UNIVERSIDAD DE COSTA RICA | CCP Centro Centroamericano de Población | Doi: https://doi.org/10.15517/psm.v21i2.55311
Volume 21, issue 2, Sci art. january-june 2024

Población y Salud en Mesoamérica

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Cómo citar este artículo:

Monge-Rojas, R., Alvarado-Barrantes, R., Vargas-Quesada, R., & Chinnock, A. (2024). Validity and reliability of a Food Frequency Questionnaire (FFQ) assessing food groups consumption and nutrients intake in Costa Rican adolescents. *Población y Salud en Mesoamérica, 21*(2). https://doi.org/10.15517/psm.v21i2.55311

ISSN-1659-0201 http://ccp.ucr.ac.cr/revista/

Revista electrónica semestral
Centro Centroamericano de Población
Universidad de Costa Rica

https://doi.org/10.15517/psm.v21i2.55311
Volume 21, issue 2, Sci art. january-june 2024

Validity and reliability of a Food Frequency Questionnaire (FFQ) assessing food groups consumption and nutrients intake in Costa Rican adolescentes

adaptação dos profissionais ao home working e seus efeitos

Validez y fiabilidad de un Cuestionario de Frecuencia Alimentaria (FFQ) que evalúa el consumo de grupos de alimentos y la ingesta de nutrientes en adolescentes costarricenses

Rafael Monge-Rojas[1], Ricardo Alvarado-Barrantes[2], Rulamán Vargas-Quesada[3] and Anne Chinnock[4]

Abstract: Introduction: Food Frequency Questionnaires (FFQ) have been widely used in several age groups, including adolescents, due to their greater advantages over other dietary measurement methods. Therefore, this study was designed to assess the validity and reliability of a FFQ designed for use on Costa Rican adolescents. **Methodology:** The validation and reproducibility studies were carried out in a sample of 107 adolescents of San José province selected through convenience sampling. For validation, a comparison of the nutrient intake and food consumption data obtained with the FFQ was made with those derived from the 3-day food record (3FR). Reliability was assessed by comparing nutrient intake and food consumption derived from the first FFQ with another FFQ performed four weeks after the first. **Results:** FFQ overestimates 3FR, with an average overestimation of 40.2% for foods and 38.8% for nutrients. The cross-classification was good for 24 of 26 nutrients and for 12 of the 21 food groups, and the weighted kappa showed an acceptable discriminant ability of the FFQ to categorize individuals into broad nutrient intake (except for protein and cholesterol) and food groups categories (dairy products, white rice, beans, vegetables, fruits and fruit juice, sugary drinks, breakfast cereal, candies and sweets, snacks, fast foods, fat, and ice cream). **Conclusions:** The FFQ designed for Costa Rican adolescents was unable to assess absolute dietary intakes; however, it is a reasonable tool to categorize adolescents into broad ranges of dietary intakes and could be used to evaluate dietary patterns in epidemiological studies of diet-disease associations.

Keywords: Validity, reliability, food frequency questionnaire, adolescents, Costa Rica.

Resumen: Introducción: Debido a sus mayores ventajas sobre otros métodos de medición dietética, el Cuestionario de Frecuencia de Consumo de Alimentos (CFCA) ha sido ampliamente utilizado en varios grupos de edad, incluyendo los adolescentes. Por lo tanto, este estudio fue diseñado para evaluar la validez y confiabilidad de un CFCA diseñado para ser utilizado en adolescentes costarricenses. **Metodología:** El estudio de validación y confiabilidad se realizó en una muestra de 107 adolescentes de la provincia de San José seleccionados mediante un muestreo por conveniencia. Para la validación, se realizó una comparación de los datos de ingesta de nutrientes y el consumo de alimentos obtenidos con el CFCA con aquellos derivados del registro de alimentos de 3 días (RA3d). La confiabilidad se evaluó comparando la ingesta de nutrientes y el consumo de alimentos derivados del primer CFCA con otro CFCA realizado cuatro semanas después del primero. **Resultados:** El CFCA sobreestima al RA3d, con una sobreestimación promedio de 40.2% para alimentos y 38.8% para nutrientes. La clasificación cruzada fue buena para 24 de los 26 nutrientes y para 12 de los 21 grupos de alimentos, además el kappa ponderado mostró una capacidad discriminante aceptable del FFQ para categorizar a las personas en una amplia ingesta de nutrientes (excepto proteínas y colesterol)

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https://doi.org/10.15517/psm.v21i2.55311
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y categorías de grupos de alimentos. (productos lácteos, arroz blanco, frijoles, vegetales, frutas y jugos de frutas, bebidas azucaradas, cereales para el desayuno, dulces y golosinas, bocadillos, comidas rápidas, grasas y helados). **Conclusiones:** El CFCA diseñado para adolescentes costarricenses no es adecuado para evaluar las ingestas dietéticas absolutas; sin embargo, es una herramienta razonable para categorizar a los adolescentes en amplios rangos de ingestas dietéticas y podría usarse para evaluar patrones dietéticos en estudios epidemiológicos que buscan asociaciones entre dieta y enfermedad.

Palabras clave: Validez, confiabilidad, cuestionario de frecuencia de consumo de alimentos, adolescentes, Costa Rica.

Received: 02 jun, 2023 | **corrected:** 15 nov, 2023 | **accepted:** 30 nov, 2023

1. Introduction

Evidence suggests that adolescent eating habits are associated with diet-related chronic diseases in adulthood (Craigie et al., 2011; Cruz et al., 2018; Fardet & Boirie, 2014; Mikkilä et al., 2005; Movassagh et al., 2017); thus adolescents' diet assessment is a matter of public health interest. However, challenges remain in identifying the best dietary assessment tool for this age group (Ochola & Masibo, 2014; Sherwood, 2009). Dietary intake is difficult to measure because any diet assessment method is subject to error (Shim et al., 2014). Various methods have been developed, ranging from relatively simple diet assessments, such as 24-hour recalls, to more complex approaches, measuring biomarkers of dietary intake in diverse biological samples (Shim et al., 2014).

Food Frequency Questionnaires (FFQ) have been widely used in several age groups, including adolescents, due to their advantages over other dietary measurement methods. In general, the FFQ assesses usual dietary intakes, it is cost-effective and time-saving, practical and economical for the collecting of dietary data, and is a modest burden on both interviewers and participants when compared to diet records (Shim et al., 2014).

