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Relative validity of dietary patterns derived from a self-administered diet history questionnaire using factor analysis among Japanese adults

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Abstract

Objective: Although dietary pattern approaches derived from dietary assessment questionnaires are widely used, only a few studies in Western countries have reported the validity of this approach. We examined the relative validity of dietary patterns derived from a self-administered diet history questionnaire (DHQ) among Japanese adults.

Design: The DHQ, assessing diet during the preceding month, and 4 d dietary records (DR) were collected in each season over one year. To derive dietary patterns, 145 food items in the DHQ and 1259 in the DR were classified into thirty-three predefined food groups, and entered into a factor analysis.

Setting: Three areas in Japan; Osaka (urban), Nagano (rural inland) and Tottori (rural coastal).

Subjects: A total of ninety-two Japanese women and ninety-two Japanese men aged 31–76 years.

Results: We identified three dietary patterns ('healthy', 'Western' and 'Japanese traditional') in women and two ('healthy' and 'Western') in men, which showed a relatively similar direction and magnitude of factor loadings of food groups across the first and mean of four DHQ (DHQ1 and mDHQ, respectively) and 16 d DR. The Pearson correlation coefficients between DHQ1 and 16 d DR for the healthy, Western and Japanese traditional patterns in women were 0·57, 0·36 and 0·44, and for the healthy and Western patterns in men were 0·62 and 0·56, respectively. When mDHQ was examined, the correlation coefficients improved for women (0·45–0·69).

Conclusions: Dietary patterns derived from the DHQ could be used for epidemiological studies as surrogates of those derived from DR.

Keywords
Dietary patterns
Relative validity
Diet history questionnaire
Factor analysis

Epidemiological studies on the relationship between diet and disease have traditionally focused on the effects of single nutrients or foods. However, nutrients and foods are consumed in many complex combinations, and studies of individual nutrients and foods can be difficult to interpret because of strong intercorrelations between them. Recently, the dietary pattern approach, namely the measurement of overall diet assessed a priori using a score-based approach[1–3] or a posteriori using a data-driven technique such as factor analysis or cluster analysis[4,5], has become an important alternative to the traditional single nutrient-oriented approach. The dietary pattern approach has been used in numerous nutritional epidemiological studies among different populations investigating associations with various health outcomes[5], including CVD[6–8], several types of cancer[9–12], type 2 diabetes[13], obesity[14,15], osteoporosis[16] and health behaviours[17].

Dietary assessment questionnaires are commonly used to characterize and explore dietary patterns predicting a health–disease risk[5]. Most dietary questionnaires used in

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these studies have already been validated at the nutrient and/or food intake levels. These results may suggest a reasonable validity of dietary patterns even if without evaluating the validity of dietary pattern. However, this indirect validity would be insufficient to interpret the results on the association between dietary pattern and health–disease risk exactly, which may sometimes mislead the results. Therefore, direct validity of dietary patterns should be examined. Only four studies have reported information regarding the direct validity of dietary patterns, for example as defined by factor analysis[18–21]. In the first such validation study, reported by Hu *et al.* in 1999[18], two dietary patterns (prudent and Western patterns) were derived from both an FFQ and a 1-week dietary record among US male health professionals, with uncorrected correlation coefficients ranging from 0·34 to 0·64. Similar studies have been conducted among Swedish women[19], Danish men and women[20] and pregnant UK women[21]. However, these studies were limited to Western countries; no similar studies have been reported in Asian countries, including Japan, with different subject characteristics and culture-specific dietary habits.

Here, we examined the relative validity of dietary patterns derived from a self-administered diet history questionnaire (DHQ)[22–24] by factor analysis against 4 d weighed dietary records in each season over one year (16 d in total) among adult Japanese men and women.

Subjects and methods

Subjects

The study was conducted in three areas in Japan: Osaka (urban), Nagano (rural inland) and Tottori (rural coastal)[25,26]. In each area, we recruited apparently healthy women aged 30–69 years such that eight women were equally distributed in each 10-year age stratum (30–39, 40–49, 50–59 and 60–69 years). Their husbands were also invited to participate in the study without consideration of their age. The total number recruited was ninety-six women and ninety-six men. None of the subjects was currently receiving or had recently received dietary counselling from a doctor or dietitian, or had a history of educational hospitalization for diabetes or nutritional education from a dietitian.

Prior to the study, we held group orientations for the subjects at which we explained the study purpose and protocol. Written informed consent was obtained from each subject. A total of ninety-two women aged 31–69 years and ninety-two men aged 32–76 years completed the study protocol and were included in the present analysis. Body height and weight were measured to the nearest 0·1 cm and 0·1 kg, respectively, with subjects wearing light clothing and no shoes. BMI was calculated as body weight (in kilograms) divided by the square of body height (in metres).

Dietary records

The subjects completed four 4 d weighed dietary records (DR) on non-consecutive days, one in each season, at intervals of approximately 3 months from November 2002 to September 2003[25,26]. Each of the four recording days consisted of three weekdays and one weekend day. During the orientation session, the staff (registered dietitians) gave the subjects both written and verbal instructions on how to keep the dietary record and provided a completed recording sheet as an example. Each couple was given recording sheets and a digital scale (Tanita KD-173; ±2 g precision for 0–250 g and ±4 g precision for 250–1000 g), instructed how to weigh each food and drink, and asked to record and weigh all foods and drinks consumed on each recording day. When measurement was difficult (e.g. eating out), they were instructed to record the size and quantity of foods they ate using household measures in as much detail as possible. For each recording day, the subjects were asked to fax the completed forms to the local staff (registered dietitians). The study staff reviewed the submitted forms and asked the subjects to add and/or modify the records as necessary by telephone or fax. In some cases, the responses were handed directly to the study staff.

