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Repeatability and validity regarding food groups, energy, and macro-nutrients intake of a semi-quantitative Food Frequency Questionnaire for children: the Stance4Health-FFQ

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Abstract

Background and objective: The aim of this work was to evaluate the repeatability and the validity of a food frequency questionnaire (FFQ).

Methods: The semi-quantitative FFQ included 200 questions regarding the frequency of consumption of all main food groups and beverages usually consumed among children. Ninety-one individuals (8±2.5 yrs., 38.5% males) were recruited for the repeatability process, and also completed 3-Day Diaries (3DD) for the validation process.

Results: The repeatability of the FFQ was very good for all food items tested (all p-values >0.05 for Wilcoxon signed rank test). Moderate validity of the FFQ, as compared to 3DD was observed for "starchy products", "sweets" and "fats and oils" (all Wilcoxon signed rank test p values <0.05), whereas very good validity was observed for the rest food groups (all p values >0.05). The FFQ was also valid regarding protein and fat intake, while for energy and carbohydrates showed good but lower validity. Sensitivity analyses by sex and body weight category confirmed the good validity of the FFQ for all food groups, as well as for energy and nutrient intake.

Conclusions: The proposed FFQ was found repeatable and valid for foods' intake, and therefore could be used for nutritional assessment purposes in children.

Introduction

In biomedical research the need for using reliable tools in order to accurately measure and evaluate health related associations is dominant.1 Although current recommendations suggest the combined use of repeated 24-h recall diaries, i.e., 3-day diaries and food frequency questionnaire (FFQ) to assess individuals' dietary habits, in the majority of studies the FFQ is the only tool that has been used, as it is convenient, cost effective and gives information on long-term intake.2-4 However, for a FFQ to be used in practice, its repeatability and validity should be first proven. In brief, repeatability refers to the consistency of measurements on more than one administration (agreement) to the same individuals at different time points. Validity of an FFQ refers to the degree at which the questionnaire measures the parameters which the tool was designed to measure (e.g., energy or nutrients intake), and it is usually tested versus a "referent" or "gold-standard" method (i.e., 24-hour recall, dietary diaries, or food weighted records).1,5 The length of the FFQ is also one of the parameters that may affect its reliability, since moderate scaled FFQs (i.e., up to 50 questions), may suffer from incomplete listing of foods that are essential to evaluate diet-disease associations, from errors in frequency estimation or in estimation of usual portion size. Cade et al., reported that questions included in various FFQs used up today ranged from 5 to 350, with a median number of 79.6 However, researchers have not concluded yet the optimal number of food items should be listed in a FFQ. In addition, inaccuracies in measuring true intake may also occur due to seasonal effect and other personal characteristics (i.e., body weight, education level, etc.). Furthermore, the FFQs should be able to apply to a wide range of the world population in order the collected diet information to be comparable across countries, cultures, and regions.

Although there are several published FFQs, very few are focused on pediatric populations, and even less are focused on gut microbiota.7 In order to study the effect of diet in gut microbiota, selecting the appropriate dietary assessment tool is majorly important. The assessment of dietary patterns and behaviors, as well as nutrient intake in epidemiologic studies is challenging, considering that record and perception of food consumption can be subjective and therefore can vary among individuals. Thus, the aim of this work was to adapt and test the repeatability as well as the validity, in terms of food groups, energy and macronutrient intake, of a semi-quantitative, 200-item FFQ (the Stance4health-FFQ) applied to children for the study of gut microbiota.

