Public Health Nutrition: 13(9), 1364–1372 doi:10.1017/S1368980009993065

Reproducibility of an FFQ validated in Spain

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Submitted 12 January 2009: Accepted 26 November 2009: First published online 28 January 2010

Abstract

Objective: To evaluate the reproducibility of a semi-quantitative FFQ used in the Seguimiento Universidad de Navarra (SUN) project.

Design: The data that were analysed were collected from an FFQ answered twice by a 326-participant subsample of the SUN project (115 men, 35·3 %; 211 women, 64·7 %), with either less than 1 year or more than 1 year between responses. The questionnaire included 136 items. Pearson correlation coefficients (r) were calculated to evaluate the magnitude of the association between both measures after energy adjustment and correcting for within-person variability. We also evaluated misclassification by quintiles distribution.

Results: The highest corrected correlations among participants who answered before 1 year were found for PUFA ($r = 0{\cdot}99$). Among participants who answered after 1 year between both questionnaires, olive oil had the highest corrected correlation ($r = 0{\cdot}99$). The highest percentage of gross misclassification, lowest quintile in FFQ1 and highest quintile in FFQ2 or highest quintile in FFQ1 and lowest quintile in FFQ2 was for cereals, fish or seafood, and *n*-3 fatty acids (7·6 %). Alcoholic drinks had the highest percentage of reasonable classification, same or adjacent quintile, in FFQ1 and FFQ2 (86·4 %).

Conclusions: Our study suggests that FFQ reproducibility is acceptable for participants who answered the same questionnaire twice less than 1 year apart. Participants who answered FFQ more than 1 year apart showed worse values on reproducibility. We consider this Spanish FFQ as an important, valid and reproducible tool in nutritional epidemiology.

Keywords
SUN project
Food frequency questionnaire
Cohort
Dietary assessment
Reproducibility

What foods we choose to consume can be one of the most important factors that influence our health. The prevalence of overweight, obesity and CVD has highly increased in the recent years and is strongly related with the type of diet[1–4]. To provide public health recommendations to prevent chronic diseases, we must first assess the food and nutrient intake of the population.

There are many methods to estimate food and nutrient intake, such as dietary records, 24 h dietary recalls, dietary history and FFQ. Some of these are very complicated and more prone to error to be self-reported by participants as a dietary record or 24 h dietary recall[5]. Epidemiological studies have commonly used the FFQ to assess usual food consumption. Although an FFQ does not have the same accuracy as a dietary record or a 24 h dietary recall, the FFQ can reasonably report intake over a large period of time and with limited resources[6], which is very important in order to study a large sample of the population.

In Spain, the Seguimiento Universidad de Navarra (SUN) project is an open-enrollment cohort with currently more than 19 000 university graduates. It studies how dietary behaviour is related to the incidence of chronic disease[7]. To evaluate dietary intake, we use an FFQ, which is included in the baseline questionnaire of the SUN project and was previously validated for the Spanish population[8]. However, the reproducibility of the FFQ has not been reported. Therefore, the aim of our study was to assess the reproducibility of the SUN FFQ.

Material and methods

Study population

The SUN project was designed in collaboration with the Harvard School of Public Health in 1998 and the methodology is similar to that used in large American cohorts

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such as the Nurses' Health Study[9] and the Health Professionals Follow-up Study[10]. The recruitment of the cohort started in December 1999 and as a dynamic prospective cohort it is permanently open. So far, the cohort consists of >19 000 university graduates. Among others, the main areas of investigation of the SUN cohort are centred on hypertension and other CVD, cancer, obesity, diabetes, depression, fertility and injuries by traffic accidents[11].

For the present analyses, we assessed 326 participants of the SUN cohort: 115 men (35·3 %) and 211 women (64·7 %). The participants completed a self-administered optically readable FFQ two times, sixty-six of them in less than 1 year and 260 of them in more than 1 year. They were not randomly selected; they were participants who answered the FFQ twice by mistake. Though our participant selection was not randomized, and therefore this represents a study limitation, relevant differences did not exist between the subsample and the whole cohort (Table 1).

We wanted to assess FFQ reproducibility and not actual changes in the diet. For this reason, we divided the sample in two groups, depending on the period of time between the answer from the first and the second questionnaires. Participants who answered within a time difference of less than 1 year were included in group 1; the mean (SD) difference was 7·06 (4·12) months, the minimum difference was for the questionnaire answered the same day and the maximum value was for questionnaires answered with 11·9 months of difference. In group 2, we included participants with a time difference greater than 1 year; the mean (SD) was 26·91 (14·84) months. The questionnaire answered with the lowest value of time difference was 12·4 months and the highest value of difference was 7 years (84·64 months).