All the collected records were checked by trained registered dietitians in each local centre and then again in the study centre. The coding of records and conversion of other measurements of quantities into grams were performed by trained registered dietitians in the survey centre in accordance with uniform procedures. A total of 1299 food and beverage items appeared in the dietary records.

Diet history questionnaire

The subjects answered the DHQ four times, once in each season, at intervals of approximately 3 months from November 2002 to September 2003[25,26]. In each season, the DHQ was answered two days before the start of the dietary recording period. Responses to the DHQ were checked at least twice for completeness, and when necessary reviewed with the subject to ensure the clarity of answers.

The DHQ is a previously validated 16-page questionnaire which assesses dietary habits in the previous month[22–24]. It consists of the following seven sections: (1) general dietary behaviours; (2) major cooking methods; (3) consumption frequency and amount of six alcoholic beverages; (4) consumption frequency and semi-quantitative portion size of 118 selected food and non-alcoholic beverage items; (5) dietary supplements; (6) consumption frequency and semi-quantitative portion size of eighteen staple foods (rice, bread, noodles, and other wheat foods) and *miso* soup (fermented soyabean paste soup), with questions on the size the of cups (bowls) usually used for rice and *miso* soup; and (7) open-ended items for foods consumed regularly (at least once per week) but not appearing in the DHQ. The food and beverage items selected were those commonly consumed in Japan, mainly from a food list used in the National Nutrition Survey of Japan, and standard portion sizes of cups (bowls) for rice and *miso* soup were derived mainly from several recipe books for Japanese dishes[22].

Estimates of dietary intake for 150 food and beverage items and energy were calculated using an *ad hoc* computer algorithm for the DHQ according to the following procedure. For most items (145 items listed in sections 3, 4 and 6), dietary intake was calculated based on the reported consumption frequency and portion size according to the semi-quantitative food frequency methodology. Dietary intake of the remaining five items (four seasonings used during cooking and soya sauce) was estimated according to the diet history method, using the qualitative information in sections 1 and 2 of the DHQ and the quantitative information in section 4. Information on dietary supplements (section 5) and data from the open-ended questionnaire items (section 7) were not used in the calculation of dietary intake. For men, the intake of foods categorized into white meat, red meat, processed meat, fish, sea products, shellfish and eggs was calculated as the product of reported consumption frequency and portion size multiplied by a factor of 1·2, for several reasons[26]. First, standard portion sizes in the DHQ may be generally considered as those for women, not only because the recipe books for Japanese dishes (from which standard portion sizes were derived) generally show portion sizes for women, but also because the DHQ was originally developed for women[22]. Second, the possibility of gender differences in portion size is likely to be higher for foods used as a main dish (such as meats, fish and shellfish, eggs) than for other foods[27]. Finally, intake of meats, fish and shellfish, eggs and rice, but not other foods, is generally higher in men than in women in Japan[28].

Food groupings

Individual food items obtained from DR and DHQ data were classified directly into one of thirty-three predefined food groups (Table 1). The food grouping scheme was generally based on the principles of similarity of nutrient profiles or culinary usage of the foods, mainly according to the food composition tables of Japanese foods, 5th revised and enlarged edition[29], the classification of food groups used by the National Nutrition Survey[28], and that used in previous studies[15,16]. Foods expressed in the DR data in the dry-weight state and before cooking were corrected to represent the amount as consumed. Of the total 1299 food items obtained from the DR data, assignment of some constituents of cooked dishes in the DR (e.g. flour excluding that in bread and confectionery, wheat gluten, vinegar, liquor used as seasoning, spices, herbs) to food groups was not possible as they had been coded as separate items for energy and nutrient calculations. The forty food codes of these constituents were excluded from the analysis. Of the total 150 food items included in the DHQ, five items (cornflakes, nutritional supplement bars, Japanese-style pancakes, noodle soup, drinking water) were difficult to group or estimate amounts for and were therefore omitted in the current study. Finally, 1259 food items obtained from DR data and 145 food items included in the DHQ were classified into the thirty-three predefined food groups, and used for analysis.

Statistical analysis

All statistical analyses were performed for women and men separately using the SAS statistical software package version 9·1 (SAS Institute Inc., Cary, NC, USA).

Mean energy intake was calculated based on the 1259 food items obtained from the DR and 145 from the DHQ using the *Standard Tables of Food Composition in Japan*[29]. Mean differences in energy and energy-adjusted food group intakes among dietary assessment methods were tested by the paired t test, with a two-sided P value of 0·05 considered significant.

Factor (principal component) analysis was used to derive dietary patterns based on the thirty-three food groups for each of the DHQ and DR. Intakes of these food groups (g/d) estimated by each dietary assessment method were log-transformed to achieve normality and then adjusted for total energy intake by the residual method[30]. Analyses were done using the FACTOR PROCEDURE of SAS software. The factors were rotated by orthogonal transformation (Varimax rotation function in SAS) to achieve a simpler structure with greater interpretability. The number of factors was determined by scree plots and the combination of foods on the factors. A factor solution with three factors for women and two for men was found to be reasonable and meaningful. The proportion of variance explained by each factor was calculated by dividing the sum of the squares of the respective factor loadings by the number of variables. The factor scores for each pattern and for each individual were determined by summing the intake of each food group weighted by the factor loading[31]. All data presented herein are from the Varimax rotation.

Pearson correlation coefficients between factor scores on similar dietary patterns derived from the first DHQ (DHQ1) and DR were calculated to examine the relative validity of dietary patterns derived from DHQ1. Furthermore, the agreement between factor scores derived from DHQ1 and DR was analysed by the method proposed by Bland and Altman[32], using a plot of the difference between DHQ1 and DR against the mean of DHQ1 and DR. The limits of agreement were given as 1·96 times the standard deviation of the difference. The DHQ1 (administered before the experience of recording), rather than the other DHQ, was used to exclude the influence of dietary attention required to complete the DR. Mean of four DHQ (mDHQ) was also used in the same analyses as above to match the evaluation period with that of DR.

