Public Health Nutrition: 9(7), 934–941 DOI: 10.1017/PHN2005922

Validation of an estimated food record

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Submitted 16 April 2004: Accepted 28 November 2005

Abstract

Objective: To validate an estimated food record (EFR), using a weighed food record (WFR) as the reference method, for the determination of food consumption and nutrient intakes in a group of Costa Rican adults.
Design: For the WFR, all foods consumed by subjects during seven consecutive days were weighed and recorded by nutrition students. Two EFRs (a 4-day and a 3-day record) were recorded by subjects with the use of home measures and photographs to estimate amounts.
Setting: Costa Rica.
Subjects: Sixty adults: 30 men and 30 women; 30 living in urban and 30 in rural areas.
Results: The EFR gave statistically significant lower average intake estimates for energy and 12 of the 22 nutrients examined. The correlation coefficients ranged from 0.68 (polyunsaturated fats) to 0.87 (calcium). The percentage of subjects classified into the same quartile ranged from 45.0% (polyunsaturated fats) to 68.3% (vitamin B_{12}). For all nutrients except vitamin C, 0 or 1.7% were misclassified into extreme quartiles. For food group consumption, the EFR gave statistically significant lower estimates for six of the 17 groups and correlation coefficients ranged from 0.22 (fish) to 0.93 (beverages). Greater differences in estimates of mean energy and nutrient intakes were detected among subjects from rural areas, caused in part by a tendency to underestimate the amounts of rice and beans consumed.
Conclusion: Validation of the EFR using a WFR as the reference method gave results that compare favourably with those reported by other authors, and support the use of the EFR for dietary surveys among Costa Rican adults.

Keywords
Estimated food record
Dietary assessment methods
Nutritional epidemiology

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

Studies of the diet–health relationship in Costa Rica reported in the literature over the last decade include health problems associated with poverty, such as anaemia and childhood stunting[2], and studies on the relationship between diet and chronic diseases, such as those on the prevalence of cardiovascular risk factors[3,4], cervical cancer[5–7] and gastric cancer[8–12]. The latter is of special interest as Costa Rica has one of the highest incidence and death rates for this type of cancer in the world[13].

Methods that were used to measure food consumption in these studies include food records, 24-hour recalls and food-frequency questionnaires. The use of food records has an advantage over other methods that measure food consumption retrospectively in that it does not include error due to memory. The food record method was first used in Costa Rica in a National Nutrition Survey in the 1960s, conducted by the Nutrition Institute for Central America and Panama[14]. Two versions of the food record were used, a weighed food record and a daily food record; in both types of records the data collection was carried out by trained fieldworkers. In the case of the weighed food record, the fieldworkers remained in each home throughout the day in order to weigh all food consumed by the family or individual. The daily food record[15] was devised as a means of reducing costs because it enabled fieldworkers to collect data from two households simultaneously; the fieldworkers visited each house twice a day, between meals, to collect data on the previous and next meal of that family or individual. However, survey costs remain high with this method as it depends on the use of trained fieldworkers to carry out all the data collection.

The work reported in the present paper was undertaken in response to the need to develop and validate other methods which can be used to study the relationship between diet and disease in this country. Methods that estimate food consumption over longer periods of time

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and methods which reduce costs by getting the subjects to register their food consumption are suitable for use in epidemiological studies. The use of food records in which the subjects register their consumption has not been reported in previous literature on Costa Rica. This paper presents the results of a validation of an estimated food record (EFR), carried out by the subjects, using a weighed food record (WFR), collected by undergraduate nutrition students, as the reference method.

Methods

Data collection

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: (1) Costa Rican; (2) between 20 and 65 years of age; (3) if not literate, lived with someone who was literate; and (4) in the case of rural residents, formed part of families whose income depended in part or totally on agricultural work. In the rural area, subjects were contacted with the help of a primary health worker in the community; in the urban area, the subjects lived within the same neighbourhood as the two nutrition students who collected the WFR data.

