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REPRODUCIBILITY AND VALIDITY OF DIETARY ASSESSMENT INSTRUMENTS

I. A SELF-ADMINISTERED FOOD USE QUESTIONNAIRE WITH A PORTION SIZE PICTURE BOOKLET

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A self-administered food use questionnaire which included 276 food items and mixed dishes and a portion size picture booklet with 122 photographs was developed for a large lung cancer intervention trial among approximately 27,000 Finnish men aged 50–69 years. The reproducibility and validity of this questionnaire were studied from March to October 1984. In the reproducibility study, 121 men aged 55–69 years completed the questionnaire three times, at three-month intervals. The intraclass correlations varied from 0.56 for vitamin A to 0.88 for alcohol, with most falling between 0.60 and 0.70. In the validity study, 190 men of similar age 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 nutrient intake values from the food records and the food use questionnaires ranged from 0.40 for selenium to 0.80 for alcohol. Among subjects who belonged to the lowest quintile on the basis of the food record measurement, an average of 51 per cent fell into the same quintile and 76 per cent fell into the lowest two quintiles when they were categorized on the basis of the food use questionnaire. Findings were similar for the upper tail of the distribution. These data indicate that the self-administered food use questionnaire is useful for measuring individual or group intakes for a variety of nutrients.

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

The diet history (1), which measures quantitatively the habitual dietary intake of individuals over a specified time period, is in theory an ideal method for studying the relation between diet and cancer. Originally, the diet history method consisted of

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three parts: the actual food intake of the preceding day, a detailed list of foods that were checked with the subject, and a menu recorded for three days by the subject. However, in spite of numerous modifications (2–5), the diet history method remains time-consuming and is difficult to use in studies involving a large number of participants. Therefore, food frequency questionnaires have largely replaced the diet history in epidemiologic studies (6–9).

We developed a new dietary assessment method to assess the habitual dietary intake of various nutrients in approximately 27,000 middle-aged Finnish men participating in a randomized beta-carotene, alpha-tocopherol (vitamin E) lung cancer intervention trial (10). The method is a modified diet history which assesses both the frequency of consumption during the previous year and the usual portion size of over 200 food items and mixed dishes and which partly takes into account the usual meal pattern. To help the subject estimate the proper portion sizes, we produced a picture booklet of foods and mixed dishes. The questionnaire, which we call a food use questionnaire, was designed to be completed by subjects at home and to be checked by a nurse during the subsequent appointment.

A simple food frequency questionnaire without portion size assessment was developed simultaneously, and both questionnaires were tested for reproducibility and validity in the same pilot study. The results of the food frequency questionnaire are described in the companion paper (11).

Materials and methods

Study design

The reproducibility and validity of both the food use questionnaire and the food frequency questionnaire were studied from March to October 1984. The study design is shown in figure 1. Subjects were divided into three groups. Participants in the validity study filled in both questionnaires three weeks apart, both at the beginning and at the end of a six-month period. Food consumption records were kept during the same period for 24 days (12 times for two consecutive days, distributed evenly over the period). In the reproducibility study, the participants filled in either the food use questionnaire or the food frequency questionnaire three times, at three-month intervals.

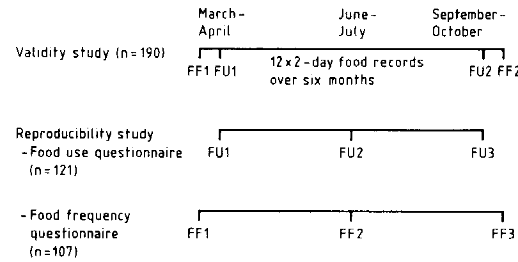

FIGURE 1. Study design of the validity and reproducibility studies of the food use questionnaire (FU) and the food frequency questionnaire (FF).

Food recording was chosen as the reference method, since it has high validity for measuring the actual food consumption of an individual, provided that the time period covered is sufficiently long and the number of days on which consumption is recorded is high. Six months (March to October) was considered long enough to capture seasonal variation in the Finnish diet (12), while 24 days was adequate for a reasonably good estimate of food consumption, according to previous reports on intraindividual variation in daily nutrient intakes (13, 14).