Table 1 The thirty-three food groupings used in the present study for dietary pattern analysis

Food group†	Food items‡
Rice	Well-milled rice, rice with barley (70 % rice and 30 % barley), rice with embryo, half-milled rice, 70 %-milled rice, brown rice
Bread	White bread, butter roll, croissant, pizza
Noodles	Japanese noodle (buckwheat/Japanese wheat noodle), instant noodles, Chinese noodles, pasta, spaghetti
Potatoes	White potatoes, French fries, sweet potatoes, taro, *konnyaku*
Nuts	Peanuts, other types of nut
Pulses	Tofu (soyabean curd), tofu products such as *atsuage* (deep-fried tofu cutlet), *ganmodoki* (deep-fried tofu burger), *aburaage* (deep-fried tofu pouch), *natto* (fermented soyabeans), cooked beans, *miso* as seasoning
Sugar	Sugar for coffee and tea, sugar for cooking, jam, marmalade
Confectioneries	Japanese sweetened bun, hot-cake, potato chips, *sembei* and *arare* (rice snacks), crackers, salted snacks, Japanese sweets with or without azuki beans, cakes, hard cookies, soft cookies, chocolates, candies, caramels, chewing gums, jellies, doughnut, ice cream
Butter	Butter
Vegetable oil	Margarine, vegetable oils, salad dressings with oil, mayonnaise
Fruits	Oranges, grapefruits, bananas, apples, strawberries, grapes, peaches, pears, kiwifruits, persimmons, melons, water melon, raisons, canned fruits
Green and yellow vegetables	Carrots, pumpkins, tomatoes, green pepper, broccoli, lettuce, green leafy vegetables such as spinach
Other vegetables	Cabbage, cucumber, Chinese cabbage, bean sprouts, Japanese radish, onion, cauliflower, aubergine, burdock, lotus root
Pickled vegetables	Salted pickles, *umeboshi* (pickled and dried plum), *kimchi* (Korean pickles)
Mushrooms	Shiitake mushroom, shimeji mushroom, enoki mushroom
Seaweeds	Wakame seaweed, purple laver, brown algae
Alcoholic beverages	Beer, sake (rice wine), *shochu* (distilled spirits), *chuhai* (*shochu* highball), whisky, wine
Fruit and vegetable juice	Vegetable juice, tomato juice, 100 % fruit juice, sweetened fruit drinks (50 % fruit)
Japanese and Chinese tea	Green tea, oolong tea, barley tea
Tea	Black tea
Coffee and cocoa	Coffee, cocoa
Soft drinks	Cola, non-fruit juices, soft drinks without sugar such as sports beverages, lactic acid bacteria beverages
Fish	Eel, fish with white meat (sea bream, flatfish, cod, others), fish with a blue back (mackerel, sardine, herring, others), fish with red meat (tuna, salmon, skipjack)
Shellfish	Shrimps, squids, octopus, oysters, other shellfish
Sea products	Dried fish, small fish with bones, canned tuna, fish eggs, boiled fish in soya sauce, salted guts, *surimi* (ground fish-meat products)
Chicken	Chicken, liver
Beef and pork	Beef, pork, ground beef/pork
Processed meat	Ham, sausage, bacon, salami
Dairy products	Whole milk, low-fat milk, skimmed milk, yoghurt, cheese, cottage cheese, coffee cream
Eggs	Eggs
Miso soup	*Miso* (fermented soyabean paste) soup
Other soup	Corn soup, Chinese soup
Salt-containing seasonings	Table salt, salt and salt-rich seasonings used during cooking, soya sauce, non-oil dressings, curry or stew roux

†Individual food items obtained from four 4 d dietary records (DR) and a self-administered diet history questionnaire (DHQ) data were classified into thirty-three predefined food groups independently.
‡Of the total 150 food items included in the DHQ, five items (cornflakes, nutritional supplement bars, Japanese-style pancakes, noodle soup, drinking water) were difficult to group or estimate the amount of and were therefore omitted in the present study. Of the total 1299 food items obtained from DR, forty constituents of cooked dishes (e.g. flour excluding that in breads and confectionery, wheat gluten, vinegar, liquor as a seasoning, spices, herbs) could not be assigned to a food group, and were therefore omitted from food classification. Finally, 1259 food items obtained from the DR data and 145 food items included in the DHQ were classified into thirty-three predefined food groups.

Results

Subject characteristics have been reported in previous studies[25,26]. Mean age of the ninety-two Japanese women and ninety-two Japanese men was 49·6 (SD 11·4) and 52·8 (SD 12·1) years, respectively. Mean energy intake estimated from DHQ1, mDHQ and DR was 8000 (SD 1538), 7859 (SD 1387) and 7816 (SD 1150) kJ/d for women, and 9608 (SD 2409), 9785 (SD 2053) and 9974 (SD 1785) kJ/d for men, respectively, showing no difference across dietary assessment methods in either sex.

