Relative validities of 3-day food records and the food frequency questionnaire

Yoon Jung Yang[1], Mi Kyung Kim[1§], Se Hee Hwang[1], Younjhin Ahn[2], Jae Eun Shim[3] and Dong Hyun Kim[4]

[1]*Department of Preventive Medicine, College of Medicine, Hanyang University, 17 Haengdang-dong, Sungdong-gu, Seoul 133-791, Korea*
[2]*Center for Genomic Science, National Institute of Health, Center for Disease Control and Prevention, Seoul 122-701 Korea*
[3]*Department of Kinesiology and Community Health, University of Illinois, Urbana-Champaign, Urbana, IL 61801, USA*
[4]*Department of Social and Preventive Medicine, Hallym University College of Medicine, Chuncheon 200-702, Korea*

Abstract

The food frequency questionnaire (FFQ) has been used as an important dietary assessment tool in epidemiologic studies, but the usefulness of the FFQ has been debated in recent years. This study was performed to evaluate the relative validities of 3-day food records and the semi-quantitative FFQ. A total of 124 subjects finished 3-day food records (FRs) during each of the four seasons, as well as the FFQ from December 2002 to May 2004. The FFQ was a food based semi-quantitative FFQ including 103 items. Three-day FRs from each season and a randomly selected season were compared with the remaining 9-day FRs. The remaining 9-day FRs, as a reference measurement, were also compared with the FFQ. Pearson's correlation coefficients between the 3-day FRs and the 9-day FRs were between 0.14 and 0.56. Pearson's correlation coefficients between the FFQ and the 9-day FRs ranged between 0.07 and 0.41. Average proportions of classification into the same quartiles, adjacent quartiles, and distant quartiles between the 3-day FRs and the 9-day FRs were 35.8%, 40.5%, and 5.2%, respectively. On average, the proportions of classification into the same quartiles, adjacent quartiles, and distant quartiles between the FFQ and the 9-day FRs were 31.1%, 39.4%, and 6.9%, respectively. Three-day FRs showed higher correlations and higher agreement proportions of quartile classification with the 9-day FRs than did the FFQ, but both relative validities of 3-day FRs and the FFQ appear to be acceptable as dietary assessment tools. Further studies for validating food intake by reliable biomarkers are necessary.

Key Words: Relative validity, food records, food frequency questionnaire

Introduction

To investigate the relation between diet and chronic disease, several dietary assessment methods have been developed and evaluated. The food frequency questionnaire (FFQ) has been used most frequently in large-scale epidemiologic studies, because FFQ is less expensive to administer than are other dietary assessment methods, and the FFQ evaluates long-term diet rather than 24-h dietary recall or food records. In addition, dietary intakes estimated by FFQs have shown clear associations with coronary heart disease, type 2 diabetes, and blood lipids [1-3]. However, several studies [4-7] suggested that other types of dietary assessment need to be used in epidemiologic studies of diet and diseases to overcome the limitations of FFQs. These limitations include weak associations with dietary biomarkers and a lack of consistency across studies examining diet and cancer risk. The usefulness of FFQs in epidemiologic studies is inconclusive.

Food records ask participants to record all foods and beverages consumed over a specific period of time, usually 3 to 7 days or during multiple periods within a year. Because food records do not rely on memory, food records have been used as a reference method to validate other dietary assessment methods. However, due to day-to-day variations and seasonal variations in food records, multiple-day food records over four seasons have been used as a reference standard to evaluate other dietary assessment methods. Food records have revealed relationships not observed in the FFQ [8-9]. A significant relationship between dietary fat and the risk of breast cancer was found based on multiple-day food records, but was not seen in the FFQ [8-9]. However, multiple-day food records require highly motivated participants, and they are expensive to administer in large samples, thus 3-day food records have been commonly used in practical settings.

Given these aspects, it has been debated which dietary assessment method would be appropriate in large-scale epidemiologic studies. In the present study, we investigated the relative validities of 3-day food records and the FFQ, respectively, by comparing them with 9-day food records.

Subjects and Methods

Subjects

Subjects were recruited from December 2002 to May 2004 in the Health Examination Center at Hallym University Sacred Heart Hospital located in Anyang, Korea. Full details of the methods used in the study are given elsewhere [10] and are summarized below. A total of 199 subjects between the ages of 40 to 70 years consented to join the study and completed the first food record (FR). Among them, 130 subjects completed the 3-day FRs over four seasons, as well as the FFQ. Six people who changed their diet for weight-loss purposes during the study period were excluded. Thus, 124 participants were included in the final analyses.

