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A study testing the usefulness of a dish-based food-frequency questionnaire developed for epidemiological studies in Korea

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The purpose of the present study was to test the usefulness of dish items selected in developing a dish-based FFQ (DFFQ) to be used for epidemiological studies in Korea. The dietary data of 6817 subjects from the 2001 Korean National Health and Nutrition Examination Survey were used for the analysis. The 24 h recall method was employed for the dietary survey. Initially, ninety-five dish items were selected in developing the DFFQ based on consumption frequency, contribution of selected nutrients and coverage of between-person variations. The usefulness of the selected ninety-five dish items was tested based on their degree of contribution in supplying nutrients in the cumulative percentage contribution (cPC), as well as on their degree of explanation for between-person variation in the cumulative regression coefficient (cMRC). According to the results, the ninety-five selected dish items accounted for an average of 92·3 % of seventeen nutrients consumed by the study subjects based on cPC estimation. The top twenty items among the ninety-five dish items covered 70 to 91 % of the between-person variation for the seventeen nutrients based on cMRC estimation. Thus, the results suggest that the ninety-five items would be useful in developing a FFQ for use in epidemiological studies of Koreans, within less than 10 % underestimation.

Food-frequency questionnaires: Epidemiological studies: Korean National Health and Nutrition Examination Survey: Korea

A epidemiological transition has occurred in Korea, characterised by rapid increases in the incidence and mortality of chronic disease[1]. In order to understand the association between diet and chronic disease during this transitional period, there has been an increased demand for both prospective and retrospective epidemiological studies in Korea[2]. An important issue in conducting such studies is establishing valid dietary assessment tools for the estimation of average long-term intake of food and nutrients in individuals rather than for precise measurements of absolute dietary intake[3–5]. A number of questionnaires, mainly food-based FFQ (FFFQ), have been widely employed in epidemiological studies in both Western countries[6–8] and Asian countries[9,10], including Korea[11,12]. However, the dietary practices of Koreans are quite different from those of Europeans and Americans, which are typically based on the consumption of a single food. Koreans eat many kinds of mixed dishes with various seasonings and cooking oils; thus, a FFFQ is not sufficient to evaluate the effects of the seasonings and cooking oils in the Korean diet. The use of a FFFQ could underestimate the proportion of certain micronutrients, including antioxidant vitamins, fatty acids and phyto-oestrogens. Therefore, the development of a dish-based FFQ (DFFQ) could account for the different dietary practices of Koreans.

The purpose of the present study was to test the usefulness of ninety-five dish items selected in developing a DFFQ for the epidemiological study of Koreans. The 2001 Korean National Health and Nutrition Examination Survey (KNHANES) data were used as representative data from the Korean population.

Materials and methods

Data source

The dietary data of 6817 subjects aged 20 years and older, from the 2001 KNHANES, were used in the analysis. Detailed information about the 2001 KNHANES is described elsewhere[13,14]. In brief, the nationwide KNHANES is conducted every 3 years, and information is collected from a stratified multistage probability sample of South Korean households representing the civilian, non-institutionalised population. The KNHANES is comprised of four parts: the Health Interview Survey, the Health Behavior Survey, the Health Examination Survey, and the Nutrition Survey. There were 246 097 primary sampling units, with sixty households in each unit. Sampling units were randomly selected from the primary sampling units using a stratified multistage probability method. A total of 600 sampling units encompassing 13 200 households were selected. A total of 37 769 subjects

Abbreviations: cPC, cumulative percentage contribution; DFFQ, dish-based FFQ; FFFQ, food-based FFQ; KNHANES, Korean National Health and Nutrition Examination Survey.

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(aged 1 year and older) from the 13 200 households were selected and participated in the Health Interview Survey. The remaining three surveys were conducted on randomly selected 200 sampling units encompassing 4015 households from the original 600 sampling units. All household members participating in the remaining three surveys were examined to determine health status, and were interviewed for the dietary survey using a 24 h dietary recall (9968 subjects).

