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REPRODUCIBILITY AND VALIDITY OF DIETARY ASSESSMENT INSTRUMENTS

II. A QUALITATIVE FOOD FREQUENCY QUESTIONNAIRE

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Pietinen, P. (National Public Health Institute, SF-00280 Helsinki, Finland), A. M. Hartman, E. Haapa, L. Räsänen, J. Haapakoski, J. Palmgren, D. Albanes, J. Virtamo, and J. K. Huttunen. Reproducibility and validity of dietary assessment instruments. II. A qualitative food frequency questionnaire. *Am J Epidemiol* 1988;128:667–76.

The reproducibility and validity of a food frequency questionnaire designed to measure intakes of total fat, saturated and polyunsaturated fats, vitamins A, C, and E, selenium, and dietary fiber were tested from March to October 1984 among 297 Finnish men aged 55–69 years. The questionnaire asked about consumption of 44 food items. In the reproducibility study, 107 subjects filled in the questionnaire three times, at three-month intervals. Intraclass correlations varied from 0.52 for vitamin A to 0.85 for polyunsaturated fat. In the validity study, 190 subjects kept food consumption records for 12 two-day periods distributed evenly over a period of six months and filled in the questionnaire both before and after this period. Correlations between the nutrient intake values from the food records and those from the food frequency questionnaires ranged from 0.33 for selenium to 0.68 for polyunsaturated fat. On the average, 40–45% of the subjects in the lowest and highest quintiles based on food records were in the same respective quintiles when assessed by the food frequency questionnaire, and 70–75% were in the two lowest and two highest questionnaire quintiles, respectively. The food frequency questionnaire and a quantitative food use questionnaire tested in the same study were compared. Use of these two instruments in large-scale epidemiologic studies is discussed.

diet; dietary fiber; nutrition surveys; selenium; vitamin E

Food frequency questionnaires that can either be mailed to participants or be administered by lay interviewers (1) have been widely used in studies dealing with the relation between diet and cancer (2–4). The reproducibility of such questionnaires is fairly good (5–8), and the validity is acceptable when frequencies or group means of estimated intakes of different food items or food groups are compared (6, 9–11). On the other hand, nutrient intakes are difficult to assess with these instruments, and at-

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tempts to develop vitamin intake scores based on food frequencies have varied in success (8, 12–14).

A food frequency questionnaire was developed for monitoring major changes in the diets of approximately 27,000 middle-aged Finnish men participating in a randomized beta-carotene, alpha-tocopherol (vitamin E) lung cancer intervention trial (15). At the beginning of the trial, a detailed evaluation of dietary intake was obtained by means of a quantitative food use questionnaire described in the accompanying paper (16). The food frequency questionnaire was administered at baseline and will be repeated once every three years. The questionnaire was designed to measure the intakes of total fat, saturated and polyunsaturated fats, vitamins A, C, and E, selenium, and dietary fiber. The goal was to rank the subjects into quintiles of the relevant nutrient distributions rather than to measure absolute intake levels.

Reproducibility and validity of both the food frequency questionnaire and the food use questionnaire were tested together in a pilot study among middle-aged men living in Helsinki. This paper describes our experience with the food frequency questionnaire and briefly compares these results to those obtained with the food use questionnaire. A detailed analysis of the food use questionnaire is given in the companion paper (16).

Materials and methods

Study design and subjects

One hundred nineteen men were enrolled in the reproducibility study of the food frequency questionnaire. Of these, 107 repeated the questionnaire three times during a six-month period from March to October 1984. Twelve subjects were excluded because of missing forms ($n = 7$) or major changes in diet ($n = 5$).

A different group of 217 men were enrolled in the validity study. They filled in both the food use questionnaire and the food frequency questionnaire three weeks apart, at the beginning and the end of the same six-month period. Validity was tested against food consumption records kept by the same men for 24 days (12 records for two consecutive days each) spread evenly over this six-month period. Twenty-seven men were excluded because of incomplete forms ($n = 12$), major changes in diet ($n = 9$), inability or unwillingness to cooperate ($n = 5$), or other reasons ($n = 1$).

The characteristics of the men included in the analysis of this paper are given in the companion paper (16).