Mean daily energy-adjusted consumption of the thirty-three food groups assessed with DHQ1, mDHQ and DR are shown in Table 2. The number of foods underestimated by DHQ1 and mDHQ compared with the DR was eleven and ten for women, and fifteen and nine for men, respectively. Foods underestimated by the DHQ1 compared with the DR data included potatoes, pickled vegetables and tea for men; and bread, noodles, nuts, pulses, butter, green and yellow vegetables, white vegetables, sea products, processed meat, eggs, other soup and salt-containing seasonings for both sexes. In contrast, foods overestimated by the DHQ1 included mushroom and beef and pork for women; confectionery for men; and sugar, vegetable oil and fruits for both sexes. Pearson correlation coefficients between DHQ1 and DR for the comparison of daily consumption among women and men ranged from 0·13 for seaweed and 0·15 for salt-containing seasonings to 0·85 and 0·82 for alcoholic beverages, respectively. Correlation coefficients between

Table 2 Daily energy-adjusted intake of thirty-three food groups (g/d) assessed with the first and mean of four self-administered diet history questionnaires (DHQ1 and mDHQ, respectively) and the mean of four 4 d weighed dietary records (DR) among ninety-two Japanese women and ninety-two Japanese men

	Women (*n* 92)								Men (*n* 92)							
	DHQ1		mDHQ		DR		Pearson correlations‡		DHQ1		mDHQ		DR		Pearson correlations‡	
Food group†	Mean	SD	Mean	SD	Mean	SD	DHQ1 *v.* DR	mDHQ *v.* DR	Mean	SD	Mean	SD	Mean	SD	DHQ1 *v.* DR	mDHQ *v.* DR
Rice	294	92	296*	93	281	76	0·60	0·77	432	154	420	121	418	116	0·65	0·76
Bread	34·1**	29·6	32·7**	21·5	37·5	23·1	0·69	0·77	34·1*	32·1	35·5	29·0	39·6	31·4	0·54	0·68
Noodles	59·2***	48·9	62·7	37·9	65·6	36·4	0·48	0·45	69·1***	58·7	77·3	54·3	80·2	45·8	0·48	0·51
Potatoes	47·4	30·7	37·3**	18·4	42·7	17·2	0·31	0·37	42·8***	31·9	34·9***	19·8	45·3	21·3	0·39	0·53
Nuts	1·4***	3·9	1·8	2·6	2·4	2·4	0·24	0·24	2·0***	4·3	2·5	3·6	3·1	3·4	0·23	0·36
Pulses	51·9**	28·2	50·8**	21·4	60·1	30·7	0·36	0·47	47·2***	27·1	47·5***	22·2	61·3	36·9	0·47	0·55
Sugar	15·4***	8·3	14·4	6·5	10·5	6·5	0·54	0·56	15·3***	8·7	14·9***	6·9	10·9	6·5	0·42	0·49
Confectioneries	57·8	28·1	64·0	26·8	53·4	20·5	0·27	0·35	48·5**	31·4	59·7***	31·2	38·7	27·2	0·40	0·55
Butter	0·5***	0·9	0·6***	0·9	1·1	1·0	0·38	0·41	0·3***	0·6	0·4***	0·8	1·4	1·5	0·21	0·39
Vegetable oil	22·7***	11·0	22·0***	7·0	15·8	5·3	0·31	0·49	22·3*	9·3	24·2	8·2	18·7	6·7	0·46	0·48
Fruits	155***	92	121	59	114	60	0·45	0·71	128*	100	101	66	102	86	0·71	0·85
Green and yellow vegetables	80·2***	43·6	88·4*	38·6	97·5	43·3	0·48	0·66	69·4***	45·1	76·8***	36·4	97·4	39·2	0·30	0·59
White vegetables	130***	59	113***	35	149	49	0·44	0·46	113***	50	105***	37	158	48	0·34	0·49
Pickled vegetables	24·8	25·7	24·4	25·5	21·9	17·4	0·58	0·70	22·6*	23·9	24·6	24·3	26·2	21·9	0·54	0·71
Mushrooms	15·3*	10·7	12·9	7·9	11·7	7·8	0·37	0·53	12·8	10·9	11·2	7·1	12·4	8·9	0·42	0·61
Seaweeds	15·5	12·3	15·2	9·1	14·9	10·8	0·13	0·32	13·9	11·5	13·5	8·3	13·9	9·8	0·17	0·46
Alcoholic beverages	70	137	67	120	62	117	0·85	0·89	319	386	334	349	292	318	0·82	0·91
Fruit and vegetable juice	19·9	38·9	32·8***	45·9	16·9	28·1	0·27	0·44	31·2	72·0	39·2***	75·1	20·7	49·1	0·39	0·47
Japanese and Chinese tea	547	351	507	267	481	279	0·55	0·69	488	371	503**	299	441	257	0·39	0·55
Tea	30·8	70·6	31·8	50·2	30·9	54·4	0·50	0·64	11·8***	37·0	13·3	33·8	15·5	33·7	0·48	0·58
Coffee and cocoa	292	251	261***	190	204	152	0·72	0·79	295	278	286***	228	225	192	0·68	0·82
Soft drinks	21·9	31·3	31·3	46·3	25·2	31·1	0·18	0·41	45·2	80·7	63·2*	90·8	40·5	50·6	0·40	0·59
Fish	37·2	23·7	35·4	17·0	33·8	17·7	0·47	0·43	44·7	27·9	44·0	20·6	42·5	24·8	0·47	0·53
Shellfish	15·4	11·5	16·2	8·8	16·0	10·1	0·46	0·54	19·7	14·2	21·2	13·6	21·4	13·7	0·39	0·56
Sea products	23·7**	15·7	23·1**	11·4	27·5	13·7	0·31	0·40	29·0***	16·7	28·5***	14·8	37·0	18·2	0·35	0·41
Chicken	15·3	11·3	15·0	8·8	13·7	10·0	0·52	0·52	18·4	14·2	18·8	11·7	19·6	14·8	0·44	0·57
Beef and pork	35·5*	20·1	35·1*	15·8	31·8	14·7	0·59	0·67	46·1	28·3	46·4	21·0	44·6	22·9	0·47	0·54
Processed meat	7·3***	6·2	7·4***	5·6	9·7	6·6	0·58	0·55	9·2***	8·7	9·4***	7·7	13·0	8·2	0·53	0·61
Dairy products	182	142	179***	104	151	86	0·48	0·72	117	112	126	94	124	104	0·71	0·79
Eggs	36·2*	19·4	34·8	15·5	37·6	14·7	0·28	0·43	42·3**	26·5	43·2	21·2	44·8	16·2	0·47	0·57
Miso soup	153	97	139	84	140	72	0·45	0·51	156	92	144	77	150	77	0·59	0·67
Other soup	2·8***	5·1	3·5***	5·9	15·9	26·0	0·20	0·38	3·0***	8·5	3·2***	6·7	15·0	26·7	0·34	0·40
Salt-containing seasonings	13·8***	7·0	13·0***	4·5	31·8	9·3	0·16	0·09	15·2***	6·8	15·1***	5·7	37·8	14·6	0·15	0·16