Food-frequency questionnaire

A 103-item food FFQ was administered by two trained dietitians. This food-based FFQ was developed with 24-h data from the Korea National Health and Nutrition Examination Survey in 1998. The procedures of development and evaluation of the FFQ are described in detail elsewhere [10-11]. Briefly, food items were selected based on the cumulative percent contribution of each food and the cumulative R^2 of multiple regression of each nutrient. The consumption frequency was classified into nine categories: never or seldom, one a month, two to three times a month, one to two times a week, three to four times a week, five to six times a week, once a day, twice a day, or three or more times a day. For the food items with different seasonal availability, like fruits, participants were additionally asked to mark one of four categories with respect to how many months they ate each particular item: three, six, nine and 12 months. Portion size was classified into three categories: small, medium, or large. Several photos of serving sizes of certain foods were presented to help in the understanding of portion sizes.

Food record

Each participant was asked to keep 12-day FRs for one year. To capture seasonal variations and weekly variations, participants were asked to keep non-consecutive 3-day FRs including one weekend day or holiday during each of the four seasons. Eighty-five percent of the total participants adhered precisely to the recording days. The participants were asked to record the amounts of foods consumed with multiples of household tableware in order to increase the accuracy of portion size. A standardized protocol was developed by a research dietitian supervisor, which included the manual providing information for FR procedure in detail. Dietitians trained participants with the manual and reviewed unclear descriptions, errors, omissions, or doubtful entries in FRs and asked the participants to clarify them.

The research dietitian supervisor checked all completed records for accuracy.

Twelve-day FRs were collected to validate the FFQ. In the previous validation study between 12-day FRs and the FFQ [10], the Pearson's correlation coefficients between 12-day FRs and the second FFQ were between 0.10 and 0.46 (median for all nutrients 0.33). Pearson's correlation coefficients between the first FFQ and the second FFQ ranged between 0.24 (carbohydrate) and 0.58 (cholesterol) [10]. In the current study, 3-day FRs and the remaining 9-day FRs were used to evaluate the relative validities of 3-day FRs and the FFQ.

Statistical analysis

Nutrient intake in the FFQ was calculated using a weighted frequency per day and a portion size per unit of each food item. The daily nutrient intakes of each participant were the sum of the nutrient intakes of each food item. The seventh edition of the Food Composition Table of Korea was used as the nutrient database [12].

Three-day FRs from each season and a randomly selected season were compared with the remaining 9-day FRs, respectively. The remaining 9-day FRs, as references, were also compared with the FFQ. The mean difference of each nutrient between the 12-day FRs and the FFQ was tested by paired t-test. Correlations of nutrient intake were assessed by Pearson's correlation coefficient after adjustment for sex. Most nutrient distributions were skewed, thus, all nutrients were natural log transformed prior to analysis. De-attenuated correlation coefficients were applied to correct the within-person error in the measurements of the FRs. The observed correlations were multiplied by the de-attenuation factor $(1+\gamma/n)^{1/2}$, where γ is the ratio of the within- and between-person variances and n is the number of repeats. Using the SAS Varcomp procedure, within- and between-person variances were calculated. Nutrient intakes were also adjusted for total energy intake using the residual method [13].

The agreement of 3-day FRs with 9-day FRs and the agreement of 9-day FRs with the FFQ were compared by cross-classification analysis. Subjects were classified into quartiles based on nutrient intake, and the percentages of agreement and disagreement were calculated. All statistical analyses were performed using the SAS software (version 9.1 SAS Institute Inc., Cary, NC), and *P* values < 0.05 were considered to be significant.

Results

General characteristics of the subjects are shown in Table 1. Men made up 26.6% of the total number of subjects, and the mean age of the subjects was 47.4 years. The mean body mass index (BMI) of the subjects was 23.4 kg/m^2. The proportions of current alcohol drinkers and current smokers were 41.1% and 12.9%, respectively.

Table 1. General characteristics of the study subjects

	Total	Men	Women
n	124	33	91
Age (year)	47.4 ± 6.0	49.0 ± 6.7	46.8 ± 5.7
Height (cm)	161.2 ± 6.3	166.8 ± 6.2	159.2 ± 5.0
Weight (kg)	61.1 ± 10.1	67.4 ± 11.5	58.8 ± 8.5
BMI (kg/m^2)	23.4 ± 3.0	24.1 ± 3.5	23.2 ± 2.7
Alcohol consumption (%)			
Non-drinker	4.0	9.1	2.2
Current drinker	41.1	63.6	33.0
Smoking (%)			
Non-smoker	14.5	36.4	6.6
Current smoker	12.9	36.3	5.5
Education level (%)			
< 9 years	16.3	15.2	16.7
9-12 years	39.0	33.3	41.1
> 12 years	44.7	51.5	42.2

Mean daily intakes of nutrients estimated by four 3-day FRs and the FFQ are given in Table 2. When four 3-day FRs were used to estimate energy and nutrient intakes, mean intakes of energy, protein, fat, carbohydrate, vitamin B_1 and B_2, niacin, phosphorus, Na, Fe, zinc, and cholesterol in men were higher than those of women. Whereas, mean intakes of vitamin C, folate, and calcium in women were higher than those of men. When the FFQ was applied to estimate energy and nutrient intakes, there were no differences in nutrient intakes between men and

women. The intakes of fat, fiber, vitamins A, E, and B_6, β-carotene, and Na in four 3-day FRs were higher than those of the FFQ. The intake of carbohydrate in the FFQ was higher than that of the four 3-day FRs.

