3	17·8
Cereals (g/4·18 MJ)	67	51	93	124	86	153	0·37	49·5	11·2
Legumes (g/4·18 MJ)	25	17	35	13	0	29	0·25	36·4	16·8
Dairy (g/4·18 MJ)	102	38	165	94	54	136	0·38	47·7	11·2
Olive oil (g/4·18 MJ)	12	8	18	6	3	8	0·33	47·6	16·8
Fruit and nuts (g/4·18 MJ)	123	70	186	171	85	239	0·31	39·3	12·1
Red wine (ml)†	6·7	0	50·0	10·0	0·0	45·4	0·69	73·8	0·0
Fast food (g/4·18 MJ)	6·3	0	35·3	3·8	0·0	10·6	0·41	48·7	11·3
Added sugar (g/4·18 MJ)	0	0	3·5	1·1	0·2	4·4	0·67	67·6	7·6
Pastry (g/4·18 MJ)	1·4	0	4·5	2·4	0	6·3	0·37	45·8	15·6
Soft drinks (ml/4·18 MJ)‡	0	0	11·3	11·5	0	35·3	0·32	56·1	14·9
Low-fat dairy products (g/4·18 MJ)	67	0	124	23	0	65	0·56	54·2	8·4
Mean	–	–	–	–	–	–	0·39	48·4	12·4

P25, 25th percentile; P75, 75th percentile
*Spearman's correlation coefficients between food intake obtained through the FFQ and 24 h recalls.
†For cross-classification categorized into 0 ml, 0·1–100 ml and >100 ml of red wine consumption.
‡Sugar-sweetened carbonated beverages.

Table 3 Mean, correlation coefficients, between-method agreement and limits of agreement between the FFQ and the 24 h-R

	Modified Mediterranean diet score		Mediterranean-like diet score	
	Energy unadjusted	Energy adjusted	Energy unadjusted	Energy adjusted
FFQ				
Mean	20·00	20·11	26·07	26·01
SD	2·92	2·77	3·73	3·84
24 h-R				
Mean	19·99	20·00	26·44	26·61
SD	2·83	2·92	3·68	3·84
Mean difference	0·01	0·11	−0·38	−0·61
95 % CI	−0·68, 0·70	−0·45, 0·67	−1·11, 0·34	−1·25, 0·04
Mean agreement (%)*	101	102	99	99
95 % CI	98, 105	99, 105	97, 102	96, 101
LOA (%)†	64, 139	69, 134	70, 129	72, 125
r (FFQ *v.* 24 h-R)‡	0·33	0·48	0·42	0·62
ICC (FFQ *v.* 24 h-R)	0·33	0·48	0·41	0·61

24 h-R, 24 h recalls; LOA, limits of agreement; ICC, intraclass correlation coefficient.
*Mean agreement expressed as (FFQ/24 h-R) × 100 and 95 % CI of mean agreement.
†95 % limits of agreement.
‡Pearson's correlation coefficient.

the extent of differences between the scores derived from the FFQ and those derived from 24 h recalls. There was little difference in mean agreement, or in LOA, between energy-adjusted *v.* unadjusted MDS and MLDS (Table 3). The mean percentage of agreement was close to 100 for all measures, with lower LOA above 50 % and upper limits well below 200 % for both indices. Moreover, for both energy-adjusted and non-adjusted scores of both indices, agreement did not vary with the magnitude of ratings (Fig. 1), indicating no proportional bias.

To analyse construct validity, we hypothesized *a priori* relationships between higher scores and more favourable intake profiles for fifteen nutrients. We found that, of these fifteen nutrients, 73·3 % and 86·7 % of the 24 h recall-derived intake estimates were associated significantly and in the anticipated direction with tertiles of the FFQ-derived mMDS and MLDS, respectively (Table 4).

Discussion

The present study determined the concurrent and construct validity of two variants of the MDS. Compared with data derived from multiple 24 h recalls spanning a 12-month period, the FFQ showed an adequate capacity to rank participants on the basis of two MDS, the mMDS and the MLDS. LOA was in a reasonable range for both scores. Furthermore, our results indicate sound evidence for construct validity, particularly for the MLDS score, which incorporated several modifications into the traditional MDS.

