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Validation of a diet history questionnaire for use with Costa Rican adults

Anne Chinnock*
School of Nutrition, University of Costa Rica, Apartado Postal 28-2050, San Pedro Montes de Oca, San José, Costa Rica, Central America

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Abstract

Objective: To validate a diet history questionnaire (DHQ) using a weighed food record (WFR) as the standard method in the estimation of food consumption and nutrient intake in a group of adults.
Design: WFR: all foods consumed by subjects during 7 consecutive days were weighed and recorded by nutrition students. Two DHQ interviews were carried out on days 1 (first diet history questionnaire, DHQ1) and 28 (second diet history questionnaire, DHQ2).
Setting: Costa Rica.
Subjects: Sixty adults: 30 men and 30 women; 30 living in urban and 30 in rural areas.
Results: In comparison to the WFR, the DHQ1 gave statistically significant higher estimates of the mean intake of 19 nutrients for men and of three nutrients for women. The uncorrected correlation coefficients for nutrient intake according to both methods ranged from 0.40 to 0.83 for males and from 0.22 to 0.62 for females. Percentage of subjects classified in the same quartiles of nutrient intake according to each method ranged from 33.3% to 63.3% for males and from 23.3% to 53.3% for females. Misclassification in extreme quartiles ranged from 0% to 13.3% for both sexes. The mean food group consumption, according to the DHQ1, when compared with the WFR, gave statistically significant differences for three of the 18 food groups for men and for two groups in the case of women. The two applications of the DHQ gave similar results.
Conclusion: Validation of a DHQ using a WFR as the standard method gave results that compare favourably with those reported by other authors. This study found important differences in the response of men and women to the DHQ: among men, the estimates of mean nutrient intake from DHQ1 were significantly greater than those of the WFR, while in the case of women, the mean nutrient intake estimates from both methods were not significantly different. There was a higher degree of correlation between the DHQ1 and the WFR mean nutrient intakes among men than among women. The DHQ showed good reproducibility.

Keywords
Diet History Questionnaire
Dietary assessment methods
Nutritional epidemiology

The health and nutrition situation of the Costa Rican population is one of transition. The health indicators show a reduction in the incidence of childhood infectious diseases and an increase in chronic diseases among adults[1], a transformation that is associated, among other things, with changing lifestyle patterns and, more specifically, changes in diet.

A few studies have been carried out in Costa Rica on the relationship between diet and chronic diseases. Data have been published on the prevalence of cardiovascular risk factors[2], cervical cancer[3–5] and gastric cancer[6–10], which is of special interest as Costa Rica has one of the highest incidence and death rates for this type of cancer in the world[11].

The study of diet in epidemiological research requires methods that measure food consumption over the longer rather than shorter term, which can be applied to groups with different characteristics and not just those who are highly motivated and that do not incur high costs. Interview-based methods such as the diet history questionnaire (DHQ) and food frequency questionnaire (FFQ) are likely candidates. The latter has been applied in several studies of diet and health and recently in Costa Rica[12]. However, use of the FFQ has been questioned by some researchers due to insufficient precision[13–15]. Use of the DHQ has not been reported in this country. The DHQ was first described by Burke[16] and has since been

**Corresponding author:* Email achinnoc@cariari.ucr.ac.cr

reported in the literature with variations in its structure. Although it is also interview-based, the DHQ offers the following advantages over the FFQ in that the subject describes, in an unstructured manner, which foods have been consumed rather than being limited to a predefined list; food consumption over the period in question is described for each mealtime rather than on a daily basis and probing questions are used to aid the subjects' capacity to remember items consumed.

Responding to a need to develop and validate methods that can be used to study the relationship between diet and disease in Costa Rica, this article presents the results of a validation study of an interview-based DHQ, with a 7-day weighed food record (WFR), collected by undergraduate nutrition students used as the standard method.

Methods

Sample

Data were collected from 60 adults: 15 men and 15 women from a rural community, and 15 men and 15 women living in urban areas. The subjects were selected according to the following criteria: (a) Costa Rican; (b) between 20 and 65 years of age; (c) if not literate, lived with someone who was literate; (d) in the case of the rural residents, formed part of families whose income depended, in part or totally, on agricultural work. Convenience sampling was used: in the rural area, subjects were contacted with the help of a primary health worker who asked people in the homes he/she visited whether they would take part in the study. In the urban area, two nutrition students visited people living in their neighbourhood, inviting them to participate in the study.

