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Validity and reproducibility of a food frequency questionnaire focused on the Mediterranean diet for the Quebec population

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Abstract *Background and aims:* Validated dietary assessment methods specific to population and food habits are needed to conduct randomized clinical trials evaluating the efficacy of the Mediterranean diet in primary and secondary prevention of cardiovascular disease. Therefore, the aim of our study was to assess the reproducibility and the relative validity of a French language semi-quantitative food frequency questionnaire (FFQ) focused on the Mediterranean diet within the population of Quebec.
Methods and results: Fifty-three participants aged 19–86 years with and without coronary heart disease were recruited, and randomized in 3 groups in a crossover design where the sequence of administration of two FFQs and a dietary record (DR) differed in each group. The FFQ includes 157 food items and was designed to measure food intake over one month. It was administered twice 3–5 weeks apart to assess reproducibility and was compared to a 12-day DR to assess validity. For reproducibility ($n = 47$), intraclass correlation coefficients (ICCs) for energy and 33 nutrients ranged from 0.38 to 0.91 (mean 0.63). For validity, the Pearson's correlation coefficients between the DR and the FFQ pre-DR ranged from 0.26 to 0.84 (mean 0.55) and ICCs ranged from 0.25 to 0.84 (mean 0.54). As for the DR and the FFQ post-DR, the Pearson's correlation coefficients ranged from 0.36 to 0.83 (mean 0.55) and the ICCs ranged from 0.36 to 0.83 (mean 0.53).
Conclusion: This FFQ demonstrates good reproducibility and validity for most key nutrients of the Mediterranean diet for the Quebec population.

Introduction

Initially described by Keys et al. in the Seven Countries Study [1], the Mediterranean diet is characterized by high intakes of olive oil, grain products, legumes, vegetables and fruits, moderate intakes of dairy products, low intake of meat and meat products and moderate consumption of alcoholic beverages during meals [2,3]. This diet has been

Abbreviations: BMI, body mass index; CI, confidence interval; CVD, cardiovascular disease; Centre EPIC, Montreal Heart Institute's Prevention and Physical Activity Center; DR, dietary record; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; FFQ, food frequency questionnaire; ICC, intraclass correlation coefficient; SD, standard deviation.

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shown to reduce all-cause and cardiovascular mortality [4,5], and also plays a role in the primary [1,6] and secondary prevention of cardiovascular disease (CVD) [7]. Several mechanisms may explain the cardioprotective effects of the Mediterranean diet including beneficial effects on cardiometabolic parameters [8,9], endothelial function [10,11], vascular inflammation [10,12] and oxidative stress [13,14]. These mechanisms are possibly mediated by a combination of key nutrients found in greater amount in Mediterranean foods and foodstuffs as compared to those found in a Western-type diet, such as potassium, magnesium, calcium, vitamin E, vitamin C, dietary fiber, monounsaturated fat and omega-3 fatty acids, as well as polyphenols [3,15,16]. In the Quebec and Canadian populations, CVD is the second most common cause of death [17]. At the same time, few clinical trials have been conducted on the cardioprotective effects of the Mediterranean diet in the Canadian setting. In the context of our desire to conduct such studies, validated dietary assessment methods to measure food intake and especially nutrients characteristic of the Mediterranean diet are needed. While dietary records (DR) represent a “gold standard” method for capturing usual food intake, they result in high burden (time and cost) for patients and investigators alike [18]. Food frequency questionnaires (FFQs) are widely used in epidemiological studies. However, they may also be useful in clinical trials to capture changes in diet following a nutritional intervention [6,19]. The aim of our study was therefore to assess the reproducibility and relative validity of the Latour questionnaire, a FFQ developed at the Montreal Heart Institute’s Prevention and Physical Activity Center (Centre EPIC) for the purpose of conducting clinical trials evaluating the efficacy of the Mediterranean diet for improving cardiovascular health.

Methods

Study population

Fifty-three participants, men and women, between the ages of 19 and 86 years were recruited. The sole inclusion criterion was age $\geq$18 years. Exclusion criteria were pregnancy, participation in a weight loss program including dietary modification and insufficient knowledge of the French language. Participants were primarily recruited at Centre EPIC. This study was approved by the ethics committee of the Montreal Heart Institute and written informed consent was obtained from all participants.