The 24 h dietary recall questionnaire requested detailed descriptions of the type and amount of all foods consumed on the day before the interview, including snacks, beverages, and ingredient information for all sauces and condiments. Additionally, information regarding the time and the place of each meal was recorded. Subjects were also asked to assess whether or not the time period in question represented typical dietary intake. If it was not a typical day (for example, birthday party, family gathering, eating at a restaurant), the subjects were asked to report 2 d before the interview date, or the most recent typical day. The 24 h dietary recall began with the first meal or beverage consumed at waking until midnight of the reporting day. Trained dietitians administered the 24 h dietary recall using measuring cups, portion-size booklets and photographs. All completed records were checked by a research dietitian for accuracy. Nutrient intake of each food item was calculated using the Diet Analysis program (version 4.0; Nutritional Epidemiology Laboratory, National Cancer Center) for a total of seventeen nutrients (total energy, protein, fat, carbohydrate, fibre, Ca, P, Fe, Na, K, vitamin A, retinol, carotene, vitamin B_1, vitamin B_2, niacin and vitamin C). Nutrient intake was calculated based on the 5th Edition Food Composition Table[15] and a database of processed and fast foods[16]. Individuals aged less than 20 years (2990 subjects) and individuals with extreme total energy intake (defined as 2·93–25·1 MJ/d for males and 2·51–16·7 MJ/d for females) (forty males and 121 females) were excluded, resulting in 6817 study participants for the analysis.

Initial selection of the ninety-five dish items for developing the dish-based food-frequency questionnaire

The selection of the dish items was implemented using Willett's method[5], with the 24 h dietary recall data of the 2001 KNHANES[13], and is described by flow chart in Fig. 1. For the initial selection of foods items contributing to total nutrient intake, the contribution analysis was performed. The percentage contribution of each nutrient by the 629 dishes was computed as the arithmetic mean of the individual percentage contribution of each nutrient by dish. The 411 dish items that were selected accounted for 90 % of the cumulative percentage contribution (cPC). Multiple regression analysis (MRA) was performed with the total intake of each nutrient as the dependent variable and the overall amounts of each nutrient from each of the 411 items as the independent variables for each participant. This estimated the degree of explanation of between-person variation. The items were selected until the cumulative multiple regression coefficients (cumulative partial R^2) reached 0·90. Finally, similar dishes were aggregated into groups based on the nutrient content per portion eaten, the cooking method and the food ingredients in the dish; they were coordinated when a name, a main food ingredient, or more than 90 % of recipe ingredients for a dish were similar to another dish. Several seasonal food items, for example, seasonal fruits (strawberry, watermelon, etc.) and celebration foods, were not covered by the survey period of the 2001 KNHANES, but were included in the DFFQ. The composition values of the dishes were derived from standard recipes based on a publication by the Korean Ministry of Health and Welfare[16].

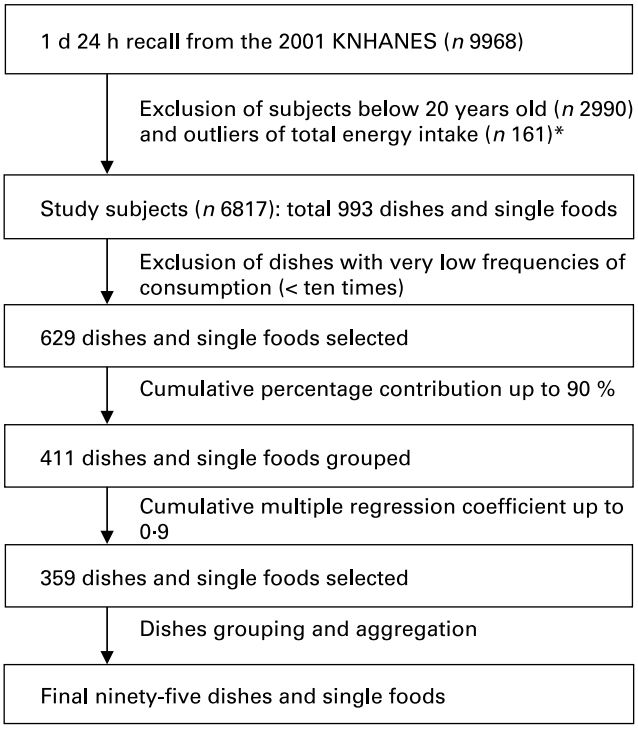

Fig. 1. Flow chart for the selection of dish and food items from the 2001 Korean National Health and Nutrition Examination Survey (KNHANES). *Males 2930–25 100 kJ/d (700–6000 kcal/d); females 2510–16 740 kJ/d (600–4000 kcal/d).