When designing an FFQ for use among adolescents, there are several specific aspects of their cognitive development that should be considered, in addition to the recommended methodological aspects (Tabacchi et al., 2014). Several literature has shown that a shorter recall period, particularly when asking participants about their routines or certain frequent events, is preferable over a longer one (Althubaiti, 2016). Adolescents especially, have problems remembering their diet over a long period of time. Some reasons for this include unstructured eating patterns, snacking, meal skipping, and eating more frequent meals outside their homes (Livingstone et al., 2004; Truthmann et al.,

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

https://doi.org/10.15517/psm.v21i2.55311
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2011). In addition, dietary assessment methods based on recall have a memory bias which increase as a function of time, because up to 30% memory on food consumption may be lost from previous day (Tabacchi et al., 2014). Previous studies report that foods consumed on a regular basis and main courses are more accurately reported than foods that are less often eaten (Speck et al., 2001; S. S. Wong et al., 2008). A systematic review of child/adolescent FFQ studies performed in several countries showed that the highest average variability correlation was obtained when the questionnaire measured a shorter time span (i.e. the previous week (Kolodziejczyk et al., 2012). On the other hand, it has been suggested that the recall period for previous months or years is strongly related to reporting current dietary intake (Cade et al., 2004).

Estimating the amount of food consumed is a complex cognitive task. It requires one to think abstractly about food while viewing generic food models of different volumes and dimensions or other tools, such as photographs of food. As a result, it is highly likely that the estimation of portion size is compatible with the perceptual and conceptual capacities of adolescents who have reached the stage of abstract reasoning, typically around 10 – 11 years of age (Dumontheil, 2014; Livingstone et al., 2004).

In spite of the potential pitfalls mentioned, different studies developed worldwide confirm that FFQ is a robust instrument for ranking adolescents according to energy and nutrient intake levels, regardless of the lack of demonstrated validity (Tabacchi et al., 2016). Most FFQs have been designed and widely used on adolescents in developed countries, but very little in Latin American countries (Brazil, Peru y Mexico) (Denova-Gutiérrez et al., 2016; Rodriguez et al., 2017; S. M. A. Matos, 2012). Recently, a semiquantitative FFQ was developed to use in a South American Youth/Child Cardiovascular and Environmental (SAYCARE) observational, multicenter, feasibility study, to assess dietary intake among children and adolescents aged 3 to 17 years from seven cities (Buenos Aires, Lima, Medellin, Montevideo, Santiago, Sao Paulo, and Teresina) in six South American countries (Saravia et al., 2018). To date, however, there are no other FFQs that target adolescents in other Latin American countries.

Unlike other dietary intake assessment methods, FFQs are dependent on each population group's diet which is shaped by the dynamic interaction between individuals and their sociocultural environment over time (Sobal & Bisogni, 2009). This requires them to be specifically developed for each study group (Shim et al., 2014). Therefore, one cannot adapt an FFQ to be used in another context; although, it can be similar to the one originally created. The purpose of this study was to assess the validity and reliability of a FFQ designed for use with Costa Rican adolescents using 3-day food records as the reference method.

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

https://doi.org/10.15517/psm.v21i2.55311
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2. Methods

2.1 Design and development of the FFQ

Information on food consumption was collected using 3-day food records (3FR) from 133 adolescents (aged 13 to 18 years) who attended schools in urban and rural areas of the San José province (Fiatt & Romero, 2011). Nine high schools (6 urban and 3 rural) were selected using a proportional-size probability method (Alam, 2015) and participants from each school were selected through convenience sampling (Lohr, 2010).

Data from the 3FR collected on 2015 from 133 adolescents were analyzed to determine the average daily intake of energy and nutrients of each adolescent, using a program developed in Epi Info, version 7.0 (Centers for Disease Control and Prevention - CDC, 2009) and a food composition table developed in the School of Nutrition, University of Costa Rica, based mainly on information from the USA food composition database (United States Department of Agriculture - USDA, 2018). Then the following analysis was performed: a) frequency of consumption of 19 different food groups b) degree of association between consumption of each food group and average daily intake of energy and nutrients and c) percent contribution of each food group to average daily intake of energy and nutrients.

This analysis showed that 11 of the 19 food groups had a higher frequency of consumption, a higher degree of correlation with, and contributed by a larger percentage, to energy and nutrient intake. These 11 food groups contributed 78% of the average daily energy intake of the group of adolescents. Due to this finding, it was decided to include in the list of foods for the FFQ, all commonly consumed individual foods belonging to these 11 groups and in the case of the remaining 8 groups, more general items were included in the list (Supplementary materials: Food Frequency Questionnaire applied to Costa Rican adolescents).

In total, the FFQ included 183 foods and preparations and the following methods were used to estimate the portion size consumed: number of units, household measures, photos and for some foods, an average portion size was used. The questionnaire was designed to be administered in a face-to-face 30-minutes interview. The literature indicates higher correlation coefficients between the FFQ and reference method when the questionnaire is applied by interview than when it is self-administered (Cade et al., 2004). The reference period for reporting usual food intake was the week preceding the interview.

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

https://doi.org/10.15517/psm.v21i2.55311
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For this study, food consumption data from the FFQ was classified into 21 groups: dairy products, meats and eggs, processed meat, fish and seafood, legumes, non-starchy vegetables, starchy vegetables, fruits, breakfast cereals, pasta, rice, bread, tortillas, cookies, pastries and desserts, gelatin and ice cream, beverages with added sugars, pastries, soups, fast foods, and snacks. Consumption of alcoholic drinks, whole grains, and nuts were excluded because consumption among Costa Rican adolescents was negligible (5.98 g/d, 2.78 g/d, and 0.72 g/d, respectively).

2.2. Validation and reproducibility

2.2.1 Sample

On 2017, we recruited a convenience sample of 107 participants who consented to participate in a transversal study aimed to identify dietary intake and food sources of added sugars, which has been described previously (Monge-Rojas et al., 2022). The Bioethics Committee of the Costa Rican Institute for Research and Education on Nutrition and Health (INCIENSA) approved the study, and all guidelines for human subject research were strictly followed.

2.2.2 Dietary assessment

During a face-to-face interview, a previously trained nutritionist applied the FFQ to the adolescent and asked him/her if he/she had consumed each of the foods listed in the FFQ during the week prior to the interview. If the adolescent answered affirmatively, he/she was then asked how often it was eaten daily or weekly. It was an open-ended question because the frequency of consumption was not previously categorized. This allowed for declarative memory stimulation and would not influence the response. Allowing memory usage was proposed as one of the strategies to reduce recall bias that often occurs in retrospective study designs (Althubaiti, 2016). The adolescent might have also felt overwhelmed if he/she was subjected to multiple answer options simultaneously (Crone, 2017), potentially increasing the response bias.