Food frequency questionnaire

The purpose of the food frequency questionnaire was to assess the habitual consumption of a selected list of foods during the previous 12-month period. The list of food items included in the questionnaire was based on information derived from previous studies on major sources of the nutrients of interest in the Finnish diet (17). Food items with a high content of these nutrients were included even though they were not considered a major source of the nutrients in the general population. The final questionnaire included 44 food items. Questions asked about quality and daily consumption of milk, sour milk, coffee, tea, bread, and butter or margarine. Questions on frequency of consumption of all the other food items (table 1) included the following possible responses: more often than once per day, daily, almost daily, several times per week, once per week, once or twice per month, and less frequently than that or never. The subjects were asked to circle the number that indicated their response.

An average portion size for calculation of nutrient intakes was assumed (18), and the daily intakes of nutrients were computed as described in the companion article (16). These analyses were limited to total fat, saturated fat, polyunsaturated fat, vitamins A, C, and E, selenium, and fiber. Energy intake, the percentages of energy derived from protein, fat, and carbohydrate, and the ratio of polyunsaturated to saturated fat are also reported to show the overall intake levels.

Statistical analysis

On the food item level, the percentage of subjects falling within the same frequency category or within one frequency category on subsequent administrations of the food frequency questionnaire was computed for each food item. On the nutrient intake level, the reproducibility and validity of data were evaluated by the methods described in the companion paper (16). These methods included calculation of means, standard deviations, product-moment correlations, and intraclass correlations, as well as classification into quintiles of the nutrient intake distributions.

In addition, comparison was made between the ability of the food use questionnaire and the food frequency questionnaire to explain variation in nutrient intake. Intake values from the two questionnaires were correlated. The square of this correlation coefficient measures the proportion of the variation in intake from the food use questionnaire that was captured by the food frequency questionnaire. To relate the comparison of the two questionnaires to intake values from the food records, we computed partial correlation coefficients between intake values from the food records and one of the questionnaires while controlling for values obtained from the other questionnaire. These partial correlations indicate whether one of the questionnaires could explain additional variation in food record intake that was not captured by the questionnaire that was controlled for.

RESULTS

Reproducibility

The reproducibility of the frequency categories chosen by the subjects was analyzed by examining the agreement among the three administrations of the food frequency questionnaire. On the average, the level of exact agreement in the reported frequency of consumption was 36 per cent (table 1). When the adjacent category was also included, the level of agreement for all three pairwise comparisons was, on the average, 76 per cent. The agreement was generally best for foods eaten infrequently, such as kidney and liver dishes, wheat bran, and

TABLE 1

Proportion of subjects falling into the same frequency category on all three food frequency questionnaires and into the same or an adjacent frequency category for all three pairwise comparisons (n = 107): Helsinki Diet Methodology Study, 1984

Food item	Exact agreement between frequency categories (%)	Agreement within one frequency category (%)
Cabbage	11	42
Citrus not in season	19	57
Sausages	22	57
Carrots	21	50
Cooked mixed vegetables	23	64
Berries in season	21	69
Cucumbers not in season	21	68
Citrus fruits in January–April	25	76
Cucumbers in summer	28	70
Meat stews	26	81
Tomatoes not in season	28	70
Apples not in season	28	71
Sausage dishes	30	77
Pickled fish or herring	31	77
Apples in the fall	36	62
Coffee bread, etc.	33	68
Cheese	30	79
Eggs and omelettes	31	82
Berries not in season	35	76
Juice	37	68
Steaks, chops, and roast beef	35	84
Porridges and gruels	37	77
Sweet pepper	36	75
Tomatoes in summer	37	76
Cabbage dishes	35	93
Meat, pea, and sausage soups	41	87
Liver sausage	43	78
Ground meat dishes	40	84
Fish dishes	42	84
Turnips or rutabagas	45	75
Mushroom dishes	43	89
Liver dishes	46	89
Potatoes	52	90
Chicken dishes	52	93
Wheat bran	71	86
Kidney dishes	76	97
Wheat germ	86	92

wheat germ, and for everyday foods such as potatoes. The level of agreement was lowest for vegetables, fruits, and berries.