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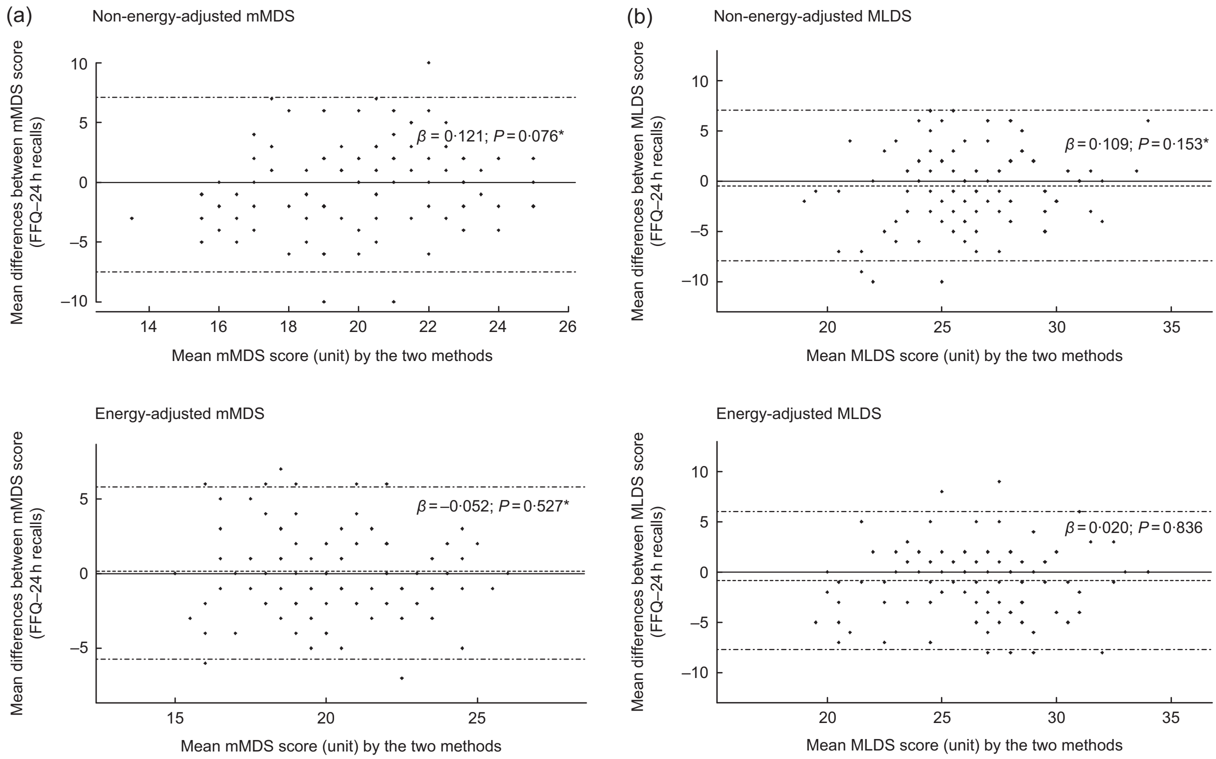

Fig. 1 Mean differences of the modified Mediterranean diet score (mMDS; a) and the Mediterranean-like diet score (MLDS; b) derived from the FFQ and 24 h recalls. Lines are mean differences (- - - -) and upper and lower 95 % limits of agreement (-·-·-·); *regression coefficient and statistical significance of the slope from the linear regression of the mean of the methods against the difference between methods

Table 4 Nutrient intake by quartile of energy-adjusted dietary scores

	Modified Mediterranean diet score					Mediterranean-like diet score				
	1st quartile (*n* 32)		4th quartile (*n* 21)			1st quartile (*n* 21)		4th quartile (*n* 25)		
	Mean	SD	Mean	SD	*P**	Mean	SD	Mean	SD	*P**
Saturated/unsaturated fat	0·52	0·10	0·45	0·07	0·020	0·51	0·09	0·44	0·07	0·015
Cholesterol (mg/d)	156	34·5	151	29·5	0·293	167	41·3	160	47·1	0·666
Trans fatty acids (g/4·18 MJ)	0·49	0·36	0·45	0·35	0·405	0·71	0·47	0·39	0·37	0·009
Fibre (g/4·18 MJ)	8·1	2·5	10·2	2·9	0·009	6·5	2·2	10·6	2·8	<0·001
Na (mg/4·18 MJ)	1315	235	13 475	417	0·775	1320	260	1407	412	0·392
K (mg/4·18 MJ)	1405	272	1647	290	0·004	1268	247	1699	365	<0·001
Mg (mg/4·18 MJ)	127	22·9	146	24·1	0·002	116	16·1	152	29·5	<0·001
Ca (mg/4·18 MJ)	452	125	458	91·1	0·650	388	96·4	501	103	<0·001
Vitamin C (mg/4·18 MJ)	42·1	20·6	72·5	26·4	0·001	34·2	20·0	69·7	28·9	<0·001
Vitamin E (mg/4·18 MJ)	3·0	0·8	3·7	0·9	0·004	2·9	0·7	3·9	1·1	<0·001
Folic acid (μg/4·18 MJ)	112	28·4	141	28·8	0·002	96·8	25·5	148	37·7	<0·001
Carotene (mg/4·18 MJ)	12·3	8·2	18·6	9·4	0·034	12·1	9·2	18·4	9·9	0·015
Lycopene (mg/4·18 MJ)	0·56	0·49	1·20	0·97	<0·001	0·52	0·41	1·21	0·86	<0·001
Phytosterols (mg/4·18 MJ)	68·5	17·0	93·6	28·6	<0·001	66·7	19·1	93·2	28·6	<0·001
Flavonoids (mg/4·18 MJ)	31·0	18·4	50·0	19·5	0·003	29·8	19·6	46·5	23·1	0·011