Dietary assessment

To assess dietary exposures, we used a semi-quantitative 136-item FFQ. For each food item, a commonly used portion size was specified (slices, glass, teaspoons, etc.), and the participants were asked how often they had consumed that unit on average over the previous year. Emphasis was added to ensure that the answers were related to long-term dietary exposures and not to recent changes in diet. Nine options for frequency of consumption were offered: never or hardly ever, one to three times a month, once a week, two to four times a week, five to six times a week, once a day, two to three times a day, four to six times a day and more than six times a day. All completed questionnaires were checked by a dietitian for accuracy and completeness. In the present study, we selected only completed FFQ. In addition, particular questions regarding oil consumption used in frying, as a spread, or as salad dressing, and the type of fat used in frying were specifically assessed.

A dietitian updated the nutrient databank using the latest available information included in the food composition tables for Spain[12,13], after receiving and processing the FFQ. Nutrient intake scores were computed with an *ad hoc* computer program that was specifically developed for this purpose, by calculating it as the sum of frequency of consumption multiplied by nutrient composition of a specified portion size[14]. The selected frequency item was converted to a daily intake. For example, if a response was 5–6 times a week, it was converted to 0·78 servings per day (5·5 week/7 d).

Food groupings are specified in Table 2.

Statistical analyses

We selected only complete FFQ for the analyses (93·4 % of 347). We compared self-reported variables such as sex,

Table 1 Comparison of some values of variables from the Seguimiento Universidad de Navarra cohort (February 2008) and from reproducibility study subsample

	SUN cohort (*n* 18568)		Reproducibility study subsample (*n* 326)	
Variables	Mean	SD	Mean	SD
Women (%)	60·5		64·7	
Age (years)	38·31	12·29	35·49	13·11
Weight (kg)*	67·10	13·61	64·91	13·21
BMI† (kg/m^2)*	23·56	4·09	22·79	3·28
Underweight (BMI < 18·5 kg/m^2; %)**	3·8		5·5	
Normal weight (18·5–24·9 kg/m^2, %)**	65·8		72·1	
Overweight (25–29·9 kg/m^2, %)**	25·3		19·0	
Obese (≥30 kg/m^2, %)**	5·0		3·4	
Current smokers (%)	23·3		23·2	
Energy (kJ/d)	11 154	3883	11 738	4400
Carbohydrates (g/d)	289·13	125·80	299·10	127·04
Proteins (g/d)	119·13	45·61	123·04	39·40
Fats (g/d)	113·90	53·87	120·63	56·41
Fibre (g/d)	29·40	16·34	30·26	15·56
Alcohol (g/d)	6·96	11·24	6·20	9·40

SUN, Seguimiento Universidad de Navarra.
*P value from Student's t test <0·05.
**P value from χ^2 test <0·05.
†Classification according to the WHO.

https://doi.org/10.1017/S1368980009993065 Published online by Cambridge University Press

age, weight, BMI, smoking habit, energy and macronutrient intake and alcohol consumption from the SUN cohort and from the reproducibility study subsample, to ensure that there were no relevant differences. Weight and BMI were previously validated in a subsample of our cohort (correlation coefficient was 0·99 for weight and 0·94 for BMI)[15].

To evaluate the magnitude of the association and the comparison between the two time periods, Pearson correlation coefficients were computed between both measures in both study groups (95 % CI). Pearson correlation coefficients are presented since we analysed a sufficiently large sample, and for that reason, we assumed that the outcomes were normally distributed[16].

All foods, groups of food, drinks and nutritional variables were adjusted for total energy intake through the residual method: total energy intake was used as an independent variable in a regression model with the nutrient intake as a dependent variable. Residuals were added to the expected nutrient intake for the mean energy intake of the sample, giving, as a result, a nutrient score uncorrelated with total energy intake[17–19].

The presence of intra-individual variations tends to attenuate the correlation between the two FFQ, and for that reason, we calculated the Pearson correlation coefficients deattenuated for within-person variability[20,21] based on the adjusted values. We corrected for within-person variablility using the following formula: $r_c = r_0\sqrt{[1+(\sigma_w^2/\sigma_b^2)/n]}$, where r_c is the corrected correlation coefficient, r_0 is the observed correlation coefficient for adjusted nutrient intake, σ_w^2 is the within-person variation, σ_b^2 is the between-person variation and n is the number of replicate measurements[18].

The average of Pearson correlation coefficients for foods and drinks and for nutrients was calculated taking coefficients as a continuous variable to give a measurement of central tendency.