The crude Pearson's correlation coefficients after adjustment for sex between 3-day FRs and 9-day FRs for spring, summer, fall, and winter were 0.18-0.54, 0.20-0.50, 0.16-0.56, and 0.14-0.49, respectively. The Pearson's correlation coefficients after adjustment for sex between the FFQ and the 9-day FRs with exclusions of spring, summer, fall, and winter were 0.07-0.39, 0.12-0.41, 0.11-0.41, and 0.09-0.38, respectively. The crude Pearson's correlation coefficients between the 3-day FRs and the 9-day FRs were higher than the crude Pearson's correlation coefficients between the FFQ and the 9-day FRs in most nutrients (Table 3). Among the crude correlation coefficients between the 3-day FRs and the 9-day FRs, energy, carbohydrate, fiber, folate, phosphorus, sodium, and iron showed higher correlations (≥ 0.4) than did the other nutrients. Vitamin A, retinol, and β-carotene showed seasonal differences in the correlations. Among the crude correlation coefficients between the FFQ and the 9-day FRs, vitamin A, vitamin E, vitamin B_2, and sodium showed lower correlations (≤ 0.2) than did the other nutrients. De-attenuated correlation coefficients in most nutrients were improved in the comparisons (3-day FRs vs. 9-day FRs and FFQ vs. 9-day FRs). De-attenuated correlation coefficients of vitamin A, retinol, and β-carotene between 3-day FRs and

Table 2. Mean daily intakes of energy and nutrients estimated from four 3-day food records (FRs) and the food frequency questionnaire (FFQ)

Nutrients	12day FRs		FFQ	
	Men (n = 33)	Women (n = 91)	Men (n = 33)	Women (n = 91)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Energy (Kcal)	1928.8 ± 535.0	1707.6 ± 441.7[a]	1953.3 ± 473.5	1843.0 ± 449.7[b]
Protein (g)	74.4 ± 24.8	66.6 ± 22.8[a]	65.6 ± 18.4	63.0 ± 18.8
Fat (g)	47.2 ± 25.9	42.4 ± 21.3[a]	34.6 ± 13.9[b]	30.8 ± 12.5[b]
Carbohydrate (g)	274.1 ± 69.7	263.4 ± 70.0[a]	339.8 ± 88.5[b]	325.4 ± 79.3[b]
Fiber (g)	6.7 ± 2.6	6.9 ± 2.9	5.4 ± 2.0[b]	5.6 ± 2.1[b]
Vit.A (R.E.)	629.1 ± 413.2	651.0 ± 465.0	444.8 ± 229.0[b]	450.8 ± 240.5[b]
Retinol (ug)	90.2 ± 162.7	86.7 ± 146.2	57.5 ± 31.2	66.4 ± 38.8
β-Carotene (ug)	3014.8 ± 2241.3	3149.7 ± 2545.7	2240.4 ± 1361.6[b]	2240.4 ± 1334.9[b]
Vit.E (mg)	13.4 ± 7.8	13.2 ± 7.1	8.1 ± 3.2[b]	8.0 ± 3.0[b]
Vit.C (mg)	101.0 ± 72.9	120.2 ± 85.1[a]	92.7 ± 41.1	112.4 ± 52.0
Vit.B$_1$ (mg)	1.3 ± 0.6	1.2 ± 0.5[a]	1.1 ± 0.3	1.0 ± 0.3
Vit.B$_2$ (mg)	1.5 ± 1.1	1.2 ± 0.7[a]	0.9 ± 0.2[b]	1.0 ± 0.3
Niacin (mg)	18.1 ± 7.6	16.2 ± 6.9[a]	16.6 ± 7.5	18.5 ± 13.5[b]
Vit.B$_6$ (mg)	2.2 ± 1.2	2.1 ± 1.1	1.5 ± 0.4[b]	1.5 ± 0.5[b]
Folate (ug)	233.4 ± 101.1	246.1 ± 114.4[a]	213.7 ± 89.8[b]	221.9 ± 86.6
Ca (mg)	486.7 ± 231.6	522.6 ± 281.2[a]	441.0 ± 198.8	522.0 ± 222.5[b]
P (mg)	1091.7 ± 338.6	1020.9 ± 309.4[a]	961.0 ± 279.0	993.0 ± 299.6
Na (mg)	4538.1 ± 1555.6	4007.9 ± 1606.6[a]	2699.8 ± 1132.4[b]	2519.1 ± 989.4[b]
K (mg)	2657.5 ± 886.8	2644.6 ± 889.1	2389.5 ± 1115.7	2880.7 ± 1684.8[b]
Fe (mg)	12.6 ± 5.2	12.0 ± 4.7[a]	10.7 ± 4.2	11.6 ± 4.4
Zinc (ug)	9.3 ± 6.5	8.2 ± 5.0[a]	8.4 ± 2.4	7.9 ± 2.4
Cholesterol (mg)	295.0 ± 204.1	235.8 ± 173.6[a]	164.7 ± 70.0	149.1 ± 72.9

[a] $P < 0.05$ for the differences by paired t-test between men and women in FRs and FFQ, respectively.
[b] $P < 0.05$ for the differences by paired t-test between FRs and FFQ in men and women, respectively.

