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A SEMIQUANTITATIVE FOOD FREQUENCY QUESTIONNAIRE FOR USE IN EPIDEMIOLOGIC RESEARCH AMONG THE ELDERLY: VALIDATION BY COMPARISON WITH DIETARY HISTORY

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Abstract—A self-administered semiquantitative food frequency questionnaire including 75 food items and providing information on the habitual intake of 31 nutritional parameters, based on the intake of protein, fat, carbohydrate, fiber and 11 vitamins and minerals, was developed for use in epidemiologic research on chronic disease among the elderly, such as diabetes and cardiovascular disease. By means of detailed frequency and quantity questions, specifications of types of food, preparation methods and seasonal variation, the questionnaire was expected to be an improvement on existing instruments. The relative validity of the questionnaire was examined in 74 men and women, aged 50–75, by comparison with a modified dietary history. Systematic differences were absent or negligible for all nutrients, except vitamin C. Bias depending on the level of intake could be ruled out for all but seven nutrients. Pearson correlation coefficients for estimates from the questionnaire and dietary history were on average 0.71(range: 0.65–0.78) and 0.66 (range: 0.36–0.81) for macronutrients, and vitamins and minerals, respectively. Classifying individual intake estimates into tertiles of the distribution for both methods, on average 62.4 and 54.7% of the intakes were categorized into the same tertile and 3.9 and 5.9% into the opposite tertile for macronutrients, vitamins and minerals, respectively. These results demonstrate an acceptable relative validity for this newly developed questionnaire, as compared to the dietary history method.

Diet Dietary history Epidemiologic methods Nutrition Questionnaires Validity

INTRODUCTION

There is a growing need for easily manageable instruments to quantitate relevant nutrients in the habitual diet as determinants in the etiology and prognosis of chronic diseases, such as diabetes and cardiovascular disease. For this purpose we designed a diet assessment method for use in epidemiology research among the elderly and report on its validity.

To gain insight into the quality and quantity of the diet the investigator can use either recall or record techniques. Recall techniques can be based on interview, such as 24 hour recall or

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dietary history, or on self administration, including food frequency questionnaires. Record techniques include diaries and weighed food records. The method of choice will depend on the aim of the study, the population at issue and the amount of time, money and human resources available. Recall interview methods are generally time-consuming and costly. Consequently, these assessment methods are often not suitable for use in large-scale population-based studies. With record techniques, such as diaries and food records, only a limited number of days can be taken into account and considerable time commitment is required from both subjects and investigators.

In contrast, self-administered questionnaires determining food frequency and, if possible, the amount of food products consumed are from an efficiency point of view very attractive, especially for use in epidemiologic studies. Various questionnaires have been developed and tested for validity [1]. However, most of these are food frequency questionnaires which nutritionists have considered only to be useful for limited purposes, such as cross-validation or qualitative assessment, but inadequate for making quantitative estimates of dietary intake [2]. Semiquantative food frequency questionnaires have been designed for measuring food consumption both qualitatively and quantitatively [3, 4].

We developed a semiquantative food frequency questionnaire (SFFQ) which inquired about an extensive variety of foodstuffs in order to estimate the habitual intake of nutrients among the elderly as comprehensively as possible. In SFFQs described so far, foodstuffs are indicated in terms of a particular portion size (e.g. 1 glass of milk) [5]. Consumption at irregular times and of more portions per day will demand some arithmetic work from the respondent. Our questionnaire deals with this weakness in design by splitting up the question into two parts. Firstly, the subject is asked *how often* the product is consumed and secondly, *how much* (in average household portions) of the product is consumed. These questions can be answered more easily and probably also with more accuracy. Another new feature of our questionnaire in comparison to others, is the attention paid to type of food (high/low-fat, brand names), seasonal variation and size of products, in which notable differences are often found.

In dietary research there is no assessment method available that measures the actual food intake, and which can serve as a 'gold standard' for validity studies. Consequently, in principle, *absolute* (criterion) validity cannot be measured. Therefore, the *relative* (construct) validity of the SFFQ has to be evaluated against a reference method, with a generally accepted, but unknown validity [6, 7]. In addition, the accuracy and precision of the reference method must be high and measure habitual intake, as does the SFFQ [6, 8]. Food records and 24-hour recalls do not measure the habitual intake [9, 10], unless multiple assessments are performed. The latter is, however, time consuming for both participants and investigators and was considered less feasible in the context of the present study. Moreover, 24-hour recall methods tend to measure lower mean intakes, especially in the elderly [11, 12]. The modified dietary history is an alternative reference method that measures the habitual dietary intake and can be used to study the relative validity of a SFFQ. In this case, both assessment methods estimate the usual intake. Accuracy, precision and validity of the dietary history are generally accepted [6, 13–16].

However, the use of these two methods depends on memory and it is suggested that the validity of the SFFQ relative to the dietary history can be overestimated, since measurement errors might be correlated in both methods. In general, the dietary history produces higher estimates of group mean intakes than the seven-day record method, especially if the estimated usual consumption for the dietary history has been assessed over a relatively long time period (e.g. 6 months to 1 year [17, 18]. Unfortunately, it is not possible to decide whether this difference arises from underestimation of food intake by recording, or from overestimation by the diet history, or both [19, 20]. We used a modified dietary history as the reference method, since this is probably the most accurate and feasible method in our study population to measure usual mean food intake. In a cross-over design we studied the performance of both dietary assessment methods in a Dutch population aged 50–75.