To compare the correlation coefficients r between the two groups (<1 year *v.* ≥1 year), an approximate variance-stabilising transformation for r (the Fisher transformation) was used. This transformation gets the outcome that the variance of the transformed coefficient is approximately constant and allows hypothesis testing using a conventional approach (unpaired t test)[22].

To assess gross misclassification, participants were categorised into quintiles of nutrient intake or food consumption according to the measures from the first and second

Table 2 Food groupings used in the reproducibility analysis assessed with the FFQ

Food group	Food items
Potatoes	Boiled or roast potatoes and French fries
High-fat dairy products	Whole milk, sweetened condensed milk, cream, milk shake, yoghurt (whole), petit-suisse cheese, curd, cream cheese or cheese wedge, old cheese (hard and semi-hard cheese, Swiss/emmental cheese and Manchego cheese), custard and ice cream
Low-fat dairy products	Semi-skimmed milk, non-fat milk, skimmed yoghurt, fresh cheese ('Burgos' cheese and goat cheese)
Eggs	(Hen) egg
Meat	Chicken or turkey with skin, chicken or turkey without skin, beef or veal meat, pork meat, lamb meat, rabbit, liver, entrails (brain, heart), hamburger, cured ham, boiled ham, meat products (mortadella salami, bologna, cured meats and cold cuts), sausages, foie-gras, pâté, blood sausage, bacon, meatballs, soft pork and sausage
Chicken, turkey and rabbit	Chicken, turkey and rabbit
Red meat	Beef or veal meat, pork meat, lamb meat, liver, entrails (brain, heart)
Meat products	Cured ham, boiled ham, meat products (bologna, cured meats and cold cuts) foie-gras, pâté, blood sausage and bacon
Fish	White fish, blue fish, cod and salad or smoked fish
Seafood	Clam, oyster, mussels, prawn, king prawn, crayfish, octopus, squid and cuttlefish
Vegetables	Spinach, Swiss chard, cabbage, cauliflower, Brussels sprouts, lettuce, endive, tomato, carrot, pumpkin, green bean, eggplant, zucchini, cucumber, peppers, asparagus, 'gazpacho' and other vegetables
Fruits	Oranges, grapefruit, tangerine, banana, apple, pear, strawberry, peach, apricot, nectarine, cherry, plum, fig, early fig/black fig, watermelon, melon, grapes, avocado, mango, papaya and kiwi
Nuts	Almonds, peanuts, hazelnuts and nuts
Legumes	Lentils, chickpeas, beans and peas
Cereals	White bread, whole-grain bread, cold breakfast cereal, rice and pasta: noodles, macaroni and spaghettis
Animal fats	Butter and lard
Vegetable fats	Margarine, olive oil, sunflower oil, corn oil and other fat or oils
Processed pastries	Industrial bakery, croissants, muffins (processed) and doughnuts
Cookies	Simple cookies and home-made pastries
Chocolate	Chocolate and chocolates
Juices	Natural orange juice, natural other fruits juices and bottled fruit and vegetable juices
Soft drinks	Sugar-sweetened soft drinks and diet soft drinks
Wine	Red wine and other types of wine
Distilled liqueurs	Whisky, gin, cognac and anisette
Alcoholic drinks	Red wine, other types of wines, beer, whisky, gin, cognac and anisette
Processed meal	Croquettes and packet soup or creamy soup
Fast food	Pizza, hamburger and sausages
Sauces	Tomato sauce and mayonnaise
Sugar, jam and honey	Sugar, jam and honey

https://doi.org/10.1017/S1368980009993065 Published online by Cambridge University Press

questionnaires. The percentage of misclassification was estimated. Data were considered as misclassified, if the difference in classification by both questionnaires was in the lowest quintile in FFQ1 and in the highest quintile in FFQ2 or the highest quintile in FFQ1 and the lowest quintile in FFQ2. We considered a reasonable classification when an item was in the same or adjacent quintile in the first and the second questionnaires[18,23,24,25].

All analyses were performed with Statistical Package for the Social Sciences statistical software package version 15·0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

The study subsample was small in comparison with the whole cohort. Subsample selection was not done randomly, which is a limitation for our study, but we considered these results as being applicable to the other participants. Data of sex, age, weight, height and smoking status were also self-reported along with the FFQ. As shown in Table 1, differences did not exist between the subsample and the whole cohort except for weight and BMI in which we observed significant differences. By comparing BMI difference classified by categories according to the WHO, we also found a statistically significant difference.