All the interviews carried out as part of the EFR were performed by the investigator. The food records for each subject were carried out during a 2-week period, between February 1996 and March 1998. The WFR was performed on days 1 to 7, the first EFR on days 1 to 4 and the second EFR on days 12 to 14. As both methods were used simultaneously over four days, this allowed measurement of the degree to which the EFR recorded the same types and amounts of foods as were reported by the WFR.

In the case of the WFR, the nutrition students weighed ingredients of food preparations and 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 of 2 kg) were used. On all possible occasions, the foods consumed outside the home were weighed prior to consumption. When this was not possible, the students visited the site and weighed a similar portion of the same food. Where it was not possible to weigh the ingredients of preparations consumed away from home, published recipes for the same preparations were used. Subjects were weighed using bathroom scales (sensitivity of 0.5 kg) on days 1 and 8. Their height was measured on day 1.

In order to collect data by the EFR, the investigator visited the subject during the morning of day 2, to instruct the person on how to complete the 4-day EFR. Food consumption for day 1 was registered in the booklet using a 24 hour-recall, which served the additional purpose of demonstrating to the subject how to record the data. The subject was revisited on day 5 in order to revise, complete any missing information and collect the EFR. The same process was repeated on days 11 and 15, except that on day 11 the EFR booklet was given to the subject with the instruction to record consumption on days 12, 13 and 14. The EFR booklet contained the following sections: (1) instructions on how to record consumption of different foods; (2) pages on which the subject records food consumption for each day, divided into seven mealtime periods; (3) a series of questions at the end of each day to record foods that are commonly eaten between mealtimes and had not been recorded; and (4) aids for the description of portion size, such as drawings of flat, rounded and heaped spoons, diagrams of different sizes and thickness of slices, a centimetre scale and pages containing photographs of between three and six portion sizes for 25 different foods. Each booklet permits the recording of 4 days' food consumption. The portion sizes used for the food photographs were determined in a previous study[16].

Data analysis

All 60 subjects completed a total of 7 days of WFR and 7 days of EFR (combination of the 4-day and 3-day records). The estimated amounts of foods consumed according to the EFR were converted to gram weights by the investigator using local tables of food portion sizes[17] and the weights of foods displayed in photos[18]. The addition of codes for each food for the EFR was performed by the investigator and, in the case of the WFR, by nutrition students previously trained by the investigator. All food consumption data (EFR and WFR) were converted to nutrient values using Central American food composition tables[19,20] and software created in Epi Info[21]. The average daily nutrient intakes for the WFR and EFR were calculated. Statistical analysis was performed using SPSS version 12.0 for Windows (SPSS Inc., Chicago, IL, USA, 2003). All nutrients with a non-normal distribution were converted to natural logarithms with the exception of vitamin A, which remained non-normal after conversion; the conversion used for this nutrient was $1/\sqrt{x}$. The converted nutrient estimates were compared using the paired Student *t*-test and the degree of association was measured by the Pearson's correlation coefficient. The within- and between-person variance was calculated for both types of record using repeated-measures analysis of variance. The coefficients of variation were calculated by expressing the standard deviation as a percentage of the mean. The intraclass correlation coefficients were calculated using the original, non-transformed nutrient intake values for WFR and EFR. Linear regression analysis was

https://doi.org/10.1017/PHN2005922 Published online by Cambridge University Press

performed for the difference* between WFR and EFR energy and nutrient estimates (WFR – EFR) as the dependent variable and sex, area of residence, age and body mass index (BMI) as independent variables. The mean consumption of food groups was compared by Wilcoxon's signed rank test and the degree of association by Spearman's correlation coefficient. The ability of both methods to similarly classify individuals into quartiles of the distributions was also examined.

Results

Study group characteristics

The characteristics of the group of subjects are presented in Table 1. There was no difference in average age and educational level of men and women. Significant differences were observed between rural and urban residents: rural residents had spent fewer years in formal education, a higher proportion of them were unskilled rather than skilled workers, and a larger percentage had a monthly income below $US 250. No association was found between being overweight (BMI $> 25\,kg\,m^{-2}$) and sex or between being overweight and area of residence (chi-square test).