To facilitate the adolescent with estimating the portion size consumed during the FFQ interview, he/she was presented with various alternatives: household measurements (e.g. cup, teaspoon, cup, glass, bottle), natural units (e.g. slice of cheese), tridimensional food models, and a booklet with three to six age-appropriate portion size photos of different foods commonly eaten in Costa Rica. Studies have shown a higher correlation coefficient between the FFQ and the reference method when subjects are able to describe their own portion size as opposed to not having a specified portion size listed on the questionnaire (would use average portion weights) (Cade et al., 2004; Kolodziejczyk et al., 2012). The 3FR was used as the reference method because it is considered a gold standard of

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http://ccp.ucr.ac.cr/revista/

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accuracy among quantitative accounts of diet during a specific period, usually more than a 24 hour dietary recall (Rockett et al., 2003).

After concluding the FFQ interviews for all of the adolescents in one school, they gathered in a classroom and two nutritionists explained how to record their food consumption. 3FRs were completed on 2 weekdays (either Monday, Tuesday, Thursday, or Friday) and 1 weekend day (either Saturday or Sunday). Half of the participants from each high school were randomly asked to record the foods and drinks consumed on Thursday, Friday, and Saturday. The rest of the participants were asked to record their foods on Sunday, Monday, and Tuesday. This ensured that the data captured any variability in food consumption from weekday to weekend, and weighted food intake to represent weekly intake. Participants were asked to record detailed descriptions of all the foods and drinks consumed during the entire day and they also learned how to estimate portion sizes using the aforementioned booklet (that contains commonly consumed foods and preparations in Costa Rica), as well as kitchen measurement tools or volume and mass units. The students were asked to submit their 3FRs immediately after completion. On submission day, the nutritionists conducted a thorough review of the records with each participant during school hours. The nutritionists prompted the participants to provide information on commonly missed items or ingredients, inquired about missing details for the types of food or drinks consumed, and clarified any illegible items. Four weeks after the first FFQ interview (FFQ1), the adolescents were called again for another interview that followed the same methodology described (FFQ2). This four-week interval was chosen to minimize the variation in food intake response due to true changes over time.

The data from the FFQ and the 3FR were then gathered and entered into the software to assess the dietary composition of various foodstuffs. The software uses a food composition table developed in the School of Nutrition, University of Costa Rica, based mainly on information from the USA food composition database (United States Department of Agriculture - USDA, 2018). The software uses information about commonly consumed foods available in the food composition tables of the Institute of Nutrition for Central America and Panama and the USDA. It also includes updated information regarding the nutritional value of commonly consumed dishes and local fruits and vegetables. Nutritional information of new foods available in the domestic market, food reformulations introduced by the local food industry, and new dishes is also included. Therefore, an updated food composition database was used to reflect the foods and food compositions (including processed package and fortified foods) available for the year the data were collected. The coding procedure of the individual food items was carried out by qualified nutritionists who had been trained in food coding by the research team. The nutritionists followed an updated food codebook developed by the study researchers for each cohort and used it to classify and describe each food

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

https://doi.org/10.15517/psm.v21i2.55311
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item. All coding decisions and food portion size determinations were reviewed with the research team and double-checked for accuracy.

2.3 Statistical analysis

Crude data from food and nutrient intake estimated with both the FFQ1 and the 3FR were analyzed using boxplot (outliers determined ±2 SD were removed before data analysis). The validity of the FFQ was assessed by comparing the intake of each nutrient/food group estimated from the FFQ with that estimated from the average of the 3FR. Because there were high correlations between total energy intake and individual nutrient intakes estimated by the 3FR and the FFQ, variables were adjusted for total energy intake using the residual model (Kabagambe et al., 2001; Willett, 2013). Mean values ± standard deviation (SD) of daily energy, nutrients, and food intake were calculated from the FFQ1 and 3FR. Wilcoxon signed-rank test was used to compare means values obtained from the FFQ1 and 3FR, as the data were not normally distributed. Wilcoxon signed rank test results with p-values > 0.05 indicate good agreement between two measures at group level, but p-values ≤ 0.05 indicate poor agreement (Lombard et al., 2015).

The Spearman correlation coefficient was determined to measure the strength and direction of the association between the two dietary assessment methods. Random within-subject errors in estimating the intake of foods and nutrients tend to attenuate correlations toward zero (Willett, 2013). Therefore, Spearman correlation coefficient was de-attenuated by removing the within-person variability for the 3FR data (Kabagambe et al., 2001; Willett, 2013). De-attenuated energy-adjusted correlations ≥ 0.50 indicate a good relationship; those from 0.20 to 0.49 suggest an acceptable relationship, and values < 0.20 indicate a weak or no relationship (Lombard et al., 2015).

Relative agreement between the 3FR and FFQ methods was tested using cross-classification of food and nutrient intake. The proportion of participants was classified by the two methods in the same/opposite tertile of the intake of nutrients and foods. A good agreement was considered if more than 50% of subjects were correctly classified and less than 10% of subjects were grossly misclassified (Masson et al., 2003). As has been suggested by Manson et al. (2003), the Fleiss and Cohen's weighted Kappa (Kw) coefficient was used as a summary of cross-classification (Fleiss & Cohen, 1973). Values of K_W ≥ 0.61 indicate good agreement, from 0.20-0.60 acceptable agreement, and < 0.20 poor agreement (Lombard et al., 2015).

Bland-Altman method (Bland & Altman, 1999) was used to detect systematic differences between two methods. Traditional Bland-Altman plots show heteroscedasticity for most nutrient/food groups, with an increase in variability of the differences from FFQ and 3FR as the magnitude of the measurement increases. Giavarina (2015) suggests, in these cases, to express the differences of

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measurements under two methods as percentages of the values on the axis (i.e. proportionally to the magnitude of measurements) (Giavarina, 2015). Presenting the plots using the percentage of differences has the advantage that all the plots can be made with the same scale and are more comparable. The scale used in this study ranges from -200 to 200%.

For the reliability of the FFQ, Spearman's correlation was used to assess the relationship between FFQ1 and FFQ2. Differences between mean food groups consumption and energy-adjusted mean nutrients intake between the FFQ1 and FFQ2 were also compared using the Wilcoxon signed-rank-test. Likewise, the proportion of participants classified by the first and second FFQ in the same/opposite tertile of the intake of nutrients and foods, and the weighted kappa was used to assess the agreement between FFQ1 and FFQ2.

3. Results

The sample for the validation of the FFQ comprised for 107 adolescents; 52.5% from urban areas and 66.3% girls, while the sample for determining reliability consisted of 80 adolescents, 54% from urban areas and 64% girls. Mean age was 14.7±1.5-year-old.