Mean energy-adjusted food group intakes were significantly different from those of DR data (paired *t* test): *$P<0·05$, **$P<0·01$, ***$P<0·001$.

†Food intakes presented here were energy-adjusted by the residual method.

‡Food intakes were log-transformed to achieve greater normality in the distribution and were energy-adjusted by the residual method before the Pearson correlation coefficients between DHQ1, mDHQ and DR were calculated.

mDHQ and DR were higher than those between DHQ1 and DR for nearly all items.

In factor analysis, we identified three factors for women and two for men. The factor loadings for each pattern derived from DHQ1, mDHQ and DR are shown in Table 3. High positive loadings indicate strong associations between given food groups and patterns, whereas negative loadings indicate negative associations with the patterns. Because the order of extracted patterns differed between dietary assessment methods (DHQ and DR) in both sexes, we decided to compare similar patterns loaded on the same foods between dietary assessment methods. Derived dietary patterns were descriptively labelled based on the food groups that were highly loaded. For women, the factors were labelled 'healthy' (high positive loading on green and yellow vegetables, fish, fruits, mushrooms, white vegetables, sea products, seaweeds, pickled vegetables, shellfish and pulses, and negative loading on beef and pork in common among DHQ1, mDHQ and DR), 'Western' (positive loadings on vegetable oil, processed meat, butter and eggs) and 'Japanese traditional' (positive loadings on *miso* soup and rice, and negative loading on shellfish and bread). For men, the factors were labelled 'healthy' (high positive loading on green and yellow vegetables, fruits, mushrooms, white vegetables, seaweeds, daily products, sugar, *miso* soup and pulses in common among DHQ1, mDHQ and DR) and 'Western' (positive loadings on chicken, vegetable oil, processed meat, beef and pork, and negative loading on rice). Although the number of foods with a factor loading $>|0{\cdot}25|$ differed among patterns, the direction and magnitude of factor loadings for each dietary pattern among DHQ1, mDHQ and DR were relatively similar in the two sexes. Overall, the total explained variance of dietary patterns derived from DHQ1, mDHQ and DR was 30·1%, 31·2% and 30·8% for women, and 21·5%, 24·4% and 25·8% for men, respectively.

Pearson correlation coefficients between DHQ1 and DR were 0·57 for the healthy, 0·36 for the Western and 0·44 for the Japanese traditional pattern in women; and 0·62 for the healthy and 0·56 for the Western pattern in men (Table 4). Correlation coefficients of the respective dietary patterns between mDHQ and DR were improved for women (0·45–0·69).

The Bland–Altman plots of all dietary patterns for women (Fig. 1) and men (Fig. 2) showed that the mean differences between factor scores derived from DHQ1 and DR were zero. The 95% limits of agreement for the difference between factor scores derived from DHQ1 and DR lay within −1·81 and +1·81 for the healthy pattern, within −2·22 and +2·22 for the Western pattern and within −2·08 and +2·08 for the Japanese traditional pattern in women; and within −1·83 and +1·83 for the healthy pattern and within −1·71 and +1·71 for the Western pattern in men. The agreements of all dietary patterns between mDHQ and DR were improved except for the Western pattern in men (data not shown).

Discussion

Using factor analysis, we identified three dietary patterns among ninety-two Japanese women (labelled healthy, Western and Japanese traditional patterns) and two among ninety-two Japanese men (healthy and Western patterns) from both the DHQ and DR data. Pearson correlation coefficients between patterns derived from DHQ1 and DR were 0·36–0·57 for the three patterns among women, and 0·56–0·62 for the two patterns among men, suggesting that the validity of the DHQ against DR in characterizing dietary patterns among Japanese adults was reasonable. To our knowledge, the present study is the first one to evaluate the relative validity of the major dietary patterns derived from a dietary assessment questionnaire in comparison with those from DR as a reference method in an Asian population.

Although numerous studies have examined the relationship between diet and various health outcomes using the dietary pattern approach rather than the single nutrient-oriented approach[5], only four have directly compared dietary patterns derived from different dietary assessment methods in the same study subjects[18–21]. Among them, uncorrected correlation coefficients between dietary questionnaires and reference methods (e.g. multiple-day DR or diaries) were 0·34–0·64 for prudent and Western patterns among 127 US male health professionals[18]; 0·41–0·73 for healthy, Western and drinker patterns among 111 Swedish women[19]; 0·34–0·61 for green, sweet and traditional patterns for 879 Danish men and 927 Danish women[20]; and 0·35–0·67 for prudent and Western patterns among 585 UK pregnant women[21]. Moreover, reasonable agreement between the FFQ and food diary scores was observed among pregnant UK women[21]. The 95% limits of agreement lay within −1·58 and +1·58 for the prudent and within −2·22 and +2·22 for the Western pattern. The present findings for the validity of dietary patterns are comparable to these previous results.