Comparison of mean daily energy and nutrient intakes

Table 2 presents a comparison of the mean intakes of energy and 21 nutrients analysed for the 60 subjects using the 7-day WFR and the 7-day EFR. In the case of energy and 12 nutrients, the EFR estimates were significantly lower than those of the WFR.

The results of linear regression analysis for the effects of the independent variables sex, age, area of residence and BMI on differences between the WFR and EFR estimates for energy and nutrients showed a significant effect only in the case of area of residence for seven nutrients. Another linear regression analysis was performed, with the difference in WFR and EFR nutrient estimates as the dependent variable and area of residence as the independent variable. The results of this analysis are presented in Table 3, where it can be seen that area of residence had a significant effect on the size of the difference between WFR and EFR estimates for energy and 11 nutrients; the difference being greater in rural residents. For example, the degree of underestimation of energy intake by the EFR was 312 kcal greater among rural residents compared with urban residents.

*The distribution of differences between the WFR and EFR nutrient estimates was not significantly different from the normal distribution except for the differences corresponding to vitamins A and B_{12}. In the case of these two vitamins, the differences were converted to positive numbers by adding a constant amount to all values and then converted to their natural logarithms.

Table 1 Characteristics of the study group

Characteristic	Total	Urban	Rural
Age (years), range; mean (SD)	22–61; 44.3 (11.6)		
Number of years spent in formal education, mean (SD)	8.7 (4.1)	11.2 (3.9)	6.2 (2.6)†
Monthly income below $US 250 (%)	38.6	13.3	66.7‡
Distribution according to occupation (%)			
Unskilled workers	36.7	16.7	56.7§
Housewives	25.0	13.3	36.7
Skilled, technical or professional workers	18.3	30.0	6.7
Pensioners	18.3	36.7	0
Full-time university student	1.7	3.3	0
Overweight and obesity (%)	50.8		

SD – standard deviation.
† Significant difference between urban and rural residents (Student's *t*-test): $P < 0.001$.
‡ Significant difference between urban and rural residents (chi-square test): $P < 0.001$.
§ Significant difference in the proportion of skilled and unskilled workers in urban and rural areas (chi-square test): $P < 0.01$.

Table 4 presents the ratio of within- to between-person coefficients of variation for energy and nutrients, for the WFR and the EFR. The nutrients that presented ratios above 1 were vitamins, fats and dietary fibre. Pearson's correlation coefficients for energy and nutrients as estimated by the two methods ranged from 0.68 for polyunsaturated fats to 0.87 for calcium. The intraclass correlation coefficients were lower than the Pearson correlation coefficients in the case of 10 nutrients, and ranged from 0.56 for polyunsaturated fats to 0.90 for calcium.

Table 5 presents the number (and percentage) of subjects who were classified into the same quartile of the distribution according to the energy and nutrient intake estimates from the WFR and the EFR. The values ranged from 45.0% for polyunsaturated fats to 68.3% for vitamin B_{12}. For most of the nutrients, 0 or 1.7% were misclassified into extreme quartiles of the distribution, except in the case of vitamin C where 3.3% were misclassified.

Comparison of mean daily food group consumption

Table 6 compares the mean consumption of different food groups* as estimated by the WFR and the EFR. In the case of six food groups (chicken, processed meats, legumes, cereals, bread, sugars), the EFR estimates were significantly lower than those of the WFR. The largest mean differences were found for the cereals and legumes food groups. The Spearman correlation coefficients were significant for 16 of the 17 groups.