Table 3. Comparisons of Pearson's correlation coefficients; nutrients by 3-days FRs and nutrients by 9-days FRs vs. FFQ and nutrients by 9-days FRs

Nutrients	Sex adjusted crude										Sex adjusted de-attenuated										Sex and energy adjusted									
	3D vs. 9D					FFQ vs. 9D					3D vs. 9D					FFQ vs. 9D					3D vs. 9D					FFQ vs. 9D				
	ran	spr	sum	fall	win	E-ran	E-spr	E-sum	E-fall	E-win	ran	spr	sum	fall	win	E-ran	E-spr	E-sum	E-fall	E-win	ran	spr	sum	fall	win	E-ran	E-spr	E-sum	E-fall	E-win
Energy (Kcal)	0.46	0.50	0.47	0.39	0.44	0.35	0.33	0.36	0.31	0.31	0.54	0.59	0.56	0.51	0.51	0.42	0.40	0.43	0.41	0.36										
Protein (g)	0.41	0.43	0.42	0.32	0.44	0.38	0.31	0.34	0.31	0.30	0.51	0.54	0.53	0.40	0.54	0.47	0.38	0.43	0.38	0.38	0.30	0.32	0.32	0.27	0.25	0.26	0.14	0.24	0.28	0.26
Fat (g)	0.26	0.34	0.40	0.34	0.28	0.32	0.31	0.28	0.21	0.26	0.35	0.46	0.59	0.49	0.38	0.42	0.42	0.41	0.30	0.36	0.30	0.41	0.34	0.41	0.36	0.35	0.29	0.28	0.23	0.28
Carbohydrate (g)	0.50	0.52	0.50	0.45	0.46	0.40	0.39	0.41	0.41	0.38	0.57	0.59	0.57	0.51	0.51	0.46	0.45	0.47	0.47	0.43	0.28	0.41	0.41	0.33	0.36	0.32	0.25	0.22	0.27	0.27
Fiber (g)	0.40	0.54	0.42	0.50	0.38	0.23	0.27	0.24	0.26	0.25	0.47	0.64	0.49	0.59	0.44	0.27	0.32	0.27	0.31	0.29	0.38	0.54	0.39	0.50	0.38	0.22	0.27	0.23	0.23	0.28
Vit.A (R.E.)	0.30	0.40	0.26	0.46	0.25	0.16	0.10	0.14	0.16	0.09	0.36	0.50	0.32	0.59	0.30	0.20	0.13	0.17	0.20	0.11	0.20	0.21	0.38	0.45	0.22	0.27	0.20	0.25	0.23	0.24
Retinol (ug)	0.16	0.35	0.32	0.34	0.14	0.36	0.29	0.38	0.41	0.32	0.25	0.65	0.60	0.50	0.24	0.55	0.55	0.72	0.60	0.53	0.06	0.23	0.05	0.12	0.10	0.26	0.19	0.29	0.30	0.21
β-Carotene (ug)	0.32	0.39	0.24	0.44	0.30	0.25	0.21	0.20	0.25	0.22	0.38	0.47	0.30	0.56	0.35	0.30	0.25	0.25	0.32	0.26	0.20	0.21	0.42	0.45	0.25	0.30	0.26	0.28	0.28	0.31
Vit.E (mg)	0.37	0.30	0.29	0.32	0.36	0.15	0.16	0.12	0.14	0.16	0.49	0.42	0.38	0.43	0.50	0.20	0.22	0.16	0.18	0.23	0.32	0.24	0.18	0.26	0.30	0.05	0.00	0.05	0.03	0.04
Vit.C (mg)	0.27	0.45	0.38	0.35	0.30	0.25	0.30	0.28	0.32	0.29	0.33	0.55	0.45	0.42	0.36	0.31	0.37	0.34	0.38	0.34	0.19	0.39	0.31	0.25	0.25	0.17	0.23	0.22	0.22	0.18
Vit.B$_1$ (mg)	0.28	0.23	0.31	0.27	0.29	0.32	0.25	0.25	0.29	0.25	0.39	0.31	0.45	0.37	0.40	0.44	0.34	0.35	0.40	0.34	0.28	0.13	0.29	0.16	0.34	0.16	0.14	0.12	0.09	0.10
Vit.B$_2$ (mg)	0.30	0.38	0.45	0.51	0.41	0.10	0.07	0.12	0.11	0.12	0.33	0.42	0.50	0.59	0.45	0.11	0.08	0.13	0.12	0.13	0.30	0.33	0.47	0.54	0.39	0.00	-0.02	0.01	0.00	0.03
Niacin (mg)	0.40	0.34	0.35	0.41	0.27	0.27	0.27	0.19	0.23	0.22	0.52	0.45	0.45	0.55	0.34	0.36	0.36	0.25	0.31	0.27	0.34	0.27	0.27	0.36	0.21	0.02	0.07	-0.08	0.01	0.05
Vit.B$_6$ (mg)	0.23	0.18	0.20	0.28	0.20	0.18	0.13	0.26	0.12	0.12	0.32	0.27	0.29	0.42	0.29	0.25	0.19	0.38	0.18	0.17	0.06	0.00	0.05	0.14	0.05	0.08	0.04	0.16	0.08	0.14
Folate (ug)	0.43	0.50	0.48	0.53	0.48	0.25	0.18	0.18	0.26	0.19	0.50	0.59	0.56	0.62	0.57	0.29	0.21	0.21	0.31	0.22	0.40	0.49	0.55	0.52	0.47	0.21	0.14	0.20	0.25	0.19
Ca (mg)	0.37	0.35	0.38	0.36	0.41	0.27	0.23	0.26	0.25	0.24	0.45	0.43	0.48	0.44	0.50	0.32	0.28	0.32	0.31	0.30	0.38	0.30	0.42	0.25	0.41	0.35	0.27	0.30	0.34	0.37
P (mg)	0.51	0.53	0.44	0.41	0.45	0.37	0.31	0.34	0.31	0.29	0.60	0.64	0.51	0.47	0.52	0.43	0.36	0.39	0.36	0.34	0.50	0.47	0.45	0.39	0.36	0.35	0.30	0.33	0.39	0.37
Na (mg)	0.43	0.52	0.41	0.56	0.49	0.14	0.15	0.18	0.16	0.13	0.49	0.60	0.46	0.65	0.56	0.16	0.18	0.21	0.19	0.15	0.30	0.39	0.30	0.41	0.33	0.05	0.06	0.13	0.06	0.10
K (mg)	0.42	0.46	0.45	0.51	0.38	0.29	0.29	0.26	0.27	0.24	0.49	0.54	0.52	0.60	0.44	0.34	0.35	0.30	0.32	0.27	0.47	0.42	0.46	0.56	0.41	0.17	0.20	0.12	0.12	0.11
Fe (mg)	0.49	0.52	0.47	0.41	0.45	0.35	0.30	0.32	0.33	0.29	0.57	0.62	0.55	0.48	0.52	0.41	0.36	0.38	0.38	0.34	0.46	0.47	0.47	0.38	0.41	0.26	0.21	0.23	0.29	0.27
Zinc (ug)	0.18	0.20	0.26	0.16	0.27	0.26	0.19	0.25	0.27	0.16	0.27	0.29	0.39	0.23	0.42	0.38	0.28	0.39	0.39	0.26	0.01	0.02	0.17	0.04	0.14	0.21	0.20	0.20	0.25	0.13
Cholesterol (mg)	0.35	0.39	0.43	0.33	0.31	0.34	0.34	0.33	0.37	0.35	0.46	0.49	0.56	0.40	0.40	0.45	0.43	0.43	0.45	0.44	0.30	0.27	0.34	0.25	0.23	0.33	0.30	0.29	0.41	0.34
Average	0.36	0.40	0.38	0.39	0.35	0.27	0.25	0.26	0.26	0.24	0.44	0.50	0.48	0.49	0.43	0.34	0.31	0.34	0.33	0.30	0.29	0.31	0.33	0.33	0.30	0.21	0.18	0.19	0.21	0.20