MATERIALS AND METHODS

Study design

Between January and March 1990, 200 men and women, aged 50–75, randomly selected from the population registers of Hoorn, a medium-sized town in The Netherlands, were invited to complete a SFFQ and to attend an interview.

The questionnaire was entirely self-administered and had to be returned within 2 weeks after it was received by mail. The questionnaires were checked for completeness after receipt and incomplete questions were supplemented by telephone interview. The dietary history interview was performed at the participants home by three trained interviewers (dietitians), using a modification of Burke's dietary history method with cross-check [21]. Since the completion of one method might affect the performance of the other, a cross-over method was used. One-half of the participants had to fill in the questionnaire before being interviewed; the other half was interviewed first. Both groups were comparable as far as age and sex are concerned, whereas between both food assessment methods a four-week time-interval was used.

Semiquantitative food frequency questionnaire

The SFFQ included questions on frequency and amount of intake in household measures of 75 food items. Food items contributing substantially to energy and macronutrient intake were selected on the basis of earlier research [22]. Ideally, the contribution of micronutrient intake should also have been considered. An open-ended section involved foods not referred to, but consumed on a regular basis.

Questions focused on bread consumption and filling, dairy products, mixed dishes and hot meal components, fruit, sweet and savory snacks and drinks, in that order. To prevent over-assessment, the questionnaire dealt first with less common items (e.g. buttermilk or fried potatoes) and subsequently with more common products (e.g. ordinary milk or boiled potatoes). Seasonal variation in consumption was taken into account by using separate questions for winter and summer intake of the following foodstuffs: fruits, salad/raw vegetables, buttermilk, milk, icecream, but not drinks. Detailed questions about fish and fat consumption were included to determine fatty acid intake.

The 92 questions were similar in composition and provide information about the habitual dietary intake. An example question-format is given in Fig. 1.

Subjects were asked about their usual diet and were requested to answer on the following issues: (A) *frequency of consumption.* Eleven answer-options are given: the number of days a week (1–7), once every 2 or 3 weeks, once a month, rarely or never. (B) *Mean number of portions consumed per frequency of consumption.* Answer-options are presented in average household portions (e.g. glasses of milk). Because of the variation in household measures, attempts were made to quantify the contents more accurately for a number of products by asking how many glasses/mugs, dishes/plates could be filled from 1 l. of milk, yoghurt, fruit juice, etc. (C) *Portion weights for products of which the portion sizes may differ widely.* Included are meat, fish and chicken for hot meals, etc. (D) *Type of product.* For some products more details were asked, such as high-fat/low-fat or high-fiber/low-fiber product, sort of fats used, brand names, etc. A copy of an English version of the questionnaire is available on request from the first author.

Dietary history

The interview method was more detailed than the questionnaire and consisted of two parts. Firstly, the subject was interviewed about the usual frequency and amount of food consumption. Subjects were asked to describe the foods eaten on a typical day. This was done on a meal-by-meal basis, including snacks. For each

HOW OFTEN DO YOU USUALLY DRINK:

1a) Milk in the summer?

7	6	5	4	3	2	1	
☐	☐	☐	☐	☐	☐	☐	**day(s) a week**

☐ **1 day in the 2-3 weeks** ☐ **1 day a month** ☐ **seldom or never**

b) If so, on average, how much do you drink that day? ..... glasses or mugs

c) Is this usually? ☐ **full-fat milk** ☐ **medium-fat milk** ☐ **low-fat milk**

Fig. 1. Example question of the semiquantitative food frequency questionnaire.

food item, information was collected on method of preparation, serving size and—where indicated—brand name. Secondly, a checklist including over 250 food items was used both as a cross-check and to provide further information about variation in the usual diet. The subjects were asked whether in the past month the food item in question had been consumed, and at which meal, and whether it had been taken as an extra or as an alternative. Seasonal variation in consumption was taken into account concerning the intake of fruits, salad/raw vegetables, etc. Portion sizes were quantified more accurately by measuring the contents of cups and glasses and by weighing food items such as bread and butter. This method provided a quantitative estimate of the foods typically eaten as well as some indication of the variation within the diet.

DATA ANALYSIS

The conversion from foodstuffs to energy and nutrient intakes was established with a computerized version of the Dutch Food Composition Table [23, 24] and included the following macronutrients: energy, total protein, vegetable protein, animal protein, total fat, monounsaturated fat, polyunsaturated fat, saturated fat, cholesterol, total carbohydrates, mono/disaccharides, polysaccharides, dietary fiber, alcohol. Although the SFFQ was primarily designed to measure the habitual intake of macronutrients as comprehensively as possible, vitamins and minerals were also calculated, including vitamins A, B_1, B_2, B_6, and C, nicotinic acid, and sodium, potassium, iron, calcium, phosphorous, and Ca/P ratio, respectively. Data on vitamin and mineral supplements are not included in these calculations. The nutrients are presented as mean ($\pm$SD) for both questionnaire and dietary history.