Subjects

To conform with the eligibility criteria for the lung cancer intervention trial, we selected male subjects aged 55–69 years for the pilot study. We recruited them from four large public and private companies in Helsinki (the Finnish Post and Telecommunications Company, a dairy plant, a pharmaceutical company, and a milling company) and, to ensure inclusion of older men, from the population register in the Punavuori section of Helsinki. The participation rate was 73 per cent in the companies (total number of invited men = 503) and 27 per cent in Punavuori (total number of invited men = 423). The difference in the participation rates is related to the fact that many of the men recruited from the population register were unable to come to the interview during working hours, while the men recruited from the companies were interviewed at their worksites.

Of the 482 participating men, 217 entered the validity study, 146 took part in the reproducibility study of the food use questionnaire, and 119 took part in the reproducibility study of the food frequency questionnaire. During the study, 27 (12 per cent), 13 (9 per cent), and 12 (10 per cent) men were excluded from the respective groups because of incomplete forms (12, eight, and seven men, respectively), major changes in diet (nine, three, and five men, respectively), or other reasons (six, two, and no men, respectively). At the analysis stage, 32 men in the validity study and 12 men in the reproducibility study of the food use questionnaire were partly excluded because one or more of the diet history assessments were unreliable (i.e., consumption of certain foods exceeded preset reasonable limits). Thus, the number of subjects in each analysis varies depending on how many men had complete data for that particular analysis. The final total number and characteristics of the subjects in each group are shown in table 1. The three study groups were similar except that there were less retired people among the subjects repeating the food frequency questionnaire. That study was carried out as the last part of the investigation, and most of the men in that group were recruited from two of the companies rather than from the community.

Food use questionnaire and portion size picture booklet

The purpose of the food use questionnaire was to assess the habitual consumption of all possible foods during the previous 12 months. The final questionnaire asked about 203 food items and 73 mixed dishes, grouped under the following subtitles: milk and sour milk; coffee and tea; bread; butter and margarine used on bread; cheeses, sausages, and prepared meats eaten as cold cuts; porridges and gruels; potatoes, rice, and macaroni; vegetables eaten raw, pickled, and cooked; mixed dishes (10 subcategories); fruit and berries; desserts;

TABLE 1

Description of the subjects in the study groups: Helsinki Diet Methodology Study, 1984

Characteristic	Validity study (both diet questionnaires) (n = 190*)	Reproducibility study	
		Repeaters of food use questionnaire (n = 133†)	Repeaters of food frequency questionnaire (n = 107)
Age (years)	59.9 ± 4.0‡	59.7 ± 3.8	58.6 ± 2.6
Body weight (kg)	79.1 ± 11.4	78.1 ± 10.8	81.9 ± 11.5
Retired (%)	22.1	24.0	1.9
Social class§			
Executives and management employees (%)	19.5	29.8	32.7
Clerical and service employees (%)	36.8	33.9	27.1
Blue-collar workers (%)	40.0	31.4	38.3
Retired with unknown previous occupation (%)	4.7	5.0	1.9

* All men completed food records. The first, second, and both food use questionnaires were successfully completed by 168, 178, and 158 men, respectively.

† The first, second, third, and all food use questionnaires were successfully completed by 125, 130, 131, and 121 men, respectively.

‡ Mean ± standard deviation.

§ Retired persons were classified according to their last occupation.

pastry; and miscellaneous items including candy, nuts, alcohol, and beverages. Under each heading, there was space for unlisted foods. Special questions inquired about meal pattern and the number of warm meals consumed on weekdays and weekends. This information was used to check the number of mixed dishes reported. Questions about the type of fat used in food preparation and the place where meals were most often eaten were also asked.

We inquired about frequency of consumption by asking the number of times an item was consumed per day, per week, or per month, depending on the food; for example, the options for milk, coffee, and bread were only per day or per week, while the only choice for mixed dishes was per month.

For the estimation of portion size, a black and white 63-page picture booklet with 122 photographs of foods was designed which gave two to five portion size choices (usually three) for each food listed on the questionnaire. Since there were only 122 photographs, the subjects were referred to the same picture for several foods. Some of the foods were shown in full size (e.g., glasses of milk, slices of bread, butter on bread, and fruit), while some were shown in reduced size. In every picture, there was a bar to show the scale. Weights and volumes of the portions were not given. Subjects were asked to indicate their usual portion size by circling the appropriate letter (*a* to *e*) on the questionnaire. Portion sizes depicted were small, average, and large and were determined from available data on the portion size of Finnish foods (15).