Materials and Methods

Adaptation of the Stance4Health Food Frequency Questionnaire (FFQ)

As part of the European Stance4Health project, a proprietary food frequency questionnaire (FFQ) has been developed and will be available in four languages: Spanish, German, Greek, and English. Two FFQs were used as starting points: the FFQ used by the European Prospective Investigation into Nutrition and Cancer (EPIC), which is widely used, adapted and validated,8-12 and the FFQ developed by Martin-Moreno et al., which has been adapted and validated for various populations and projects,13 including the PREDIMED study.14 The aim was to include more foods that are currently being consumed or are traditionally consumed in the study countries, such as algae, insects, and fermented vegetables, as well as food groups such as spices that are not often included in FFQs. Overall, the S4H FFQ was obtained with a total of 200 items divided into 14 food groups, creating a representative FFQ at the European level.

Portion sizes were validated in a previous study, in which a proposed portion size was given and different dietitian-nutritionists were asked to report whether their consumption was equal to, above, or below the proposed portion size. This FFQ has been adapted into a variant for the pediatric population, which excludes food groups that should not be consumed, such as alcoholic beverages, and takes into account specific portion sizes for this population.15

Participants and administration of the nutrition assessment tools

A sample of 91 children out of 115 original asked (mean age: 8 years; minimum age of 4.5 years; maximum age of 15 years; 38.5% males) was used for the repeatability and validity process of the FFQ (participation rate 85%). The recruitment of the children was based on a convenient sampling basis during the year 2022. Children aged 10 years and more or their parents/guardians if they were younger than 10 years, were requested to recall how often they -or their children- consumed the predefined food quantity twice over a 15-days interval. None of the children or parent/guardian reported a change in dietary habits during these days. In addition, these children if they were older than 10 years or their parents/guardians if their children were younger than 10 years, completed both the FFQ (first, as the test instrument) and then a 3-Day Diary (3DD) as the referent tool. The FFQ administered in the present study, consisted of foods, which were distinguished into the following 9 food groups: (1) Meat, (2) Fish, (3) Dairy products, (4) Legumes, (5) Starchy products, (6) Vegetables, (7) Fruits, (8) Fats & Oils, (9) Sweets, depending on their macronutrient content. More specifically, the first 3 groups include various types of meat-cured meat products (Meat), fish-seafood (Fish) as well as dairy products (Dairy products). Intermediate groups 4-7 encompass legumes (Legumes), basic starchy foods

(Starches) like bread, pasta, rice, vegetables (Vegetables), fruits and juices (Fruits). Last 2 groups involve fats-oils (Fats & Oils), bakery products-sweets-sugary drinks (Sweets). The portion size for each food was adjusted either using standard local household units i.e. plate, bowl, spoons of different size (tablespoon, teaspoon), cups, or using standard food portion sizes and these were converted into grams per day. The recording period of the 3DD included two weekdays and one weekend day, during the period that the FFQ has been disseminated (i.e., last month). Detailed guidelines were given to the parents/guardians of the children in order to complete the 3DD, using standard household measures (i.e., cups, teaspoons, tablespoons) to describe food quantity, and were trained to record each food item or beverage consumption, at real time (i.e., meal-by-meal), while emphasis was given to record food items consumed between main meals (i.e., snacks). Starting days for data collection were allocated in such way to cover all days within a week in the overall sample, to ensure the representativeness of all weekdays. To account for seasonal variation in consumption both FFQ and 3DD were administrated the same period of the year. Thus, particular foods usually consumed during summertime (i.e., some fruits, ice cream, etc.) or during winter (i.e., soups) had almost equal probabilities to be reported.

All the required information was collected through a computer-based administration of the FFQ with detailed instructions with respect to the validation process and the repeatability study, while the 3DD was provided by experienced in the field researchers in the participated children and their families. The retrieved data were confidential and the study followed the ethical considerations provided by the World Medical Association (52nd WMA General Assembly, Edinburgh, Scotland, October 2000).