Among the dietary patterns identified, several differences were noted in the order of extracted dietary patterns and in the factor loadings for food items between DHQ1, mDHQ and DR. As mentioned previously[18,19], these differences appeared to be derived from methodological differences between dietary assessment methods[30,33], random statistical variation and different assessment periods. Several foods were under- or overestimated by the DHQ in both sexes (Table 2). These discrepancies in estimation might have affected the extraction of dietary pattern when grams were used as an input variable in the factor analysis. In addition, the difference in loading of food items between dietary assessment methods in the current study was greater than those in the previous studies, which might have been caused by the food grouping process. In nearly all previous studies evaluating the validity of dietary patterns, food groups were defined from the examined dietary assessment questionnaire, and only matched foods appearing in the reference method were entered into factor analysis. As a

Table 3 Factor-loading matrix for the major dietary patterns identified from the first and mean of four self-administered diet history questionnaires (DHQ1 and mDHQ, respectively) and mean of four 4 d weighted dietary records (DR) among ninety-two Japanese women and ninety-two Japanese men†

	Women (*n* 92)									Men (*n* 92)					
	Healthy			Western			Japanese traditional			Healthy			Western		
Food group‡	DHQ1 (Factor 1)§	mDHQ (Factor 1)	DR (Factor 1)	DHQ1 (Factor 2)	mDHQ (Factor 2)	DR (Factor 3)	DHQ1 (Factor 3)	mDHQ (Factor 3)	DR (Factor 2)	DHQ1 (Factor 1)	mDHQ (Factor 1)	DR (Factor 2)	DHQ1 (Factor 2)	mDHQ (Factor 2)	DR (Factor 1)
Green and yellow vegetables	0·73	0·77	0·73	0·03	−0·17	−0·06	0·16	−0·01	0·26	0·80	0·82	0·66	0·10	−0·03	−0·43
Fish	0·69	0·64	0·68	−0·04	0·03	0·00	−0·20	0·03	0·07	0·49	0·54	0·19	0·03	0·05	−0·54
Fruits	0·64	0·53	0·44	−0·15	−0·32	−0·13	−0·24	−0·08	0·19	0·60	0·56	0·68	−0·27	−0·37	−0·21
Mushrooms	0·63	0·68	0·59	0·28	0·23	0·12	−0·09	−0·19	−0·05	0·60	0·64	0·28	0·20	0·21	−0·32
White vegetables	0·63	0·69	0·67	0·14	0·15	0·18	0·17	−0·05	0·20	0·57	0·67	0·47	0·23	0·21	−0·29
Sea products	0·59	0·53	0·27	−0·06	−0·08	0·10	−0·03	0·15	0·63	0·37	0·49	0·01	−0·25	−0·01	−0·63
Seaweeds	0·56	0·53	0·57	0·24	0·13	0·08	0·13	0·34	0·28	0·56	0·64	0·42	−0·02	−0·01	−0·47
Pickled vegetables	0·51	0·44	0·26	−0·22	−0·29	−0·06	0·25	0·29	0·68	0·19	0·26	0·12	−0·24	−0·24	−0·43
Shellfish	0·45	0·46	0·33	0·27	0·33	0·14	−0·43	−0·31	−0·26	0·19	0·29	−0·08	0·19	0·51	−0·05
Potatoes	0·41	0·52	0·23	0·17	−0·01	0·04	0·12	0·08	0·18	0·62	0·56	0·22	0·01	0·16	−0·18
Nuts	0·23	0·31	0·42	0·23	−0·02	−0·31	−0·15	−0·17	0·03	0·22	0·26	0·47	0·04	−0·09	−0·07
Other soup	0·17	0·04	0·03	−0·04	0·10	0·45	0·04	−0·15	0·03	−0·09	0·04	0·17	0·00	0·14	0·22
Dairy products	−0·34	−0·20	0·42	−0·02	−0·38	−0·26	0·15	−0·08	−0·17	0·32	0·44	0·71	−0·07	−0·31	−0·13
Chicken	0·03	0·06	−0·24	0·71	0·72	0·24	−0·17	−0·14	0·00	0·12	0·05	−0·06	0·59	0·54	0·30
Vegetable oil	0·15	0·13	−0·26	0·54	0·66	0·32	−0·33	−0·15	−0·40	0·13	0·02	−0·09	0·75	0·74	0·69
Processed meat	−0·02	−0·05	−0·20	0·52	0·72	0·61	−0·13	0·06	−0·13	0·02	−0·06	−0·13	0·43	0·54	0·38
Beef and pork	−0·31	−0·28	−0·53	0·50	0·58	0·22	−0·08	−0·14	−0·32	−0·04	−0·11	−0·44	0·76	0·68	0·52
Salt contained seasonings	0·41	0·35	0·16	0·46	0·45	0·05	0·04	−0·09	−0·10	0·19	0·32	−0·24	0·57	0·54	−0·02
Coffee and cocoa	−0·08	0·04	0·00	0·45	0·20	0·06	0·06	−0·08	−0·43	−0·04	−0·07	0·27	0·23	0·11	0·48
Butter	−0·03	−0·17	−0·01	0·44	0·39	0·35	0·15	0·01	−0·42	0·06	−0·14	−0·03	0·24	0·26	0·49
Soft drinks	0·01	−0·09	−0·25	0·39	0·22	−0·41	0·02	−0·07	−0·23	−0·08	−0·24	0·14	−0·04	0·00	0·35
Fruit and vegetable juice	0·10	−0·02	0·01	0·29	−0·14	−0·15	0·21	0·00	−0·20	0·05	0·26	0·36	−0·12	0·08	0·09
Sugar	0·13	0·02	0·23	0·28	−0·04	−0·57	−0·09	−0·10	−0·30	0·32	0·27	0·49	0·21	0·22	0·12
Eggs	0·00	−0·07	0·16	0·27	0·44	0·43	0·05	0·06	−0·11	0·11	−0·05	0·03	0·36	0·28	0·21
Alcoholic beverages	0·01	−0·07	−0·15	0·23	0·34	0·30	−0·16	0·04	−0·09	−0·32	−0·23	−0·34	0·05	0·24	−0·05
Japanese and Chinese tea	−0·13	−0·16	0·01	−0·29	−0·13	−0·11	0·07	0·10	0·40	0·05	−0·19	−0·11	−0·21	−0·30	−0·38
Miso soup	0·07	0·14	0·33	−0·05	−0·19	0·11	0·74	0·65	0·43	0·28	0·27	0·37	−0·22	−0·18	−0·39
Rice	−0·01	−0·08	−0·07	−0·20	−0·20	0·03	0·62	0·82	0·60	−0·12	−0·12	0·00	−0·59	−0·61	−0·41
Pulses	0·35	0·46	0·69	0·01	−0·22	−0·24	0·40	0·12	0·05	0·59	0·68	0·48	−0·05	−0·04	−0·51
Noodles	−0·11	−0·01	−0·32	−0·10	−0·13	0·16	0·24	−0·42	0·05	−0·05	−0·08	−0·36	0·19	0·29	0·16
Bread	−0·09	0·06	−0·04	−0·16	−0·04	−0·20	−0·51	−0·80	−0·73	0·02	−0·01	0·32	0·37	0·09	0·61
Tea	0·08	−0·07	0·13	0·06	0·15	−0·31	−0·52	−0·30	−0·15	0·09	0·17	0·44	−0·11	−0·01	0·12
Confectioneries	−0·18	−0·10	−0·18	−0·10	0·03	−0·44	−0·59	−0·50	0·14	0·17	0·24	0·46	0·25	−0·05	0·06
Variation explained (%)	12·8	12·6	13·2	8·9	10·1	7·3	8·4	8·5	10·2	11·4	13·9	12·5	10·1	10·5	13·3