Brief oral and detailed written instructions were given to all participants by nutrition students. The subjects were asked to complete the questionnaires at home on two consecutive nights, with the assistance of their spouses, if necessary. According to the information collected from the participants, the average time required for completion of the questionnaire was two hours. Completed questionnaires and picture booklets were returned to the nutrition students, who took approximately 30 minutes to check the questionnaire with the subject.

Food consumption records

The 24-day food recording was carried out in two-day units representing equally all days of the week and spread out evenly over the six-month period. Subjects were given both oral and written instructions on how to fill in the blank diary forms. They were asked to record the exact description of all foods and drinks consumed during each two-day period. Postal scales measuring a maximum of 500 g were given to the participants for weighing portions. The use of household measures was recommended whenever it was not possible to use the scale.

The nutrition students checked the two-day records with the subjects in a short interview immediately after each period and gave them the forms to be used during the next period. Forms were coded by the same nutrition students, and the coding was checked by one nutritionist in order to ensure uniform coding decisions.

Analysis of food consumption data

Daily intakes of foods and nutrients were computed using the software system developed at the National Public Health Institute, Helsinki. The data base currently includes about 820 recipes for Finnish foods, 480 individual food items, and 74 nutrients. Data on minerals (16), fiber (17, 18), and vitamin E (19) are based on recent analyses of Finnish foods. Other composition data are a mixture of values obtained from Finnish food analyses and values taken from international food composition tables. Vitamin A is recorded in retinol equivalents and is based mainly on international food composition tables.

Statistical analysis

Sample means and standard deviations of nutrient intake were computed for each food use questionnaire in both the reproducibility and the validity studies, as well as for the food records in the validity study.

For the reproducibility study, differences between means were tested by analysis of variance, allowing for dependence between nutrient values on the same subject. In the validity study, the intake means from the food use questionnaire were compared with the means from the food records.

Pearson product-moment correlations and Spearman rank correlations between pairwise measurements were used to assess the reproducibility of the questionnaire and its validity with respect to the food records. Since Spearman and Pearson correlations were similar, only the latter are reported.

Intraclass correlations (20) were computed as overall measures of reproducibility. The intraclass correlation measures the fraction of total variation that is due to between-individual variability. A high correlation implies low within-individual variability. The inter- and intraindividual variance components were estimated from the reproducibility sample by an analysis of variance model with a random individual effect and a fixed effect for the three repetitions of the questionnaire.

The presence of intraindividual variation attenuates the correlation between questionnaire and food record values. To obtain a measure of validity that was corrected for this attenuation, we multiplied the correlations by the factor $(1 + S_W^2/S_B^2)^{1/2}$, where S_W^2 and S_B^2 are the intra- and interindividual variance components estimated from the reproducibility sample (21). The corrected correlations are interpreted as measures of association between "true" questionnaire values and food record values. No correction was made for the intraindividual variation when we estimated nutrient intake from the average of the 24-day food records, since it was expected to be minimal (13, 14).

Correlations between questionnaire and food record values adjusted for total energy intake were also computed. As suggested by Willett et al. (8), the adjustment was done by replacing nutrient intake values with their respective residuals from a regression model with nutrient intake as the response and total energy intake as the explanatory variable. The adjustment was done separately for the questionnaire and for the food record values.

To illustrate the agreement pattern between the food use questionnaire and food records, we cross-classified the intake values from both methods into quintiles. Cutoff points for quintiles were determined separately for food records and for questionnaires. The percentage correctly classified in the extreme quintiles and the overall percentage correctly classified within one quintile were calculated. The within-one-quintile percentage that would be expected due to chance is 0.52. It is possible to correct the observed within-one-quintile percentage for chance agreement using a kappa statistic. We did not, however, report values on the kappa statistic because of its arbitrariness when used for grouped continuous data (22).

For procedures requiring the assumption of normality, nutrient intake values were $\log_e$-transformed because most were skewed toward higher values. Values for starch and sucrose remained somewhat skewed even after this transformation.