Statistical approach

The comparison of general characteristics between males and females was performed using the *t* test for continuous variables and the χ^2 test for categorical variables. Stepwise regression models were used to determine the list of dishes to be included in the DFFQ, taking into consideration the between-person variability added by each item[5]. The data processing was carried out using SAS (version 8.0; SAS Institute Inc., Cary, NC, USA) statistical software.

Results

Characteristics of study subjects

The characteristics of the study subjects (3158 men and 3659 women) are shown in Table 1. The mean age of the male subjects was 43·7 years and that of the female subjects was 44·9 years. The residential areas of the subjects were categorised as metropolitan city (46·6 %), middle or small city (30·7 %) and rural (22·7 %). Among the study subjects, 37·7 % of the men and 23·5 % of the women had education levels of more than

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Table 1. Distribution of age, residential area, education and nutrient intake level of study subjects by sex
(Mean values and standard deviations or numbers and percentages)

	Male (*n* 3158)		Female (*n* 3659)			Total (*n* 6817)	
Variables	Mean	SD	Mean	SD	*P**	Mean	SD
Age (years)	43·7	14·6	44·9	16·0	<0·0001	44·3	15·4
20–29							
n	553		668			1221	
%	17·5		18·3			17·9	
30–39							
n	851		923			1774	
%	27·0		25·2			26·0	
40–49							
n	777		797			1574	
%	24·6		21·8			23·1	
50–59							
n	451		506			957	
%	14·3		13·8			14·0	
60–69							
n	342		427			769	
%	10·8		11·7			11·3	
70 +							
n	184		338			522	
%	5·80		9·20			7·70	
Region					0·8592		
Metropolitan city							
n	1465		1711			3176	
%	46·4		46·8			46·6	
Middle or small city							
n	988		1105			2093	
%	31·3		30·2			30·7	
Rural							
n	705		843			1548	
%	22·3		23·0			22·7	
Education					<0·0001		
≤12 years							
n	1964		2798			4762	
%	62·3		76·5			69·8	
> 12 years							
n	1190		857			2047	
%	37·7		23·5			30·2	
Energy (kJ)	9749	3655	7555	2676	<0·0001	8572	3351
Protein (g)	86·7	43·8	64·5	32·0	<0·0001	74·8	39·5
Fat (g)	46·0	36·0	33·1	25·6	<0·0001	39·1	31·5
Carbohydrate (g)	363	133	304	107	<0·0001	331	123
Fibre (g)	8·25	4·62	7·20	4·31	<0·0001	7·69	4·49
Ca (mg)	556	360	471	304	<0·0001	510	334
P (mg)	1391	591	1081	449	<0·0001	1224	542
Fe (mg)	14·8	9·08	12·1	9·45	0·018	13·4	9·38
Na (mg)	6116	3342	5023	3169	0·002	5529	3295
K (mg)	3363	1552	2820	1417	<0·0001	3072	1505
Vitamin A (R.E.)	757	1081	603	657	<0·0001	674	883
Retinol (μg)	97·9	791	62·7	228	<0·0001	79·0	564
Carotene (μg)	3752	4271	3040	3352	<0·0001	3370	3822
Vitamin B_1 (mg)	1·47	0·87	1·16	0·68	<0·0001	1·30	0·79
Vitamin B_2 (mg)	1·29	0·78	1·01	0·55	<0·0001	1·14	0·68
Niacin (mg)	20·8	11·9	15·7	9·17	<0·0001	18·1	10·8
Vitamin C (mg)	136	111	149	125	<0·0001	143	119

R.E., retinol equivalents.
* *P* values for comparison between sex by *t* test.

12 years. The BMI for the men and women were 23·7 and 23·4 kg/m^2, respectively.

Selected ninety-five dish items for developing the dish-based food-frequency questionnaire

The initial analysis yielded a total of 993 dish items consumed by the 6817 participants. Dishes with very low frequencies of consumption were excluded (*n* 364) and dishes with minimal contribution to the dietary acquisition of the aforementioned seventeen nutrients (*n* 218) were excluded. This left a final count of 411 dishes, which accounted for 90 % of the cPC. The next stage of selection among the 411 items was carried out based on the degree of explanation for between-person variation. Therefore, 359 dish items were retained. Finally, after grouping and aggregation of 359 dishes, a total of

ninety-five dish items were selected for the DFFQ (Fig. 1). The publication categories[16] of the ninety-five dish items included (Table 2) in the DFFQ were rice and cereals (seven items), noodles (three items), breads (seven items), soups or stews (eleven items), fish and shellfish (ten items), meats (ten items), eggs (two items), pulses (three items), vegetables (thirteen items), kimchies (six items), milk and milk products (two items), fruits (six items), beverages (nine items) and snacks (six items).