A minimal sample size of 47 participants was computed for reproducibility using the large sample normal approximation for an intraclass correlation coefficient (ICC) with an expected parametric ICC of 0.63 and a one-sided 95.0% confidence interval (CI) lower limit of 0.48. As for validity, a sample size of 31 participants was computed using the large sample normal approximation for a Pearson’s correlation coefficient with an expected parametric Pearson’s correlation coefficient of 0.55 and a one-sided 95.0% CI lower limit of 0.30.

Design

Participants completed two FFQs and one DR. Subjects were randomized in 3 groups in a crossover design where the sequence of administration of FFQs and DR differed in each group (Fig. 1). This design was chosen to minimize bias and verify the influence of the food record on the answers to the questionnaire. In order to lower bias related to within-person variability of food intake, participants were asked not to modify their diet for the duration of the study. To reduce the social desirability bias, it was emphasized to all participants that the aim of the study was to evaluate the FFQ as opposed to their food habits.

Measurements

Sociodemographic characteristics and medical history were obtained from participants’ medical files when available and completed with the participants at their first visit. Anthropometric measures (weight, height, waist circumference, percentage body fat (segmental bioelectric impedance/Tanita BC-418)) were also taken at that time.

Reproducibility assessment

The FFQ was administered twice, 3–5 weeks apart, to assess reproducibility. This interval was chosen in order to reduce bias related to memory as well as real changes in food intake. All questionnaires were self-administered by the participants at Centre EPIC and reviewed by a registered dietitian (JC) for completeness. Food models and household measurements were used by the dietitian to assure adequacy of portion size reported by the participants. Additional questions were also asked by the dietitian to refine answers, such as proportions of vegetables eaten raw and cooked and proportions of types of nuts eaten.

Validity assessment

The FFQ was compared to a 12-day DR carried out over a one-month period to assess relative validity. Days were predetermined (8 week days and 4 week-end days) by the investigators and were non-consecutive. The DR was chosen over other dietary assessment methods to reduce correlated bias with the FFQ. The number of days chosen for the DR was established through a compromise between the number of days required to assess usual intake of the nutrients measured [20] and participant burden. All DRs were revised by the same registered dietitian with the participants.

Group 1	DR	FFQ1	FFQ2
Group 2	FFQ1	DR	FFQ2
Group 3	FFQ1	FFQ2	DR

Figure 1 Sequence of administration of FFQs and DR.

Food frequency questionnaire

The Latour FFQ is a French language self-administered semi-quantitative questionnaire designed to assess food intake over a one-month period. It was initially developed in 1998 at Centre EPIC for clinical purposes. It was revised on two subsequent occasions including prior to this validation study to notably include missing key foods of the Mediterranean diet. The revised FFQ includes 157 food items grouped into 11 sections: milk and alternatives, vegetables, potatoes, fruits, grain products, meat and alternatives, combination foods, oils and fats, sweets, beverages and other foods. A reference portion size is indicated for each food. However, participants are told to modify portion sizes, if necessary, to better reflect their food intake, the aim of the FFQ being to estimate absolute intake of energy and nutrients. Moreover, in order to increase accuracy of food intake, 2–3 questions are asked for every food item. The FFQ also comprises 4 open-ended questions, one of which asks participants at the end of the questionnaire if they ate foods not included in the FFQ. Lastly, a conversion table of volume measurements (milliliters, measuring cups/spoons and ounces) with visual comparisons (tennis ball = 1/2 cup, deck of cards = 75 g of meat) is included at the beginning of the FFQ.

Nutritional analysis

FFQs and DRs were all analyzed using The Food Processor software. The Canadian Database was prioritized and completed when necessary with the USDA Nutrient Database for Standard Reference for missing food items. Data entry was carried out by two students undergoing their bachelor in dietetics and reviewed by the same registered dietitian (JC).

Three FFQs were removed from analyses because energy intake was judged implausible according to the values suggested by Willett (500–3500 kcal per day for women and 800–4000 kcal per day for men) [18]. All DRs provided plausible energy intake values.