*Three food groups (pork meat, nuts & seeds, snacks) were not included due to a large number of zero values.

https://doi.org/10.1017/PHN2005922 Published online by Cambridge University Press

Table 2 Comparison of mean energy and nutrient intakes estimated by the weighed food record (WFR) and the estimated food record (EFR)

Nutrient	WFR Mean	WFR SD	EFR Mean	EFR SD	Difference (WFR – EFR) Mean†	Difference (WFR – EFR) SE
Energy (MJ day^{-1})	9.07	3.19	8.23	2.90	0.83***	0.22
Protein (g day^{-1})	72.2	27.05	65.1	24.10	7.1**	2.12
Carbohydrate (g day^{-1})	324.9	123.96	292.3	111.78	32.5***	8.47
Total fat (g day^{-1})	66.8	24.09	62.5	24.85	4.3	2.48
Monounsaturated fat (g day^{-1})	24.63	11.18	22.37	9.93	2.26*	1.21
Polyunsaturated fat (g day^{-1})	14.27	7.61	13.11	7.10	1.16	0.89
Saturated fat (g day^{-1})	20.54	8.20	19.19	8.45	1.35*	0.76
Cholesterol (mg day^{-1})	280	167.54	262	141.22	18	12.20
Dietary fibre (g day^{-1})	17.01	6.39	15.05	5.92	1.96**	0.56
Calcium (mg day^{-1})	689	349.28	673	345.34	16	19.97
Iron (mg day^{-1})	19.1	7.70	17.4	7.22	1.7**	0.51
Phosphorus (mg day^{-1})	1087	403.60	1000	373.24	87**	29.48
Potassium (mg day^{-1})	2429	738.39	2347	748.19	82	65.54
Magnesium (mg day^{-1})	235	76.84	217	74.18	18**	6.21
Zinc (mg day^{-1})	8.94	3.65	8.02	3.28	0.91***	0.27
Retinol equivalents (μg day^{-1})‡	1018	1178.54	903	854.49	114	71.26
Thiamin (mg day^{-1})	1.54	0.63	1.40	0.58	0.14**	0.04
Riboflavin (mg day^{-1})	1.51	0.67	1.45	0.66	0.05	0.04
Vitamin B_6 (mg day^{-1})	1.42	0.46	1.32	0.54	0.10**	0.04
Vitamin B_{12} (μg day^{-1})	5.54	9.62	5.06	7.59	0.48	0.52
Vitamin C (mg day^{-1})	127	80.91	143	96.34	−17	6.86
Folate (μg day^{-1})	340	147.81	300	117.03	40**	12.78

SD – standard deviation; SE – standard error.
Significant difference (Student's *t*-test): *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.
† Values for energy and all nutrients, except retinol equivalents, converted to natural logarithms before performing Student's *t*-test.
‡ Values converted to $1/\sqrt{x}$ before performing Student's *t*-test.

Table 7 presents the number (and percentage) of subjects classified into the same quartile of the distributions for food group consumption, according to the WFR and the EFR. The values ranged from 36.7% for soups to 71.7% for milk & milk products. For most of the food groups, 5% or less were misclassified into extreme quartiles of the distribution, except in the case of fish where 6.7% were misclassified.

Comparison of estimates of energy intake to basal metabolic rate

When the mean daily energy intake of each individual was compared with the value calculated from the equation energy intake = basal metabolic rate × 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 EFR data, 22 subjects were identified as underreporters, of whom nine lost weight during the week when the 7 days of WFR data and the first four days of the EFR data were collected. No association was found between the variable underreporting (in the WFR or the EFR) and overweight, sex or area of residence. However, those individuals who underreported with the WFR were also more likely to underreport with the EFR (chi-square test, $P < 0.001$).

Table 3 Regression analysis of the difference between energy and nutrient intakes estimated by the weighed food record (WFR) and the estimated food record (EFR) (WFR – EFR, dependent variable) and area of residence (independent variable)

WFR – EFR for:	Regression coefficient	Level of significance
Energy	312.18	0.003
Protein	12.32	0.003
Total fat	16.76	0.000
Monounsaturated fat	7.41	0.002
Polyunsaturated fat	3.98	0.025
Saturated fat	4.43	0.003
Cholesterol	51.13	0.035
Iron	2.17	0.031
Phosphorus	151.13	0.007
Magnesium	26.58	0.031
Zinc	1.10	0.043
Folate	61.37	0.015

Factors contributing to differences in mean estimates of energy and nutrient intakes

The EFR can include two types of error: it can omit foods consumed/include foods not consumed or it can register a different amount of the food consumed. To determine how much these two types of error occurred in the EFR, the data corresponding to the three days* on which both the WFR and the EFR were performed were analysed as follows:

- A comparison was made of the frequency of consumption of different foods and food groups according to the EFR and the WFR.