Food and nutrient intake calculations

Weekly consumption in portions was calculated from the FFQ by calculating the frequency of consumption of the standard serving size of each one defined food item in the questionnaire as follows never-almost never=0; 1-3 times/month=0.5; 1 time/week=1; 2-4 times/week=3; 5-6 times/week=5.5; 1 times/day=7; 2-3 times/day=17.5; 4-6 times/day=35; >6 times/day=49. Nine main food groups (i.e., dairy products, starchy products, meat, fish, legumes, vegetables, fruits, sweets, fats and oils,) were then created. Data from 3DD were categorized in the same food groups as in the FFQ and a weekly portion consumption was calculated for each participant in order to perform the statistical analysis and compare the two methods. Estimation of energy and macro-nutrient intake was made for both the FFQ and the 3DD, using the United States Department of Agriculture Food Composition Tables16 and local Food Composition Tables.17

Other participants' characteristics

Beyond the aforementioned characteristics, children's body height and weight were measured using standard protocols. Specifically, height (without wearing shoes) was measured to the nearest 0.5 cm, and weight was measured with a lever balance, to the nearest 100 g, without shoes, in light undergarments. Body mass index (BMI) was then calculated according to the formula: weight (kg)/height2 (m2). Afterwards, participants were classified to those with normal values of BMI and overweight/ obese according to the age- and sex- specific cutoff values proposed for pediatric populations as proposed by the International Obesity Task Force.18 This information was collected in order to be used in sensitivity analyses of the validation and repeatability process of the FFQ.

Statistical methods

Descriptive statistics are presented as mean and standard deviations (SD). To evaluate the results for the agreement between the two administrations of the FFQ (repeatability), as well as with the 3DD (validity), the Wilcoxon signed-rank test for the difference (i.e., Δ(FFQ-FFQ' or 3DD)) in intake (bias), as well as the Bland & Altman method of agreement,19 were also applied. With respect to the Bland & Altman method the limits of agreement were calculated as mean(difference) ± 1.96*standard deviation(difference), assuming normal distribution of the differences. Normality was tested using Q-Q plots. Moreover, the percent of differences within the limits of agreement were calculated as an indicator of the distributions' compliance to the theoretical distribution (i.e., values close or greater than 95% suggest very good compliance). In addition, Spearman's rho coefficient between the difference and the average (i.e., (FFQ+3DD)/2) in consumption was calculated to assess potential bias towards the low or high intakes. Sub-group (sensitivity) analysis to further evaluate the validity of the FFQ was performed for both genders and for participants according to their obesity status. The significance level for all two-sided hypotheses tested was considered at 0.05. All statistical analyses were performed using the Stata version 16 (StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC.).

Results

Regarding participants' characteristics, mean BMI was 18.1 (3.5) kg/m2, while 28.6% children were classified as overweight or obese.

Repeatability of the FFQ

Food groups' comparisons suggested that the FFQ was repeatable for 9 out of 9 groups studied (Table 1). All

Table 1: *Results regarding the repeatability of the FFQ in terms of food groups intake. Two administrations, within 15-days interval.*

	1st administration	2nd administration			Bland & Altman method		
Food Group	Median (P25-P75)	Median (P25-P75)	*p*†	Mean difference	Limits of agreement	% of agreement	Spearman's rho
Dairy products, (g/day)	8.5 (6.5-11.7)	8.0 (5.5-12.0)	0.17	0.3	(-6.75,9.35)	97	-0.07
Starchy products (cereals, pasta, potato), (g/day)	16.0 (12.5-20.2)	14.3 (10.0-19.6)	0.56	0.31	(-12.8, 13.4)	98	-0.34*
Meat (red, poultry, products), (g/day)	7.0 (5.0-9.0)	7.0 (5.0-10.5)	0.17	1.2	(-8.3, 10.6)	99	-0.39*
Fish, (g/day)	1.5 (1.0-2.5)	1.5 (1.0-3.0)	0.22	0.09	(-1.5,1.6)	97	-0.19
Legumes, (g/day)	2 (1.3-2.5)	1.5 (1.2-2.5)	0.19	0.11	(-1.1,1.2)	97	-0.09
Vegetables, (g/day)	7.5 (2.0-9.1)	7.5 (4.0-12.0)-	0.40	0.49	(-5.8,6.8)	99	-0.02
Fruit, (g/day)	10.5 (7.1-15.9)	12.0 (8.5-16.0)	0.36	3.1	(-12.7,18.8)	99	-0.16
Sweets, (g/day)	9.5 (6.4-13)	10.3 (7.0-14.9)	0.86	-0.18	(-7.8,7.4)	97	-0.27*
Fats and oils, (mL/day)	11.5 (8.5-15.9)	12.0 (7.5-15.0)	0.83	0.1	(-10.5,10.6)	98	-0.04