RESULTS

Reproducibility

The mean daily intakes of energy and nutrients and related measures in the reproducibility study are presented in table 2. For most nutrients, the first measurement gave higher mean values than did the second and third measurements. The differences between measurements were statistically significant for 14 of the 29 items. Pearson product-moment correlations between pairwise measurements ranged from 0.54 for vitamin A (95 per cent confidence interval (CI) 0.40–0.65) to 0.90 for alcohol (95 per cent CI 0.86–0.93), with most values falling between 0.60 and 0.70. The intraclass correlations varied from 0.56 for vitamin A to 0.88 for alcohol.

TABLE 2

Mean daily intake of energy and nutrients and intraclass correlations from the food use questionnaire reproducibility sample (n = 121): Helsinki Diet Methodology Study, 1984

Nutrient	First measurement		Second measurement		Third measurement		Intraclass correlation*
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	
Energy (kcal)	2,520	833	2,335	724	2,343	704	0.66
Protein (g)	94	31	88	29	88	29	0.66
Total fat (g)	109	48	98	35	98	35	0.64
Saturated fat (g)	53.6	26.3	48.5	19.2	48.6	18.9	0.67
Monounsaturated fat (g)	37.7	16.7	34.4	12.9	34.3	12.5	0.63
Polyunsaturated fat (g)	16.0	9.4	13.7	7.3	13.7	7.6	0.73
Cholesterol (mg)	510	230	474	191	465	175	0.66
Total carbohydrate (g)	279	101	260	97	265	90	0.70
Starch (g)	136	63	130	58	130	51	0.69
Sucrose (g)	45.6	30.0	40.5	25.1	41.4	23.7	0.72
Dietary fiber (g)	25.1	11.6	25.5	11.3	23.9	10.5	0.73
Alcohol (ethanol) (g)	13.0	16.8	13.9	18.3	13.4	18.4	0.88
Vitamin A (retinol equivalents) (μg)	1,366	581	1,213	484	1,238	521	0.56
Vitamin C (mg)	133	60	123	62	122	58	0.69
Vitamin D (mg)	4.11	2.56	3.77	3.39	3.69	2.30	0.70
Vitamin E (mg)	10.4	5.3	9.0	4.3	9.1	4.4	0.70
Sodium (mg)	4,493	1,472	4,239	1,420	4,311	1,380	0.70
Potassium (mg)	4,546	1,414	4,346	1,342	4,350	1,411	0.72
Calcium (mg)	1,280	627	1,202	518	1,201	597	0.70
Magnesium (mg)	438	141	419	141	417	136	0.70
Copper (mg)	1.93	0.76	1.78	0.66	1.80	0.66	0.69
Zinc (mg)	14.6	5.0	13.7	4.6	13.8	4.6	0.68
Selenium (μg)	42.6	15.1	40.1	16.4	40.0	13.6	0.63
Lead (μg)	58	19	54	21	57	32	0.62
Protein, % energy	15.1	2.6	15.2	2.4	15.1	2.1	0.71
Fat, % energy	38.5	6.5	37.7	6.4	37.3	5.9	0.61
Carbohydrate, % energy	42.6	7.3	42.7	7.3	43.3	6.4	0.65
Alcohol, % energy	3.9	5.1	4.3	5.5	4.2	5.8	0.86
P/S ratio†	0.33	0.18	0.31	0.17	0.31	0.17	0.82

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

Validity

The mean nutrient intake values given by the two food use questionnaire measurements and by the food records in the validity study are presented in table 3. On the average, the first food use questionnaires gave 18 per cent higher values and the second food use questionnaires 9 per cent higher values than did the food records. Overreporting was most obvious for vitamins A and C.

The unadjusted Pearson correlation coefficients between food records and food use questionnaires varied between 0.40 (95 per cent CI 0.26–0.52) for selenium and 0.80 (95 per cent CI 0.73–0.85) for alcohol, although most values were between 0.40 and 0.60 (table 4). Adjustment for total energy intake did not change correlation coefficients much. The correction for attenuation improved the correlations to 0.60–0.70 for most nutrients.