Statistical analysis

Descriptive analyses were performed for energy and 33 nutrients measured by both FFQs and the 12-day DR. Results are presented as mean ± standard deviation (SD). For the reproducibility assessment, the ICC was used as a measure of agreement. For the validity assessment, the Pearson's correlation coefficient was used as a measure of association. The ICC was also calculated since the aim of the FFQ is to estimate absolute nutrient intake, rather than to rank individuals by their nutrient intake as seen in epidemiological studies. Calorie-adjusted intakes were not computed for the same reason. Validity was explored separately for FFQs administered before the DR (FFQ pre-DR)[1] and FFQs administered after the DR (FFQ post-DR)[2] in order to obtain minimal and maximal estimates of validity respectively, as suggested by Willett [18]. The FFQ pre-DR can be biased by changes in food habits since it does not assess food intake over the same period of time as the DR and so provides a minimal estimate of validity. As for the FFQ post-DR, it might be influenced by the awareness of food intake induced by the DR, hence providing a maximal estimate of validity. Therefore, taken together, the two analyses give a better estimation of the true validity of the FFQ.

When studying reproducibility or validity of a FFQ with respect to a DR, it is more appropriate to use CIs than testing the null hypotheses that the parametric ICC or the parametric Pearson's correlation coefficient are null (H_0: ICC = 0 or H_0: $r = 0$). Thus, one-sided (lower limits) 95.0% CIs were used for all analyses. Finally, the Bland-Altman approach was also used to assess validity and reproducibility [21]. Data were transformed with logarithmic or inverse transformations when they did not follow a normal distribution. All statistical analyses were carried

Table 1 Baseline characteristics of subjects.

	Total (n = 50) (mean ± SD)	Men (n = 22) (mean ± SD)	Women (n = 28) (mean ± SD)
Age (years)	53 ± 18	57 ± 20	51 ± 16
Weight (kg)	77 ± 17	85 ± 13	71 ± 16
Height (cm)	166 ± 9	174 ± 6	160 ± 6
BMI (kg/m^2)	28 ± 5	28 ± 4	28 ± 6
Waist circumference (cm)	95 ± 15	101 ± 14	90 ± 14
Percentage body fat (%)	30 ± 10	25 ± 8	34 ± 9
Glucose (mmol/L)	5.4 ± 0.9	5.6 ± 0.8	5.3 ± 1.0
Triglycerides (mmol/L)	1.14 ± 0.52	1.12 ± 0.46	1.15 ± 0.58
Total cholesterol (mmol/L)	4.55 ± 1.11	3.91 ± 0.85	5.08 ± 1.03
LDL-cholesterol (mmol/L)	2.58 ± 0.93	2.13 ± 0.78	2.95 ± 0.90
HDL-cholesterol (mmol/L)	1.46 ± 0.41	1.28 ± 0.33	1.61 ± 0.41
Total cholesterol/ HDL-cholesterol	3.26 ± 0.95	3.21 ± 0.99	3.30 ± 0.94
Sex (%)	100	44	56
Diabetes type II (%)	4	5	4
Dyslipidemia (%)	40	55	29
Hypertension (%)	32	32	32
Coronary heart disease (%)	18	36	4
Metabolic syndrome (%)	41	53	32
Educational level (%)			
Secondary	10	14	7
College	32	32	32
University	58	55	61
Current smokers (%)	6	5	7
Physical activity[a] (%)	66	73	61

[a] ≥30 min exercise per day.

[1] For group 3, only the FFQ2 was used to compute analyses.
[2] For group 1, only the FFQ1 was used to compute analyses.

out using the Statistical Package for Social Sciences version 21.0 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.).

Results

Forty-eight participants completed the DR and both FFQs. Five participants did not complete the study, however data from two were sufficient to be included in the analyses. Withdrawals were voluntary (2 subjects) or for medical reasons (3 subjects).

Baseline characteristics of study participants are presented in Table 1. Mean age was 53 ± 18 years. Women were slightly more represented than men (56% of sample). Mean body mass index (BMI) was 28 ± 5 kg/m^2. Main risk factors for CVD, such as type II diabetes, dyslipidemia, hypertension and the metabolic syndrome were present in 4%, 40%, 32% and 41% of subjects respectively and 18% of subjects had coronary heart disease. Subjects were well educated, 58% of the study population having completed a university degree and most were physically active.

Mean daily intake of energy, macronutrients, fatty acids, cholesterol, vitamins and minerals measured by the first and second FFQ as well as the 12-day DR are shown in Table 2. Energy and nutrient intakes were generally higher when measured by the FFQs as compared to the DR (Table S1, Supplementary material).