Table 3 shows Pearson correlation coefficients and corrected correlations for foods and food groups between the two FFQ stratified by time between the completion and *P* values for between-group comparisons. The foods reported less than 1 year apart and that had the highest corrected correlation values were butter and animal fats ($r = 0{\cdot}94$), vegetable fats ($r = 0{\cdot}80$), French fries ($r = 0{\cdot}72$), processed pastries ($r = 0{\cdot}70$), high-fat dairy products and meat products ($r = 0{\cdot}66$); olive oil ($r = 0{\cdot}99$), low-fat dairy products ($r = 0{\cdot}86$) and French fries ($r = 0{\cdot}74$) were among the foods with the highest corrected correlation reported after 1 year.

All the correlations for the drink items that were analysed (Table 3) were statistically significant ($P < 0{\cdot}05$). The highest corrected correlations were observed in the group with less than a 1-year period between both FFQ (group 1), for beer ($r = 0{\cdot}93$), diet soft drinks ($r = 0{\cdot}90$), alcoholic drinks ($r = 0{\cdot}89$), wine ($r = 0{\cdot}72$) and soft drinks ($r = 0{\cdot}66$).

To sum up, we observed that for foods and drinks, the average corrected correlation for questionnaires answered less than 1 year apart, was 0·56, and the values ranged from 0·22 for eggs to 0·94 for animal fats and butter. However, for questionnaires answered more than 1 year apart, the average corrected correlation was 0·48, and values ranged from 0·17 for distilled liqueurs to 0·99 for olive oil.

Table 4 presents corrected Pearson's correlation coefficients of nutrients and *P* values between groups. For the first group, noteworthy results were seen for PUFA ($r = 0{\cdot}99$), alcohol ($r = 0{\cdot}85$), caffeine ($r = 0{\cdot}80$), folic acid ($r = 0{\cdot}78$), iron ($r = 0{\cdot}77$), vitamin B_2, magnesium and vegetable fibre ($r = 0{\cdot}69$), potassium ($r = 0{\cdot}64$), and vitamin B_1 and vitamin C ($r = 0{\cdot}62$). Otherwise, the lowest values of correlation were shown for fruit fibre ($r = 0{\cdot}21$), MUFA ($r = 0{\cdot}25$), selenium ($r = 0{\cdot}24$), glycaemic load ($r = 0{\cdot}25$) and cereal fibre ($r = 0{\cdot}27$) for FFQ reported less than 1 year apart. In contrast, all the nutrients had significant correlations when reported more than a year apart. The highest values were observed for cereal fibre ($r = 0{\cdot}89$), fruit fibre (0·66), caffeine ($r = 0{\cdot}66$), magnesium ($r = 0{\cdot}65$) and PUFA ($r = 0{\cdot}64$).

To summarise Table 4, for nutrients, the average correlation was 0·53 with a range from 0·21 for fruit fibre to 0·99 for PUFA, and 0·51 with a value ranging from 0·37 for glycaemic load and vitamin E to 0·89 for cereal fibre, among the questionnaires answered less than 1 year and more than 1 year apart, respectively.

With regard to *P* values in between-group comparisons, statistically significant differences were observed for PUFA, folic acid, vitamin B_2, vitamin E, Iron, Sodium, fruit fibre, cereal fibre and alcohol.

In the misclassification analysis (Table 5), no gross misclassification was apparent for eggs, vegetables, alcoholic drinks, vitamin B_6 and folic acid in group 1 and for fruits in group 2. The highest misclassification in group 1 (<1 year apart) was observed for fish or seafood (7·6% of misclassification), cereals (7·6% of misclassification) and *n*-3 fatty acids (7·6% of misclassification). The worst values in group 2 (≥1 year apart) were for fat (4·6% of misclassification) and glycaemic load (4·6% of misclassification).

In the same or adjacent quintile, we observed the best results for alcoholic drinks (86·4%), energy (83·3%), carbohydrates (83·3%) and eggs (80·3%) for participants who answered both questionnaires in less than 1 year. For those who answered the questionnaires with more than 1 year in between, the highest proportions of participants in the same or adjacent quintile were observed for fibre (75·4%), fruits (74·2%) and folic acid (73·5%).

Discussion

Our study suggests that FFQ reproducibility might be acceptable for most nutrients and food items, supporting the finding that this FFQ is a valid tool for nutritional epidemiology. Participants were not aware that any reproducibility study was being conducted.

Our results are consistent with findings from previous European studies. An FFQ was self-administered twice to a sample of volunteers of a Mediterranean region of Spain, with a 6-week interval. The correlation values ranged from 0·60 to 0·95 (mean = 0·86) and from 0·52 to 0·94 (mean = 0·83) for Pearson's and intra-class correlation coefficients, respectively[26].