Intake frequency and portion size

The food intake frequency in the semi-quantitative FFQ was classified into nine categories: almost never, once per month, two or three times per month, once or twice times per week, three or four times per week, five or six times per week, once per d, twice per d, and three times per d. In short, the standard portion size of each dish item per meal was determined using the mean amount, the typical or standard value, or the natural unit and also referred to the Korean Ministry of Health and Welfare portion-size booklet[16]. Portion size in the semi-quantitative FFQ was divided into three categories: small (half the medium portion), medium and large (1·5 times or greater than the medium portion). The medium intake was determined as the mean amount from the study subjects. For an example of the semi-quantitative FFQ, see the Appendix.

Usefulness of a diet-based food-frequency questionnaire

We wished to quantify the usefulness of the ninety-five selected dishes and the top twenty items in explaining between-person variations in nutrient consumption for energy and nutrients as estimated by cumulative multiple regression coefficient (R^2) and the coverage of total nutrient consumption as estimated by cPC (%) (Table 2).

The top twenty dish items accounted for 77, 70, 91 and 82 % of the between-person variation for total energy, protein, carbohydrate and fat intake, respectively. Among the twenty items, rice, the main staple for Korean people, was shown to account for 32 and 52 % of the between-person variation for total energy and carbohydrate intake, respectively. Rice also covered 45·3 and 59·7 % of the total intake of energy and carbohydrate, respectively. Roasted pork, spicy pan-fried pork and roasted beef accounted for 45 % of the between-person variation of fat intake.

A relatively limited number of dish items can explain the $>$ 90 % of the between-person variation of vitamins, compared with those of macronutrients and minerals. Only one item accounted for 96 and 79 % of the between-person variation for retinol (grilled fatty fish) and vitamin C (orange-coloured fruit) intake. Furthermore, the top twelve items reached almost 100 % of the between-person variation for retinol, and between seven and sixteen items reached 90 % of the between-person variation for vitamin C and carotene, respectively. Grilled fatty fish accounted for 96 % of the between-person variation for retinol. The analysis suggested that the top twelve dish items were sufficient enough to cover 100 % of the between-person variation.

The top twenty dish items accounted for 85, 67, 81, 83 and 71 % of the between-person variations for total intakes of Ca, P, Fe, Na and K, respectively. Soyabean paste soup was the top contributor in terms of Ca and Fe intake, and the major contributors to Na intake were Korean cabbage kimchi, radish kimchi and soyabean paste stew (Table 2).

The number of dish items required to meet the 90 % of consumed foods as well as the between-person variation of the seventeen nutrients are listed in Table 3. The number of items that covered 90 % of the total intake of each nutrient, as estimated by cPC, varied from thirty-three for vitamin C to seventy-two for retinol. The number of items that accounted for 90 % of the between-person variability also varied from one for retinol to forty-one for K.

Table 4 summarises the values of the ninety-five selected dish items in terms of coverage of total nutrient intake and between-person variation. The ninety-five selected items covered an average of 92·3 % of the intake of the seventeen nutrients by the study subjects, ranging from 88·6 % for retinol to 95·4 % for vitamin C. The ninety-five items could also explain 99·9 % of the between-person variation for the consumption of the seventeen nutrients in the study subjects.

Discussion

The major functions of a rational FFQ are whether it is a useful tool for measuring average long-term dietary intake and for ranking the typical nutrient intakes of individuals. It does not precisely estimate the absolute consumption of nutrients for an entire study population. The use of a food item must vary from person to person for food discrimination according to dietary intake. A more important issue in the design of FFQ is the selection of food items with high between-person variations identified through multiple regression analyses for each nutrient compared with the total nutrient intake in order to identify food items with the most discrimination. Recently, many dietary assessment questionnaires[12,17,18] have been developed and several among them were validated for use in Korea[11,19]. Nevertheless, most existing FFFQ[12] with a few exceptions[11] lacked the appropriate analyses for food discrimination. In compiling a food list of FFQ, the food consumed frequently by Koreans and the foods with substantial nutrient content were selected based on the data of the Report on the National Nutrition Survey[20]. However, selection of foods was not based on between-person variations.