Classification of the nutrient intake distributions into quintiles was used to evaluate the degree of similarity between categorization of subjects on the basis of food records and food use questionnaires (table 5). On the average, 76 per cent of the subjects classified by the food records fell into

TABLE 3

Mean daily intakes of energy and nutrients based on food records and on the food use questionnaire at the beginning and end of the validity study (n = 158): Helsinki Diet Methodology Study, 1984

Nutrient	Food records		Food use questionnaire 1			Food use questionnaire 2		
	Mean	Standard deviation	Mean	Standard deviation	% of food record measure	Mean	Standard deviation	% of food record measure
Energy (kcal)	2,349	482	2,658	795	113	2,464	784	105
Protein (g)	87	18	102	33	117	93	30	107
Total fat (g)	103	24	113	39	110	102	37	99
Saturated fat (g)	50.3	14.1	53.8	20.5	107	48.5	19.0	96
Monounsaturated fat (g)	35.7	8.5	40.0	14.2	112	36.3	13.5	102
Polyunsaturated fat (g)	14.3	5.5	17.4	9.0	122	15.8	8.2	110
Cholesterol (mg)	481	136	526	207	109	481	193	100
Total carbohydrate (g)	258	70	301	101	117	285	101	110
Starch (g)	123	36	147	56	120	142	55	115
Sucrose (g)	57.8	31.3	51.7	30.2	89	50.2	31.2	87
Dietary fiber (g)	20.4	6.7	26.4	11.1	129	24.6	10.4	121
Alcohol (ethanol) (g)	9.9	11.1	10.5	13.4	106	10.4	13.9	105
Vitamin A (retinol equivalents) (μg)	1,144	471	1,584	683	138	1,349	630	118
Vitamin C (mg)	106	46	156	75	147	135	70	127
Vitamin D (mg)	4.43	2.56	4.49	2.79	101	3.89	2.24	88
Vitamin E (mg)	8.7	3.3	11.4	5.4	131	10.3	5.3	118
Sodium (mg)	4,126	921	5,069	1,679	123	4,643	1,541	113
Potassium (mg)	3,915	749	4,923	1,485	126	4,607	1,347	118
Calcium (mg)	1,065	333	1,345	568	126	1,203	496	113
Magnesium (mg)	378	79	459	142	121	432	133	114
Copper (mg)	1.69	0.51	2.02	0.72	120	1.87	0.70	111
Zinc (mg)	13.3	2.8	15.8	5.1	119	14.4	4.7	108
Selenium (μg)	41.6	11.7	44.9	15.9	108	41.1	14.5	99
Lead (μg)	50	15	62	24	124	59	26	118
Protein, % energy	15.1	2.4	15.4	2.2	102	15.1	2.2	100
Fat, % energy	39.4	4.7	38.1	5.1	97	37.2	5.3	94
Carbohydrate, % energy	42.5	6.1	43.5	5.7	102	44.5	6.1	105
Alcohol, % energy	3.0	3.2	3.0	4.1	100	3.3	4.6	110
P/S ratio*	0.30	0.13	0.35	0.19	117	0.35	0.18	117

* Ratio of polyunsaturated to saturated fat.

the same quintile or into the within-one-quintile category when classified by the food use questionnaire. Of those subjects belonging to the lowest quintile on the basis of food records, 51 per cent fell into the same quintile and 76 per cent into the lowest two quintiles when categorized by the food use questionnaire. Similar results were observed at the high end of the nutrient intake distributions (data not shown). Gross misclassification was rare; on the average, only 4 per cent of subjects belonging to the lowest or highest quintile on the basis of food records fell into the highest or lowest quintile, respectively, when categorized by the food use questionnaire.

To determine which foods were easy or difficult to report in the food use questionnaire, we also analyzed the results at the food group level for the 17 food groups shown in table 6. The intraclass correlations varied from 0.65 for berries to 0.74 for alcohol. The food intake estimated from the first and second food use questionnaires was, on the average, 21 per cent and 10 per cent higher, respectively, than the intake obtained from the food records (table 6). Overreporting was greatest for potatoes, fruits, and juices, while the consumption of