There were no significant differences in the mean nutrient intake values among the three repeated measurements (table 2). Pearson correlations between pairwise measurements of the selected nutrients ranged from 0.48 to 0.86, and intraclass correlations ranged from 0.52 to 0.85, both being lowest for vitamin A and highest for polyunsaturated fat.

Validity

Although the food frequency questionnaire was primarily meant to rank the subjects according to their nutrient intake values, it is interesting to compare the absolute nutrient intake levels with those based on the food records (table 3). Only about two thirds of the intakes of energy, total fat, and saturated fat were measured by the food frequency method, whereas nearly 100 per cent of the intakes of vitamins A and C and dietary fiber were measured by this method. The intake levels of polyunsaturated fat, vitamin E, and selenium based on the food frequency method were approximately 70–80 per cent of the intake levels based on food records.

Unadjusted correlation coefficients between the nutrient intake values based on the food records and those based on the food frequency questionnaire varied from 0.33 to 0.68, being lowest for selenium and highest for polyunsaturated fat (table 4). Adjustment for total energy intake improved the correlations slightly except those for vitamin A and dietary fiber. Correction for attenuation improved the correlations only marginally, because the reproducibility for most nutrients was already high.

Quintile categorization of relevant nutrient distributions was used in the cross-classification of subjects on the basis of both food frequency questionnaires and food records. On the average, 72 per cent of the subjects when classified by the food records fell into the same quintile or into the within-one-quintile category when classified by the first food frequency questionnaire (table 5). Of those subjects belonging to the lowest quintile according to food records, on the average, 41 per cent fell into the same quintile and 68 per cent fell into

TABLE 2

Mean daily intake of selected nutrients and intraclass correlations from the food frequency questionnaire reproducibility sample (n = 107): Helsinki Diet Methodology Study, 1984

Nutrient	First measurement		Second measurement		Third measurement		Intraclass correlation*
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	
Total fat (g)	75.0	28.6	75.2	26.5	75.5	24.2	0.78
Saturated fat (g)	36.9	16.3	37.1	15.5	37.7	14.3	0.82
Polyunsaturated fat (g)	10.8	5.5	10.8	5.4	10.6	5.4	0.85
Vitamin A (retinol equivalents) (μg)	1,204	654	1,168	703	1,117	573	0.52
Vitamin C (mg)	122	52	120	56	114	56	0.74
Vitamin E (mg)	6.7	2.8	6.9	2.9	6.6	2.7	0.81
Selenium (μg)	35.4	15.7	37.0	15.8	34.5	13.2	0.67
Dietary fiber (g)	21.6	8.8	21.6	8.3	21.7	8.5	0.67
Energy (kcal)	1,666	530	1,678	503	1,656	472	0.76
Protein, % energy	17.6	2.6	17.5	1.9	17.2	2.2	0.63
Fat, % energy	40.2	5.8	40.2	5.4	40.9	5.1	0.75
Carbohydrate, % energy	42.2	6.4	42.3	5.6	41.9	5.2	0.67
P/S ratio†	0.33	0.20	0.34	0.22	0.32	0.19	0.88

* Based on $\log_e$-transformed values.

† Ratio of polyunsaturated to saturated fat.

TABLE 3

Mean daily intake of selected nutrients based on food records and the food frequency questionnaire at the beginning and end of the validity study (n = 189): Helsinki Diet Methodology Study, 1984

Nutrient	Food records		Food frequency questionnaire 1			Food frequency questionnaire 2		
	Mean	Standard deviation	Mean	Standard deviation	% of food record measure	Mean	Standard deviation	% of food record measure
Total fat (g)	103.8	25.0	70.8	23.3	68	67.7	22.4	65
Saturated fat (g)	50.8	14.6	33.7	13.2	66	32.3	13.0	64
Polyunsaturated fat (g)	14.5	5.5	11.3	6.1	78	11.1	6.7	77
Vitamin A (retinol equivalents) (μg)	1,149	469	1,172	534	102	1,033	501	90
Vitamin C (mg)	109	48	118	54	108	101	46	93
Vitamin E (mg)	8.9	3.4	7.2	3.4	81	6.8	3.6	76
Selenium (μg)	42.5	12.6	32.4	12.2	76	30.7	12.4	72
Dietary fiber (g)	20.5	6.7	20.8	8.5	101	20.6	8.8	100
Energy (kcal)	2,378	493	1,610	447	68	1,562	442	66
Protein, % energy	15.1	2.3	17.3	2.5	115	16.9	2.4	112
Fat, % energy	39.3	4.6	39.4	4.9	100	38.8	5.1	99
Carbohydrate, % energy	42.4	6.2	43.3	5.3	102	44.3	5.3	104
Alcohol, % energy	3.6	3.9						
P/S ratio*	0.30	0.13	0.38	0.24	127	0.40	0.27	133