*The first day of the EFR was not included because the information on foods consumed on that day was collected by a 24-hour recall.

https://doi.org/10.1017/PHN2005922 Published online by Cambridge University Press

Table 4 Pearson's and intraclass correlation coefficients for energy and nutrient intakes as estimated by the weighed food record (WFR) and the estimated food record (EFR)

Nutrient	Ratio of within- to between-person variation WFR	Ratio of within- to between-person variation EFR	Pearson's correlation coefficient†	Intraclass correlation coefficient
Energy (MJ day^{-1})	0.64	0.66	0.85***	0.84***
Protein (g day^{-1})	0.77	0.80	0.80***	0.80***
Carbohydrate (g day^{-1})	0.62	0.68	0.86***	0.85***
Total fat (g day^{-1})	1.04	0.87	0.73***	0.69***
Monounsaturated fat (g day^{-1})	1.06	0.91	0.72***	0.61***
Polyunsaturated fat (g day^{-1})	1.71	1.20	0.68***	0.56***
Saturated fat (g day^{-1})	1.08	0.96	0.77***	0.75***
Cholesterol (mg day^{-1})	1.07	1.15	0.84***	0.81***
Dietary fibre (g day^{-1})	1.08	1.02	0.80***	0.75***
Calcium (mg day^{-1})	0.81	0.74	0.87***	0.90***
Iron (mg day^{-1})	0.93	0.90	0.85***	0.86***
Phosphorus (mg day^{-1})	0.72	0.71	0.84***	0.84***
Potassium (mg day^{-1})	0.92	0.91	0.76***	0.77***
Magnesium (mg day^{-1})	0.83	0.83	0.80***	0.80***
Zinc (mg day^{-1})	0.94	1.07	0.83***	0.82***
Retinol equivalents (μg day^{-1})‡	1.40	2.02	0.75***	0.86***
Thiamin (mg day^{-1})	0.76	0.84	0.82***	0.85***
Riboflavin (mg day^{-1})	1.17	1.19	0.84***	0.86***
Vitamin B_6 (mg day^{-1})	1.19	0.99	0.76***	0.77***
Vitamin B_{12} (μg day^{-1})	1.61	2.22	0.84***	0.89***
Vitamin C (mg day^{-1})	1.30	1.12	0.74***	0.82***
Folate (μg day^{-1})	0.90	0.97	0.79***	0.72***

Significant correlation: ***, $P < 0.001$.
† Values for energy and all nutrients, except retinol equivalents, converted to natural logarithms before calculating correlation coefficient.
‡ Values converted to $1/\sqrt{x}$ before calculating correlation coefficient.

Table 5 Classification of subjects in quartiles of energy and nutrient intakes as estimated by the weighed food record and the estimated food record

Nutrient	No. (%) classified into the same quartile	No. (%) misclassified into extreme quartiles
Energy	36 (60.0)	1 (1.7)
Protein	38 (63.3)	1 (1.7)
Carbohydrate	33 (55.0)	0
Total fat	31 (51.7)	1 (1.7)
Monounsaturated fats	30 (50.0)	0
Polyunsaturated fats	27 (45.0)	1 (1.7)
Saturated fat	31 (51.7)	1 (1.7)
Cholesterol	32 (53.3)	0
Dietary fibre	35 (58.3)	0
Calcium	32 (53.3)	0
Iron	33 (55.0)	0
Phosphorus	37 (61.7)	1 (1.7)
Potassium	33 (55.0)	1 (1.7)
Magnesium	37 (61.7)	1 (1.7)
Zinc	35 (58.3)	0
Retinol equivalents	34 (56.7)	1 (1.7)
Thiamin	32 (53.3)	1 (1.7)
Riboflavin	39 (65.0)	0
Vitamin B_6	34 (56.7)	1 (1.7)
Vitamin B_{12}	41 (68.3)	1 (1.7)
Vitamin C	28 (46.7)	2 (3.3)
Folate	33 (55.0)	1 (1.7)