For the assessment of reproducibility, ICCs between both FFQs for energy and nutrients are presented in Table 3. They ranged from 0.38 for folate to 0.91 for alcohol (mean 0.63). The assessment of validity evaluated by Pearson's correlations coefficients and ICCs is shown in Table 4. The Pearson's correlation coefficients between the DR and the FFQ pre-DR ranged from 0.26 for vitamin A and potassium (but did not reach significance) to 0.84 for alcohol (mean 0.55) and ICCs ranged from 0.25 for vitamin A (but did not reach significance) to 0.84 for alcohol (mean 0.54). As for the correlation between the DR and the FFQ post-DR, the Pearson's correlation coefficients ranged from 0.36 for vitamin B6 to 0.83 for linolenic acid (mean 0.55) and the ICCs ranged from 0.36 for vitamin B6 to 0.83 for linolenic acid (mean 0.53). Assessment of validity with the

Table 2 Mean daily intake of energy and nutrients measured by the first and second FFQ (FFQ1 and FFQ2) and the 12-day DR.

	FFQ1 (n = 48)		FFQ2 (n = 48)		DR (n = 49)	
	Mean	SD	Mean	SD	Mean	SD
Energy (kcal)	2602.47	488.88	2441.90	514.52	2172.11	482.68
Macronutrients						
Protein (g)	109.16	25.40	101.92	22.89	91.76	23.79
Carbohydrates (g)	317.44	59.11	300.17	66.62	264.12	66.64
Dietary fiber (g)	30.29	9.22	29.02	9.03	24.59	8.39
Fat (g)	97.74	29.29	90.41	23.62	78.67	20.08
Saturated fat (g)	31.46	10.71	28.94	9.67	25.31	7.41
Monounsaturated fat (g)	39.71	14.30	35.97	10.41	30.58	8.46
Polyunsaturated fat (g)	17.56	6.24	16.88	5.84	14.82	5.35
Oleic acid (g)	36.57	13.64	33.15	9.83	28.18	8.20
Linoleic acid (g)	14.06	5.40	13.45	4.71	11.98	4.49
Linolenic acid (g)	2.06	1.09	2.22	1.77	1.76	1.19
EPA (g)	0.19	0.16	0.18	0.14	0.14	0.14
DHA (g)	0.39	0.35	0.37	0.30	0.29	0.30
Trans fatty acid (g)	0.51	0.46	0.47	0.37	0.49	0.41
Cholesterol (mg)	311.91	105.05	295.42	112.51	279.22	105.89
Alcohol (g)	10.85	10.88	11.56	11.27	12.08	11.83
Vitamins						
Vitamin A (mcg)	1147.02	612.34	1153.86	660.64	998.79	961.30
Vitamin B1 (mg)	2.22	0.50	2.04	0.45	1.94	0.49
Vitamin B2 (mg)	2.79	0.67	2.66	0.66	2.30	0.63
Vitamin B3 (mg)	48.98	11.96	46.95	10.92	42.32	11.53
Vitamin B6 (mg)	2.51	0.57	2.35	0.56	2.07	0.60
Vitamin B12 (mcg)	7.40	4.50	6.66	3.24	6.47	5.10
Vitamin C (mg)	222.72	99.02	198.15	88.50	161.49	78.06
Vitamin D (mcg)	6.95	2.79	6.96	2.98	5.32	2.84
Vitamin E (mg)	10.68	4.45	10.69	4.12	8.64	3.74
Folate (mcg)	548.13	142.31	506.40	129.01	470.07	127.27
Vitamin K (mcg)	204.88	142.13	212.37	176.92	138.59	89.79
Minerals						
Calcium (mg)	1241.43	396.05	1213.99	342.49	967.48	343.26
Iron (mg)	19.24	5.20	17.56	3.84	16.16	4.49
Magnesium (mg)	496.37	162.52	470.69	142.92	386.71	133.11
Phosphorus (mg)	1842.04	389.91	1747.66	411.86	1475.55	409.46
Potassium (mg)	4484.30	965.69	4216.86	1097.64	3537.07	1028.09
Selenium (mcg)	140.04	51.72	131.98	51.63	124.06	53.28
Sodium (mg)	3562.35	938.81	3417.65	816.43	2739.72	750.14