†Absolute values <−0·25 or >0·25 are underlined.
‡Sorted by loadings on DHQ1 factors for women.
§Order of extracted dietary pattern in parentheses.

Table 4 Pearson correlation coefficients between factor scores on similar dietary patterns derived from the first and mean of four self-administered diet history questionnaires (DHQ1 and mDHQ, respectively), and four 4 d weighed dietary records (DR) among ninety-two Japanese women and ninety-two Japanese men*

	Women (*n* 92)			Men (*n* 92)	
	Healthy	Western	Japanese traditional	Healthy	Western
DHQ1 *v.* DR	0·57	0·36	0·44	0·62	0·56
mDHQ *v.* DR	0·63	0·45	0·69	0·65	0·53

*All correlations: $P < 0{\cdot}001$.

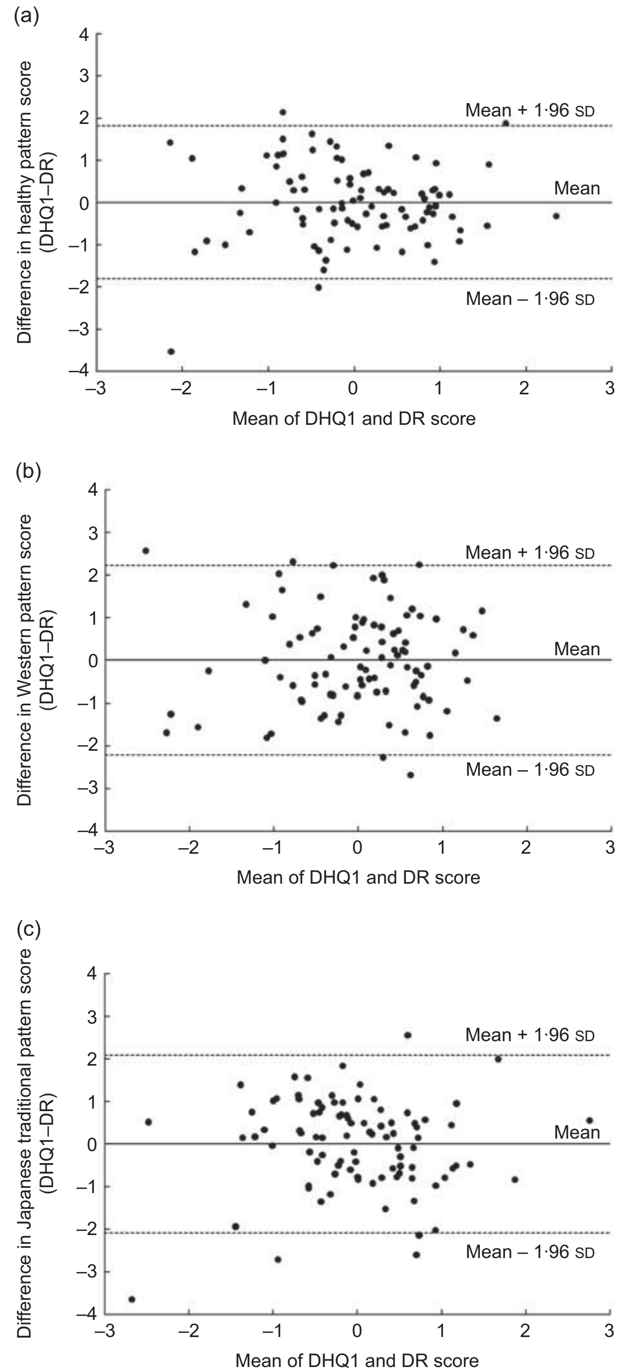

Fig. 1 Bland–Altman plots for agreement between healthy (a), Western (b) and Japanese traditional (c) pattern scores derived from the first self-administered diet history questionnaire (DHQ1) and four 4 d weighed dietary records (DR) among ninety-two Japanese women

result, many food items appearing in the reference method were excluded from the food item list, for example 22 %[18] and 54 %[19], and were not considered in the subsequent validation analysis. Validity with this methodology would therefore be theoretically better than the actual validity. To minimize this problem, we predefined thirty-three food groups, and allocated to them all 145 food items in DHQ and 1259 in DR (Table 1).