TABLE 4

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

Nutrient	Food use questionnaire 1 vs. food records (n = 168)			Food use questionnaire 2 vs. food records (n = 178)		
	Unadjusted	Energy-adjusted	Corrected for attenuation	Unadjusted	Energy-adjusted	Corrected for attenuation
Energy	0.57		0.70	0.59		0.73
Protein	0.53	0.63	0.65	0.51	0.57	0.63
Total fat	0.51	0.39	0.64	0.60	0.52	0.75
Saturated fat	0.56	0.62	0.68	0.65	0.73	0.79
Monounsaturated fat	0.47	0.38	0.59	0.54	0.43	0.68
Polyunsaturated fat	0.65	0.69	0.76	0.73	0.76	0.85
Cholesterol	0.54	0.57	0.67	0.61	0.65	0.75
Total carbohydrate	0.60	0.55	0.71	0.63	0.64	0.75
Starch	0.71	0.73	0.86	0.67	0.68	0.81
Sucrose	0.54	0.50	0.63	0.67	0.56	0.79
Dietary fiber	0.71	0.72	0.83	0.70	0.73	0.82
Alcohol	0.80	0.80	0.85	0.80	0.81	0.85
Alcohol users only†	0.69	0.71	0.76	0.67	0.69	0.74
Vitamin A	0.41	0.31	0.55	0.51	0.49	0.68
Vitamin C	0.58	0.58	0.70	0.59	0.60	0.71
Vitamin D	0.47	0.54	0.58	0.52	0.52	0.64
Vitamin E	0.64	0.66	0.76	0.69	0.69	0.82
Sodium	0.49	0.58	0.59	0.52	0.59	0.62
Potassium	0.53	0.57	0.63	0.55	0.68	0.65
Calcium	0.61	0.68	0.73	0.62	0.66	0.74
Magnesium	0.59	0.57	0.71	0.62	0.67	0.74
Copper	0.53	0.42	0.64	0.54	0.53	0.65
Zinc	0.57	0.62	0.69	0.55	0.59	0.67
Selenium	0.40	0.46	0.50	0.49	0.53	0.62
Lead	0.47	0.47	0.60	0.52	0.60	0.66
Protein, % energy	0.63		0.75	0.60		0.71
Fat, % energy	0.38		0.49	0.50		0.64
Carbohydrate, % energy	0.56		0.70	0.63		0.78
Alcohol, % energy	0.75		0.81	0.75		0.81
P/S ratio‡	0.76		0.83	0.83		0.91

* Based on $\log_e$-transformed values.

† n = 141 for the first food use questionnaire and 149 for the second food use questionnaire.

‡ Ratio of polyunsaturated to saturated fat.

fats, fish, coffee, alcohol, and sugar was underreported. Pearson correlation coefficients between the food records and questionnaires varied from 0.20 (95 per cent CI 0.05–0.35) for berries to 0.82 (95 per cent CI 0.76–0.87) for alcohol.

DISCUSSION

The food use questionnaire attempts to measure the habitual dietary intake over the previous year as completely as possible. The new method has the following special features: It is self-administrative, contains an extensive section of mixed dishes, and uses a picture booklet for portion size assessment. A self-administered questionnaire is imperative in our beta-carotene, alpha-tocopherol lung cancer intervention trial, since our resources are constrained by the size of the study (i.e., 27,000 participants).

Since the lung cancer intervention trial is being conducted among middle-aged men, it is necessary to collect information on the foods as the participants see them on their plates. Photographs of foods have

TABLE 5

Cross-classification of nutrient distribution quintiles from food records and both the first (FU1) and the second (FU2) food use questionnaires: Helsinki Diet Methodology Study, 1984

Nutrient	Lowest quintile on food record (n = 168)			Lowest quintile on food record (n = 178)			Overall proportion classified within one quintile of food record quintile	
	Lowest quintile on FU1 (%)	Lowest two quintiles on FU1 (%)	Highest quintile on FU1 (%)	Lowest quintile on FU2 (%)	Lowest two quintiles on FU2 (%)	Highest quintile on FU2 (%)	FU1 (%)	FU2 (%)
Energy	55	73	0	49	77	0	72	77
Protein	46	73	3	43	69	6	70	73
Total fat	39	79	3	43	83	0	70	79
Saturated fat	42	85	3	54	77	0	74	80
Monounsaturated fat	39	67	9	34	71	11	72	76
Polyunsaturated fat	52	79	3	54	91	3	83	86
Cholesterol	46	76	3	54	77	3	69	77
Total carbohydrate	49	73	6	46	74	6	76	79
Starch	55	88	3	57	80	6	79	76
Sucrose	55	79	3	57	74	3	71	80
Dietary fiber	61	82	3	63	80	3	80	79
Alcohol	76	88	3	77	91	0	92	92
Alcohol users only*	52	88	0	48	82	0	86	82
Vitamin A	42	67	15	51	74	3	69	71
Vitamin C	46	79	3	54	77	6	74	76
Vitamin D	46	70	6	57	69	3	70	69
Vitamin E	46	67	3	51	83	3	75	80
Sodium	39	70	3	46	69	6	68	69
Potassium	42	64	6	49	80	3	69	75
Calcium	55	79	9	60	77	3	82	75
Magnesium	52	85	6	57	83	0	76	76
Copper	52	76	6	49	69	3	74	73
Zinc	49	70	6	54	74	3	73	77
Selenium	33	58	12	51	66	9	64	69
Lead	49	82	0	57	74	3	73	75
Protein, % energy	52	76	0	34	69	0	74	68
Fat, % energy	42	70	12	37	63	0	70	70
Carbohydrate, % energy	36	79	3	60	80	6	73	75
Alcohol, % energy	73	85	0	77	91	0	93	92
P/S ratio†	61	91	3	57	83	0	85	91