An analysis of variance was carried out to study whether the interviewers, the time order of methods and their mutual interactions influenced the estimates of energy and nutrients.

To examine the existence of systematic bias both the mean difference of nutrients between both assessment methods and the relative difference with the dietary history as reference were calculated. The 95% confidence limits of the mean difference were calculated using a t-distribution of paired observations. The Pearson correlation coefficient was used as a global measure of the degree of linear association between the two estimates.

Agreement of mean intakes from the questionnaire relative to the dietary history does not exclude the possibility of a non-constant bias, i.e. a bias which depends on the level of intake. Low intakes may be underestimated and high intakes overestimated, or vice versa, leaving the agreement of mean intakes unaffected. To examine the possibility of non-constant bias the differences between the two measurements x (= dietary history) and y (= SFFQ) for each individual [$d_i = y_i - x_i$] and the mean values [$m_i = (x_i + y_i/2]$ were computed. The association between both parameters d_i and m_i was studied by means of regression analysis [$d_i = \alpha + \beta(m_i]$, as advocated by Altman and Bland [25] and by Burema *et al.* [26].

Finally, we cross-classified the nutrient scores into tertiles to evaluate the ability of both methods to classify individuals similarly in broad categories of nutrient intake. Tertiles were defined for both assessment methods separately. The overall percentage of individuals classified into same or opposite tertiles was calculated. Within the extreme tertiles of the dietary history we also calculated the proportion of individuals classified by the questionnaire in the same or in the opposite tertiles.

RESULTS

The sample of registry consisted of 200 subjects, of whom 15 inhabitants had left town. From the 185 eligible subjects, 44 (23.8%) refused, 66 (35.7%) did not respond after the invitation and 75 (40.5%; 33 men and 42 women with a mean age of 61 years) agreed to participate. The subjects were asked about the time it took them to complete the questionnaire. However, this was not successively registered, and detailed information is not available. On average, the administration of the questionnaires required approx. 45 minutes. In other studies, the time needed to complete the questionnaire is not always reported, but varies from 15 minutes to 1 hour [1]. Half of the people had to be contacted by telephone because of incomplete data. Mostly 2 or 3 questions had been overlooked, without consequences for the mean nutrient intake, because in most cases the products were not consumed. One person who was unable to fill in the questionnaire was excluded.

No significant differences among the interviewers were observed and the results were independent of the sequence in which the two

Table 1. Daily intake of macronutrients, energy, the proportion of energy derived from these nutrients (energy %), P/S ratio, assessed by dietary history and semi-quantitative food frequency questionnaire and Pearson correlation coefficients (data based on information provided by 74 men and women aged 50–75 in Hoorn, The Netherlands, 1990)

	Questionnaire mean (± SD)	Dietary history mean (± SD)	Mean difference (95% CI)		Relative difference* (%)	r†
Total protein (g)	72 ± 19	71 ± 16	1	(−3;4)	1.0	0.69
Vegetable protein (g)	22 ± 7	23 ± 6	−2‡	(−3;1)	−6.8	0.73
Animal protein (g)	50 ± 17	49 ± 14	2	(−1;4)	3.3	0.68
Total fat (g)	94 ± 27	89 ± 29	5	(0;10)	5.7	0.70
Monounsaturated fat (g)	35 ± 11	33 ± 12	3‡	(1;5)	7.9	0.72
Polyunsaturated fat (g)	19 ± 8	17 ± 8	2‡	(1;4)	11.9	0.68
Saturated fat (g)	38 ± 12	36 ± 12	2	(−4;4)	4.5	0.73
Cholesterol (mg)	254 ± 88	256 ± 88	−2	(−19;14)	−0.8	0.68
Total carbohydrates (g)	201 ± 55	212 ± 51	−11‡	(−20;2)	−5.1	0.72
Mono/disaccharides (g)	100 ± 38	105 ± 35	−5	(−11;2)	−4.3	0.70
Polysaccharides (g)	98 ± 27	101 ± 29	−3	(−8;2)	−2.7	0.73
Dietary fiber (g)	26 ± 7	23 ± 7	3‡	(2;4)	12.5	0.70
Alcohol (g)	7 ± 10	7 ± 11	0	(−2;2)	−0.4	0.77
Energy (kJ)	8308 ± 2037	8309 ± 1900	−1	(−343;340)	0.0	0.72
Energy % protein	14.7 ± 2.8	14.6 ± 2.5	0.1	(−0.4;0.5)	0.5	0.71
Energy % fat	42.4 ± 4.5	39.7 ± 6.1	2.7‡	(1.6;3.8)	6.9	0.65
Energy % carbohydrates	40.5 ± 5.5	43.0 ± 6.2	−2.5‡	(−3.6; −1.4)	−5.8	0.67
Energy % alcohol	2.7 ± 3.4	2.7 ± 3.9	0	(−0.6;0.9)	0.5	0.78
P/S ratio	0.52 ± 0.21	0.49 ± 0.19	0.04‡	(0.01;0.07)	7.6	0.78

*100 × (questionnaire–dietary history)/(dietary history).
†Pearson's product moment correlation; all coefficients significant with $p < 0.001$.
‡Differences significant at $p < 0.05$.