Table 3 Reproducibility assessment: correlations between FFQ1 and FFQ2 for energy and nutrients ($n = 47$).[a]

	ICC	CI lower limit
Energy	0.58	0.39
Macronutrients		
Protein	0.52	0.31
Carbohydrates	0.53	0.33
Dietary fiber	0.78	0.66
Fat	0.63	0.46
Saturated fat	0.58	0.39
Monounsaturated fat	0.62	0.45
Polyunsaturated fat	0.75	0.63
Oleic acid	0.63	0.46
Linoleic acid	0.73	0.60
Linolenic acid	0.76	0.64
EPA	0.64	0.47
DHA	0.62	0.44
Trans fatty acid	0.77	0.65
Cholesterol	0.54	0.34
Alcohol	*0.91*	0.85
Vitamins		
Vitamin A	0.61	0.44
Vitamin B1	0.43	0.22
Vitamin B2	0.65	0.48
Vitamin B3	0.62	0.45
Vitamin B6	0.65	0.49
Vitamin B12	0.65	0.48
Vitamin C	0.61	0.43
Vitamin D	0.49	0.29
Vitamin E	0.68	0.53
Folate	*0.38*	0.15
Vitamin K	0.75	0.62
Minerals		
Calcium	0.61	0.44
Iron	0.57	0.38
Magnesium	0.78	0.66
Phosphorus	0.58	0.40
Potassium	0.71	0.57
Selenium	0.55	0.36
Sodium	0.58	0.40
Mean	0.63	

[a] Lowest and highest correlations are shown in italics.

complete sample yielded similar results (data not shown). In this study, the DR does not appear to have influenced answers to the FFQ since mean Pearson's correlation coefficient and mean ICC between DR and FFQ pre-DR were equal or slightly higher than between DR and FFQ post-DR.

Results of the Bland-Altman analyses are presented in Table S2 (Supplementary material). Most of the Pearson's correlation coefficients (73%) were not statistically significant. Plots for the nutrients presenting the highest and lowest level of agreement for both reproducibility and validity assessments are depicted in Fig. 2.

Discussion

The main findings of our study are that our FFQ demonstrated good reproducibility and relative validity compared to a 12-day DR in a heterogeneous sample of individuals in both the primary and secondary prevention of CVD.

As previously stated, the assessment of reproducibility may be influenced by changes in the participants' diet which might in turn lower correlations obtained. Nevertheless, our results show that our FFQ presents good reproducibility for energy and most nutrients, since only three nutrients (vitamin B1, vitamin D and folate) yielded correlations lower than 0.5. Moreover, mean ICC (0.63) was comparable to values obtained with other FFQs. Goulet et al. found a mean Spearman correlation coefficient of 0.66 for their FFQ also validated within the population of Quebec [19], whereas Fernandez-Ballart et al. found a mean ICC of 0.78 for their FFQ used in the PREDIMED Study, a Spanish multicenter clinical trial for the primary prevention of CVD by the Mediterranean diet [22]. As for the Harvard FFQ, a questionnaire largely used in the United States, the mean ICC was 0.60 [23].

Our FFQ also presents good validity. Shatenstein et al. previously validated a FFQ in the population of Quebec and observed a lower agreement with a 4-day DR (Spearman correlation coefficients ranging from 0.30 for vitamin A to 0.57 for energy, lipids and SFA with a mean of 0.45) [24]. Goulet et al. also obtained lower agreement with a 3-day DR (Spearman correlation coefficients ranging from 0.19 for vitamin C to 0.61 for alcohol with a mean of 0.34) [19]. However, the assessment of validity reported in these studies is most likely an underestimation of the actual validity of the FFQs. Indeed, the number of days of the DR in these studies would appear insufficient to measure the usual intake of most nutrients due to high within-person variability. In our study, a 12-day DR was used as the reference method, which has been shown to achieve better results than a 4-day DR [25]. The PREDIMED FFQ was also validated against 12 days of DR and ICCs were similar to those observed in our study (ICCs ranging from 0.38 for vitamin D to 0.78 for vitamin C with a mean of 0.55) [22]. As stressed by Willett, correlations higher than 0.7 are very rare in FFQ validation studies [26]. Therefore, our FFQ appears to assess intake of polyunsaturated fat, trans fat, linolenic acid and alcohol with a very good accuracy. It also provides a good estimate of other key nutrients of the Mediterranean diet, such as marine omega-3 fatty acids (EPA, DHA), vitamin C and vitamin E. Inversely, an ICC below 0.5 means that the variance due to error represents at least 50% of the total variance. Therefore, absolute intake of monounsaturated fat, oleic acid, folate, vitamin K, phosphorus and potassium measured with this FFQ should be interpreted carefully since ICCs were below 0.5 for both FFQs pre-DR and post-DR.