A DFFQ could have advantages over the several FFFQ developed and validated in Korea[11,12,17,18], as it could include ingredients such as seasonings, spices and cooking oils. This would allow for a more accurate calculation of nutrient intake, especially for micronutrients such as antioxidant vitamins, phytochemicals and fatty acids. The relatively low coverage rates of FFFQ were most likely secondary to a food list that did not include seasonings and oils, which are among the main sources of fat, Na and β-carotene in the Korean diet[12,21]. The estimated coverage of the intake of seventeen nutrients selected by this DFFQ was much higher (92·3 % overall, ranging from 88·6 to 95·4 %) than those of FFFQ[9,12]. Additionally, our DFFQ was developed on the basis of national representative data (KNHANES) with a substantially larger sample size (6817 subjects) as compared

Table 2. Item list of the dish-based FFQ

		Energy				Retinol				Na			
		MRC		PC		MRC		PC		MRC		PC	
Composite no.	Dish name	R^2	Ranking*	%	Ranking*	R^2	Ranking*	%	Ranking*	R^2	Ranking*	%	Ranking*
Staple foods													
1	Cooked rice	0·144	1	29·7	1	0·000		0·11		0·001		1·95	12
2	Cooked rice with cereals	0·091	2	12·9	2	0·000		0·07		0·001		0·76	
3	Rice gruels	0·010		0·37		0·000		0·23		0·006		0·25	
4	Rice topped with vegetable or meat	0·017	15	0·82	18	0·001	9	2·58	8	0·006		0·59	
5	Rice rolled in laver	0·086	3	2·76	5	0·002	5	5·20	4	0·011	20	1·37	15
6	Noodles	0·042	6	1·91	9	0·000	20	1·74	12	0·053	5	3·61	6
7	Udong, spaghetti	0·042	5	2·26	8	0·000	15	1·27	18	0·018	13	2·01	11
8	Ramyeon (instant noodles)	0·039	7	2·68	6	0·000	14	2·47	9	0·022	11	3·25	8
9	Rice cake soup, dumpling soup	0·019	12	0·94	15	0·000		1·29	17	0·009		0·94	
10	Loaf bread, toast, sandwich	0·003		0·20		0·003	4	1·78	11	0·000		0·04	
11	Powder of roasted grain, cereals	0·010		0·46		0·000	17	0·66		0·001		0·16	
Dishes													
16	Pizza, hamburger	0·017	16	0·49		0·001	13	1·39	16	0·002		0·31	
17	Fried potato chips	0·000		0·00		0·000		0·00		0·000		0·00	
18	Broth (vegetable, potato)	0·002		0·27		0·000	19	1·16	20	0·013	14	1·59	13
19	Soyabean paste soup	0·003		1·02	14	0·001	11	0·46		0·024	9	4·64	4
20	Meat soup	0·005		0·79	19	0·000		0·68		0·086	3	3·70	5
21	Fish soup	0·003		0·42		0·000		1·08		0·013	15	1·29	16
22	Boiled bone stew	0·012	18	0·89	16	0·000		1·73	13	0·021	12	1·19	18
23	Spicy beef soup with various condiments	0·004		0·47		0·000	16	1·11		0·011	19	0·97	
24	Soyabean paste stew	0·004		0·41		0·000		0·18		0·006		0·52	
25	Kimchi stew	0·004		0·74		0·024	2	6·53	3	0·012	16	1·54	14
26	Meat stew	0·007		1·15	12	0·000		0·43		0·024	8	3·52	7
27	Fish stew	0·005		1·23	11	0·000		0·07		0·058	4	5·48	3
28	Tofu stew	0·002		0·22		0·000		0·91		0·009		0·35	
29	Braised non-fatty fish	0·003		0·29		0·000		0·63		0·012	17	0·64	
30	Broiled non-fatty fish	0·009		0·51		0·000		0·70		0·007		0·79	
31	Pan-fried non-fatty fish fillet	0·008		0·40		0·000		0·80		0·002		0·31	
32	Raw non-fatty fish	0·006		0·34		0·000		0·60		0·006		0·42	
33	Braised fatty fish	0·004		0·36		0·000		0·85		0·004		0·38	
34	Broiled fatty fish	0·011	20	0·36		0·956	1	17·9	1	0·010		0·79	
35	Raw fatty fish	0·000		0·00		0·000		0·00		0·000		0·00	
36	Braised anchovies/dried small shrimp	0·002		0·39		0·000		0·03		0·003		0·60	
37	Pan-fried cuttlefish seasoned with red pepper	0·002		0·37		0·000		0·04		0·006		0·81	
38	Spicy steamed cuttlefish with vegetable	0·001		0·10		0·000		0·02		0·001		0·18	
39	Roasted beef with seasoning	0·004		0·16		0·000		0·30		0·002		0·18	
40	Pan-fried beef with seasoning	0·002		0·16		0·000		0·14		0·001		0·14	
41	Braised beef with seasoning	0·018	14	0·45		0·000		0·39		0·005		0·31	
42	Roasted pork with seasoning	0·012	17	0·53		0·000		0·40		0·004		0·45	
43	Spicy pan-fried pork	0·033	8	1·66	10	0·000		1·45	15	0·007		1·13	20
44	Braised pork	0·072	4	2·28	7	0·000		1·10		0·005		0·54	
45	Ham, sausage	0·002		0·20		0·000		0·25		0·001		0·24	
46	Whole chicken soup	0·010		0·28		0·001	10	1·47	14	0·006		0·31	
47	Seasoned and simmered chicken	0·009		0·42		0·001	8	2·79	7	0·005		0·43	
48	Stir-fried chicken	0·010		0·41		0·001	12	1·92	10	0·003		0·29	
49	Steamed egg	0·001		0·17		0·002	6	4·57	5	0·002		0·29	
50	Fried eggs	0·005		0·60		0·001	7	3·40	6	0·002		0·54	