methods were applied. Table 1 summarizes the results with regard to macronutrients, energy and the proportion of energy derived from those macronutrients (energy percent), and ratio between polyunsaturated and saturated fatty acids (P/S ratio), as measured by both dietary assessment methods. Table 2 presents the results regarding vitamins and minerals and the ratio between calcium and phosphorous (Ca/P ratio). Mean values are shown and standard deviations, together with the difference between the two means, expressed both absolute and relative to the dietary history mean. The 95% confidence intervals of the mean differences are close to zero for all nutrients. The point estimates of the relative difference are less than 8% for most nutrients except polyunsaturated fat (11.9%), dietary fiber (12.5%), vitamins B_1 and B_6 (10.5 and 9.9%, respectively), nicotinic acid (15.5%) and vitamin C (27.6%). The Pearson correlation coefficients are around 0.70 in most cases, with energy percent of fat, vitamin A

Table 2. Daily intake of vitamins, minerals and Ca/P ratio, assessed by dietary history and semi-quantitative food frequency questionnaire and Pearson correlation coefficients (data based on information provided by 74 men and women aged 50–75 in Hoorn, The Netherlands, 1990)

	Questionnaire mean (± SD)	Dietary history mean (± SD)	Mean difference (95% CI)		Relative difference* (%)	r†
Vitamin A (mg)	0.84 ± 0.28	0.87 ± 0.37	−0.03	(−0.11;0.06)	−4.0	0.36
Vitamin B_1 (mg)	1.07 ± 0.24	0.98 ± 0.19	0.09‡	(0.04;0.14)	10.5	0.52
Vitamin B_2 (mg)	1.65 ± 0.58	1.63 ± 0.45	0.01	(−0.09;0.11)	1.4	0.69
Vitamin B_6 (mg)	1.32 ± 0.32	1.22 ± 0.29	0.1	(0.04;0.16)	9.9	0.61
Nicotinic acid (mg)	11.4 ± 3.6	10.2 ± 3.2	1.3	(0.69;1.86)	15.5	0.73
Vitamin C (mg)	102.2 ± 48.6	85.9 ± 43.6	16.3	(8.01;24.5)	27.6	0.70
Sodium (g)	2.25 ± 1.09	2.29 ± 0.85	−0.03	(−0.21;0.04)	−0.1	0.69
Potassium (g)	3.60 ± 0.81	3.60 ± 0.67	0.008	(−0.15;0.17)	0.8	0.62
Iron (mg)	12.0 ± 2.9	11.7 ± 2.9	0.31	(−0.16;0.79)	−2.7	0.74
Calcium (g)	1.11 ± 0.46	1.15 ± 0.33	−0.04	(−0.12;0.17)	−3.8	0.75
Phosphorous (g)	1.45 ± 0.42	1.47 ± 0.31	−0.02	(−0.08;0.04)	−1.4	0.72
Ca/P ratio	0.75 ± 0.14	0.78 ± 0.12	−0.03‡	(−0.05; −0.01)	−3.5	0.81

*100 × (questionnaire–dietary history)/(dietary history).
†Pearson's product moment correlation; all coefficients significant with $p < 0.001$.
‡Differences significant at $p < 0.05$.

Table 3. Comparison of semiquantitative food frequency questionnaire scores with mean daily intakes of macronutrients derived from dietary history, based on joint classification by tertiles (data based on information provided by 74 men and women aged 50–75 in Hoorn, The Netherlands, 1990)

	Overall proportion of subjects classified		Lowest tertile on dietary history		Highest tertile on dietary history	
	into same tertile (%)	into opposite tertile (%)	Lowest tertile on questionnaire (%)	Highest tertile on questionnaire (%)	Highest tertile on questionnaire (%)	Lowest tertile on questionnaire (%)
Total protein	54.1	2.7	58.3	4.2	68.0	4.0
Vegetable protein	62.2	2.7	70.8	8.3	68.0	0.0
Animal protein	56.8	1.4	65.2	4.3	64.0	8.0
Total fat	64.9	5.4	70.8	4.2	68.0	12.0
Monounsaturated fat	59.5	4.1	68.0	4.0	64.0	8.0
Polyunsaturated fat	66.2	6.8	72.0	8.0	68.0	12.0
Saturated fat	67.6	2.7	80.0	4.0	68.0	4.0
Cholesterol	55.4	5.4	57.7	7.7	68.0	8.0
Total carbohydrates	59.5	5.4	58.3	8.3	72.0	8.0
Mono/disaccharides	62.2	5.4	66.7	4.2	72.0	4.0
Polysaccharides	64.9	5.4	71.0	8.0	68.0	8.0
Dietary fiber	55.4	2.7	70.8	8.3	56.0	0.0
Alcohol	70.3	0.0	83.3	0.0	72.0	0.0
Energy (kJ)	56.8	4.1	65.2	0.0	64.0	12.0
Energy % protein	66.2	4.1	75.0	4.2	65.4	7.7
Energy % fat	62.2	2.7	75.0	4.2	64.0	4.0
Energy % carbohydrates	54.1	9.5	58.3	16.7	60.0	12.0
Energy % alcohol	77.0	0.0	83.3	0.0	83.3	0.0
P/S ratio	70.3	4.1	72.0	4.0	76.0	8.0
Overall mean	62.4	3.9	69.6	5.4	67.8	6.3

and vitamin B_1 as extremes on the one side (0.65, 0.36 and 0.51, respectively) and energy percent of alcohol, P/S ratio and Ca/P ratio as extremes on the other (0.78, 0.78 and 0.81, respectively).