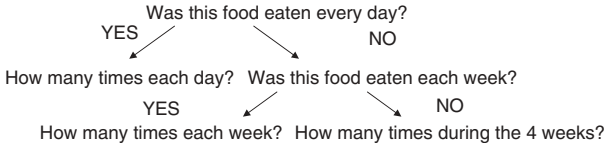
Data collection

All the interviews carried out for the DHQ were performed by the investigator. The data for each subject were collected during a 4-week period, from February 1996 to March 1998. The WFR was performed during days 1–7, the first diet history questionnaire (DHQ1) on day 1, and the second diet history questionnaire (DHQ2) on day 28*. In the case of the WFR, the nutrition students weighed ingredients of food preparations, food portions as served and plate waste, visiting the house during preparation and consumption of meals. In some cases, where another member of the household was able and willing to assist in the data collection, they were trained to weigh foods consumed by the subject when the nutrition student was not present. Soehnle scales (sensitivity of 1 g and capacity for 2 kg) were used. Whenever possible, foods consumed outside the home were weighed before consumption. However, when this was not possible, the students visited the site and weighed a similar portion of the same food. On some occasions, it was not possible to weigh the ingredients of preparations consumed away from home, and published recipes for the same preparations were used. Subjects were weighed using bathroom scales on the morning of days 1 and 8. Their height was measured on day 1.

*The number of days between the two applications of the DHQ ranged from 25 to 35.

Diet history questionnaire

The DHQ used in this study consists of the following six stages: (1) The subject is questioned about how usual food consumption over the past 4 weeks is, as compared with earlier periods. (2) The subject is asked to describe foods and drinks consumed over the past 4 weeks at each mealtime. The interviewer records the information without interrupting, and when the subject has finished, asks whether foods that are common in the Costa Rican diet and not mentioned were in fact consumed. (3) The interviewer asks the subject to describe the frequency with which each item was consumed, using the following sequence of questions:



(4) The interviewer asked the subject to describe the usual amount of each food eaten, using number of units, dimensions, photographs of food portions[17],* homely measures or amount as specified on food labels. (5) The interviewer asked the subject to read the names of foods and drinks on four series of cards in case items had been consumed and not mentioned. The four series of cards are for fruits, sweet snacks, savoury snacks and drinks. (6) Recipes for frequently consumed preparations were described by the subject or the person in charge of food preparation. Each interview lasted 1–1$\frac{1}{2}$ h.

Data analysis

All 60 subjects completed a total of 7 days of WFR and the two DHQ interviews. The estimated amounts of foods consumed according to the DHQs were converted to gram weights by the investigator using local tables of food portion sizes[19] and using the weights of foods displayed in photos[17]. These amounts were multiplied by the frequency of consumption, resulting in estimates of the amount of each food consumed during the 28-day period. The addition of codes for each food for the DHQs

*This publication contains 114 series of between three and six portion sizes for a total of 91 different foods and preparations commonly consumed in Costa Rica. The portion sizes used for the food photographs were determined in a previous study18.

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Table 1 Regression analysis of the influence of the variable sex on the difference between energy and nutrient estimates from the WFR and DHQ1

Dependent variable: difference between WFR and DHQ1 estimates	Value of β	Level of significance	Value of R_a^2
Total fat	−16.817	0.013	0.086
Monounsaturated fat	−6.851	0.013	0.086
Saturated fat	−6.235	0.013	0.086
Folate	−100.936	0.005	0.114

WFR – weighed food record; DHQ1 – first diet history questionnaire.

was performed by three nutrition students and, in the case of the WFR, by a fourth nutrition student, all of whom were previously instructed by the investigator. All food consumption data (DHQs and WFR) were converted to nutrient values using Central American Food Composition Tables[20,21] and software created in Epi 2000[22]. The nutrient intake estimates for the DHQs were expressed on a per day basis and the average daily nutrient intake for the WFR was calculated. Statistical analysis was performed using SPSS, version 12.0 for Windows (SPSS Inc., 2003). The nutrients with a non-normal distribution were converted to natural logarithms. Regression analysis was performed using the difference between the WFR and DHQ1 nutrient estimates as the dependent variable, and sex, age, area of residence and body mass index (BMI) as the independent variable. Nutrient estimates were compared using the paired Student's *t*-test and the degree of association was measured by the Pearson's correlation coefficient. The within- and between-person variance was calculated for the WFR using a repeat measures analysis of variance. The consumption of food groups was compared by the Wilcoxon's signed ranks test and the degree of association by Spearman's correlation coefficient. The ability of both methods to similarly classify individuals in quartiles of the distributions for food groups and for nutrients was also examined.

Results

Study group characteristics

The socio-economic characteristics of the study group are provided in a previous article[23]. There was no difference in average age and educational level of men and women. Rural residents had spent less years in formal education, a higher proportion of them were unskilled as opposed to skilled workers, and received a monthly income below 250 US dollars. No association was found between being overweight (BMI $> 25\,kg\,m^{-2}$) and sex, or between being overweight and area of residence (χ^2).

Regression analysis

The results of the regression analysis of the effects of the variables sex, age, area of residence and BMI on differences between the WFR and DHQ1 nutrient estimates showed a significant effect only in the case of sex, and for the nutrients folate, total fat, monounsaturated and saturated fats. A second regression model was performed, with the difference in WFR and DHQ1 estimates for the four nutrients as the dependent variable and sex as the independent variable, the results of which are presented in Table 1. This analysis shows that the differences in estimates of folates, total fat, monounsaturated and saturated fats between the WFR and the DHQ1 are significantly greater in male subjects.