Table 2. *Continued*

Composite no.	Dish name	Energy				Retinol				Na			
		MRC		PC		MRC		PC		MRC		PC	
		R^2	Ranking*	%	Ranking*	R^2	Ranking*	%	Ranking*	R^2	Ranking*	%	Ranking*
51	Soyabean curds	0·002		0·25		0·000		0·10		0·002		0·29	
52	Soyabean milk	0·001		0·12		0·000		0·00		0·001		0·16	
53	Soyabean boiled with soya sauce	0·000		0·00		0·000		0·00		0·000		0·00	
54	Vegetable pancake	0·009		0·25		0·000		0·22		0·009		0·39	
55	Stir-fried vegetable	0·008		0·39		0·000		0·05		0·024	10	0·94	
56	Braised vegetable with soya sauce	0·006		0·17		0·000		0·15		0·000		0·04	
57	Deep-fried vegetables	0·001		0·09		0·000		0·00		0·001		0·16	
58	Cooked green and yellow vegetable	0·001		0·31		0·000		0·00		0·003		0·68	
59	Green and yellow vegetable	0·000		0·09		0·000		0·00		0·001		0·12	
60	Cooked white vegetable	0·001		0·37		0·000		0·00		0·009		1·14	19
61	Cruciferous vegetable	0·001		0·28		0·000		0·04		0·012	18	1·23	17
62	Acorn starch jelly, mung bean jelly	0·000		0·06		0·000		0·00		0·001		0·13	
63	Mushrooms	0·001		0·09		0·000		0·11		0·000		0·12	
64	Salad (vegetable and fruits)	0·003		0·30		0·000		0·25		0·000		0·09	
65	Toasted laver	0·001		0·16		0·000		0·00		0·004		0·38	
66	Seaweeds	0·000		0·10		0·000		0·00		0·005		0·47	
67	Korean cabbage kimchi	0·000		0·76		0·000		0·00		0·162	2	18·2	1
68	Radish kimchi	0·001		0·48		0·000		0·01		0·191	1	8·62	2
69	Other kimchi	0·000		0·17		0·000		0·00		0·034	6	2·73	9
70	Pickled vegetables	0·000		0·12		0·000		0·04		0·033	7	2·08	10
71	Seasoned crab	0·000		0·06		0·000		0·01		0·003		0·26	
72	Salt-fermented fish	0·000		0·06		0·000		0·00		0·005		0·47	
92	Potatoes and starches (potato, sweet potato)	0·011	19	0·77	20	0·000		0·08		0·003		0·43	
Fruits													
75	Orange-coloured fruits (orange, persimmon)	0·026	10	2·93	4	0·000		0·00		0·000		0·17	
76	Red-coloured fruits (strawberry, apple)	0·008		0·89	17	0·000		0·00		0·000		0·02	
77	Green-coloured fruits (melon, kiwi)	0·000		0·02		0·000		0·00		0·000		0·00	
78	White-coloured fruits (banana, white peach)	0·005		0·59		0·000		0·00		0·001		0·06	
79	Purple-coloured fruits (grapes, plum)	0·000		0·05		0·000		0·00		0·000		0·03	
80	Tomato, cherry tomato	0·000		0·00		0·000		0·00		0·000		0·00	
Dairy food and beverages													
73	Milk	0·018	13	1·05	13	0·004	3	11·5	2	0·001		0·35	
74	Milk products	0·003		0·38		0·000	18	1·26	19	0·000		0·11	
81	Tea	0·004		0·18		0·000		0·00		0·000		0·01	
82	Coffee	0·028	9	3·67	3	0·000		0·11		0·000		0·33	
83	Carbonated beverages	0·002		0·33		0·000		0·00		0·000		0·01	
84	Korean traditional beverages	0·001		0·17		0·000		0·01		0·000		0·01	
85	Beer	0·006		0·19		0·000		0·00		0·000		0·01	
86	Soju	0·021	11	0·62		0·000		0·00		0·000		0·03	
87	Western liquors (vodka, brandy)	0·000		0·00		0·000		0·00		0·000		0·00	
88	Wine	0·000		0·00		0·000		0·00		0·000		0·00	
89	Makgeolli (unrefined rice wine)	0·000		0·00		0·000		0·00		0·000		0·00	
Bread and snacks													
12	Doughnut	0·000		0·00		0·000		0·00		0·000		0·00	
13	Bread 1 (cream bun, muffin)	0·005		0·33		0·000		0·33		0·000		0·08	
14	Bread 2 (bread rolls, garlic bread)	0·008		0·45		0·000		0·50		0·000		0·10	
15	Cakes	0·004		0·20		0·000		0·83		0·000		0·03	
90	Chocolate	0·000		0·00		0·000		0·00		0·000		0·00	