*† P-values derived from the Wilcoxon signed-rank test for the difference between paired observations. Spearman's rho was calculated between the difference and the average values of the two administrations. * P<0.05.*

Table 2: *Results regarding the validity of the FFQ as compared with a 3DD in terms of food groups.*

Food Group	FFQ	3DD	*p*†	Bland & Altman method			
	Median (P25-P75)	Median (P25-P75)		Mean difference	Limits of agreement	% of agreement	Spearman's rho
Dairy products, (portion/week)	8.5 (6.5-11.7)	8.4 (6.5-12.4)	0.10	1.2	(-8.9,11.4)	98	0.6
Starchy products (cereals, pasta, potato), (portion/week)	16.0 (12.5-20.2)	17.9 (11.2-22.2)	0.15	-0.9	(-17.5,15.7)	99	0.34*
Meat (red, poultry, products), (portion/week)	7.0 (5.0-9.0)	5.4 (3.5-9.3)	0.12	-1.2	(-10.6, 8.3)	98	0.18
Fish, (portion/week))	1.5 (1.0-2.5)	0.0 (0.0-2.3)	<0.001	0.6	(-3.5,4.7)	97	-0.19
Legumes, (portion/week)	2 (1.3-2.5)	2.3 (0.0-3)	0.06	0.4	(-3.3,4.1)	99	-0.77*
Vegetables, (portion/week))	7.5 (2.0-9.1)	5.8 (4.6-7.9)	0.11	1.3	(-6.6, 9.1)	97	0.28*
Fruit, (portion/week))	10.5 (7.1-15.9)	9.3 (5.1-14.0)	0.65	0.5	(-14.8,15.8)	99	0.09
Sweets, (portion/week))	9.5 (6.4-13)	7 (3.7-12.8)	<0.001	3.4	(-10.54,14.9)	94	-0.14
Fats and oils, (portion/week))	11.5 (8.5-15.9)	7 (4.7-10.5)	<0.001	1.8	(-12.3,33.9)	97	0.34

*† P-values derived from the Wilcoxon signed-rank test for the difference between paired observations. Kendall's tau-b was calculated between the FFQ and the 3DD. Spearman's rho was calculated between the difference and the average values of the two tools. *P<0.05.*

Table 3: *Results regarding the validity of the FFQ as compared with a 3DD in terms of nutrients intake, in 91 participants of the study*

	FFQ	3DD		Bland & Altman method			
Nutrients	Median (P25-P75)	Median (P25-P75)	*p*†	Mean difference	Limits of agreement	% of agreement	Spearman's rho†
Energy, (kcal/day)	1907 (1601-2071)	1734 (1488-1938)	0.012	191.8	(-354.1,936.7))	97	0.19
Carbohydrates, (g/day)	212 (180-234)	189 (163-220)	0.01	27.1	(-74.0,128.2)	95	-0.34
Protein, (g/day)	77.2 (67.4-86.4)	72.1 (59,4-84.9)	0.63	1.6	(-46.6,49.8)	97	0.41*
Fat, (g/day)	75.2 (56.3-84.0)	73.2 (56.1-84.5)	0.62	7.5	(-31.5,46.5)	96	0.27*