* Ratio of polyunsaturated to saturated fat.

TABLE 4

Pearson correlation coefficients between the daily intake of nutrients based on food records and either the first or the second food frequency questionnaire: Helsinki Diet Methodology Study, 1984*

Nutrient	Food frequency questionnaire 1 vs. food records (n = 190)			Food frequency questionnaire 2 vs. food records (n = 189)		
	Unadjusted	Energy-adjusted	Corrected for attenuation	Unadjusted	Energy-adjusted	Corrected for attenuation
Total fat	0.41	0.40	0.46	0.42	0.47	0.48
Saturated fat	0.56	0.71	0.62	0.56	0.75	0.62
Polyunsaturated fat	0.60	0.73	0.65	0.68	0.77	0.74
Vitamin A	0.40	0.35	0.55	0.38	0.36	0.53
Vitamin C	0.44	0.41	0.51	0.40	0.53	0.47
Vitamin E	0.53	0.62	0.59	0.59	0.67	0.66
Selenium	0.33	0.36	0.40	0.36	0.45	0.44
Dietary fiber	0.61	0.54	0.74	0.67	0.61	0.82
Energy	0.45		0.52	0.43		0.49
Protein, % energy	0.45		0.56	0.59		0.74
Fat, % energy	0.38		0.44	0.45		0.44
Carbohydrate, % energy	0.42		0.56	0.40		0.53
P/S ratio†	0.81		0.84	0.85		0.89

* Based on $\log_e$-transformed values.
† Ratio of polyunsaturated to saturated fat.

the lowest two quintiles when categorized by the first food frequency questionnaire. Similar results were observed at the higher end, with 43 per cent of the subjects falling into the same quintile and 72 per cent falling into the within-one-quintile category (data not shown). The results of cross-classification of subjects based on the sec-

TABLE 5

Cross-classification of nutrient distribution quintiles from food records and both the first (FF1) and the second (FF2) food frequency questionnaire: Helsinki Diet Methodology Study, 1984

Nutrient	Lowest quintile on food records (n = 190)			Lowest quintile on food records (n = 189)			Overall proportion correctly classified within one quintile of food record quintile	
	Lowest quintile on FF1 (%)	Lowest two quintiles on FF1 (%)	Highest quintile on FF1 (%)	Lowest quintile on FF2 (%)	Lowest two quintiles on FF2 (%)	Highest quintile on FF2 (%)	FF1 (%)	FF2 (%)
Total fat	42	71	3	35	73	0	67	68
Saturated fat	47	79	0	43	68	0	78	72
Polyunsaturated fat	45	79	5	43	87	3	80	82
Vitamin A	42	61	11	41	51	8	61	63
Vitamin C	42	58	8	46	84	5	68	76
Vitamin E	37	68	8	38	73	5	74	77
Selenium	29	55	8	32	57	8	68	68
Dietary fiber	47	76	3	49	76	5	76	77
Energy	42	71	11	35	57	5	71	69
Protein, % energy	37	61	5	51	76	5	65	75
Fat, % energy	32	66	5	38	68	5	66	68
Carbohydrate, % energy	42	61	5	32	43	8	58	58
P/S ratio*	61	84	0	70	100	0	88	94

* Ratio of polyunsaturated to saturated fat.

ond food frequency questionnaire were generally slightly better.