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Table 2. *Continued*

Composite no.	Dish name	Energy				Retinol				Na			
		MRC		PC		MRC		PC		MRC		PC	
		R^2	Ranking*	%	Ranking*	R^2	Ranking*	%	Ranking*	R^2	Ranking*	%	Ranking*
91	Rice cakes	0·005		0·39		0·000		0·00		0·000		0·01	
93	Nuts and seeds (groundnuts, chestnuts)	0·002		0·15		0·000		0·00		0·000		0·00	
94	Snacks	0·005		0·31		0·000		0·10		0·000		0·12	
95	Cookie	0·007		0·32		0·000		0·02		0·000		0·08	
Sum of top twenty dishes		0·769		72·2		0·998		73·4		0·832		70·3	

MRC, multiple regression coefficient; PC, percentage contribution.
*Ranking order for the top twenty dishes.

Table 3. Number of dishes contributing to seventeen nutrients with up to 90 cumulative percentage contribution (cPC) and 0·9 cumulative multiple regression coefficient (cMRC) from the model with ninety-five dishes

Nutrients	cPC	cMRC
Energy	66	39
Protein	64	36
Fat	67	31
Carbohydrate	36	19
Fibre	52	28
Ca	63	26
P	62	40
Fe	71	34
Na	70	29
K	61	41
Vitamin A	68	12
Retinol	72	1
β-Carotene	57	17
Vitamin B_1	55	25
Vitamin B_2	63	39
Niacin	59	31
Vitamin C	33	8

with previous developed FFQ in Korea[11,17,18] and other countries[4,9,10,22].

The main reduction from the initial 993 dishes compiled in the 24 h recall to the ninety-five dishes in the FFQ resulted from aggregating 359 items to ninety-five usable dishes in the last step. Therefore, there was a minimal loss of information, but all the nutrients provided by 359 foods and dishes remained in the calculation. The regression analysis resulted in the greatest reduction in the number of items (87 % reduction to 359 items) as compared with the contribution analysis (65 % reduction to 411 items). The number of dish items that covered 90 % of the total nutrients consumed by the study subjects varied from thirty-three items for vitamin C to seventy-two items for retinol. To test the function of ranking individuals using the DFFQ, cumulative regression coefficients were estimated. As a result, the top twenty dish items among the ninety-five items accounted for 67 to 100 % of the between-person variation of the main

Table 4. Percentage coverage and cumulative multiple regression coefficient (cMRC) of the total population intake of seventeen nutrients by the selected ninety-five dish items