Regression analysis demonstrated that the differences between the individual pairs of intake estimates $[d_i = y_i - x_i]$ were not significantly related to the means $[m_i = (x_i + y_i)/2]$ for the majority of the macronutrients. However, low intakes were underestimated and high intakes overestimated for total protein and animal protein, and vice versa for energy percent, resulting in a regression equation: $y_i - x_i = \alpha +$

Table 4. Comparison of semiquantitative food frequency questionnaire scores with mean daily intakes of vitamins and minerals derived from dietary history, based on joint classification by tertiles (data based on information provided by 74 men and women aged 50–75 in Hoorn, The Netherlands, 1990)

	Overall proportion of subjects classified		Lowest tertile on dietary history		Highest tertile on dietary history	
	into same tertile (%)	into opposite tertile (%)	Lowest tertile on questionnaire (%)	Highest tertile on questionnaire (%)	Highest tertile on questionnaire (%)	Lowest tertile on questionnaire (%)
Vitamin A	56.8	9.5	66.7	8.3	56.0	16.0
Vitamin B_1	54.1	9.5	64.0	16.0	52.0	12.0
Vitamin B_2	59.5	8.1	66.7	4.2	60.0	20.0
Vitamin B_6	33.8	8.1	58.3	16.7	56.0	8.0
Nicotinic acid	54.4	2.7	58.3	8.3	68.0	4.0
Vitamin C	58.1	2.7	64.0	4.0	68.0	4.0
Sodium	39.2	4.1	62.5	12.5	68.0	0.0
Potassium	58.1	9.5	62.5	16.7	60.0	12.0
Iron	59.5	5.4	66.7	8.3	64.0	8.0
Calcium	67.6	2.7	75.0	4.2	72.0	4.0
Phosphorous	55.4	6.8	54.2	4.2	68.0	16.0
Ca/P ratio	59.5	1.2	64.0	0.0	72.0	4.0
Overall mean	54.7	5.9	63.6	8.6	63.7	9.0

$\beta(x_i + y_i)/2$, in which β (with 95% confidence interval) was equal to 0.23 (0.3; 0.43), 0.25 (0.05; 0.45) and -0.37 (-0.58; -0.16), respectively. Non constant bias was also found for three minerals and one vitamin where low intakes were underestimated and high intakes overestimated (calcium, phosphorous, sodium and vitamin B_1), in which β (95% CI) was equal to 0.36 (0.19; 0.54), 0.32 (0.18; 0.51), 0.30 (0.10; 0.50) and 0.27 (0.04; 0.51), respectively, and vice versa for vitamin A (β (95% CI): -0.43 (-0.74; -0.12).

The results of the comparison of macronutrients, and vitamins and minerals based on the classification in tertiles for both assessment methods separately, are shown in Table 3 and 4, respectively. To evaluate the identical classification and gross misclassification of nutrient intakes for both methods, the overall percentage of individuals in the same and in the opposite tertile were calculated (Table 3 and 4, first two columns). On average 62.4% of the individuals were grouped into the same tertiles for macronutrients, ranging from 54.1% for total protein to 77.0% for energy percent of alcohol. For vitamins and minerals, 54.7% of the subjects were grouped into the same tertiles, varying from 33.8% for vitamin B_6 to 67.6% for calcium. Gross misclassification (the percentage of individuals in the opposite thirds) for macronutrients, and vitamins and minerals was 3.9 and 5.9% on average, respectively.

Within the extreme tertiles of the dietary history we evaluated the proportion of individuals ranked by the questionnaire in the same or in the opposite tertile (Table 3 and 4, last four columns).

The proportion of individuals belonging to the lower tertile on the basis of the dietary history, and classified by the questionnaire into the lower or upper tertile, was on average 69.6% (Table 3 column 3, range: 58.3–83.3) and 5.4% (Table 3 column 4, range: 0–16.7), respectively, for macronutrients, and 63.6% (Table 4 column 3, range: 54.2–75) and 8.6% (Table 4 column 4, range: 0–16.7), respectively, for vitamins and minerals.

The proportion of individuals belonging to the upper tertile of the dietary history distribution and classified into the upper or lower tertile by the questionnaire was on average 67.8% (Table 3 column 5, range: 64–83.3) and 6.3% (Table 3 column 6, range: 0–12), respectively, for macronutrients, and 63.7% (Table 4 column 5, range: 52–72) and 9.0% (Table 4 column 6, range: 0–20), respectively, for vitamins and minerals.