In a questionnaire carried out by the German part of the European Prospective Investigation into Cancer and

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Table 3 Pearson correlation coefficients (*r*) for foods, groups of food and drinks between the two FFQ

	Pearson correlation coefficients				Between-group comparisons	
	<1 year between FFQ1 and FFQ2, *n* 66		≥1 year between FFQ1 and FFQ2, *n* 260		*P* value between groups with time difference between FFQ1 and FFQ2, <1 and ≥1 year†	
	r adjusted‡	*r* corrected§	*r* adjusted‡	*r* corrected§	*r* adjusted‡	*r* corrected§
Foods						
Cereals	0·29*	0·29	0·27**	0·27	0·91	0·91
Chicken, turkey and rabbit	0·37**	0·44	0·40**	0·40	0·83	0·76
Chicken	0·39**	0·39	0·38**	0·38	0·94	0·94
Chocolate	0·34**	0·34	0·54**	0·60	0·08	0·007
Cookies	0·57**	0·57	0·40**	0·41	0·08	0·099
High-fat dairy products	0·66**	0·66	0·40**	0·45	0·001	0·003
Eggs	0·19 (*P* = 0·13)	0·22	0·37**	0·41	0·31	0·23
Fast food	0·54**	0·55	0·50**	0·52	0·65	0·81
Fish	0·40**	0·41	0·23**	0·23	0·30	0·26
French fries	0·53**	0·72	0·48**	0·74	0·59	0·46
Boiled or roast potatoes	0·42**	0·50	0·22**	0·31	0·21	0·15
Fruits	0·22 (*P* = 0·08)	0·27	0·61**	0·64	<0·01	<0·01
Legume	0·45**	0·45	0·36**	0·45	0·49	0·95
Meat	0·29*	0·40	0·44**	0·66	0·30	<0·01
Meat products	0·64**	0·66	0·27**	0·53	<0·01	0·03
Nuts	0·47**	0·47	0·65**	0·65	0·01	0·01
Olive oil	0·39**	0·61	0·46**	0·99	0·57	<0·01
Processed meal	0·34**	0·35	0·40**	0·40	0·67	0·70
Processed pastries	0·43**	0·70	0·56**	0·59	0·17	0·02
Red meat	0·42**	0·54	0·40**	0·42	0·87	0·26
Seafood	0·54**	0·54	0·26**	0·30	0·03	0·05
Low-fat dairy products	0·45**	0·47	0·51**	0·86	0·56	<0·01
Sugar, jam and honey	0·56**	0·60	0·56**	0·56	1·00	0·51
Vegetables	0·60**	0·61	0·43**	0·47	0·05	0·09
Whole-wheat bread	0·25*	0·25	0·30**	0·33	0·78	0·65
White bread	0·36**	0·37	0·30**	0·31	0·71	0·71
Sauces	0·47**	0·56	0·26**	0·33	0·14	0·03
Animal fats	0·94**	0·94	0·35**	0·35	<0·01	<0·01
Butter	0·94**	0·94	0·34**	0·34	<0·01	<0·01
Vegetable fats	0·63**	0·80	0·43**	0·49	0·014	<0·01
Drinks						
Alcoholic drinks	0·87**	0·89	0·59**	0·59	<0·01	<0·01
Distilled liqueurs	0·56**	0·58	0·15*	0·17	<0·01	<0·01
Beer	0·84**	0·93	0·64**	0·64	<0·01	<0·01
Juices	0·39**	0·44	0·40**	0·42	0·55	0·21
Soft drinks	0·61**	0·66	0·64**	0·64	0·01	0·21
Sugar-sweetened soft drinks	0·42**	0·48	0·35**	0·38	<0·01	<0·01
Diet soft drinks	0·90**	0·90	0·67**	0·67	<0·01	<0·01
Wine	0·71**	0·72	0·39**	0·41	<0·01	<0·01

*$P < 0·05$ for adjusted correlation coefficients.
**$P < 0·01$ for adjusted correlation coefficients.
†*P* value between groups was calculated using an approximate variance-stabilising transformation for *r* (the Fisher transformation) $\lambda = z_1 - z_2/\sqrt{(1/n_1 - 3) - (1/n_2 - 3)}$, where $z_1 = \frac{1}{2}\log[(1 + r_{c1})/(1 - r_{c1})]$ and $z_2 = \frac{1}{2}\log[(1 + r_{c2})/(1 - r_{c2})]$[22].
‡Items adjusted for total energy intake.
§Corrected for within-person variablility using the following formula: $r_c = r_0\sqrt{[1 + (\sigma_w^2/\sigma_b^2)/n]}$, where r_c is the corrected correlation coefficient, r_0 is the observed correlation coefficient for adjusted nutrient intake, σ_w^2 is the within-person variation, σ_b^2 is the between-person variation and *n* is the number of replicate measurements[18].