Table 6 Food group consumption† (g day^{-1}) as estimated by the weighed food record (WFR) and the estimated food record (EFR)

Food group	Mean (SD) WFR	Mean (SD) EFR‡	Spearman's correlation coefficient
Milk & milk products	215.9 (170.7)	231.6 (192.8)	0.85***
Eggs	27.0 (26.4)	27.4 (23.9)	0.72***
Chicken (raw)	37.5 (33.1)	28.4 (29.4)**	0.57**
Beef (raw)	61.2 (48.5)	60.7 (49.9)	0.73***
Processed meats	13.5 (14.9)	10.4 (10.2)**	0.65***
Fish (raw)	18.2 (20.3)	19.0 (20.8)	0.22
Legumes (raw)	33.5 (29.2)	22.0 (18.0)***	0.79***
Beverages	519.7 (379.8)	517.2 (354.2)	0.93***
Soups	42.7 (46.9)	47.3 (53.9)	0.53***
Starchy vegetables	57.3 (38.6)	61.6 (44.4)	0.60***
Other vegetables	166.1 (84.6)	179.1 (98.5)	0.72***
Cereals (raw)	128.2 (66.1)	105.2 (62.2)***	0.79***
Bread	113.1 (73.4)	100.0 (57.6)*	0.77***
Fruit	159.6 (140.4)	166.7 (156.9)	0.75***
Sugars	72.6 (51.3)	65.7 (54.0)*	0.81***
Fat	29.7 (18.5)	26.2 (19.5)	0.42**
Cakes	18.7 (22.2)	22.2 (26.8)	0.55***

SD – standard deviation.
Significant difference or correlation: *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.
† Three food groups (nuts & seeds, pork meat, snacks) were excluded due to a large number of zero values.
‡ Wilcoxon's signed rank test.

- The difference in quantity of each food recorded by the EFR and the WFR was calculated.

The exact same foods were reported by both methods at the same mealtime on 70.8% of occasions (5735 of a total of 8105 records). Some 1137 additional foods (an average of 2.7 foods per person per day) were recorded for the EFR but not for the WFR, and 1233 (an average of 2.9 foods per person per day) were reported in the WFR but not in the

Table 7 Classification of subjects in quartiles of food group consumption† as estimated by the weighed food record and the estimated food record

Food group	No. (%) classified into the same quartile	No. (%) misclassified into extreme quartiles
Milk & milk products	43 (71.7)	0
Eggs	32 (53.3)	0
Chicken (raw)	31 (51.7)	1 (1.7)
Beef (raw)	29 (48.3)	1 (1.7)
Processed meats	33 (55.0)	3 (5.0)
Fish (raw)	27 (45.0)	4 (6.7)
Legumes (raw)	37 (61.7)	0
Beverages	40 (67.7)	0
Soups	22 (36.7)	2 (3.3)
Starchy vegetables	28 (46.7)	3 (5.0)
Other vegetables	35 (58.3)	0
Cereals (raw)	34 (56.7)	1 (1.7)
Bread	34 (56.7)	0
Fruit	32 (53.3)	1 (1.7)
Sugars	31 (51.7)	0
Fat	26 (43.3)	2 (3.3)
Cakes	30 (50.0)	2 (3.3)

† Three food groups (nuts & seeds, pork meat, snacks) were excluded due to a large number of zero values.

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EFR. In the case of nine food groups, the EFR tended to overestimate the number of times foods were consumed; for seven food groups it tended to underestimate the number of times foods were consumed; and for two food groups there was no tendency in either direction. From this finding, it can be said that no marked tendency was observed among the food groups to either under- or overestimate the number of times foods were recorded.