3.1. Relative validity (FFQ1 vs 3FR)

The FFQ overestimated most nutrients and food groups intake; except for cholesterol, niacin, vitamin E, sugary drinks, snacks, meat and eggs, processed meat, fat, soup, and refined bread and cookies. Energy-adjusted de-attenuated Spearman correlation between nutrient intake assessed by the FFQ and 3FR ranged from 0.121 (zinc) to 0.634 (thiamin); and all were statistically significant, except for zinc and carbohydrates. Regarding Spearman correlations, 5 out of 27 nutrients had good correlations, 20 nutrients showed acceptable values and only 2 had weak correlations. The proportion of adolescents classified in the same tertile of nutrient intake ranged from 41.3% for protein to 77.6% for vitamin D (Table 1).

Energy-adjusted de-attenuated Spearman correlation between food groups consumption assessed by the FFQ and the reference method ranged from 0.024 (fat) to 0.839 (breakfast cereal). The correlation was not statistically significant for vegetables, starchy vegetables, fat, pasta, fish and seafood, refined bread and cookies, pastries, and ice cream. Six out of 21 food groups presented good correlations, while seven and eight food groups had acceptable and weak correlations, respectively. The proportion of adolescents classified in the same tertile of food group consumption ranged from 31.0% for pastries to 70.0% for breakfast cereal (Table 2). Analysis of Bland-Altman plots, using a range from -200 to 200%, showed that for most of the nutrients intake and food groups

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

https://doi.org/10.15517/psm.v21i2.55311
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consumption have a constant bias, except for the soups, with a higher bias for lower values (Figure 1 and Figure 2 show depicted bias between FFQ and 3FR for some examples of nutrients and food groups, according to Bland-Altman plots).

In general, FFQ overestimates 3FR, with an average overestimation of 40.2% for foods and 38.8% for nutrients (Tables 1 and 2). FFQ-derived estimates for some food groups are much higher than 3FR: processed meat (82.0%), fish (60.9%), vegetables (74.4%), fruits (87.4%), and fast foods (92.1%) (Table 2). Confidence limits for most food groups are very wide, except for sugar-sweetened beverages. An element that makes these confidence limits so wide is the fact that several individuals registered no consumption in the 3FR, while reporting a different value in the FFQ. On the other hand, three nutrients present more than 50% overestimation for the FFQ: vitamin C (73.5%), vitamin A (52.8%) and vitamin D (55.7%) (Table 1).

The cross-classification (more than 50% of subjects were correctly classified and less than 10% of subjects grossly misclassified) was good for 24 of 26 nutrients and for 12 of the 21 food groups (Tables 3 and 4). However, cross-classification of data is limited in that the percentage of the agreement includes chance agreement (Lombard et al., 2015). Nevertheless, the weighted kappa that excludes chance agreement showed an acceptable discriminant ability of the FFQ to categorize individuals into broad nutrient intake (except for protein and cholesterol) and food groups categories (dairy products, white rice, beans, vegetables, fruits and fruit juice, sugary drinks, breakfast cereal, candies and sweets, snacks, fast foods, fat, and ice cream).

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

https://doi.org/10.15517/psm.v21i2.55311
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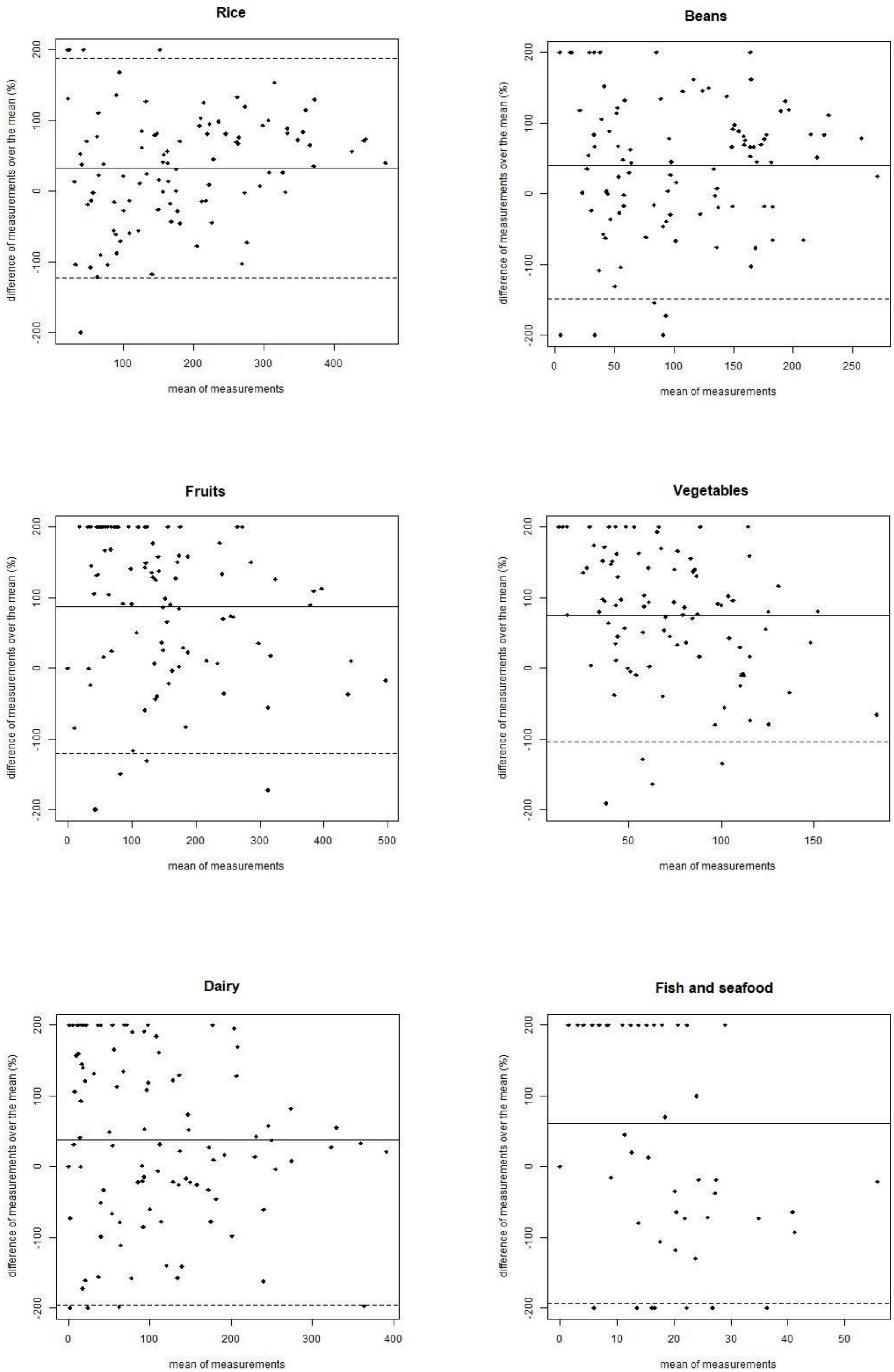
Figure 1.