Nutrients	Coverage (%)	cMRC (R^2)
Energy	92·3	0·9971
Protein	92·2	0·9997
Fat	91·2	0·9959
Carbohydrate	95·2	0·9983
Fibre	93·2	0·9999
Ca	92·1	0·9999
P	93·0	0·9996
Fe	91·5	0·9999
Na	90·5	1·0000
K	92·8	0·9872
Vitamin A	90·5	1·0000
Retinol	88·6	1·0000
β-Carotene	90·7	1·0000
Vitamin B_1	94·3	0·9997
Vitamin B_2	92·6	0·9998
Niacin	93·1	0·9998
Vitamin C	95·4	1·0000

seventeen nutrients consumed by the entire study subject population. Each nutrient composition defined the number of dish items required to meet an underestimation factor of less than 10 %. Some micronutrients, including retinol and vitamin C, had a limited number of dish items accounting for more than 90 % of the between-person variation in intake, and were assessed relatively easily *via* a small number of items in the DFFQ. In contrast, thirty-one to thirty-nine items were needed to reach the 90 % level for the between-person variation in energy, protein and fat intake, which is similar to other studies[9,12,23]. Even some items with a limited amount of specific nutrients may still be effective in discriminating between individuals. In this population, grilled fatty fish accounted for 96 % of the between-person variability in retinol intake, but only contributed 17·9 % of the total retinol intake, indicating that this dish was not a major contributor of retinol. However, this explained a relatively large amount of the variability within populations. As for vitamin C intake, only eight items were needed to account for over 90 % of the between-person variability.

The cPC estimation results imply that there are limited dish and food sources for some nutrients such as vitamin C and carbohydrate in the Korean diet, whereas there is a variety of dish and food sources for other nutrients such as fat and retinol. Therefore, the length of the dish list used during the development of a DFFQ could depend on a nutrient of interest in relation to a disease.

The present study has several limitations originating from the KNHANES data we used. First, the use of the single day 24 h dietary recall meant that it was not possible to estimate within-person variations. Second, seasonal variation of food was not included in the survey of the 2001 KNHANES, as it was conducted from November through December. For example, the contributions of fruits more readily available during the survey period might be overestimated, and the contributions of other fruits that were less available might be underestimated. Therefore, several seasonal food items, for example, seasonal fruits (strawberry, watermelon, etc) and celebration foods not covered by the survey period of the 2001 KNHANES were included in the DFFQ, taking into consideration the seasonal variation of the Korean diet.

In conclusion, the selected ninety-five dish items that were included in the DFFQ covered 90 % of the total seventeen nutrients consumed by subjects, as well as 99 % of the between-person variation for the nutrients of interest. Therefore, the ninety-five selected items could be useful in developing a DFFQ for use in large-scale epidemiological studies of Koreans, within less than 10 % underestimation.

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Appendix

Sample questionnaire for staple food in a developed dish-based food-frequency questionnaire.

				
< Cooked rice with cereals >	< Rice topped with vegetable or meat >	< Noodles >	< Dumpling soup >	< Sandwich >

Dish	Frequency of intake									Quantity of intake
	Day			Week			Month		Never	
	3	2	1	5-6	3-4	1-2	2-3	1	0	
Cooked rice	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐ < 0.5 bowl ☐ 1 bowl ☐ > 1.5 bowls
Cooked rice with cereals	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐ < 0.5 bowl ☐ 1 bowl ☐ > 1.5 bowls
Rice gruels	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐ < 0.5 bowl ☐ 1 bowl ☐ > 1.5 bowls
Rice topped with vegetable or meat	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐ < 0.5 serving ☐ 1 serving ☐ > 1.5 servings
Rice rolled in laver	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐ < 0.5 serving ☐ 1 serving ☐ > 1.5 servings
Noodles	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐ < 0.5 serving ☐ 1 serving ☐ > 1.5 servings
Udong, spaghetti	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐ < 0.5 serving ☐ 1 serving ☐ > 1.5 servings
Ramyeon (instant noodle)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐ < 0.5 serving ☐ 1 serving ☐ > 1.5 servings
Rice cake soup, dumpling soup	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐ < 0.5 serving ☐ 1 serving ☐ > 1.5 servings
Loaf bread, toast, sandwich	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐ < 1 slice ☐ 2 slices ☐ > 3 slices
Powder of roasted grain, cereals	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐ < 0.5 cup ☐ 1 cup ☐ > 1.5 cups

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