**P* for linear trend.

The Mediterranean diet is a healthy eating pattern associated with better health and lower risk of premature mortality[5–9,19–21]. Since 1995, adherence to this dietary pattern has been assessed by FFQ-derived composite scores that include foods that are characteristic of the Mediterranean olive grove areas[4]. Although considered an adequate dietary assessment tool for the estimation of overall diet quality, the MDS has varied between studies because of differences in the scoring criteria[4]. The present study assessed the validity of a score previously proposed by our group[16]. In a further adjustment, we omitted inverse scoring for dairy products, including

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instead low-fat and fat-free (skim) dairy products as healthy foods. We also added fast food, sugar-sweetened carbonated beverages, added sugars and pastry as detrimental foods. Finally, we excluded poultry and rabbit from the meat and sausage food group, scoring these meats separately as a healthy choice. We hypothesized that these changes would increase the accuracy of the construct to measure diet quality. Indeed, overall, both the magnitude of correlations and the proportion of nutrients supporting construct validity were somewhat higher for the modified score than for the original score.

Correlation coefficients for individual food group components of the mMDS and MLDS ranged from 0·19 to 0·69, which is comparable to results from other similar validation studies[10]. In addition, we found a reasonable frequency of agreement and gross misclassification of food groups between methods. Both the mMDS and the MLDS were moderately correlated between assessment methods, indicating that the FFQ reasonably ranks participants according to these diet-quality indices. Unfortunately, the limited literature on concurrent validity of dietary indices makes it somewhat difficult to compare our results with those of other studies. However, a few studies have reported correlations of similar magnitude. Newby *et al.*[22] reported good correlations ($r = 0{\cdot}66$) between the Diet Quality Index Revised derived from an FFQ and those from two 1-week dietary records. Results from Hu *et al.*[23] showed the validity of two major dietary patterns derived using principal component analysis from dietary estimates of an FFQ compared with multiple dietary records, with correlations of 0·45–0·58 for the first FFQ.

Ideally, studies on the validity of an FFQ should include multiple methodological tools to determine validity. This permits an accurate interpretation of the strengths and weaknesses of the instrument and provides insight into possible biases of the dietary assessment method. For this reason we assessed the relative validity of the mMDS and MLDS using cross-classification, correlation coefficients, Bland–Altman plots and the LOA method proposed by Bland and Altman[17]. The mean agreement of scores between methods was reasonable in the present study, and LOA was well within the acceptable boundaries of 50 % and 200 %[18]. In the present study, the LOA for both scores was in a narrow range compared with levels reported in previous studies for individual nutrients[18,24]; for example, the FFQ under- and overestimated the dietary recall estimates of the energy-adjusted MLDS by only 28 % and 25 %, respectively. Furthermore, Bland–Altman plots showed no significant proportional variations over the range of average ratings for any of the three dietary indices. This means that the errors were not proportional to the ratings.

Construct validity is an additional aspect to be considered in selecting a dietary assessment tool. To address this issue we hypothesized that both of the FFQ-derived dietary quality indices would be positively associated with a favourable nutrient intake profile estimated by 24 h recalls. Intakes of K, Mg, folic acid, vitamins C and E, phytosterols and dietary fibre were positively associated with mMDS ratings. In addition to these nutrients, inclusion in the MLDS of additional detrimental foods such as fast food, added sugars, sugar-sweetened soft drinks and pastry – as well as modification of the dairy component – improved the construct validity of the score and yielded a positive association with *trans* fatty acids and Ca.

An inherent limitation of our study, and of all validation studies using multiple dietary recalls or records as the reference method, is that these methods themselves are not error free. Errors in the two methods may be correlated. However, the measures used in the present study have important strengths, including the use of unannounced recalls spanning a 12-month period, enabling us to capture seasonal differences in intake.

We conclude that the FFQ accurately allocates participants across the distribution of ratings of the mMDS and MLDS intakes. For both scores, the construct estimates were valid compared with multiple recalls, and the LOA was in a reasonable range with no indication of bias.

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