Ran, randomly selected three days vs. remaining nine days; spr, three spring days vs. remaining nine days; sum, three summer days vs. remaining nine days; fall, three fall days vs. remaining nine days; win, three winter days vs. remaining nine days; E-ran, exclusion of randomly selected three days vs. FFQ; E-spr, exclusion of three spring days vs. FFQ; E-sum, exclusion of three summer days vs. FFQ; E-fall, exclusion of three fall days vs. FFQ; E-win, exclusion of three winter days vs. FFQ.

9-day FRs constantly showed seasonal differences. After adjusting for sex and energy intake, the correlation coefficients of most nutrients in the comparison were decreased. The crude, de-attenuated, and energy-adjusted correlation coefficients between the 3-day FRs and the 9-day FRs were constantly higher than those between the FFQ and the 9-day FRs.

The results of the cross-classification analysis are presented in Table 4. The average proportions of classification into the same quartiles, adjacent quartiles, and distant quartiles between the 3-day FRs and the 9-day FRs were 35.8%, 40.5%, and 5.2%, respectively. The nutrients which showed ≥ 10% seasonal differences in the classification into the same quartiles or adjacent quartiles between the 3-day FRs and 9-day FRs were energy, fiber, vitamin A, retinol, vitamin B$_2$, phosphorus, iron, and zinc. On average, the proportions of classification into the same quartiles, adjacent quartiles, and distant quartiles between the FFQ and 9-day FRs were 31.1%, 39.4%, and 6.9%, respectively.