Comparison with the food use questionnaire

Correlations between nutrient intake values from the food use questionnaire and the food frequency questionnaire were highest for polyunsaturated fat (0.80) and lowest for vitamin A (0.50) (table 6). Accordingly, for these nutrients, 64 and 25 per cent, respectively, of the variation in food use values was explained by the variation in food frequency values. The partial correlations between food record and food use questionnaire values, controlling for food frequency questionnaire values, were significantly different from zero for all nutrients examined. The partial correlations were generally about 0.4, with retinol and selenium being the lowest (0.27 and 0.31, respectively). The partial correlations between food record and food frequency questionnaire values, controlling for food use questionnaire values, were significantly different from zero only for retinol, saturated fat, polyunsaturated fat, and fiber.

TABLE 6

Correlations between the daily nutrient intake from the first food use questionnaire (FU1) and the first food frequency questionnaire (FF1), and partial correlations between values of food records (FR) and either FU1 or FF1, controlling for the other method: Helsinki Diet Methodology Study, 1984

Nutrient	FU1 vs. FF1	FR vs. FU1, controlling for FF1	FR vs. FF1, controlling for FU1
Total fat	0.64	0.38	0.07
Saturated fat	0.66	0.34	0.22
Polyunsaturated fat	0.80	0.36	0.16
Vitamin A	0.50	0.27	0.23
Vitamin C	0.60	0.45	0.09
Vitamin E	0.74	0.43	0.10
Selenium	0.60	0.31	0.04
Dietary fiber	0.69	0.49	0.25
Energy	0.67	0.42	0.07

Discussion

The reproducibility of the food frequency questionnaire was good compared to that in other studies (5, 7, 8). The validity study demonstrated that the food frequency questionnaire captured nearly 100 per cent of the intakes of vitamins A and C, about 80 per cent and 75 per cent of the intakes of vitamin E and selenium, respectively, and about two thirds of the total energy intake. Other food frequency questionnaires have yielded slight overestimations and underestimations of intake when compared with food records or recalls, depending on the completeness of the list of food items included (8, 10, 19).

The reference method used in previous food frequency questionnaire validation studies has been either a detailed diet history interview (13, 20, 21) or food records covering time periods from a few weeks to one month (10, 11, 22) or, as in one study (8), four weeks within one year. The length of time covered by the reference method is important because of the large daily variation in individual nutrient intakes. Ratios of intra- to interindividual variability of nutrient intakes, as measured by food records, are generally greater than one for all nutrients (23–25). This is especially a problem for vitamin A (24, 25). The ratios of intra- to interindividual variability affect the precision of intake estimates (26). Also, the time period covered by the food frequency questionnaire has varied from one week (10) to one year (8). These variations in study design should be borne in mind when interpreting and comparing the results of different studies.

Earlier studies on the validity of food frequency questionnaires have included only the energy-providing nutrients (20, 22, 27–29). Correlations between nutrient intakes estimated by a food frequency method and those estimated by a reference method have varied considerably, from 0.20 to 0.80. Correlations reported here, i.e., 0.41 for total fat, 0.56 for saturated fat, and 0.60 for polyunsaturated fat, are similar to those reported by Willett et al. (8) and Gray et al. (13), whose studies are comparable to ours in many ways.

Experience in the use of food frequency questionnaires in the estimation of vitamin and trace element intake is scarce. Validity has generally been poor for vitamin A, the correlations between the food frequency method and diet history interview or food records ranging from 0.16 to 0.26 without supplement use (8, 13); however, those observed by us for vitamin A (0.38–0.40) are distinctly better. Our correlation coefficients for vitamin C intake estimates correspond to the correlation coefficients of other investigators (8, 13).

There are no previous data on the use of food frequency questionnaires in the measurement of vitamin E or selenium intake. According to the present results, agreement between the food frequency questionnaire and the food records is relatively good for vitamin E: the correlation coefficients for the unadjusted data range from 0.53 to 0.59, and after adjustment for energy intake, they range from 0.62 to 0.67, respectively. The correlations for selenium intakes were lower and were generally in the same range as those observed for vitamin A.