Estimates of mean daily energy and nutrient intake

Table 2 presents a comparison of the estimates of energy and nutrient intake by the WFR and the DHQ1, according to sex. For males, the DHQ1 estimates for energy and all nutrient intake are higher than those of the WFR, and the differences were statistically significant in the case of 19 nutrients. In the case of females, the DHQ1 estimates were higher than those of the WFR for 17 nutrients, with statistically significant differences for three nutrients. It can be seen from Table 2 that the mean differences between the two estimates of nutrient intake were considerably smaller for females than males, but the standard error of the differences for males and females were of a similar magnitude. For the entire group, the DHQ1 mean nutrient estimates were significantly different from 16 of the 22 nutrients (data not shown).

When the mean daily energy intake of each individual was compared with the value calculated from the BMR × 1.2, 16 subjects underreported consumption in the WFR, of whom 10 lost weight during the week when the WFR data were collected. When the same procedure was carried out for the DHQ1 data, 17 subjects were identified as underreporters. No association was found between the variable underreporting (in the WFR or the DHQ1) and with being overweight, or with sex or area of residence. However, those individuals who underreported with the WFR were also more likely to underreport with the DHQ1 (χ^2 $P < 0.05$).

The ratio of within : between person variation as calculated from the WFR data is presented in Table 3. The ratio is greater than 1 for total and individual fats, dietary fibre and vitamins A, C, B_2, B_6 and B_{12}. Also presented in Table 3 are the Pearson's correlation coefficients for the DHQ1 and the WFR, according to sex. For all nutrients

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Table 2 Comparison of energy and nutrient intake estimated by the WFR and DHQ1, according to sex

	Male						Female					
	WFR		DHQ1		WFR − DHQ1		WFR		DHQ1		WFR − DHQ1	
Nutrient	Mean	SD	Mean	SD	Mean difference	SE difference	Mean	SD	Mean	SD	Mean difference	SE difference
Energy (MJ day^{-1})	10.82	3.24	12.79	4.64	−1.97	0.49***	7.32	1.95	7.74	2.99	−0.42	0.51
Protein (g day^{-1})	88.9	27.81	97.8	36.97	−8.92	4.22*	55.4	11.65	55.1	23.15	0.34	4.30
Carbohydrate (g day^{-1})	383.1	137.93	450.2	178.29	−67.11	18.76**	266.7	72.33	294.5	120.94	−27.84	19.45
Total fat (g day^{-1})	79.2	21.91	96.6	38.28	−17.34	4.52**	54.5	19.59	55.0	23.42	−0.52	4.74
Monounsaturated fat (g day^{-1})	29.15	10.58	34.09	14.45	−4.94	1.78**	20.11	10.01	18.20	8.89	1.91	2.01
Polyunsaturated fat (g day^{-1})	17.73	8.31	21.22	9.08	−3.49	1.63*	10.81	4.90	12.78	6.59	−1.97	1.24
Saturated fat (g day^{-1})	24.43	8.29	29.71	14.31	−5.28	1.92**	16.65	6.06	15.69	8.87	0.95	1.51
Cholesterol (mg day^{-1})†	359	191.23	467	323.03	−108.36	45.92	200	86.62	193	92.71	7.15	16.87
Dietary fibre (g day^{-1})	19.68	6.07	24.92	10.35	−5.24	1.74**	14.33	5.61	16.63	8.54	−2.30	1.30
Calcium (mg day^{-1})	820	401.79	1047	654.90	−227.47	76.52**	558	226.18	635	389.45	−77.02	66.19
Iron (mg day^{-1})	23.6	7.71	25.2	9.72	−1.59	1.22	14.6	4.38	15.5	5.21	−0.92	0.94
Phosphorus (mg day^{-1})	1323	416.29	1548	616.42	−224.54	76.11**	850	206.03	920	395.26	−69.70	70.08
Potassium (mg day^{-1})	2797	754.39	3683	1213.74	−886.46	173.14***	2061	509.91	2484	1107.58	−422.88	196.16*
Magnesium (mg day^{-1})	277	77.01	346	124.54	−68.59	17.20***	193	49.13	216	84.71	−22.89	13.63
Zinc (mg day^{-1})	11.07	3.83	12.82	5.15	−1.75	0.69*	6.80	1.74	7.03	3.10	−0.23	0.53
Retinol equivalents (μg day^{-1})†	1337	1581.67	1811	2730.44	−474.78	366.81*	699	337.31	1107	722.34	−407.93	128.96**
Thiamin (mg day^{-1})	1.84	0.69	2.13	1.01	−0.29	0.14*	1.25	0.40	1.26	0.42	0.01	0.07
Riboflavin (mg day^{-1})	1.81	0.74	2.34	1.31	−0.53	0.18**	1.21	0.43	1.34	0.62	−0.13	0.10
Vit. B_6 (mg day^{-1})	1.64	0.45	2.16	0.78	−0.52	0.13***	1.21	0.37	1.40	0.67	−0.20	0.12
Vit. B_{12} (μg day^{-1})†	7.88	12.84	10.54	23.18	−2.67	3.69	3.21	3.51	4.28	4.05	−1.07	0.59
Vit. C (mg day^{-1})†	135	73.84	243	161.17	−108.05	27.21***	118	87.83	192	174.50	−73.85	21.34***
Folate (μg day^{-1})	395	160.87	492	195.92	−97.69	28.97**	285	111.38	282	113.96	3.24	18.52

WFR – Weighed Food Record; DHQ1 – first Diet History Questionnaire; SD – standard deviation; SE – standard error.
* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.
† Values converted to natural logarithms before performing Student's *t*-test.