Nutrition study (EPIC), results on reproducibility and relative validity of measurement of food group intake were reported. The repeated administration of the FFQ to the same study subjects was carried out at a 6-month interval. Spearman test–retest correlations ranged from 0·49 for bread to 0·89 for alcoholic beverages (median = 0·70). In that study, two different versions of their FFQ were administered. Correlations were also improved by correction for attenuation due to within-person error in the reference method[27].

In another study in middle-aged Danish women, after having completed the FFQ twice at a 1-year interval, the Pearson correlation coefficients between the mean nutrient intakes from the two questionnaires ranged from 0·53 to 0·76[23].

In Finland, a sample of pregnant women completed the FFQ twice at a 1-month interval. The intra-class correlation coefficients between questionnaires ranged from 0·44 to 0·91 for foods. The correlation coefficients were highest for the items consumed daily, such as coffee (0·91), low-fat milk (0·85) and butter (0·81), and lowest for rarely eaten foods such as ice cream (0·44), oils (0·54) and low-fat spreads (0·55). The intra-class correlation coefficients for nutrients ranged from 0·42 (ethanol) to 0·72 (sucrose,

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Table 4 Pearson correlation coefficients (*r*) for nutrients between the two FFQ by group

	Pearson correlations coefficients				Between-group comparisons	
	<1 year between FFQ1 and FFQ2, *n* 66		≥1 year between FFQ1 and FFQ2, *n* 260		*P* value between groups with time difference between FFQ1 and FFQ2, <1 and ≥1 year†	
Nutrients	*r* adjusted‡	*r* corrected§	*r* adjusted‡	*r* corrected§	Adjusted‡	Corrected§
Energy	0·58 unadjusted	0·59	0·45 unadjusted	0·50	0·21	0·35
Carbohydrate	0·31*	0·31	0·37**	0·52	0·57	0·07
Protein	0·48**	0·52	0·45**	0·56	0·78	0·72
Fat	0·38**	0·57	0·37**	0·57	0·93	0·95
MUFA	0·19 ($P = 0·12$)	0·25	0·39**	0·42	0·12	0·17
PUFA	0·59**	0·99	0·38**	0·64	0·05	<0·01
SFA	0·50**	0·52	0·42**	0·42	0·47	0·38
Trans fatty acids	0·47**	0·48	0·39**	0·40	0·48	0·45
n-3 fatty acids	0·32**	0·37	0·33**	0·34	0·94	0·77
Vitamin A	0·45**	0·45	0·41**	0·44	0·73	0·93
Vitamin B_1	0·62**	0·62	0·44**	0·60	0·07	0·72
Vitamin B_3	0·44**	0·48	0·44**	0·61	1·00	0·21
Vitamin B_2	0·65**	0·69	0·47**	0·50	0·06	0·03
Vitamin B_6	0·60**	0·61	0·49**	0·53	0·26	0·41
Vitamin B_{12}	0·45**	0·48	0·40**	0·46	0·66	0·81
Vitamin C	0·57**	0·62	0·51**	0·52	0·55	0·30
Vitamin D	0·38**	0·51	0·37**	0·37	0·93	0·25
Vitamin E	0·53**	0·67	0·38**	0·44	0·18	0·01
Calcium	0·48**	0·55	0·34**	0·38	0·23	0·11
Iron	0·77**	0·77	0·43**	0·59	<0·01	0·01
Iodine	0·46**	0·46	0·42**	0·45	0·72	0·95
Potassium	0·64**	0·64	0·46**	0·60	0·06	0·65
Magnesium	0·69**	0·69	0·53**	0·65	0·06	0·59
Sodium	0·36**	0·37	0·44**	0·60	0·50	0·03
Selenium	0·20 ($P = 0·10$)	0·24	0·32**	0·38	0·36	0·26
Phosphorus	0·50**	0·51	0·48**	0·48	0·85	0·83
Zinc	0·30*	0·34	0·45**	0·47	0·21	0·27
Phytates	0·42**	0·43	0·50**	0·51	0·47	0·47
Folic acid	0·75**	0·78	0·49**	0·49	0·00	<0·01
Fruit fibre	0·20 ($P = 0·12$)	0·21	0·62**	0·66	<0·01	<0·01
Legume fibre	0·51**	0·51	0·36**	0·47	0·19	0·66
Vegetable fibre	0·60**	0·69	0·43**	0·45	0·09	0·12
Cereal fibre	0·24 ($P = 0·05$)	0·27	0·27**	0·89	0·82	<0·01
Total fibre	0·61**	0·62	0·57**	0·62	0·66	0·94
Caffeine	0·75**	0·80	0·64**	0·66	0·13	0·03
Alcohol	0·85**	0·85	0·48**	0·48	<0·01	<0·01
Glycaemic load	0·24 ($P = 0·05$)	0·25	0·26**	0·37	0·88	0·35