Bland-Altman plots depicting bias between FFQ and 3FR for selected foods



ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

https://doi.org/10.15517/psm.v21i2.55311
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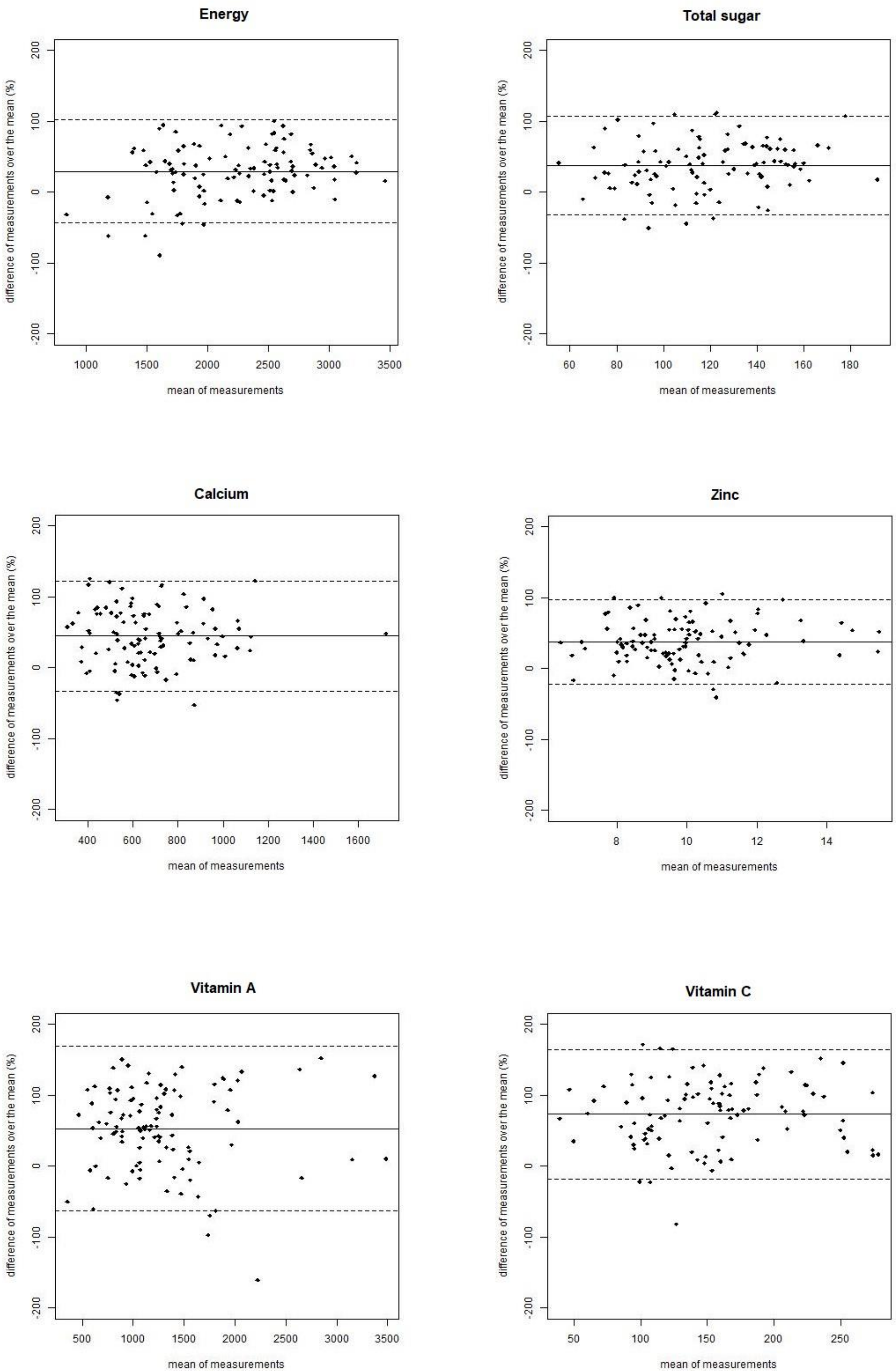
Figure 2

Bland-Altman plots depicting bias between FFQ and 3FR for selected nutrients



ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

https://doi.org/10.15517/psm.v21i2.55311
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3.2. Test-Retest reliability (FFQ1 vs. FFQ2)

Mean food consumption and mean energy and nutrients intake from FFQ1 and FFQ2 are reported in Tables 3 and 4. In general terms, both means of food consumption and nutrients intake obtained in FFQ1 were significantly higher than those obtained in FFQ2. Energy-adjusted de-attenuated Spearman correlation ranged between 0.182 for vitamin E ($p < 0.05$) to 0.570 for magnesium ($p < 0.05$), and between 0.003 for ice cream ($p > 0.05$) to 0.626 for beans ($p < 0.05$). Most of nutrients had acceptable correlations (21 out of 27), while in the rest of the nutrients the correlation was good (5 out of 27) or weak (1 out of 27). On the other hand, most food groups (12 out of 21) had good correlations and only three food groups showed weak correlations. As expected, the FFQ is unable to assess absolute dietary intakes, however, the analysis of the cross-classification and the Kw, confirm that FFQ is able to categorize and rank individuals either by their usual frequency of food consumption or nutrient.

4. Discussion

A systematic literature review on validation and reproducibility of dietary assessment methods in adolescents published in 2013, evidenced that almost all studies were considered valid and reproducible when using either Pearson's or Spearman's correlation coefficient as the only validity criterion (Tabacchi et al., 2014). Nevertheless, the use of correlation analysis in assessing the validity of a questionnaire has been questioned, because it measures the strength of association between two variables, rather than agreement (Ambrosini et al., 2009; Cade et al., 2002; Chinn, 1990; Fraser et al., 1998). In addition, Lombard et al. (2015) noted that one to three statistical tests may not be sufficient to provide a comprehensive view of the various facets of FFQ validity and that only the application and interpretation of multiple statistical tests (i.e. correlation coefficient, paired t-test/Wilcoxon signed-rank test, percent difference, cross-classification, weighted kappa coefficient, and Bland-Altman analysis) support conclusions regarding the validation for dietary intake assessment methods. Among the statistical tests proposed by Lombard et al. (2015), a p-value > 0.05 is required in the Bland-Altman analysis to obtain a good outcome in the validation phase related to the presence, direction, and extent of bias at the group level; however, the results of the Bland-Altman analysis in this study showed p-values ≤ 0.05, indicating a poor outcome.