Table 3 Pearson's correlation coefficients for energy and nutrient intake estimated by the WFR and the DHQ1

		WFR and DHQ1			
		Males		Females	
Nutrient	Ratio of within to between person variation for WFR	Uncorrected correlation coefficient	Corrected correlation coefficient	Uncorrected correlation coefficient	Corrected correlation coefficient†
Energy (MJ day^{-1})	0.64	0.83***	0.86	0.43*	0.45
Protein (g day^{-1})	0.77	0.78***	0.82	0.22	0.25
Carbohydrate (g day^{-1})	0.62	0.82***	0.84	0.49*	0.52
Total fat (g day^{-1})	1.04	0.79***	0.86	0.28	0.31
Monounsaturated fat (g day^{-1})	1.06	0.74***	0.79	0.33	0.37
Polyunsaturated fat (g day^{-1})	1.71	0.47**	0.59	0.32	0.37
Saturated fat (g day^{-1})	1.08	0.69***	0.75	0.44*	0.49
Cholesterol (mg day^{-1})‡	1.07	0.71***	0.76	0.62***	0.73
Dietary fibre (g day^{-1})	1.08	0.42*	0.47	0.56**	0.60
Calcium (mg day^{-1})	0.81	0.79***	0.82	0.40*	0.43
Iron (mg day^{-1})	0.93	0.73***	0.80	0.43*	0.46
Phosphorus (mg day^{-1})	0.72	0.74***	0.77	0.32	0.35
Potassium (mg day^{-1})	0.92	0.62***	0.66	0.29*	0.32
Magnesium (mg day^{-1})	0.83	0.66***	0.70	0.48**	0.52
Zinc (mg day^{-1})	0.94	0.68***	0.73	0.40*	0.46
Retinol equivalents (μg day^{-1})‡	1.40	0.54**	0.61	0.23	0.31
Thiamin (mg day^{-1})	0.76	0.68***	0.71	0.54**	0.58
Riboflavin (mg day^{-1})	1.17	0.65***	0.72	0.41*	0.47
Vit. B_6 (mg day^{-1})	1.19	0.43*	0.48	0.35	0.39
Vit. B_{12} (μg day^{-1})‡	1.61	0.64***	0.74	0.54**	0.74
Vit. C (mg day^{-1})‡	1.30	0.40*	0.47	0.53**	0.56
Folate (μg day^{-1})	0.90	0.62***	0.67	0.60**	0.63

WFR – weighed food record; DHQ1 – first diet history questionnaire.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$.
† Correction according to formula $(1/(1+s^2$ within person$/ns^2$ between person$))^{1/2}$, where s^2 is variance and n number of days[40].
‡ Values converted to natural logarithms before calculating correlation coefficients.

except dietary fibre and vitamin C, the correlation coefficients are higher for males than for females. The uncorrected correlation coefficients between the WFR and DHQ1 for males are all significant and range from 0.40 to 0.83. In the case of females, the uncorrected correlation coefficients for the WFR and DHQ1 range from 0.22 to 0.62, with 16 coefficients reaching statistical significance. The uncorrected correlation coefficients for the entire group of subjects ranged from 0.38 to 0.78, with 11 of the correlation coefficients being above 0.7 and 20 being above 0.5 (data not shown). All the correlation coefficients are increased by correcting for the ratio of within : between person variation.

Between 33.3% and 63.3% of the males were classified in the same quartiles of the distributions of DHQ1 and WFR intakes (Table 4) while between 0% and 13.3% were misclassified in extreme quartiles. In the case of females, between 23.3% and 53.3% were classified in the same quartiles while 0–13.3% were misclassified in extreme quartiles.

Table 5 presents a comparison of food group consumption* as estimated by the different methods, according to sex. Three food groups were significantly different for males and two in the case of females. The largest percentage differences were found for nonstarchy vegetables and fruits, with the DHQ1 overestimating their consumption. The Spearman's correlation coefficients between DHQ1 and the WFR were statistically significant for 10 food groups for males and for 11 food groups for females.

Between 16.7% and 60.0% of the males were classified in the same quartiles of the distributions of DHQ1 and WFR food group consumption estimates (Table 6), while between 0% and 20.0% were misclassified in extreme quartiles. In the case of females, between 20.0% and 63.3% were classified in the same quartiles while 0–16.7% were misclassified in extreme quartiles.