*$P < 0·05$ for adjusted correlation coefficients.
**$P < 0·01$ for adjusted correlation coefficients.
†*P* value between groups was calculated using an approximate variance-stabilising transformation for *r* (the Fisher transformation) $\lambda = z_1 - z_2 / \sqrt{(1/n_1 - 3) - (1/n_2 - 3)}$, where $z_1 = \frac{1}{2}\log[(1 + r_{c1})/(1 - r_{c1})]$ and $z_2 = \frac{1}{2}\log[(1 + r_{c2})/(1 - r_{c2})]$[22].
‡Items adjusted for total energy intake.
§Corrected for within-person variablility using the following formula: $r_c = r_0\sqrt{[1 + (\sigma_w^2/\sigma_b^2)/n]}$, where r_c is the corrected correlation coefficient, r_0 is the observed correlation coefficient for adjusted nutrient intake, σ_w^2 is the within-person variation, σ_b^2 is the between-person variation and *n* is the number of replicate measurements[18].

riboflavin and calcium). The average of all correlation coefficients for foods and nutrients was 0·65[28].

Similar results were shown in other worldwide studies. In the Nurses' Health Study, the average correlation coefficients between repeated questionnaires administered at an interval of about 1 year was 0·57. For 23 % of the food items, the correlation coefficient was ≥0·70, and for 73 % was ≥0·50. This level of reproducibility is comparable to that of many biological measurements that are strong predictors of disease in epidemiological studies[29].

A study from the University of Toronto suggested that an FFQ is comparable with an interviewer-administered diet history as a predictor of nutrients as estimated from a 7 d food record[30].

Similar results were shown in a North Indian population. There was good a correlation between the nutrient values as calculated by the FFQ and a 5 d diet record. The correlation for energy intake was 0·80, and for other nutrients (after adjusting for calories) varied between 0·45 and 0·68. In general, the FFQ overestimated the energy-adjusted nutrient intake by 6 %–17 %. Referring to reproducibility, after the readministration of the FFQ (3 months interval), a moderate-to-strong correlation (energy-adjusted $r = 0·49$–$0·90$) was observed between the two evaluations for various nutrients[31].

A major limitation of the present study is that the sample was not randomly chosen. We sent unintentionally twice the FFQ to potential participants (university graduates,

https://doi.org/10.1017/S1368980009993065 Published online by Cambridge University Press

Table 5 Percentage of participants at the highest levels of classification and misclassification

	Lowest quintile in FFQ1 and highest quintile in FFQ2 or FFQ1 and lowest quintile in FFQ2		In the same or adjacent quintile in FFQ1 and FFQ2	
	<1 year between FFQ1 and FFQ2	≥1 year between FFQ1 and FFQ2	<1 year between FFQ1 and FFQ2	≥1 year between FFQ1 and FFQ2
Food groups				
Dairy products	4·5	2·7	63·6	65·4
Eggs	0·0	1·9	80·3	68·1
Meat or meat products	4·5	3·1	66·7	67·7
Fish or seafood	7·6	1·9	65·2	69·6
Vegetables	0·0	1·5	74·2	69·2
Potatoes	5·3	4·3	69·7	63·7
Fruits	4·5	0·0	65·2	74·2
Total nuts	4·5	1·9	72·7	69·6
Legumes	4·5	2·7	56·1	62·3
Cereals	7·6	4·2	68·2	65·0
Olive oil	4·5	2·3	60·6	66·2
Pastries, cookies or chocolates	4·0	2·3	70·7	65·7
Fast food	3·0	1·2	72·7	71·2
Alcoholic drinks	0·0	1·2	86·4	71·9
Energy and nutrients				
Energy	3·0	1·2	83·3	72·3
Protein	3·0	2·3	71·2	67·7
Carbohydrates	1·5	4·2	83·3	68·1
Fat	1·5	4·6	54·5	65·8
SFA	1·5	3·1	72·7	68·5
MUFA	6·1	1·5	51·5	64·2
PUFA	4·5	3·1	63·6	65·4
Fibre	1·5	0·4	81·8	75·4
Glycaemic load	4·5	4·6	65·2	65·4
Vitamin C (mg)	3·0	1·5	68·2	68·5
Vitamin B_1 (mg)	1·5	1·9	77·3	74·2
Vitamin B_2 (mg)	1·5	1·5	74·2	68·5
Vitamin B_3 (mg)	3·0	1·5	71·2	70·0
Vitamin B_6 (mg)	0·0	1·9	75·8	70·4
Vitamin B_{12} (μg)	4·5	3·5	63·6	66·5
Vitamin A (IU)	1·5	2·3	77·3	70·4
Vitamin D (μg)	4·5	2·7	63·6	61·9
Vitamin E (mg)	1·5	2·3	63·6	68·1
Folic acid (μg)	0·0	0·8	80·3	73·5
n-3 fatty acids	7·6	2·7	68·2	67·7