The results on dietary fiber can be compared with the crude fiber intake estimate from the food frequency questionnaire validated in Boston nurses (8) and with the dietary fiber intake from the self-administered dietary questionnaire by Jain et al. (21). These correlations with the reference methods varied from 0.45–0.58 (8) to 0.70 (21). Both these studies, however, used portion size estimation, and they were carried out among women. Our correlation coefficients for dietary fiber, 0.61–0.67, are relatively good considering that the questionnaire contained only frequencies (except for the amount of bread consumed daily, which may have improved the fiber estimation) and that the subjects were elderly men.

Classification of the subjects into quintiles of the nutrient intakes yielded slightly lower agreement between the food record and food frequency methods than that reported by Willett et al. (8). However, the intake values in that study were adjusted for total caloric intake, and the vitamin intakes included supplements. In the study by Willett et al., about 50 per cent of the subjects fell into the same lowest or highest quintile with both methods and 75 per cent fell into the same or the next quintile, while the respective percentages in our study were in the range of 45 per cent and 70 per cent for the same six nutrients reported.

The importance of portion size estimation as part of a food frequency questionnaire method has been analyzed in two studies (12, 14). Samet et al. (14) found that retinol and beta-carotene indices based on the frequency of use of about 30 food items gave essentially the same information when pictures were shown both with and without the inclusion of portion size estimation on the questionnaire. In contrast, Chu et al. (12) concluded that frequency information is satisfactory only at the food item level, whereas estimation of nutrient intake requires information on portion size. Chu et al. did not, however, compare the two methods by classifying people into quantiles of the relevant nutrient distributions (30). Furthermore, the importance of portion size estimation may be different for micronutrients and macronutrients. Finally, the homogeneity of the population (e.g., age and sex) may also affect the results (31). Further evaluation of this issue would be useful.

Estimation of total vitamin intake in epidemiologic studies should also include information on supplemental vitamin intake. In this study, we investigated only the validity and reproducibility of food intake assessment. Therefore, the use of vitamin and mineral supplements was not included in the analysis. Inclusion of supplemental intake tends to improve the correlations with reference methods, because vitamin supplements usually provide nutrients in excess of that which is supplied by diet (8, 13).

Comparison of the food frequency questionnaire and the food use questionnaire described in the accompanying paper (16) raised several important points. The food frequency questionnaire tended to be more reproducible for total fat, saturated fat, polyunsaturated fat, vitamin C, vitamin E, and selenium, but not for vitamin A and fiber. This is not surprising, since the variation of the food frequency questionnaire is limited by the nature of its design; for example, it does not include portion size variation and has only a limited number of choices for frequency of consumption. The validity of the two methods varied depending on whether mean intakes of the entire group or individual intakes were studied. On the group level, the food frequency questionnaire gave values closer to the food records for vitamins A and C and fiber, whereas for various fat measures, energy, and selenium, the agreement between the food use questionnaire and food records was better. On the other hand, quintile analysis and examination of correlation coefficients demonstrated that on the individual level the validity of the food use questionnaire was consistently better. The average of the energy-adjusted correlation coefficients between food records and the second food frequency questionnaire was 0.52, while the corresponding average for the second food use questionnaire was 0.58. The significant partial correlations between food record values and food use questionnaire values, controlling for food frequency questionnaire values, indicated that the food use questionnaire consistently added information over and above that provided by the food frequency questionnaire. Direct comparison between intake values from the food use questionnaire and the food frequency questionnaire should be interpreted with caution, since both instruments are subject to "questionnaire-specific" variability which is independent of any true variation in nutrient intake.

In conclusion, the food frequency questionnaire appears to be slightly more repro-

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ducible for some nutrients than the food use questionnaire; on the other hand, the food use questionnaire has higher general validity. Both instruments have a limited ability to assess vitamin A and selenium intake. This problem is worse for the food frequency questionnaire. The extent of misclassification and its impact on attenuating estimates of relative risk when using the food use questionnaire are discussed in the accompanying paper (16). Consideration could be given to using both the food use questionnaire and the food frequency questionnaire, since the latter appeared to provide more information for some nutrients. The food frequency questionnaire is a useful instrument in the intervention trial for monitoring qualitative changes in diet, since its reproducibility is high. On the other hand, the food use questionnaire is better suited to the assessment of an individual's "whole diet."

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