The two applications of the DHQ gave similar results (Table 7). Significant differences between the nutrient estimates by both questionnaires were observed for one nutrient in the case of males and for three nutrients in the case of females. The correlation coefficients are all statistically significant and range from 0.49 to 0.89 in the case of males, and from 0.51 to 0.74 for females (Table 8). The range of correlation coefficients for the entire group of subjects ranged from 0.6 to 0.88 (data not shown).

*Two food groups (pork meat, nuts and seeds) were not included as the majority of subjects did not consume foods from these groups.

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Table 4 Classification of subjects in quartiels of energy and nutrient intake as estiamted by the WFR and the DHQ1, according to sex

	Males		Females	
Nutrient	No. (%) correctly classified in same quartiles	No. (%) misclassified in extreme quartiles	No. (%) correctly classified in same quartiles	No. (%) misclassified in extreme quartiles
Energy	18 (60.0)	0	13 (43.3)	0
Protein	11 (36.7)	1 (3.3)	9 (30.0)	1 (3.3)
Carbohydrate	13 (43.3)	0	15 (50.0)	1 (3.3)
Total fat	16 (53.3)	0	8 (26.7)	0
Monounsaturated fats	16 (53.3)	0	13 (43.3)	3 (10.0)
Polyunsaturated fats	12 (40.0)	3 (10.0)	13 (43.3)	1 (3.3)
Saturated fat	12 (40.0)	0	12 (40.0)	1 (3.3)
Cholesterol	15 (50.0)	0	14 (46.7)	1 (3.3)
Dietary fibre	10 (33.3)	1 (3.3)	15 (50.0)	0
Calcium	13 (43.3)	1 (3.3)	16 (53.3)	1 (3.3)
Iron	12 (40.0)	0	13 (43.3)	1 (3.3)
Phosphorus	15 (50.0)	0	12 (40.0)	1 (3.3)
Potassium	10 (33.3)	0	12 (40.0)	0
Magnesium	11 (36.7)	0	12 (40.0)	0
Zinc	19 (63.3)	1 (3.3)	11 (36.7)	0
Retinol equivalents	10 (33.3)	2 (6.7)	7 (23.3)	3 (10.0)
Thiamin	16 (53.3)	0	8 (26.7)	0
Riboflavin	11 (36.7)	0	16 (53.3)	1 (3.3)
Vit. B_6	14 (46.7)	4 (13.3)	9 (30.0)	0
Vit. B_{12}	11 (36.7)	1 (3.3)	12 (40.0)	4 (13.3)
Vit. C	15 (50.0)	3 (10.0)	13 (43.3)	2 (6.7)
Folate	10 (33.3)	0	16 (53.3)	0

WFR – weighed food record; DHQ1 – first diet history questionnaire.

Discussion

In comparison with the WFR, the DHQ1 gave statistically significant higher estimates of mean intake for 19 nutrients in the case of men and for three nutrients in the case of women.

Underreporting in food records has been identified as a source of error[24–26]. It was also detected with the DHQ used in this study and occurred in a similar proportion of subjects. There was a significant tendency for the same subjects to underreport in both methods. Other studies have observed a greater tendency to underreport among overweight subjects[27,28]. Such a tendency was not observed in this study.

Six other studies were identified in the literature that compared a similar type of DHQ as used in this study (consisting of open-ended questions on foods consumed at different mealtimes) with food records[29–34]. In the study by Landig *et al.*[33], the DHQ was completed by the subjects using computers, and in all the other studies, interviews were used. The study by Harbottle and Duggan[34] involved children while in all the other studies the subjects were adults. Borrelli *et al.*[30], Mahalko *et al.*[29] and Petersen *et al.*[31] compared the DHQ with estimated food records, and Black *et al.*[32], Landig *et al.*[33] and Harbottle and Duggan[34] used WFRs. The number of days of Food Records varied between the studies: Borrelli *et al.*[30], Petersen *et al.*[31] and Harbottle and Duggan[34] used 3, 4 or 5 days, Mahalko *et al.*[29] and Landig *et al.*[33] 7 or 8 days,* and Black *et al.*[32] 21 days.

*The DHQ in this study also referred to the same 8-day period.

As none of the above-mentioned studies present their data according to sex, a comparison with the results of the present study was only possible by re-analysing the data for the entire group of 60 subjects (data not shown).

The results from this study are similar to those presented by Borrelli *et al.*[30] in that significant differences were found for approximately two-thirds of the nutrients analysed. Petersen *et al.*[31] found significant differences for almost all the nutrients analysed. Other studies reported that approximately 40% of nutrients analysed were significantly different between methods[29,33,34]. Black *et al.*[32] found no significant differences between the two methods for energy and protein, the only nutrients analysed. This study found that the DHQ gave higher estimates of nutrient intake than the food record. This phenomenon was also observed by Harbottle and Duggan[34], Borrelli *et al.*[30] and Petersen *et al.*[31]. In the studies by Mahalko *et al.*[29], Landig *et al.*[33] and Black *et al.*[32] no such tendency was found.