The Bland-Altman analyses showed no statistically significant correlations for most nutrients. The significant correlations we obtained for some nutrients, such as the vitamin K (Fig. 2d) are most likely due to skewed distributions of the differences in intake and means on account of a few participants that might have changed their food habits between questionnaires or misreported their intake in the FFQ.

In our study, energy and nutrient intakes were generally higher when measured by the FFQs as compared to the DR. FFQs have been shown to overestimate food intake.

Table 4 Validity assessment: correlations for energy and nutrients between the 12-day DR and FFQs.[a]

	Pearson's correlation coefficient (*p*-value)				ICC (CI lower limit)			
	FFQ pre-DR ($n = 31$)		FFQ post-DR ($n = 32$)		FFQ pre-DR ($n = 31$)		FFQ post-DR ($n = 32$)	
Energy	0.55	(0.001)	0.50	(0.002)	0.54	(0.29)	0.49	(0.23)
Macronutrients								
Protein	0.63	(0.000)	0.41	(0.01)	0.63	(0.41)	0.41	(0.14)
Carbohydrates	0.42	(0.009)	0.53	(0.001)	0.42	(0.14)	0.52	(0.27)
Dietary fiber	0.68	(0.000)	0.42	(0.008)	0.67	(0.47)	0.41	(0.13)
Fat	0.62	(0.000)	0.60	(0.000)	0.59	(0.36)	0.56	(0.32)
Saturated fat	0.70	(0.000)	0.60	(0.000)	0.65	(0.44)	0.56	(0.32)
Monounsaturated fat	0.54	(0.001)	0.52	(0.001)	0.49	(0.23)	0.47	(0.21)
Polyunsaturated fat	0.73	(0.000)	0.61	(0.000)	0.73	(0.55)	0.61	(0.39)
Oleic acid	0.52	(0.001)	0.52	(0.001)	0.48	(0.21)	0.47	(0.21)
Linoleic acid	0.70	(0.000)	0.54	(0.001)	0.70	(0.51)	0.53	(0.28)
Linolenic acid	0.66	(0.000)	*0.83*	(0.000)	0.66	(0.45)	*0.83*	(0.71)
EPA	0.57	(0.000)	0.57	(0.000)	0.57	(0.33)	0.55	(0.31)
DHA	0.59	(0.000)	0.55	(0.001)	0.59	(0.35)	0.53	(0.28)
Trans fatty acid	0.69	(0.000)	0.73	(0.000)	0.69	(0.49)	0.72	(0.54)
Cholesterol	0.71	(0.000)	0.52	(0.001)	0.70	(0.52)	0.52	(0.27)
Alcohol	*0.84*	(0.000)	0.82	(0.000)	*0.84*	(0.72)	0.81	(0.68)
Vitamins								
Vitamin A	*0.26*	(0.078)	0.53	(0.001)	*0.25*	(−0.06)	0.50	(0.25)
Vitamin B1	0.52	(0.001)	0.38	(0.015)	0.52	(0.27)	0.38	(0.10)
Vitamin B2	0.34	(0.029)	0.62	(0.000)	0.33	(0.04)	0.62	(0.40)
Vitamin B3	0.59	(0.000)	0.45	(0.005)	0.59	(0.35)	0.45	(0.18)
Vitamin B6	0.56	(0.000)	*0.36*	(0.022)	0.56	(0.32)	*0.36*	(0.07)
Vitamin B12	0.55	(0.001)	0.70	(0.000)	0.46	(0.19)	0.69	(0.50)
Vitamin C	0.56	(0.000)	0.55	(0.001)	0.54	(0.28)	0.54	(0.29)
Vitamin D	0.37	(0.021)	0.59	(0.000)	0.37	(0.08)	0.59	(0.35)
Vitamin E	0.60	(0.000)	0.74	(0.000)	0.60	(0.37)	0.67	(0.48)
Folate	0.50	(0.002)	0.46	(0.004)	0.49	(0.23)	0.45	(0.19)
Vitamin K	0.31	(0.043)	0.42	(0.009)	0.30	(0.00)	0.42	(0.14)
Minerals								
Calcium	0.39	(0.015)	0.66	(0.000)	0.38	(0.10)	0.64	(0.43)
Iron	0.59	(0.000)	0.41	(0.01)	0.59	(0.35)	0.39	(0.11)
Magnesium	0.46	(0.009)	0.55	(0.000)	0.46	(0.19)	0.53	(0.28)
Phosphorus	0.39	(0.016)	0.44	(0.006)	0.39	(0.10)	0.44	(0.17)
Potassium	*0.26*	(0.075)	0.47	(0.004)	0.26	(−0.04)	0.47	(0.20)
Selenium	0.68	(0.000)	0.46	(0.004)	0.68	(0.48)	0.44	(0.17)
Sodium	0.56	(0.001)	0.54	(0.001)	0.55	(0.31)	0.54	(0.30)
Mean	0.55		0.55		0.54		0.53	