Discussion

In this validation study, we evaluated the relative validities of 3-day food records (FRs) and the food frequency questionnaire

(FFQ) by comparing them with that of the 9-day FRs. Correlation coefficients between the 3-day FRs and the 9-day FRs were higher than those between the FFQ and the 9-day FRs. Vitamin A, retinol, and β-carotene showed seasonal differences in the correlation coefficients. Average proportions of classification into the same quartiles and adjacent quartiles between the 3-day FRs and the 9-day FRs were higher than those between the FFQ and the 9-day FRs, but cross-classifications of two methods (3-day FRs and FFQ) with 9-day FRs showed that both the 3-day FRs and the FFQ were able to reasonably categorize individuals by nutrient intake. Three-day FRs showed higher correlations and higher agreement proportions of quartile classification with the 9-day FRs than did the FFQ, but both of the relative validities of 3-day FRs and FFQ were acceptable for use as dietary assessment tools.

In the present study, correlations between 3-day FRs and 9-day FRs were higher than correlations between 9-day FRs and the FFQ. The FFQ used in our study was a food-based FFQ and, thus, seasonings and cooking oils were omitted, which might affect the estimations of some nutrients and correlations with FRs. In the study by Yun *et al.* [14], excluding oils and seasonings from a FFQ underestimated vegetable fat, vitamin E, and sodium intake, and Shim *et al.* [15] reported that seasonings contributed

Table 4. The proportion of agreement in quartile distribution of nutrients from 3-day FRs and 9-day FRs vs. 9-day FRs and FFQ

Nutrients	3D vs. 9D														
	Ran3 vs. E-Ran9			Spr3 vs. E-spr9			Sum3 vs. E-sum9			Fall3 vs. E-fall9			Win3 vs. E-win9		
	S (%)	A (%)	D (%)	S (%)	A (%)	D (%)	S (%)	A (%)	D (%)	S (%)	A (%)	D (%)	S (%)	A (%)	D (%)
Energy (Kcal)	45.2	33.1	2.4	41.1	37.1	1.6	49.2	34.7	4.0	33.9	44.3	2.4	38.7	38.7	6.5
Protein (g)	35.5	45.2	4.8	37.1	38.7	4.8	39.5	42	4.8	33.1	43.5	6.5	36.3	41.9	4.8
Fat (g)	27.4	41.9	6.5	33.9	39.5	7.3	33.9	39.5	4.0	34.7	37.9	5.6	29.0	41.2	8.9
Carbohydrate (g)	41.9	36.3	4.0	36.3	42.7	2.4	43.5	37.1	1.6	42.7	34.7	2.4	38.7	41.1	5.6
Fiber (g)	36.3	38.7	6.5	42.7	35.5	3.2	33.1	42.7	5.6	41.1	38.7	4.8	37.1	30.6	1.6
Vit.A (R.E.)	31.5	38.7	3.2	33.9	45.1	3.2	29.0	44.4	5.6	38.7	40.3	3.2	28.2	50.8	7.3
Retinol (ug)	33.1	43.5	9.7	39.5	42	8.1	35.5	38.7	6.5	42.7	32.3	6.5	28.2	42	6.5
Carotene (ug)	28.2	43.5	4.8	34.7	44.3	4.0	30.6	37.1	8.1	29.8	47.6	4.0	37.9	37.1	6.5
Vit.E (mg)	32.3	39.5	7.3	28.2	45.2	6.5	29.0	39.5	5.6	33.9	41.1	10.5	37.1	37.1	4.8
Vit.C (mg)	37.9	34.7	5.6	36.3	43.5	3.2	38.7	33.9	8.1	37.9	41.1	7.3	29.8	42	3.2
Vit.B$_1$ (mg)	37.9	37.9	8.9	33.1	38.7	6.5	32.3	39.5	7.3	33.1	37.9	7.3	33.1	39.5	8.9
Vit.B$_2$ (mg)	40.3	32.3	9.7	34.7	41.9	4.8	33.9	41.9	3.2	49.2	35.5	4.8	35.5	42.7	7.3
Niacin (mg)	34.7	37.9	5.6	33.9	39.5	5.6	33.9	39.5	5.6	33.1	44.3	7.3	31.5	41.1	5.6
Vit.B$_6$ (mg)	37.1	40.3	4.8	32.3	37.1	6.5	31.5	41.9	6.5	31.5	42.7	5.6	26.6	44.4	8.9
Folate (ug)	33.9	40.3	4.8	36.3	42.7	2.4	33.9	44.3	5.6	33.9	45.1	4.8	38.7	41.1	4.0
Ca (mg)	42.7	35.5	8.1	33.1	45.1	8.1	39.5	40.3	6.5	39.5	41.1	7.3	36.3	41.1	4.0
P (mg)	33.9	46.8	0.0	37.1	49.2	2.4	32.3	45.9	2.4	29.0	46	2.4	33.1	45.9	2.4
Na (mg)	35.5	41.1	4.0	38.7	43.6	1.6	36.3	37.1	4.8	41.1	42	1.6	43.5	38	5.6
K (mg)	37.9	43.5	4.8	33.9	44.3	4.0	34.7	44.3	4.0	39.5	42	4.8	39.5	39.5	5.6
Fe (mg)	40.3	37.9	5.6	39.5	41.1	2.4	29.8	46.8	1.6	40.3	38.7	4.8	39.5	36.3	7.3
Zinc (ug)	35.5	38.7	4.8	43.5	34.7	5.6	41.9	36.3	4.0	29.8	41.2	7.3	35.5	40.3	6.5
Cholesterol (mg)	36.3	41.1	5.6	37.9	40.3	6.5	35.5	38.7	4.8	34.7	35.5	4.8	33.9	40.3	6.5
Average	36.1	39.5	5.5	36.3	41.4	4.6	35.3	40.3	5.0	36.5	40.6	5.3	34.9	40.6	5.8