The uncorrected correlation coefficients found in this study for the entire group of subjects ranged from 0.38 to 0.78, values that were generally higher than those reported by Landig *et al.*[33], Borrelli *et al.*[30], Mahalko *et al.*[29] and Petersen *et al.*[31], and similar to those reported for energy and protein in the study by Black *et al.*[32]. The method used to correct the correlation coefficients in this study has the limitation that the estimates of within-person variation were based on data from 7 consecutive days of the WFR. As the within-person random error in consecutive days is correlated, this can introduce bias into the corrected correlation coefficients. For this reason, reference is made only to the uncorrected correlation coefficients.

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Table 5 Comparison of food group consumption† (g day^{-1}) as estimated by the WFR and the first application of the DHQ, according to sex

	Males					Females				
	DHQ1		WFR		Spearman's correlation coefficient	DHQ1		WFR		Spearman's correlation coefficient
Food group	Mean	SD	Mean	SD	WFR and DHQ1	Mean	SD	Mean	SD	WFR and DHQ1
Milk and milk products	374.3	327.3	261.9	189.2*	0.67***	231.5	342.8	184.4	147.4	0.72***
Eggs	58.4	65.2	35.2	30.5	0.57**	17.6	17.8	18.9	18.7	0.63***
Chicken (raw)	34.1	32.0	36.5	36.7	0.15	23.4	26.5	31.8	28.9	0.57**
Beef (raw)	86.2	67.3	80.8	57.1	0.50**	40.1	29.2	41.7	27.2	0.65***
Processed meats	15.8	16.6	17.1	17.3	0.20	9.6	10.3	9.9	11.1	0.05
Fish (raw)	18.2	23.0	18.1	18.8	0.57**	6.5	5.4	9.5	11.1	0.11
Legumes (raw)	34.9	31.6	44.2	33.5	0.36	19.0	18.8	22.9	19.4	0.22
Beverages	636.9	456.0	651.9	438.1	0.82***	431.9	312.1	387.6	255.8	0.84***
Soups	104.8	298.4	43.7	47.4	0.06	82.0	187.1	41.7	47.2	0.57**
Snacks	23.9	22.3	24.1	29.2	−0.03	24.8	56.8	8.2	14.8	0.12
Starchy vegetables	77.6	84.2	54.3	42.1	−0.00	58.8	33.4	60.3	35.2	0.16
Other vegetables	285.1	132.2	182.1	93.6***	0.30	183.3	93.8	150.1	72.6	0.34
Cereals (raw)	163.2	96.9	153.0	70.7	0.78***	83.1	52.4	103.3	51.0*	0.69***
Bread	130.6	97.1	135.6	90.0	0.58**	102.9	93.8	90.6	42.5	0.63***
Fruit	343.8	230.1	148.1	103.9***	0.42*	317.1	339.7	171.1	170.4***	0.55**
Sugars	112.0	88.1	85.8	60.4	0.72***	68.1	65.4	59.3	36.7	0.72***
Fat	33.6	20.8	26.5	14.4	0.51**	21.2	16.5	18.5	13.8	0.41*
Cakes	26.0	31.4	19.6	24.3	0.08	14.6	23.2	17.8	20.3	0.26

WFR – weighed food record; DHQ1 – first diet history questionnaire; SD – standard deviation.
* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.
† Two food groups (nuts and seeds and pork meat) were excluded due to a large number of zero values.

Table 6 Classification of subjects in quartiles of food group consumption* (g day^{-1}) as estimated by the WFR and the DHQ1 by sex

	Males		Females	
Food group	No. (%) correctly classified in same quartiles	No. (%) misclassified in extreme quartiles	No. (%) correctly classified in same quartiles	No. (%) misclassified in extreme quartiles
Milk and milk products	12 (40.0)	0	15 (50.0)	1 (3.3)
Eggs	11 (36.7)	1 (3.3)	13 (43.3)	1 (3.3)
Chicken (raw)	9 (30.0)	4 (13.3)	13 (43.3)	1 (3.3)
Beef (raw)	15 (50.0)	3 (10.0)	18 (60.0)	1 (3.3)
Processed meats	9 (30.0)	4 (13.3)	11 (36.7)	4 (13.3)
Fish (raw)	12 (40.0)	0	9 (30.0)	5 (16.7)
Legumes (raw)	10 (33.3)	1 (3.3)	12 (40.0)	4 (13.3)
Beverages	18 (60.0)	0	19 (63.3)	0
Soups	9 (30.0)	6 (20.0)	13 (43.3)	0
Snacks	11 (36.7)	4 (13.3)	10 (33.3)	4 (13.3)
Starchy vegetables	5 (16.7)	4 (13.3)	6 (20.0)	2 (6.7)
Other vegetables	9 (30.0)	1 (3.3)	11 (36.7)	3 (10.0)
Cereals (raw)	16 (53.3)	0	14 (46.7)	1 (3.3)
Bread	13 (43.3)	2 (6.7)	18 (60.0)	1 (3.3)
Fruit	11 (36.7)	2 (6.7)	12 (40.0)	1 (3.3)
Sugars	16 (53.3)	1 (3.3)	14 (46.7)	0
Fat	12 (40.0)	1 (3.3)	10 (33.3)	2 (6.7)
Cakes	8 (26.7)	4 (13.3)	10 (33.3)	2 (6.7)

WFR – weighed food record; DHQ1 – first diet history questionnaire.
* Two food groups (nuts and seeds and pork meat) were excluded due to a large number of zero values.