[a] Lowest and highest correlations for each column are shown in italics.

Fernández-Ballart et al. also found in their validation study that their FFQ tended to overestimate energy and most nutrients as compared to a DR [22]. However, no dietary assessment method comprises a total lack of bias. Indeed, the DR, which is generally considered the "gold standard" of dietary assessment methods, tends to underestimate food intake [27]. Therefore, true food intake is most likely to be between both FFQ and DR estimations of food intake.

We designed our study to assess the influence of the DR on the answers to the FFQs. Contrary to what was previously observed [23,28,29], mean correlations between the DR and the FFQ post-DR were slightly lower than between the DR and the FFQ pre-DR. It has been hypothesized that a FFQ completed after a DR would yield higher correlations because of the participants' awareness of food intake induced by the dietary recording and because the same period of time is covered by both the DR and FFQ [18]. Our distinctive study design might partly explain this discrepancy. Indeed, in previous studies, the FFQ post-DR was always the second FFQ. The second FFQ might also lead to higher correlations because participants have a better knowledge on how to fill out the FFQ. However, in our study, not all participants did their second FFQ after the DR and inversely, some participants did their first FFQ after undertaking their DR (Fig. 1).

Dietary questionnaires are culture-specific. However, in Quebec and especially in the Montreal area, ethnicity and food habits are very heterogeneous. Ethnic food is also popular among individuals from Canadian descent. Complexity of dietary instrument development is therefore further increased. An open-ended FFQ like ours might be the appropriate way to address this issue.

Participants' motivation is very important to achieve maximal accuracy of intake measurement by a FFQ. Since