DISCUSSION

In a cross-over design we compared the results of a newly developed self-administered semiquantitative food frequency questionnaire and a dietary history method in a population of 74 elderly Dutch people aged 50–75, randomly selected from the registry of a medium-sized Dutch town. The low response rate (41%) does not threaten the internal validity of our study, since we compared two different dietary assessment methods and did not aim at assessing the distribution of intake levels in the population as a whole. However, our respondents may compare favourably with other populations with regard to interest in dietary issues and, therefore, with respect to accuracy of food consumption reports and, consequently, the degree of inter method correspondence. This latter problem is probably also present in other validity studies for methods of dietary assessment, since their study populations are selected from initially on-going cohort studies [5, 27] or preselected subjects visiting a Medical Center [28–30].

Several studies have compared a self-administered SFFQ with a dietary history method. Browe *et al.* [28] compared 18 macronutrient intakes of a self-administered diet questionnaire with a Burke dietary history on 29 men involved in a cardiovascular study. Jain *et al.* [29] observed in 50 females, attending a breast cancer centre, the intake of 11 macronutrients and vitamin C by means of a questionnaire on 69 items and a detailed dietary history. Sorenson *et al.* [31] compared the intake of energy and 8 macronutrients and 10 micronutrients, obtained with a 24-hour recall, a 2-day record method, a modified dietary history and a quantitative food frequency questionnaire in 50 men and women. Brow *et al.* [28] did not report mean estimates or differences in mean intakes. Jain *et al.* [29] reported that the mean estimates of the questionnaire compared to the interview were significantly higher for total energy, total and saturated fat, oleic and linoleic acid, and significantly lower for crude and dietary fiber. Sorenson *et al.* [31] found higher mean estimates for all nutrients measured in the questionnaire compared to the dietary history, with significant differences for total energy, saturated and polyunsaturated fatty acids, crude fiber, calcium, phosphorous, potassium, vitamins A, B_2 and C. None of the authors calculated the mean or relative differences, but reported on statistical significance of differences between the two assessment methods only. However, not statistical significance *per se*, but the 95% confidence intervals of the mean differences and the magnitude of the relative differences are most informative regarding systematic bias. In our study the 95% confidence intervals of the mean differences are close to zero for all nutrients, except for vitamin C, and the relative differences were small and less than 8% for most nutrients.

In comparing different dietary assessment methods one often finds that one method systematically over- or underestimates mean intake compared with another method [13, 32]. Epstein [33] reported that mean intakes calculated from a dietary questionnaire tended to be lower than those derived from the Burke interview. Other studies found that a questionnaire gives higher mean intakes than dietary history [29, 31]. Such is not the case in our study. With regard to macronutrients the mean intake of protein estimated by the questionnaire is almost equal to the intake estimated by the dietary history; the mean intake of fat is estimated somewhat higher by the questionnaire than by the dietary history, whereas for carbohydrates the reverse applies. The mean estimates of minerals are systematically, but slightly lower in the questionnaire compared to the history, ranging from −0.11 to −3.8%. Regarding the mean intake of vitamins estimated by the questionnaire, there was no systematic over or underestimation compared to the dietary history.

The Pearson correlation coefficient, widely used in nutritional research, although notoriously difficult to interpret [34], can serve as a global measure of linear association. We compared the correlation coefficients for nutrients found in this study with those of other studies, using a dietary history as reference method. With regard to macronutrients, our results are similar to those of Browe *et al.* [28], and better than those of Jain *et al.* [29] and Sorenson *et al.* [31], who found values between 0.47 and 0.72 and between 0.24 and 0.56, respectively. Results on micronutrients were reported by Sorenson *et al.* [31] only, and the correlations appeared to be lower, (0.23–0.56) as compared to our results (0.36–0.81). Others have used diet records or 24-hour recalls as reference method [5, 27, 30, 35, 36]. Differences in validation methods, study populations and distribution of nutrients among these populations makes mutual comparison rather difficult. The mean correlation coefficients we observed for both macronutrients, and vitamins and minerals were 0.71 and 0.66, respectively. The other studies [5, 27, 30, 35, 36] reported substantially lower mean correlation coefficients for macro and micronutrients, ranging from 0.37 to 0.57 and 0.30 to 0.52, respectively.

Since no real 'gold standard' is available, and formal (criterion) validity cannot be measured, our data provide information on relative (construct) validity by comparing the SFFQ with the dietary history as reference method. Although the SFFQ and dietary history are both recall techniques, the assessment methods differ substantially, as indicated in the method section. In addition, the validity of the dietary history is generally accepted [6, 7], and it is therefore obvious that this study is not only a reliability study. As applies to any validation method in the absence of a real 'gold standard', good agreement does not necessarily indicate (criterion) validity, and may also be due to similarity of measurement errors. A possible similarity in measurement error is that the estimation of nutrients depends on memory, consequently enhancing the degree of agreement between both assessment methods. On the other hand, poor agreement may suggest that at least one of the dietary methods is less valid. As the precision and validity of the dietary history are generally accepted, our analysis indicates satisfactorily relative validity, and compares favourably to other food-frequency questionnaire validation studies [28–31]. Probably, the design of the questionnaire has contributed to its relative validity as well.