Nutrients	FFQ vs. 9D														
	FFQ vs. E-Ran9			FFQ vs. E-spr9			FFQ vs. E-sum9			FFQ vs. E-fall9			FFQ vs. E-win9		
	S (%)	A (%)	D (%)	S (%)	A (%)	D (%)	S (%)	A (%)	D (%)	S (%)	A (%)	D (%)	S (%)	A (%)	D (%)
Energy (Kcal)	34.7	41.1	4.0	29.8	45.2	3.2	33.1	45.1	4.8	29.8	46.8	4.8	26.6	46.8	4.8
Protein (g)	29.0	46.8	4.8	29.0	41.2	4.0	29.0	42.8	4.0	29.0	44.4	4.0	29.0	42.0	4.8
Fat (g)	29.0	42.0	6.5	26.6	46.0	5.6	34.7	36.3	7.3	30.6	34.7	7.3	28.2	39.5	8.9
Carbohydrate (g)	36.3	39.5	4.0	39.5	34.7	2.4	39.5	37.9	4.0	41.1	34.7	4.0	35.5	40.3	3.2
Fiber (g)	30.6	37.1	7.3	32.3	33.8	7.3	29.0	37.9	8.1	27.4	41.1	6.5	26.6	39.5	8.1
Vit.A (R.E.)	29.8	35.5	9.7	22.6	42.7	10.5	30.6	33.1	10.5	26.6	37.1	8.1	25.0	36.3	10.5
Retinol (ug)	41.9	34.7	4.0	37.1	39.5	4.0	41.1	33.9	4.8	41.1	34.7	2.4	34.7	38.7	3.2
Carotene (ug)	32.3	37.9	8.9	29.8	36.3	10.5	25.8	39.5	8.9	28.2	39.5	7.3	26.6	40.3	9.7
Vit.E (mg)	29.0	37.9	10.5	28.2	37.1	11.3	26.6	37.9	10.5	27.4	36.3	10.5	32.3	33.0	10.5
Vit.C (mg)	34.7	37.1	6.5	35.5	36.3	7.3	33.1	39.5	5.6	33.1	40.3	6.5	39.5	33.9	8.1
Vit.B$_1$ (mg)	36.3	35.5	2.4	33.9	37.9	6.5	36.3	30.6	4.0	33.1	37.1	2.4	27.4	43.6	5.6
Vit.B$_2$ (mg)	33.1	36.3	8.9	28.2	39.5	8.9	25.0	45.2	9.7	32.3	39.5	8.9	32.3	36.2	8.9
Niacin (mg)	33.1	41.9	9.7	29.0	47.6	8.9	32.3	39.5	8.9	40.3	29.1	11.3	30.6	36.3	8.9
Vit.B$_6$ (mg)	29.0	44.4	8.9	33.1	35.4	8.1	34.7	37.1	6.5	32.3	36.2	8.9	26.6	41.1	10.5
Folate (ug)	32.3	41.1	7.3	28.2	39.5	8.9	27.4	38.7	9.7	29.0	42.0	4.8	29.8	37.1	8.1
Ca (mg)	32.3	36.2	4.0	29.8	36.3	4.0	28.2	42.0	3.2	31.5	34.6	5.6	29.8	42.8	5.6
P (mg)	32.3	37.9	7.3	31.5	36.2	5.6	29.8	37.1	6.5	28.2	43.6	9.7	26.6	39.5	5.6
Na (mg)	29.8	35.5	9.7	28.2	37.9	8.9	29.8	35.5	8.1	22.6	42.7	7.3	30.6	34.7	8.9
K (mg)	31.5	42.7	7.3	30.6	43.6	6.5	25.0	44.4	7.3	30.6	41.2	5.6	33.1	37.9	7.3
Fe (mg)	31.5	41.9	6.5	25.8	44.4	5.6	30.6	43.6	8.1	33.1	37.9	5.6	27.4	42.8	7.3
Zinc (ug)	27.4	46.0	6.5	27.4	42.0	8.9	32.3	44.3	8.1	33.9	41.1	6.5	24.2	46.8	10.5
Cholesterol (mg)	32.3	47.5	5.6	37.1	38.7	4.8	33.1	45.1	8.1	32.3	44.3	2.4	38.7	33.9	4.8
Average	32.2	39.8	6.8	30.6	39.6	6.9	31.2	39.4	7.1	31.5	39.1	6.4	30.1	39.2	7.4