Table 7 Comparison of energy and nutrient intake estimated by the two applications of the DHQ

	Male						Female					
	DHQ1		DHQ2		DHQ1 − DHQ2		DHQ1		DHQ2		DHQ1 − DHQ2	
Nutrient	Mean	SD	Mean	SD	Mean difference	SE difference	Mean	SD	Mean	SD	Mean difference	SE difference
Energy (MJ day^{-1})†	12.79	4.64	12.13	4.78	0.66	0.48	7.74	2.99	7.31	2.48	0.42	0.45
Protein (g day^{-1})	97.85	36.98	97.54	43.67	0.31	3.59	55.10	23.15	51.18	16.61	3.92	3.51
Carbohydrate (g day^{-1})†	450.19	178.29	417.90	165.27	32.29	18.90	294.53	120.94	264.81	94.21	29.72	17.54
Total fat (g day^{-1})	96.55	38.28	95.25	44.30	1.30	4.76	54.99	23.42	57.99	29.38	−3.00	4.53
Monounsaturated fat (g day^{-1})	34.09	14.45	33.61	15.19	0.49	1.65	18.20	8.89	20.03	10.07	−1.83	1.68
Polyunsaturated fat (g day^{-1})	21.22	9.08	19.99	10.74	1.23	1.85	12.78	6.59	13.99	10.37	−1.20	1.41
Saturated fat (g day^{-1})†	29.71	14.31	28.12	13.61	1.59	1.68	15.69	8.87	16.42	8.93	−0.73	1.38
Cholesterol (mg day^{-1})†	467.27	323.03	439.87	340.55	27.40	41.37	193.00	92.71	194.81	106.71	−1.81	14.74
Dietary fibre (g day^{-1})	24.93	10.35	23.29	13.63	1.64	1.94	16.63	8.54	13.94	7.38	2.69	1.08*
Calcium (mg day^{-1})†	1047.37	654.90	954.40	625.13	92.97	58.23	634.52	389.45	635.03	363.05	−0.51	61.76
Iron (mg day^{-1})	25.18	9.72	24.08	11.45	1.11	1.30	15.50	5.21	13.72	4.43	1.79	0.76*
Phosphorus (mg day^{-1})	1548	616.42	1497	703.08	50.43	64.65	919.93	395.26	846.61	315.58	73.32	57.84
Potassium (mg day^{-1})	3683	1213.74	3463	1649.73	220.61	183.56	2483.68	1107.58	2148.21	792.82	335.46	175.74
Magnesium (mg day^{-1})	346	124.54	325	150.27	21.05	18.59	216.10	84.71	194.66	71.35	21.44	12.08
Zinc (mg day^{-1})	12.82	5.15	12.37	5.16	0.45	0.56	7.03	3.10	6.30	2.11	0.73	0.50
Retinol equivalents (μg day^{-1})†	1811	2730.44	1424	1060.20	387.34	372.51	1107	722.34	932	587.84	174.89	117.69
Thiamin (mg day^{-1})	2.13	1.01	2.00	1.02	0.13	0.10	1.26	0.42	1.17	0.43	0.08	0.06
Riboflavin (mg day^{-1})	2.33	1.31	2.12	1.09	0.21	0.15	1.33	0.62	1.28	0.56	0.06	0.09
Vit. B_6 (mg day^{-1})	2.16	0.78	2.11	0.96	0.05	0.14	1.40	0.67	1.26	0.53	0.14	0.10
Vit. B_{12} (μg day^{-1})†	10.54	23.17	7.74	7.08	2.80	3.46	4.28	4.05	3.98	3.82	0.30	0.62
Vit. C (mg day^{-1})†	243.24	161.17	204.77	149.10	38.47	24.03	191.90	174.50	157.82	198.64	34.07	17.68**
Folate (μg day^{-1})	492	195.92	429	189.77	63.21	29.94*	282.13	113.96	271.66	133.59	10.48	16.94

DHQ – diet history questionnaire; DHQ1 – first diet history questionnaire; DHQ2 – second diet history questionnaire; SD – standard deviation; SE – standard error.
* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.
† Values converted to natural logarithms before performing Student's *t*-test.