The good agreement we found does not exclude the possibility of a non-constant bias, i.e. a bias that depends on the level of intake. Others [1] have presented the so-called 'flat slope syndrome' as an example: the phenomenon of one dietary assessment method providing an overestimation of low intakes and an underestimation of high intakes, both relative to one another, supposedly more valid assessment method. However, as several authors have pointed out [37, 38], the 'flat slope syndrome' may very well be explained by the random measurement error which must be regarded considerable, even in the best dietary assessment methods available. If a regression analysis is carried out for one intake estimate, y, as function of another, x, the random error in x inevitably results in an underestimation of the slope β of the regression line of y on x in comparison with the real functional relationship, analogous to the well-known statistical phenomenon of 'regression to the mean' [39]. In our study, this phenomenon manifested itself most clearly. Expressing the questionnaire estimate y as a linear function of the dietary history estimate x, we found that the 95% confidence interval of the regression coefficient of y on x was situated between 0 and 1 for 28 out of the total of 31 nutritional parameters (data not shown). This systematic flatness of the regression lines of y on x, however, was not at all reflected by the results of the regression analysis with $[d_i = y_i - x_i]$ as the dependent and $[m_i = (x + y_i)/2]$ as the independent variable. In this second regression analysis, the slope of the regression line is not distorted by the statistical phenomenon 'regression to the mean'. Therefore, a slope differing significantly from 0 suggests a real relation between intake level on the one side and magnitude of bias on the other [26]. Such a statistically significant non-zero β was only found for three macronutrients, three minerals and two vitamins in our analysis. In six of them the direction of the regression line was opposite to what would be expected on the basis of the 'flat slope' of y on $x[m]$. So, in our data the 'flat slopes' of the regression lines of y on x turned out to be due to random error in the measurement of x in 26 out of 28 nutrients. The non-constant bias does not threaten the qualitative study of the relation between nutrition and the etiology or prognosis of chronic disease. It may, however, bias the quantitative study of risk increase per unit nutrient intake. Still, on balance, our analysis suggests that the semiquantitative food frequency questionnaire performs quite satisfactorily as far as relative validity is concerned.

The degree of agreement with respect to classification into percentiles (tertiles or quintiles) offers another possibility to compare our results with those of other studies. This approach is not free from interpretational difficulties either, because the division into percentiles depends strongly on the distribution of real intake levels in the study population. Consequently, it is not clear how a certain degree of misclassification in percentiles could be translated into the amount of measurement error on a quantitative scale of nutrient intake. Only Jain *et al.* [29], who compared their questionnaire with a dietary history, used the method of classifying individuals into tertiles of low, medium and high nutrient intake for both methods. They reported that on average 56% of the subjects were assigned to the same tertile, and that 4–14% were misclassified. Our questionnaire shows substantially higher percentages of agreement, except for animal protein and cholesterol, and correspondingly lower percentages of gross misclassification. More detailed information about the ability of the questionnaire to classify individuals is provided by the calculation of the proportion of individuals correctly and incorrectly classified by the questionnaire for both extreme tertiles of the dietary history. The literature reports this analysis of misclassification only for quintiles of the distribution [5, 27, 30, 36]. For purely statistical reasons, it could be expected that the percentages of individuals ranked incorrectly by the questionnaire would be less favourable for our tertile approach than for quintile ranking. This was hardly the case, however, which provides additional support for the good performance of our questionnaire.

In conclusion, the good agreement of mean intake of nutrients and high correlation coefficients between the estimates of the newly developed self-administered semiquantitative questionnaire and the dietary history method, the absence of non-constant bias for most nutrients and the ability of the questionnaire to classify individuals adequately into broad categories, demonstrates an acceptable relative validity.

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REFERENCES

1. Bingham SA. The dietary assessment of individuals; methods, accuracy, new techniques and recommendations. **Nut Abs Rev** (Series A) 1987; 57: 705–742.
2. Abramson JH, Slome C, Kosovsky C. Food frequency interview as an epidemiological tool. **Am J Publ Health** 1963; 53: 1093–1101.
3. Flegal KM, Larkin FA. Partitioning macronutrient intake estimates from a food frequency questionnaire. **Am J Epidemiol** 1990; 131: 1046–1058.
4. Chu SY, Kolonel LN, Hankin JH, *et al.* A comparison of frequency and quantitative dietary methods for epidemiologic studies of diet and disease. **Am J Epidemiol** 1984; 119: 323–334.
5. Willett WC, Sampson L, Stampfer MJ, *et al.* Reproducibility and validity of a semiquantitative food frequency questionnaire. **Am J Epidemiol** 1985; 122: 51–65.
6. Gibson RS. Validity in dietary assessment: a review. **J Can Diet Assoc** 1990; 51: 275–280.