For most nutrients, observed FFQ-derived nutrients were higher compared to those of the 3FR. Similar findings have been evidenced in previous studies. (Brunner et al., 2001; Eng & Moy, 2011),

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

https://doi.org/10.15517/psm.v21i2.55311
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particularly for FFQs that have more than (Klipstein-Grobusch et al., 1998), as was the case here. The Bland-Altman analysis shows discrepancies between the two methods, both for nutrients and food groups intake. FFQ overestimates 3FR, with an average overestimation of 40.2% for foods and 38.8% for nutrients. The overestimation of nutrient intake by the FFQ may reflect the fact that the 3FR underestimates many food groups (Kaczkowski et al., 2000). It is likely that some food items on the FFQ may not have been consumed during the 3FR and this may contribute to the evidenced difference. The variations between the two instruments in terms of the method of data collection and the manner to transform the self-reported food items into nutrients may explain these dissimilarities in estimates.

The higher consumption of dietary fiber and vitamins determined by the FFQ could be related to the variety of fruits and vegetables included in the FFQ, which provides more selection options,compared to the 3FR. In fact, in the FFQ, 36 food items were used to describe the groups of fruits, vegetables, and legumes which could explain the overestimation of vitamin C and folate equivalentsintakes in the FFQ (despite an acceptable agreement for the classification). Another possible explanation for the large differences in average nutrients and food intakes between the compared methods is the underreporting bias that interferes with the food intake data obtained from food records (Andersen et al., 2005; Chinnock, 2006). Chinnock (2006) analyzed data from 60 Costa Ricanadults and observed that food intake data collected with estimated food records were underestimated for energy, nutrients, and food groups, when compared to the results obtained froma weighed food record. Andersen et al. (2005) observed that energy intake estimated with a pre- coded food diary was 34% lower than the estimated energy expenditure among Norwegian adolescents. Possible underreporting in the food records and/or overreporting in the FFQ may haveinfluenced the results observed in this study.

Although in this study some good correlations and weighted kappa between FFQ-derived intakes and the 3FR were observed, they are likely to be underestimates of the correlations between the FFQ and real intake (Sauvageot et al., 2013). Therefore, as already stated in similar studies by other researchers (Tabacchi et al., 2016; J. E. Wong et al., 2012), the designed FFQ for Costa Rican adolescents is an inappropriate tool to estimate absolute levels of nutrients intake and food groups consumption, when considering the bias and low precision observed.

Concerning the results on cross-classification into tertiles, the FFQ performed well. After energy adjustment, 19/25 nutrients obtained a weighted kappa coefficient above 0.20 and the average correct classification rate was about 50%. These percentages of agreement were comparable to those of previous studies, which compared their FFQ with dietary records (Fernández-Ballart et al., 2010; Khairunnisa Mohamed et al., 2018; J. E. Wong et al., 2012), confirming that the FFQ designed to Costa

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

https://doi.org/10.15517/psm.v21i2.55311
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Rican adolescents is a reasonable tool to categorize adolescents into broad ranges of dietary intakes and could be used to evaluate dietary patterns in large populations of adolescents and to study the association between eating habits and cardiovascular risk factors, such as overweight/obesity. Consistent with the findings of this study, a meta-analysis of the validity of the FFQ targeting adolescents concluded that the FFQ is a suitable tool for data collection and could only be used to classify adolescents in terms of energy and nutrients intake and food groups consumption (Tabacchi et al., 2016).

This study has several strengths: 1) The FFQ was designed based on studies on the dietary intake of Costa Rican adolescents determined by 3FR, 2) the validity of the FFQ was carried out through the 3FR, which is the dietary assessment method that has the least correlated errors with the FFQ, since it is independent of memory and the size of the portion is estimated at the moment of consumption (Rankin et al., 2010; Willett, 2013), 3) the sample size was adequate for the FFQ validation study, since a sample size between 50-100 individuals has been suggested as the minimum required for an FFQ validation and reproducibility studies (Cade et al., 2004; Willett, 2013). Some limitations of this study include: 1) the effect of sex was not removed by conducting separate analyses for boys and girls; however, very few FFQ validation studies provide this type of data separately, 2) the 3FR applied in a single week is likely not to be as representative of long-term dietary habits. However, given that the adolescents have problems remembering their diet over a long period of time (Livingstone et al., 2004; Truthmann et al., 2011), it may be better to run the FFQ over several weeks spread over a year to capture seasonal variations, 3) food record was performed only on 3 days and not on 7 or more days, which may limit the capture of greater variability in food consumption and nutrient intake. Nevertheless, according to the literature (Ortega, 2015), 3 days of recordings is reasonable because declining accuracy of recording with increasing fatigue and boredom have been noticed with longer records.

Acknowledgements

The authors are grateful to Alejandra Abarca-Rojas, Graciela Méndez-Rojas, Angie Morera-Quesada, and Katherine Vindas-Chichilla for their support in data analysis.

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

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Table 1. Summary of statistical test for validation of a food frequency questionnaire to assess nutrient dietary intake in Costa Rican adolescents (n=107).