E-ran9, exclusion of randomly selected three days; E-spr9, exclusion of three spring days; E-sum9, exclusion of three summer days; E-fall9, exclusion of three fall days; E-win9, exclusion of three winter days; S, same quartile; A, adjacent quartile; D, distant quartile.

8.4% of energy intake, 34.4% of fat intake, 20.5% of iron intake, and 17.9% of β-carotene intake. Thus, intakes of seasonings and oils should be considered in the selection of the items of the FFQ. A dish-based FFQ can be a solution for including seasonings and oils in the estimation of nutrients, but due to a lack of standard Korean recipes, the development of standard recipes for Korean dishes is required first.

The correlations of the FFQ with the 9-day FRs in this study appear to be lower than western countries [16-17], but comparable to other Korean studies [18-20]. A typical Korean meal consists of cooked rice, soup, and multiple side dishes and a meal is often served family style and side dishes are shared with multiple persons. Thus, Koreans may have difficulties in answering the consumption frequency and portion size for a specific food item. Since the consumption of carbohydrate in Koreans is higher than that of western countries, more food items containing high carbohydrate were listed in the FFQ, which may result in higher mean of carbohydrate intake in the FFQ than FRs.

Lower correlations of the FFQ with the 9-day FRs than those of the 3-day FRs with the 9-day FRs in the present study may be partially attributed to a concept of FFQs. The basic assumption of FFQs is that the average long-term diet is the conceptually important factor rather than dietary intake over a few specific days [21]. In FFQs, precision is sacrificed to a certain extent [21]. Participants might have trouble remembering a consumption frequency or the amount of food consumed in a year. In a qualitative study using cognitive interviews for the FFQ used in the present study, participants had difficulties in remembering events over the course of a full year. Elements contributing to those difficulties included the consumption of diverse foods, calculating the averages for seasonal foods, estimating consumption amounts from photos, adjusting frequency when the amount consumed is higher or lower than the quantities presented, and combining the frequency and quantity of each food item when several food items are clustered into one category, etc. Lee *et al.* [22] to overcome the limitations of FFQ, several approaches including detailed questions regarding preparation, questions on seasonal intakes for several foods, inclusion of portion size ranges, additional response categories for frequency of intake, and addition of the food glossary and written cues were suggested [23-24]. However, despite these limitations of the FFQ, cross-classification showed that the FFQ classified approximately 71% of the subjects within the same or adjacent quartiles and only 7% of the subjects were classified into distant quartiles. With respect to expediency of administration and day-to-day variation, the FFQ can be a useful tool for estimating usual intake in a large epidemiologic study.

Three-day FRs showed a relatively higher validity than did the FFQ, but 3-day FRs have a weakness when it comes to characterizing an individual's usual diet due to within-person variations of day-to-day dietary intake. Kwon *et al.* [25] reported components of variance in nutrient intake with the same data used in the current study. The major components of variance were within-individual variations (57.2-87.1%) and between-individual variations (12.2-37.4%) for all nutrients. Weekly and seasonal variations contributed small components for most nutrients, but vitamin A, retinol, and β-carotene showed seasonal differences in the correlations between the 3-day FRs and 9-day FRs in the current study. Kwon *et al.* [25] suggested that to estimate usual individual intakes within 20% of the true mean with 90% confidence level, energy, protein, carbohydrate, phosphorus, and iron required 3-9 days of dietary survey, fat and calcium required 13-19 days, and vitamins A and C required 25-29 days. Depending on the nutrients of interest and the purpose of a study, the number of days for FRs should be taken into account. Despite the relatively higher validity of 3-day FRs, to overcome the limitations of 3-day FRs including day-to-day variation of intake and cost of administration, the FFQ needs to be combined in a large epidemiologic study.

This study had some limitations. Subjects were recruited in the Health Examination Center, thus, there is a restriction in generalizing the results of the study. In addition, 9-day FRs were used as a reference. The reference measurement should be independent from the evaluated method, but since 9-day FRs share common limitations with 3-day FRs, the correlation between 9-day FRs and 3-day FRs may be affected. Reliable biomarkers should be introduced to validate food intake measurements for further studies. In conclusion, 3-day FRs showed a relatively higher validity and agreement than FFQ, but the FFQ still has strength in large epidemiologic studies in terms of convenience of administration and estimation of usual intake. Therefore, many factors such as research objective and study design should be considered when selecting a dietary assessment method.

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