regional associations of physicians, nurses, pharmacists, dentists and engineers). They were supposed to answer once (specified in the invitation letter), but some participants filled the questionnaire twice. This kind of selection of a reproducibility subsample could have biased the estimate of the FFQ reproducibility. If participants completed twice the questionnaire because they forgot to have already completed it, the estimate could be lowered because the memory of these participants was probably worse than that of the whole cohort. On the contrary, if these participants intentionally completed the questionnaire twice, they could be more health conscious and recall better, thus leading to an overestimation of the reproducibility[25]. However, we believe that the second possibility is less likely to have happened and the main explanation is that participants forgot that they had already answered the questionnaire.

Another limitation is the time passed between the two FFQ. Controversy does exist referring to this issue. We know that there is no perfect method. It is unrealistic to administer the FFQ at a very short interval, such as a few days or weeks, as subjects may simply tend to remember their previous responses[19]. In contrast, when a longer interval of time is used (more than 1 year), true change in dietary intake as well as variation in response contributes to reducing reproducibility. This explanation closely fit our results, which are better in the group that answered twice in less than 1 year.

As we argued in the Results section, BMI in the subsample used for our reproducibility study was significantly lower than that of the whole SUN cohort. The lower rate of obesity in the subsample could overestimate a correlation, because as is shown in other studies, under-reporting is positively associated with obesity, special diets, smoking and age[32].

Our analysis showed that Pearson's corrected correlation coefficients were lower for individual foods than for food groups. Results for whole-wheat bread and white bread showed lower values of reproducibility than the cereal group in which they are included. We observed the

https://doi.org/10.1017/S1368980009993065 Published online by Cambridge University Press

same tendency for chicken *v.* the group (chicken, turkey and rabbit), chicken *v.* meat, olive oil *v.* vegetable fats, butter *v.* animal fats, beer *v.* alcoholic drinks and sugar-sweetened soft drinks *v.* soft drinks. This might be explained by a compensatory effect. It seemed to be easier for participants to remember their intake as a whole depending on food group than for individual foods. Also, effects of underestimation and overestimation of separated foods could be compensated within the same group of foods.

Despite the results of the present study suggesting that the FFQ is appropriate for use in a particular study, it is important to be aware of the strengths and limitations of the method. To conclude, we would like to emphasise that no dietary method can measure dietary intake without error[33]. Although improvement of dietary assessment methods is a worthy pursuit, to abandon the FFQ, which is highly informative in epidemiological applications, before alternatives are shown to be superior would be unwise[34].

As there are several studies about seasonal influences in diet[35], we propose more studies to evaluate the influence of the different seasons in which the questionnaires are completed. More studies are needed to test the best way to assess diet among population subgroups.

Conclusion

Despite the fact that our participant selection was not random, relevant differences did not exist between the subsample and the whole SUN cohort and the results of the present study can be applied to the whole cohort. In conclusion, our study suggests that FFQ reproducibility might be acceptable for participants who answered the questionnaires in less than 1 year and we could consider the SUN FFQ as a useful tool for measuring diet[19].

Acknowledgements

All authors have participated in the concept and design, interpretation of data, drafting or revising of the manuscript. The authors do not have any conflict of interest. The SUN Study has received funding from the Spanish Ministry of Health (Grants PI030678, PI040233, PI070240, PI070312 and PI081943), the Navarra Regional Government (PI141/2005) and the University of Navarra. C.F.-A. and Z.V.-R. were responsible for study concept and design. C.F.-A., Z.V.-R. and M.B.-R. were responsible for acquisition and analysis of the data. M.B.-R., L.S. and M.A.M.-G. were responsible for critical revision of the manuscript for important intellectual content. All authors approved the final version of the manuscript. The authors thank all members of the SUN Study Group for administrative, technical and material support (specially to S. Benito for her tireless task of checking duplicated questionnaires). The authors also thank participants of the SUN Study for continued cooperation and participation. Finally, the authors appreciate C.N. Lopez for her editing of the English version of the article.

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