* n = 141 for FU1 and 149 for FU2.

† Ratio of polyunsaturated to saturated fat.

previously been used in several studies in which subjects have been interviewed (6, 7, 23, 24) but have not been given self-administered questionnaires. Studies on self-administered quantitative dietary questionnaires either have used a limited number of pictures plus household measures (25) or have specified a commonly used unit (e.g., grams) (8). However, the subjects in these studies have been women, who generally have a better idea of their diets than men and who are more familiar with quantities expressed in household measures or in grams.

Since our food use questionnaire is a combination of the traditional diet history interview and quantitative food frequency methods (interviews or self-administered

TABLE 6

Mean daily consumption and Pearson correlations (r) by food group on the basis of food records (FR) and the first (FU1) and second (FU2) food use questionnaires in the validity study (n = 158): Helsinki Diet Methodology Study, 1984

Food group	Food records		FU1		FU2		FR vs. FU1 (r)	FR vs. FU2 (r)
	Mean (g)	Standard deviation	Mean (g)	Standard deviation	Mean (g)	Standard deviation		
Cereals	180	58	213	91	206	90	0.65	0.60
Potatoes	141	50	225	108	224	97	0.51	0.51
Vegetables	132	61	153	79	142	77	0.47	0.58
Fruits	94	94	169	137	131	114	0.62	0.69
Berries	40	38	44	40	40	38	0.20	0.35
Juices	31	57	61	128	50	107	0.77	0.62
Fats	51	17	46	25	41	21	0.44	0.57
Milk products	524	239	659	382	585	317	0.69	0.68
Beef, pork, and chicken	86	38	89	50	82	41	0.35	0.36
Sausages	61	35	66	53	50	36	0.44	0.42
Liver, kidney, and tongue	4	6	6	7	6	6	0.28	0.35
Fish	40	36	33	28	29	25	0.33	0.44
Eggs	34	16	42	25	41	25	0.52	0.58
Coffee	438	232	398	285	414	288	0.72	0.79
Alcoholic drinks	130	153	118	160	122	188	0.82	0.72
Sugar	36	23	32	23	32	25	0.51	0.59
Others	274	206	338	279	289	264	0.59	0.70

questionnaires), we compared the results of the reproducibility and validity studies with both of those methods.

Reproducibility of diet histories has been assessed in studies using two measurements with varying time intervals (5, 26–28). The results have varied from relatively low intraclass correlations of 0.12, 0.19, 0.32, and 0.41 for animal protein, cholesterol, saturated fat, and total fat, respectively, among Caucasian women in Hawaii (28), to high correlations of 0.67–0.91 among Dutch women (5). Overall, the reproducibility of our instrument was slightly lower than that of the Dutch diet history interview but higher than that of the semiquantitative food frequency questionnaire used by Willett et al. (8). Only Willett et al. have previously measured the reproducibility of vitamin and mineral assessments. In their study, intraclass correlation coefficients for vitamins A and C (without supplements) were 0.49 and 0.59, respectively, compared with 0.56 and 0.69 in the present study.

There is no obvious explanation why the first measurement produced higher group mean estimates than did the second and third measurements. The same phenomenon was found for the food use questionnaire in the validity study. It is possible that the subjects had a more realistic idea of their diets at the second administration of the questionnaire, and this tended to diminish the overestimation. Comparison of the protein, fat, and carbohydrate percentages of energy intake showed that the differences were the result of general overestimation at the first measurement. However, the differences were not very large, although they were statistically significant.