Variable	3-day food record (mean ± SD)	FFQ1 (mean ± SD)	Energy-adjusted de-attenuated Spearman correlation†	Bias (FFQ-3FR) over magnitude (%)	Cross-classification (tertiles)		Weighted Kappa
					Same tertile (%)	Opposite tertile (%)	
Energy, kcal	1880 ± 525	2586 ± 783 §*	0.424*	29.5	51.3	4.4	0.48
Protein, g	56.0 ± 13.9	75.6 ± 16.8*	0.237*	29.5	41.3	8.2	0.18
Carbohydrates, g	268.0 ± 35.8	369 ± 47.3*	0.176	31.7	50.2	8.6	0.27
Total sugar, g	95.9 ± 28.1	142.4 ± 42.4*	0.388*	37.7	52.4	3.1	0.29
Dietary fiber, g	13.2 ± 3.6	20.7 ± 5.9*	0.240*	42.4	59.6	8.9	0.24
Total fat, g	55.3 ± 12.4	70.0 ± 14.8*	0.410*	23.4	77.5	6.4	0.36
Saturated fat, g	17.2 ± 4.5	24.1 ± 6.4*	0.370*	32.6	53.6	5.7	0.28
Monounsaturated fat, g	18.8 ± 5.0	23.3 ± 6.0*	0.349*	21.4	52.4	6.7	0.27
Polyunsaturated fat, g	11.3 ± 3.2	18.6 ± 3.3*	0.515*	19.2	55.6	8.9	0.29
Cholesterol, mg	182.7 ± 93.9	247 ± 107.5	0.262*	31.0	58.8	8.4	0.22
Calcium, mg	527.5 ± 214.3	826.8 ± 307*	0.468*	44.7	56.5	5.8	0.31
Iron, mg	11.7 ± 2.8	15.9 ± 4.4*	0.419*	29.6	59.0	5.7	0.56
Magnesium, mg	211.6 ± 45.5	298.3 ± 54.6*	0.413*	34.3	56.4	6.4	0.38
Phosphorus, mg	919.0 ± 199.2	1225.8 ± 236.1*	0.331*	28.6	53.3	7.7	0.34
Potassium, mg	1951 ± 443.3	2839.1 ± 662.2*	0.311*	36.5	66.9	6.5	0.42
Zinc, mg	8.0 ± 2.0	11.8 ± 2.8 *	0.121	37.6	57.3	8.6	0.36
Copper, mg	0.9 ± 0.2	1.4 ± 0.4*	0.333*	44.9	54.2	5.4	0.28
Vitamin C, mg	95.4 ± 49.8	208 ± 84.8*	0.348*	73.5	56.2	9.4	0.31
Thiamin, mg	1.5 ± 0.3	2.1 ± 0.4*	0.634*	34.1	66.1	6.9	0.42
Riboflavin, mg	1.4 ± 0.4	1.8 ± 0.5*	0.573*	28.6	70.1	8.1	0.35
Niacin, mg	18.7 ± 3.9	24.2 ± 5.7*	0.260*	24.5	57.1	7.5	0.28
Vitamin B6, mg	1.3 ± 0.4	2.3 ± 0.8*	0.568*	48.0	57.1	6.8	0.22
Folate equivalents, mcg	636.4 ± 228.7	889 ± 397.6*	0.595*	29.8	57.0	6.5	0.33
Vitamin B12, mg	3.5 ± 1.6	4.8 ± 1.7*	0.342*	31.9	55.9	7.6	0.32
Vitamin A, mcg	959.1 ± 662.2	1638.2 ± 892*	0.448*	52.8	59.4	6.3	0.41
Vitamin E, mg	6.3 ± 2.8	7.4 ± 1.7	0.281*	21.7	48.8	12.3	0.18
Vitamin D, mcg	1.2 ± 0.7	2.2 ± 1.3*	0.451*	55.7	77.6	9.0	0.62

§ Wilcoxon signed-rank test was used to compare means values obtained from the 3-day dietary recalls and FFQ1, * $p < 0.05$. † De-attenuated energy-adjusted correlations ≥ 0.50: good relationship; 0.20-0.49: acceptable relationship, and <0.20: weak or no relationship.

https://doi.org/10.15517/psm.v21i2.55311
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Table 2. Summary of statistical test for validation of a food frequency questionnaire to assess food groups consumption in Costa Rican adolescents (n=107)

Variable	3-day food record (mean ± SD)	FFQ1 (mean ± SD)	Energy-adjusted de-attenuated Spearman correlation	Bias (FFQ-3FR) over magnitude (%)	Cross-classification (tertiles)		Weighted Kappa
					Same tertile (%)	Opposite tertile (%)	
Dairy products, g	96.7 ± 116.9	117.5 ± 115.9§*	0.559*	38.3	51.6	8.8	0.32
White rice, g	146.2 ± 94.3	226.8 ± 169.48	0.724*	32.7	54.3	7.1	0.28
Beans, g	82.5 ± 64.0	127.9 ± 97.2*	0.589*	40.3	52.0	6.4	0.42
Vegetables, g	50.5 ± 48.1	93.7 ± 48.4*	0.194	74.4	56.3	6.5	0.51
Starchy vegetables, g	31.9 ± 35.3	23.3 ± 25.6*	0.053	2.7	42.0	6.2	0.16
Fruits and fruit juice, g	95.2 ± 122.0	204.7 ± 145.4*	0.308*	87.4	52.7	6.7	0.42
Sugary drinks, g	775.3 ± 335.9	815.3 ± 376.8	0.522*	5.4	57.4	5.6	0.56
Breakfast cereal, g	7.6 ± 12.6	8.8 ± 13.4	0.839*	10.7	70.0	3.0	0.82
Candies & sweets, g	16.3 ± 15.5	26.0 ± 19.6*	0.470*	50.2	56.9	8.3	0.63
Snacks, g	15.3 ± 16.4	18.7 ± 16.3	0.260*	40.5	52.6	4.9	0.53
Fast foods, g	26.3 ± 16.6	36.3 ± 22.4*	0.403*	92.1	53.7	5.6	0.46
Meat and eggs, g	79.6 ± 58.2	91.3 ± 57.3	0.322*	21.7	48.8	14.3	0.13
Processed meat, g	7.3 ± 12.3	12.7 ± 11.3	0.679*	82.0	50.7	7.1	0.23
Fat, g	3.9 ± 6.7	3.2 ± 4.7	0.024	-7.8	55.9	3.2	0.38
Soup, g	25.6 ± 36.6	16.8 ± 21.4	0.304*	45.9	36.9	2.9	0.10
Pasta, g	25.8 ± 34.2	28.8 ± 31.1*	0.100	33.3	37.3	12.7	0.12
Fish and seafood, g	9.0 ± 17.2	11.5 ± 12.7*	0.175	60.9	41.4	9.0	0.14
Refined bread and cookies, g	54.7 ± 33.6	55.8 ± 33.0	0.109	4.9	31.7	19.8	0.16
Pastries, g	22.6 ± 31.7	28.8 ± 30.9*	0.170	31.0	31.0	9.0	0.03
Ice cream, g	16.3 ± 26.8	24.8 ± 29.8*	0.047	46.0	59.2	4.0	0.46
Corn-based preparations, g	17.7 ± 35.3	22.1 ± 28.3	0.536*	34.7	34.3	12.0	0.16

§ Wilcoxon signed-rank test was used to compare means values obtained from the 3-day dietary recalls and FFQ1, * $p < 0.05$. † De-attenuated energy-adjusted correlations ≥ 0.50: good relationship; 0.20-0.49: acceptable relationship, and <0.20: weak or no relationship.

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

https://doi.org/10.15517/psm.v21i2.55311
Volume 21, issue 2, Sci art. january-june 2024

Table 3. Comparison of mean consumption of nutrients and Spearman correlation between FFQ1 and FFQ2 (n=80).