*† P-values derived from the Wilcoxon signed-rank test for the difference between paired observations. Kendall's tau-b was calculated between the FFQ and 3DD. Spearman's rho was calculated between the difference and the average values of the two tools. Energy and macro-nutrients were log-transformed for the calculation of Spearman's rho. *P<0.05*

p-values derived from Wilcoxon's signed ranked test were non-significant, suggesting excellent agreement between the two different administrations of FFQ The Bland & Altman method revealed acceptable mean differences and limits of agreement, while bias between the two recordings was evident for starchy products, meat and sweets (all Spearman's rho coefficients statistical significant and negative, suggesting underreporting between the first and the second administration of the FFQ for these food groups). Sensitivity analysis according to sex and obesity status category (normal vs. overweight/obese) confirmed the aforementioned results.

Validity of the FFQ

As regards validity, the majority of the differences tested were not statistically significant except from fish, sweets and fats and oils food groups (all $p<0.05$) (Table 2). Moreover, according to the Bland & Altman method the mean differences and the limits of agreement were nutritionally acceptable. Finally, it was observed that as the average intake increases the FFQ tends to underestimate the consumption of "legumes" as compared with the 3DD (i.e., significant negative values of rho), while it tends to overestimate the intake of "legumes" and "starchy products", (significant positive values of rho) (Table2).

Furthermore, the FFQ was found valid regarding energy and nutrients intake, based on Bland & Altman method for the mean differences and the limits of agreement, but significant differences were observed, specifically for energy and carbohydrates (Table 3). Moreover, Spearman rho coefficient was found significant positive for proteins and fats, suggesting an overestimation for protein and fat intake between FFQ and 3DD. Similar results were found when the analyses were adjusted for the effect of sex and the obesity status.

Discussion

In the present work the repeatability and validity of a semi-quantitative FFQ (i.e., the Stance4Health-FFQ) designed for children aged 5-15 years was evaluated. Data analysis revealed the validity of the questionnaire regarding food groups consumed and was confirmed irrespective of the gender and the obesity status of the participants.

Several validation studies of FFQs have demonstrated a satisfactory correlation between FFQ results and gold standard methods in both adults20-22 and children for different age periods.23-25 Furthermore, our FFQ has been designed to assess daily dietary intake in a healthy children population and the validation results are in coherence also with relevant studies. Ambrosini et al., evaluated an FFQ in comparison with a 3-day food record, in 785 14-years-old adolescents in the context of a population-based cohort study in Western Australia.23 They reported Bland & Altman limits of mean agreement (LOA) ranging from 73% for starchy products to 161% for vitamin C, with most of the nutrient being overestimated by the FFQ. Bertoli et al., in their study of the validation of a 136-itemed FFQ comparing with a 7-day weighed record method in 18 children 6-10 years also reported overestimation of the nutrient intake but high correlation for all the nutrients considered.26 Moreover, Khole et al., evaluated a 191 food-items FFQ in 57 children aged 1 to 3 years coming from low-income mothers, reported an average validity correlation of 0.41 and concluded an acceptable validity for their questionnaire.27 However, there are reports regarding the use of an FFQ for dietary assessment that argue against its validity for nutrient intake estimation, especially in specific populations. Di Noia et al., examined the validity of a 5-day FFQ in a sample of 156 African-American adolescents for juice, fruit, and vegetable intake in comparison with direct observation and concluded that youth had difficulties in reporting their monthly and daily food intake, thus producing overestimations, especially in vegetables, more than fruits and juices.28 This study expands previous finding that supports the overestimation not only in the three food groups, but in all of them.29