Previous studies (2, 5, 29) have shown that the diet history method gives approximately 20 per cent higher nutrient intake estimates than do food records, a result similar to ours. Overestimation has been especially apparent for vitamins A and C (2, 4, 8). Analyses at the food group level in this study showed that overreporting was greatest for potatoes, fruits, and juices, while the consumption of fats, fish, coffee, alcohol, and sugar was slightly underreported. The over- and underreporting of these food items is consistent with observations on nutrient intakes and may be the result of a positive bias in reporting consumption of desirable items (foods considered healthy) and a negative bias in reporting less desirable items. However, alcohol, a less desirable item, was reported with high reproducibility and validity on both a group and an individual level.

The correlation coefficients between the nutrient intakes from the food use questionnaire and those from the 24-day food records were consistently higher with the second food use questionnaire. Similar experience has previously been reported by Willett et al. (8). The phenomenon is probably the result of at least two factors. First, the correlations are higher when the time periods covered by the questionnaire and the food records overlap. Second, the subjects are probably more skilled in estimating their food intake at the second administration of the questionnaire, when they are more familiar with their dietary habits from the food recording.

Energy-adjusted correlation coefficients have not been reported previously except by Willett et al. (8). In their study, adjustment for energy intake improved the correlations more than in our study, in which the effect of the adjustment was minimal. The energy-adjusted correlation coefficients observed in our study were somewhat higher than those reported by Willett et al. On the other hand, comparison of quintile classification between the two studies gives nearly identical results.

To our knowledge, this is the first published report of the reproducibility and validity of measuring vitamin E or selenium by a diet questionnaire. These nutrients are of great interest in the Finnish lung cancer intervention trial. Both the reproducibility and validity of our instrument in measuring vitamin E intake were relatively good, the correlation coefficients ranging from 0.64 to 0.82. Selenium intake was more difficult to estimate. The Pearson correlations between the selenium intakes based on the two food use questionnaires and on the food records ranged from 0.40 to 0.62. One explanation for the poor correlation is the low validity of the questionnaire method in assessing the consumption of fish, an important source of selenium in the Finnish diet.

The primary purpose of the lung cancer intervention trial is to assess the effect of beta-carotene and alpha-tocopherol supplementation in the prevention of lung cancer. The impact of dietary factors on lung cancer incidence will also be evaluated, since these factors may modify the effect of the supplementation, if there is any effect. However, imprecise measurement of an exposure factor attenuates the regression effect for that factor. Thus, the results concerning the validity of the food use questionnaire provide a basis for correcting for this attenuation when relating nutrient intake to lung cancer risk.

Walker and Blettner (30) discuss the impact of imprecise measures of exposure on relative risk assessment in cohort and case-control studies. Although their procedure is not directly applicable to the study of effect modification in an intervention trial, the following examples based on their tables illustrate the impact of the imprecision present in our nutrient intake estimates.

Assume that the true risk increases linearly with the exposure, that the true relative risk is 3 between the lowest and highest quintile of the exposure distribution, and that the average risk is 0.04. For a correlation of 0.4 between the error-prone and error-free exposure measurements, the attenuation is 50 per cent; i.e., the true relative risk of 3 appears as 1.5. For a 95 per cent chance of detecting a significant effect (alpha = 0.05), a cohort size of approximately 20,000 is needed. For a correlation of 0.7 between the error-prone and error-free exposure measurements, the corresponding attenuation and cohort size are 35 per cent and 6,000. Accordingly, in our lung cancer intervention population of about 27,000 men, with an estimate of about 600 lung cancer and 600 other cancer cases during the five-year follow-up period, one would expect the food use questionnaire to detect dietary factors that are moderately or strongly related to lung cancer incidence.

In conclusion, the food use questionnaire was reasonably accurate even in this relatively restricted, homogeneous population of middle-aged men living in the Helsinki area. Nevertheless, several improvements have been made in this questionnaire as a result of this study. The picture booklet has been printed in color, and pictures of portion sizes that differed greatly from the portions calculated from the food records have been revised. After these modifications, the food use questionnaire has worked well in the lung cancer intervention trial in which registered nurses are responsible for the practical management of the dietary assessment.

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