Table 8 Pearson's correlation coefficients for energy and nutrient intake as estimated by the two applications of the DHQ

	Males	Females
Energy (MJ day^{-1})†	0.84***	0.58**
Protein (g day^{-1})	0.89***	0.58**
Carbohydrate (g day^{-1})†	0.83***	0.70***
Total fat (g day^{-1})	0.81***	0.58**
Monounsaturated fat (g day^{-1})	0.82***	0.54**
Polyunsaturated fat (g day^{-1})	0.49***	0.67***
Saturated fat (g day^{-1})†	0.80***	0.55**
Cholesterol (mg day)†	0.79***	0.71***
Dietary fibre (g day^{-1})	0.64***	0.73***
Calcium (mg day^{-1})†	0.86***	0.74***
Iron (mg day^{-1})	0.79***	0.64***
Phosphorus (mg day^{-1})	0.86***	0.62***
Potassium (mg day^{-1})	0.80***	0.53**
Magnesium (mg day^{-1})	0.74***	0.65***
Zinc (mg day^{-1})	0.83***	0.51**
Retinol equivalents (μg day^{-1})†	0.68***	0.67***
Thiamin (mg day^{-1})	0.86***	0.68***
Riboflavin (mg day^{-1})	0.76***	0.64***
Vit. B_6 (mg day^{-1})	0.62***	0.62***
Vit. B_{12} (μg day^{-1})†	0.62***	0.63***
Vit. C (mg day^{-1})†	0.68***	0.72***
Folate (μg day^{-1})	0.64***	0.73***

DHQ – diet history questionnaire.
**$P<0.01$; ***$P<0.001$
†Values converted to natural logarithms before calculating correlation coefficients.

Van Staveren *et al.*[35], Schmidt *et al.*[36] and Wheeler *et al.*[37] have also published the results of reproducibility studies for the DHQ. While Van Staveren *et al.*[35] and Schmidt *et al.*[36] used a DHQ that was meal-based and consisted of open-ended questions on food consumption, Wheeler *et al.*[37] used a questionnaire that was completed by subjects and consisted of a list of possible food to select for each meal, with the possibility of adding other foods consumed. The time between the two DHQs was 1 month[35], 4–6 weeks or 3 months[37], and 1 year[36].

Van Staveren *et al.*[35] and Schmidt *et al.*[36] found no significant differences between the two applications of the DHQ. However, Wheeler *et al.*[37] found that the majority of nutrients were significantly different between the two applications of the three types of DHQ when applied 4–6 weeks apart, and a small number of significant differences for one of the same DHQs when applied 3 months later.

The correlation coefficients for nutrient intake reported in these reproducibility studies were in the range 0.67–0.91[35]; 0.5–0.77 and 0.51–0.72[36]; and 0.32–0.88, 0.52–0.82, 0.62–0.81, 0.59–0.8[37]. The range of correlation coefficients found in the present study (0.6–0.88) is similar to that presented by Van Staveren *et al.*[35] and higher than that in the other studies.

The true degree of similarity between the DHQ and the WFR is probably greater than that reflected in the comparison between DHQ1 and WFR, as they cover different periods of time. A comparison between the WFR and DHQ2 was not performed as the subject's attention was drawn to their food consumption during part of the 4-week-period covered by DHQ2. Although the subjects did not participate in the WFR data collection, they did carry out a 4-day and a 3-day estimated food record during the first 10 days of the 4-week-period[23].

This study found an important difference between male and female subjects in their response to the DHQ. The mean nutrient estimates from the DHQ1 were closer to those of the WFR in the case of women as compared to men; however, there was a lower degree of correlation between the nutrient estimates from both methods among women than among men. This result could not be confirmed as the other validation studies of DHQ did not present the results according to sex.

The mean food group consumption according to the DHQ1, when compared to the WFR, gave statistically significant differences for three of the 18 food groups in the case of men and for two groups in the case of women. The food groups that presented the greatest per cent differences between the two methods were nonstarchy vegetables and fruits. These food groups are generally considered as healthy foods by the Costa Rican population and this could be the reason for a conscious or unconscious overestimate in their intake by the subjects when responding to the DHQ.

The performance of the DHQ used in this study is superior to that commonly reported for FFQs. Nelson[38] presents the correlation coefficients obtained in 12 studies which compare FFQs with 'standard' estimates of nutrient intake. In only one study were the majority of correlation coefficients equal to or above 0.7. This could be due to any of the following differences between the two methods: the subject's response was not limited to a restricted list of foods; the DHQ used a meal-based structure that facilitates the subject's response; the probing questions allow inclusion of more easily forgotten foods; more time and techniques were used to help subjects estimate amounts of foods consumed; recipes for more frequently consumed preparations were described by the subject. However, the use of DHQs is more expensive than FFQs because of the longer interview time and the use of trained interviewers. This disadvantage can potentially be overcome by the use of computerized versions of the DHQ[39].

Conclusion

This study found important differences between men and women in their ability to report food consumption by the DHQ. Among men, the estimates of nutrient intake from the DHQ1 were significantly greater and more highly correlated to those of the WFR, while in the case of women, the nutrient intake estimates from the DHQ1 were not significantly different but were less correlated to those of the WFR. The level of agreement between the two methods for the group of 60 men and women compared favourably with results reported by other validation studies of the DHQ. The DHQ showed good reproducibility.

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