Moreover, differences on median intake of various food groups although were evident in some food groups according to the Wilcoxon signed-rank test, were not meaningful in terms of nutritional information. The Wilcoxon signed-rank test has been used in some validation studies6; however, by the nature of this test it could be suggested that the rejection of the null hypothesis (i.e., agreement or validity in this case) could be more frequent as compared to other statistics (e.g., Kendall's tau). Therefore, the Bland & Altman comparison method seems to be preferred in many studies.19 Results according to this method showed acceptable mean differences in intake and limits of agreement in test-retest administration of the FFQ and as compared with the 3DD. Besides, the presence of a linear correlation between the two methods (i.e., FFQ vs. 3DD) reveals the existence of bias (i.e., over- or under estimation of true intake as consumption increases). It is known that dietary interpretation is often prone to over- or under-reporting energy intake, due to various physiological, socio-demographic, psychological or lifestyle characteristics.30-32

The overestimation observed in several food groups in our study is in consistence with the literature on dietary assessments in children and it is acceptable for the use of our FFQ in dietary assessment. The absence of consensus among the two evaluation techniques (FFQ and 3-day-recalls) found in children's studies has been assigned to various factors. One of these is that parents can provide trustworthy information regarding their children's food consumption in the home setting, but not regarding the

out-of-home food intake.33 In addition, the overestimation of energy intake in the FFQ can probably be attributed to the use of adult serving sizes in each food item serving.34 Domel et al. observed over reporting of fruits and vegetables among a sample of fourth and fifth grade lower-middle socioeconomic students.35 Same results are reported also by Cullen et al. for the validation of a FFQ in 40 inner city African American boys.36 This could be attribute to that children may ate commonly consumed foods more often that they thought of or that they tend to report a more standard number of servings rather than the actual number of servings consumed.37 Another possible explanation about the difficulty that younger children had in reporting their intake is that they had not progressed to the developmental stage characterized by the ability to think abstractly and were not familiar with the concept of averaging or reporting 'usual' patterns.38 Moreover, day-to-day variability and within-person variability might be responsible for the large differences observed between the FFQ and 3-day dietary diary results. This discrepancy between food groups servings among the two assessment methods has been also found in other studies.39,40

Several studies have indicated the existence of a satisfactory correlation, between reference methods and nutritional assessment results in children and adults; however, there is scarce evidence on whether this particular correlation is applicable to cases involving gut microbiome. In their study Leong et al., after collecting food frequency questionnaires adapted to assess the intake of nutrients and food groups related to the intestinal microbiota, as well as, 3-day weighted diet records from a sample of 100 children, with an average age of 5.5 years and an average BMI of 16.0 kg/m2 concluded to the following: (a)'Acceptable' mean correlation between the food frequency questionnaires and the diet records both for nutrients (0.34) and food groups (0.41). (b)'Very good' correlation, used to assess reproducibility, between the food frequency questionnaires which were completed with a one-month gap, for nutrients (0.83) and for food groups (0.80).41 Similar FFQ validation was conducted by Yáñez et al. in a healthy adult population and the correlation for nutrients and food groups reached 0.46.42 Despite the data paucity it finally appears that common nutritional assessment tools, for example FFQs and 24h recalls can also be used to correlate dietary information in gut microbe related studies.

Despite the limitations regarding the overestimation of food intake and the generalisability of the results, the good level of agreement between the dietary tools evaluated in this project suggest that the Stance4Health FFQ is valid and can provide an acceptable assessment of dietary intakes in children living in urban areas in Greece.

Acknowledgements: This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the School of Health Sciences Ethics Committee. Written informed consent was obtained from all subjects/patients participating in the study. The project was approved by the Bioethical Committee of "Attikon" University Hospital of Athens with reference number 159/3-4-2020.

Authors' contribution: Study conception and design (GA, KD); data collection (GA, AK, TB, SZ, DM, OS, DC, JRH, DHN, FL); analysis and interpretation of results (GA, CK, SZ, DM, OS, DC); draft manuscript preparation (GA, CK, SZ, DM, OS); critical revision of the manuscript for important intellectual content (GA, CK, KD); study supervision (GA, KD); all authors have made a significant contribution to this study and have approved the final manuscript.

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