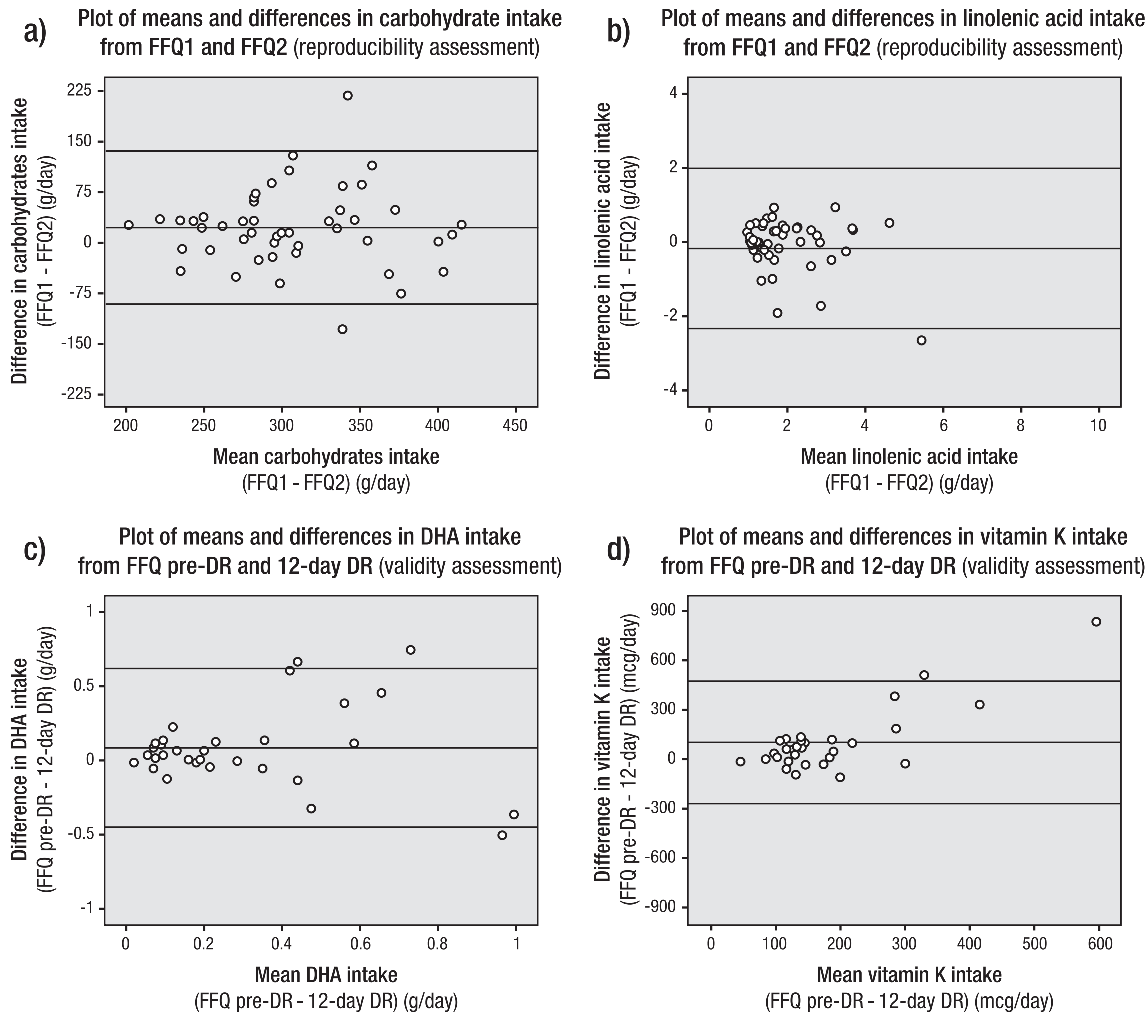

Figure 2 Bland-Altman plots showing the relationship between means and differences of nutrients presenting the highest and lowest level of agreement for both reproducibility and validity assessments, respectively: a) carbohydrates derived from both FFQs (highest result for reproducibility assessment), b) linolenic acid derived from both FFQs (lowest result for reproducibility assessment), c) DHA derived from FFQ pre-DR and 12-day DR (highest result for validity assessment), d) vitamin K derived from FFQ pre-DR and 12-day DR (lowest result for validity assessment).

participants were recruited on a voluntary basis, their motivation was most likely higher than the general population. However, our FFQ was developed to be used in clinical trials, where participants are also recruited on a voluntary basis. Nevertheless, the high level of education of our study population constitutes a selection bias, but since the FFQ is to be revised by a dietitian, the accuracy of answers will most likely not be affected by a lower level of education.

As a result, we believe our FFQ to be of utility in clinical trials including a nutritional intervention promoting the Mediterranean diet as it allows one to measure usual intake with good accuracy and minimal cost. As previously discussed, multiple DRs are needed to measure usual intake of food and nutrients eaten seldomly but with important health effects in the context of nutritional interventions, but are associated with time costs to participants and non-negligible time and financial costs to investigators [27]. Moreover, an interviewer administered FFQ is most likely better suited than a self-administered FFQ to measure absolute nutrient intake. However, we favored a self-administered FFQ that would be revised by a dietitian in order to reduce the required interviewer time.

In conclusion, our FFQ presents good reproducibility and validity for measuring most key nutrients of the Mediterranean diet. Therefore, these results support the eventual use of our FFQ in clinical trials on the prevention of CVD with a Mediterranean diet in the Quebec population.

Conflict of interest

No conflicts to disclose.

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Appendix A. Supplementary material

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.numecd.2015.11.003.

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