Variable	FFQ1 (mean ± SD)	FFQ2 (mean ± SD)	Energy-adjusted de-attenuated Spearman correlation	Cross-classification (tertiles) Same tertile (%)	Cross-classification (tertiles) Opposite tertile (%)	Weighted Kappa
Energy, kcal	2494.8 ± 799	2081.6 ± 718.7 §*	0.553*	59.7	9.1	0.42
Protein, g	73.2 ± 17.9	63.9 ± 17.3*	0.334*	45.9	13.5	0.18
Carbohydrates, g	349.7 ± 47.7	288.3 ± 43.5*	0.357*	54.9	8.9	0.32
Total sugar, g	137.2 ± 41.1	113.6 ± 35.6	0.391*	55.2	7.3	0.42
Dietary fiber, g	19.9 ± 5.7	16.8 ± 4.6*	0.401*	58.5	7.4	0.40
Total fat, g	55.3 ± 12.4	57.2 ± 13.5*	0.363*	52.6	6.1	0.38
Saturated fat, g	23.3± 6.5	19.5 ± 6.3*	0.248*	53.4	7.6	0.28
Monounsaturated fat, g	22.5 ± 5.4	19.4 ± 5.3*	0.251*	56.8	6.9	0.31
Polyunsaturated fat, g	13.2 ± 3.3	10.7 ± 2.9*	0.347*	55.3	6.4	0.28
Cholesterol, mg	241.1 ± 105.7	209.3 ± 89.8	0.257*	46.8	16.9	0.11
Calcium, mg	805.9 ± 310	756.2 ± 345.5	0.487*	53.3	5.2	0.32
Iron, mg	15.4 ± 4.6	14.2 ± 5.7*	0.376*	51.6	7.2	0.24
Magnesium, mg	288 ± 54.9	243.2 ± 54.7*	0.570*	54.8	6.8	0.28
Phosphorus, mg	1188.1 ± 243.7	1042.7 ± 260.3*	0.464*	51.3	8.3	0.23
Potassium, mg	2776 ± 674.1	2395.1 ± 688.3*	0.551*	54.5	9.1	0.26
Zinc, mg	11.2 ± 2.8	2.8 ± 9.3 *	0.315*	51.3	6.8	0.22
Copper, mg	1.4 ± 0.4	0.4 ± 1.1*	0.324*	56.2	5.4	0.26
Vitamin C, mg	204.3 ± 78.9	168.8 ± 97.9*	0.372*	52.9	5.6	0.25
Thiamin, mg	2.1 ± 0.4	1.7 ± 0.4*	0.503*	57.4	7.9	0.31
Riboflavin, mg	1.8 ± 0.5	1.7 ± 0.5	0.533*	53.3	4.0	0.29
Niacin, mg	23.3 ± 5.8	20.6 ± 6.2*	0.278*	55.6	5.8	0.36
Vitamin B6, mg	2.2 ± 0.8	2.0 ± 1.1*	0.287	56.1	5.5	0.29
Folate equivalents, mcg	876.5 ± 402.8	789.3 ± 397.2*	0.479*	52.6	7.1	0.35
Vitamin B12, mg	4.6 ± 1.7	4.6 ± 2.1	0.375*	54.9	9.0	0.34
Vitamin A, mcg	1692.3 ± 918.2	1358.7 ± 836.7*	0.390*	56.2	8.3	0.41
Vitamin E, mg	7.1 ± 1.7	6.1 ± 1.6	0.182*	42.9	18.2	0.09
Vitamin D, mcg	2.2 ± 1.4	2.2 ± 1.5	0.362*	53.4	7.8	0.48

§ Wilcoxon signed-rank test was used to compare means values obtained from FFQ1 and FFQ2, * $p < 0.05$. † De-attenuated energy-adjusted correlations ≥ 0.50: good relationship; 0.20-0.49: acceptable relationship, and <0.20: weak or no relationship.

Table 4. Comparison of mean consumption of food groups and Spearman correlation between FFQ1 and FFQ2 (n= 80)

Variable	FFQ1 (mean ± SD)	FFQ2 (mean ± SD)	Energy-adjusted de-attenuated Spearman correlation	Cross-classification (tertiles)		Weighted Kappa
				Same tertile (%)	Opposite tertile (%)	
Dairy products, g	118.3 ± 118.1	156.3 ± 103.1	0.514*	50.0	5.3	0.50
White rice, g	213.9 ± 166.8	173.1 ± 138.6	0.555*	63.2	7.9	0.54
Beans, g	125.9 ± 95.2	64.9 ± 49.8§*	0.626*	52.0	2.7	0.57
Vegetables, g	93.6 ± 49.1	90.5 ± 50.4	0.339*	52.6	3.2	0.28
Starchy vegetables, g	24.4 ± 17.5	17.3 ± 11.6	0.269*	37.2	16.7	0.14
Fruits and fruit juice, g	200.3 ± 144.8	189.3 ± 171.2	0.548*	54.2	6.9	0.50
Sugary drinks, g	807.2 ± 369.1	619.3 ± 355.1*	0.546*	54.8	5.5	0.48
Breakfast cereal, g	8.4 ± 1.7	18.3 ± 13.5*	0.435*	78.4	6.2	0.54
Candies & sweets, g	25.1 ± 20.1	22.6 ± 9.6	0.555*	59.7	9.7	0.53
Snacks, g	17.2 ± 15.7	12.7 ± 10.1*	0.347*	59.3	5.1	0.48
Fast foods, g	40.1 ± 39.7	48.3 ± 36.3*	0.047	59.2	9.7	0.27
Meat and eggs, g	83.9 ± 54.8	79.5 ± 44.6	0.393*	44.6	14.9	0.09
Processed meat, g	12.2 ± 11.4	11.8 ± 9.1	0.182	43.4	6.6	0.14
Fat, g	3.3 ± 4.7	3.4 ± 2.6	0.420*	51.1	6.9	0.26
Soup, g	16.2 ± 18.7	24.8 ± 15.6	0.214	39.2	10.1	0.07
Pasta, g	26.4 ± 28.9	32.8 ± 28.7	0.291*	43.4	7.9	0.05
Fish and seafood, g	12.2 ± 8.8	11.2 ± 9.5	0.417*	38.9	17.2	0.12
Refined bread and cookies, g	53.7 ± 31.9	43.5 ± 30.2*	0.502*	42.9	7.8	0.08
Pastries, g	29.3 ± 30.8	30.8 ± 28.7	0.282*	40.3	14.3	0.15
Ice cream, g	24.7 ± 10.6	36.1 ± 19.9	0.003	53.3	6.3	0.28
Corn-based preparations, g	22.1 ± 12.9	26.1± 20.5	0.310*	29.2	19.7	0.34

§ Wilcoxon signed-rank test was used to compare means values obtained from FFQ1 and FFQ2, * $p < 0.05$. † De-attenuated energy-adjusted correlations ≥ 0.50: good relationship; 0.20-0.49: acceptable relationship, and <0.20: weak or no relationship.

https://doi.org/10.15517/psm.v21i2.55311
Volume 21, issue 2, Sci art. january-june 2024