When the differences in quantity of each food as estimated by the EFR and the WFR were observed, there was a tendency of the EFR to underestimate amount consumed. For all foods, the EFR underestimated amount on 51.1% of occasions and overestimated amount on 42.9% of occasions. The same tendency was observed for 13 of the 18 food groups, and was more pronounced for the following food groups: processed meats, legumes, cereals, sugars and fats. Portion size of processed meats was estimated in the EFR by dimensions or number of units; sugars and fats as number of spoonfuls. The most important foods in terms of amounts eaten in the cereal and legume groups are rice and beans, respectively. The portion sizes of these foods were estimated by photographs of six portions in each case. The use of an inappropriate range of portion sizes in the photos could have caused an underestimation of amount consumed in the EFR. However, this was not the case. According to the WFR, 98.1% of values for rice consumption and 91.8% of values for bean consumption at one meal were below the maximum portion sizes displayed in the photos of these foods.

Discussion

The results of this study compare favourably with those of similar studies reported in the literature. In the studies of Bransby *et al.*[22], Edington *et al.*[23], Todd *et al.*[24], Bingham *et al.*[25] and Bonifacj *et al.*[26], an EFR was compared with a WFR. Karvetti and Knuts[27] and Crawford *et al.*[28] compared an EFR with observed intake and Nettleton *et al.*[29] compared an EFR with a semi-weighed food record.

The comparison of mean estimates of energy and nutrient intake between the two methods gave similar results to those reported by Nettleton *et al.*[29] and Karvetti and Knuts[27], where approximately half of the nutrients showed statistically significant differences. In other studies[23–25,28] fewer differences were found and in one study[26] most nutrients were significantly different. The associations between the energy and nutrient intake estimates were higher on average in this study than those reported by Bingham *et al.*[25], Edington *et al.*[23] and Bonifacj *et al.*[26], but lower than those reported by Bransby *et al.*[22], Karvetti and Knuts[27] and Crawford *et al.*[28]. The only other studies presenting the distribution in quartiles of energy and nutrient intakes were those of Bingham *et al.*[25] and Bonifacj *et al.*[26]. The present data compare favourably with those presented in these studies: the percentage of subjects correctly classified was 45–68% in this study, 37–70% in that of Bingham *et al.*[25] and 33–68% in that of Bonifacj *et al.*[26].

Bingham *et al.*[25] and Bonifacj *et al.*[26] also reported within- and between-person variation for the WFR, and in addition Bonifacj *et al.*[26] gave this information for the EFR. The present study found lower ratios of within- to between-person variation than reported by these other authors. Half of the ratios of within- to between-person variation for the WFR were less than 1 in the present study, whereas this ratio was above 1 for the majority of nutrients in the studies of Bingham *et al.*[25] and Bonifacj *et al.*[26]. A comparison of the individual coefficients of variation between the different studies showed that this difference was due to a much larger between-person variation in the present study. This is probably due to the fact that Bingham *et al.*'s study group was composed exclusively of women between 50 and 65 years of age[25]. More variation existed in Bonifacj *et al.*'s study[26]: the group consisted of 87 men and women from rural and urban areas. However, it would seem that food habits varied to a lesser extent between individuals than in the present study.

The first four days of the EFR coincided with the first four days of the WFR. While this design was chosen to permit a comparison of food consumption as estimated by both methods over the same period of time, it is possible that contamination occurred between the two methods. During data collection, every effort was made to ensure that the individual was not involved in the weighing and recording for the WFR; however, the presence of a fieldworker in the house during this period would obviously focus more attention on food consumption. When a comparison of the log-transformed average nutrient intakes as estimated by the EFR and the WFR for the same 3-day* period was made (Student's paired *t*-test), the results were similar to those of the comparison between the two 7-day periods: i.e. 13 nutrients presented statistically significant differences ($P < 0.05$). The degree of correlation (Pearson's correlation coefficient) between the log-transformed average nutrient intakes from the EFR and the WFR over the 3-day period was lower than those corresponding to the 7-day periods.

The WFR was different from the EFR in that it was performed over seven consecutive days, whereas the latter consisted of two periods of 4 days and 3 days of records. The two separate periods for the EFR was considered necessary in order to reduce the risk of losing data from subjects who might not have collaborated with recording food consumption over seven consecutive days. This was not considered a problem with the WFR as the data collection was carried out by fieldworkers.