7. Lee-Han H, McGuire V and Boyd NF. A review of the methods used by studies of dietary measurement. **J Clin Epidemiol** 1989; 42: 269–279.
8. Block D. A review of validations of assessment methods. **Am J Epidemiol** 1982; 115: 492–505.
9. Potosky AL, Block G and Hartman AM. The apparent validity of diet-record days used for comparison. **J AM Diet Assoc** 1990; 90: 810–813.
10. Rimm EB, Giovannucci EL, Stapfer MJ, *et al.* Authors' response to "invited limitations of semiquantitative food frequency questionnaires". **Am J Epidemiol** 1992; 135: 1133–1136.
11. Madden JP, Goodman SJ , Guthrie HA. Validity of the 24-hr recall: analysis of data obtained from elderly subjects. **J Am Diet Assoc** 1976; 68: 143–155.
12. Campbell VA, Dodds ML. Collecting dietary information from groups of older people. **J Am Diet Assoc** 1967; 51: 29–33.
13. Morgan RW, Jain M, Miller AB, *et al.* A comparison of dietary methods in epidemiologic studies. **Am J Epidemiol** 1978; 107: 488–498.
14. Van Beresteyn ECH, Van 't Hof MA, Van der Heiden-Winkeldermaat HJ, *et al.* Evaluation of the usefulness of the cross-check dietary history method in longitudinal studies. **J Chron Dis** 1987; 40: 1051–1058.
15. Hartman AM, Brown CC, Palmgren J, *et al.* Variability in nutrient and food intakes among older middle-aged men. **Am J Epidemiol** 1990; 132: 999–1012.
16. Van Staveren WA, De Boer JO, Burema J. Validity and reproducibility of a dietary history method estimating the usual food intake during one month. **Am J Clin Nutr** 1985; 42: 554–559.
17. Young CM, Hagan GC, Turner RE. A comparison of dietary study methods. II. Dietary history vs seven-days record vs 24-hr recall. **J Am Diet Assoc** 1952; 28: 218–221.
18. Jain MG, Howe GR, Johnson KC, *et al.* Evaluation of a diet history questionnaire for epidemiologic studies. **Am J Epidemiol** 1980; 111: 212–219.
19. Borrelli R. Collection of food intake data: a reappraisal of criteria for judging methods. **Br J Nutr** 1990; 63: 411–417.
20. Mathalko JR, Johnson LK, Gallaher SK, *et al.* Comparison of dietary histories and seven-day food records in a nutritional assessment of older adults. **Am J Clin Nutr** 1985; 42: 542–553.
21. Burke BS. The dietary history as a tool in research. **J Am Diet Assoc** 1947; 23: 1041–1046.
22. Löwik MRH, Westenbrink S, Hulshof KFAM, Kistemaker C, Hermus RJJ. Nutrition and aging: dietary intake of 'apparently healthy elderly'. **J Am Coll Nutr** 1989; 8: 347–356.
23. **NEVO Tabel: Dutch Food Composition Table 1989/1990**. The Hague (NL): Voorlichtingsbureau voor de Voeding 1989.
24. Kistemaker C, Wedel M. VEVES: Geautomatiseerd systeem voor de verwerking van voedingsenquêtes (Computerized system for processing diet questionnaires) deel 1, 2 and 3. TNO Voeding; rapportnummer 88.194, 88.303, 88.302. Zeist (NL) 1988.
25. Altman DG, Bland JM. Measurement in medicine: the analysis of method comparison studies. **The Statistician** 1983; 32: 307–317.
26. Burema J, Van Staveren WA, Van den Brandt PA. Validity and reproducibility. In: Cameron ME, Van Staveren WA, eds. **Manual on Methodology for Food Consumption Studies**. New York: Oxford Univ. Press; 1988: 171–181.
27. Rimm EB, Giovannucci EL, Stampfer MJ, *et al.* Reproducibility and validity of an expanded self-administered semiquantitative food frequency questionnaire among male health professionals. **Am J Epidemiol** 1992; 135: 1114–1126.
28. Browe JH, Gofstein RM, Morlley DM, *et al.* Diet and heart disease study in the cardiovascular health center. **J Am Diet Assoc** 1966; 48: 95–100.
29. Jain MG, Harrison L, Howe GR *et al.* Evaluation of a self-administered dietary questionnaire for use in a cohort study. **Am J Clin Nutr** 1982; 36: 931–935.
30. Pietinen P, Hartman AM, Haapa E, *et al.* Reproducibility and validity of dietary assessment instruments. **Am J Epidemiol** 1988; 128: 655–666.
31. Sorenson AW, Calkins BM, Connolly MA, *et al.* Comparison of nutrient intake determined by four dietary intake instruments. **J Nutr Education** 1985; 17: 92–99.
32. Karvetti RL, Knuts LR. Agreement between dietary interviews. **J Am Diet Assoc** 1981; 79: 654–659.
33. Epstein LM, Reshef A, Abrahamon JH. Validity of a short dietary questionnaire. **Isr J Med Science** 1970; 6: 589–597.
34. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. **The Lancet** 1986; 1: 307–310.
35. Block G, Woods M, Potosky, *et al.* Validation of a self-administered diet history using multiple diet records. **J Clin Epidemiol** 1990; 43: 1326–1335.
36. Tjonneland A, Overvad K, Haraldsdóttir J, *et al.* Validation of a semiquantitative food frequency questionnaire developed in Denmark. **Int J Epidemiol** 1991; 20: 906–912.
37. Gibson RS. Sources of error and variability in dietary assessment methods: a review. **J Can Diet Assoc** 1987; 48: 15–155.
38. Freedman LS, Carroll RJ, Wax Y. Estimating the relation between dietary intake obtained from a food frequency questionnaire and true average intake. **Am J Epidemiol** 1991; 134: 310–320.
39. Snedecor GW, Cochran WG. **Statistical Methods**. Ames, Iowa: Iowa State Univ. Press; 1980: 172.