*The first day of the EFR was not included because the information on foods consumed on that day was collected by a 24-hour recall.

https://doi.org/10.1017/PHN2005922 Published online by Cambridge University Press

Area of residence was a major contributor to differences in the mean estimates between the two methods. Rural residents presented greater differences between the EFR and WFR nutrient estimates, especially in the estimation of portion sizes of rice and beans. These are the basic staple foods in the Costa Rican diet, together providing 30.6% of total energy consumption per capita with a higher consumption in rural areas[30]. In the present study, these two foods contributed together an average of 19.1% of total energy intake (22.7% in rural areas and 14.6% among urban inhabitants). A possible reason for the underestimation of these foods in rural areas is that people are unwilling to report consuming large portion sizes, because the consumption of large amounts of these foods in combination with a low consumption of animal products could be associated with a lower socio-economic status.

The principal advantage of the EFR is that it is more accurate than methods that measure past intake[31] and, although it incurs greater error than the WFR due to estimation of amounts of foods consumed, the present study shows that the EFR is able to estimate mean energy and nutrient intakes to within 10% of the WFR values, except for vitamin C. The EFR also offers advantages in terms of fieldworker costs. In order to collect three or four days of food consumption data, the EFR requires two interviews by a fieldworker. Two 24-hour recalls would require the same fieldworker time and only collect two days of food consumption data. In Costa Rica it is not feasible for individuals to weigh their own food consumption, due to the costs of the equipment and the high degree of subject collaboration required, so a WFR has very high fieldworker costs.

One of the limitations of the EFR is that it requires more cooperation from subjects than methods which are limited to a single interview. This could produce a lower response rate. However, the degree to which individuals are motivated to participate can increase the response rate. In this study, each subject received individual dietary assessment and recommendations, and this was considered by many subjects as the factor that most motivated them to take part in the study. Even illiteracy was not an obstacle to participating and, in the few cases where the subject was illiterate, another member of the family agreed to complete their EFR for them. Another potential source of error is that subjects tend to change eating habits when keeping food records[31], particularly reducing food consumption. This has been identified as underreporting[32–34]. It was also detected in the present study and occurred in both types of food record. Although subjects were instructed to eat as normal throughout the study period, a considerable number actually lost weight during the week in which the WFR was performed. The possible reason for this is that when attention is paid to food intake, people unconsciously or consciously tend to consume less, perhaps in order to lose weight or to avoid having to record foods. It has been commented among nutritionists in Costa Rica that getting patients to keep food records helps them keep to weight-reducing diets. A partial solution to this problem would be to detect and exclude the records from those individuals who are identified as underreporters or who lose weight over the recording period. Finally, one way of reducing data processing costs and possible errors in coding of foods, and of making the task of keeping an EFR easier for individuals, is to develop a 'checklist' type of food record[25].

Conclusions

Validation of an EFR using a WFR as the reference method gave results that compare favourably with those reported by other authors, and support the use of the EFR for dietary surveys among Costa Rican adults. Greater differences in estimates of mean energy and nutrient intake were detected among subjects from rural areas, caused in part by a tendency to underestimate the amounts of rice and beans consumed. The use of additional aids is recommended in estimating portion sizes of these two foods for subjects from rural areas.

Acknowledgements

This research was made possible by the financial support provided by the Vice Rectory for Investigation of the University of Costa Rica, with additional funding by the Latin American office of UNESCO. I am grateful for the assistance provided by Dr Michael Nelson of the Department of Nutrition and Dietetics at Kings' College London, during the design and data collection stages of this project and by Dr Xinia Fernández, Dr Sandra Murillo, Dr Doris Soza, Miriam León and Ericka Méndez during the data analysis stage. My gratitude extends to the nutrition students Sylvia Chanto, Eliana Vasco, Ana Gómez and Vielka Betancourt and to all those whose willingness to provide information about their food consumption made this study possible.

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