The number of extracted dietary patterns differed between sexes, even though almost all subjects (99 %) in the present study were couples who lived together and ate similar meals. The healthy and Western patterns were common to both sexes, with the former characterized by green and yellow vegetables, fruits, mushrooms, white vegetables, seaweed and pulses, and the latter by vegetable oil, processed meat, chicken, beef and pork, eggs and butter. In addition, the correlations between dietary factor scores were in the expected direction for both sexes. In contrast, the Japanese traditional pattern, characterized by a high intake of rice and *miso* soup and a low intake of bread, was original to women. Different dietary patterns between sexes have also been reported in some[20] but not all[5] previous studies.

Several limitations of the present study warrant mention. First, because the sample size (ninety-two in each sex) was smaller than that of the previous studies (*n* 111–927), the stability of establishing dietary patterns may be questionable. Second, because the subjects were not randomly sampled from the general Japanese population, but rather were volunteers and thus likely highly health-conscious, they may not be representative. Moreover, the survey areas were not equally distributed over the country but were selected mostly from the western parts of Japan. Third, we assumed that dietary patterns derived from the DR were the ‘gold standard’. However, DR are also susceptible to measurement error due to erroneous recording and potential changes in eating behaviour[30]. Fourth, factor analysis itself has limitations, and results can be sample specific. Here, analytic decisions were subjective or arbitrary at several points including the number of classifications of food groups, the form of the food group input variables, adjustment of total energy intake, number of factors extracted, rotation method used, and naming of factors. Use of the process above may have produced a lack of consistency, and the results as well as the process by which the dietary patterns were derived should be interpreted with caution.

In conclusion, our data indicate that dietary patterns defined by factor analysis using data from DHQ have

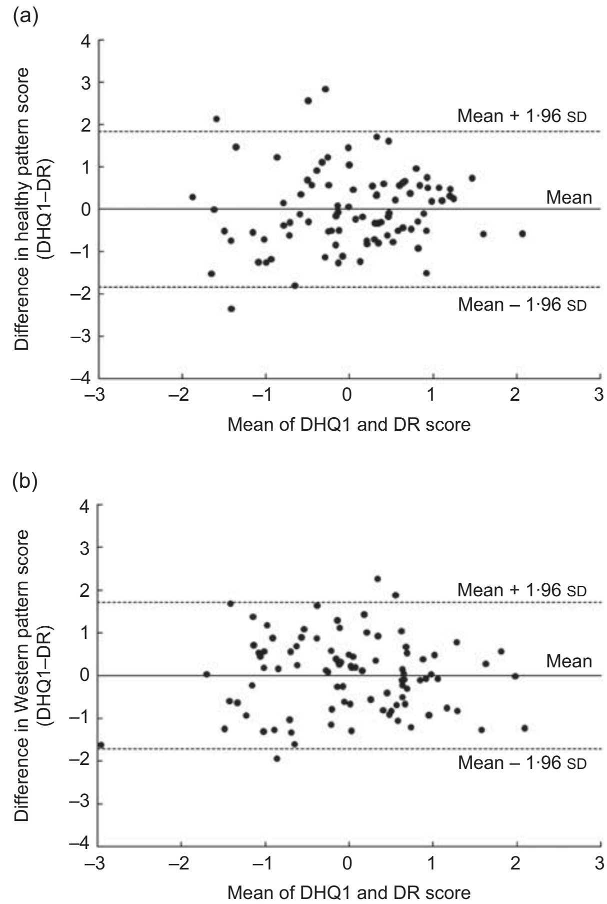

Fig. 2 Bland–Altman plots for agreement between healthy (a) and Western (b) pattern scores derived from the first self-administered diet history questionnaire (DHQ1) and four 4 d weighed dietary records (DR) among ninety-two Japanese men

reasonable validity against DR used as a reference method among Japanese adults. According to an expert review[34], the ability of a dietary pattern to reliably predict disease is also important in establishing the usefulness of the dietary pattern approach. We have already found the expected associations between dietary patterns derived from DHQ and some health outcomes such as bone mineral density[15], obesity[16] and functional constipation[35]. Together with these previous association studies, the present findings suggest the utility of the DHQ in identifying dietary patterns and in studying the relationship between dietary patterns and health in epidemiological studies among Japanese people.

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References

1. Trichopoulou A, Costacou T, Bamia C *et al.* (2003) Adherence to a Mediterranean diet and survival in a Greek population. *N Engl J Med* **348**, 2599–2608.
2. Kennedy ET, Ohls J, Carlson S *et al.* (1995) The Healthy Eating Index: design and applications. *J Am Diet Assoc* **95**, 1103–1108.
3. Kant AK (2004) Dietary patterns and health outcomes. *J Am Diet Assoc* **104**, 615–635.
4. Hu FB (2002) Dietary pattern analysis: a new direction in nutritional epidemiology. *Curr Opin Lipidol* **13**, 3–9.
5. Newby PK & Tucker KL (2004) Empirically derived eating patterns using factor or cluster analysis: a review. *Nutr Rev* **62**, 177–203.
6. Kerver JM, Yang EJ, Bianchi L *et al.* (2003) Dietary patterns associated with risk factors for cardiovascular disease in healthy US adults. *Am J Clin Nutr* **78**, 1103–1110.
7. van Dam RM, Grievink L, Ocke MC *et al.* (2003) Patterns of food consumption and risk factors for cardiovascular disease in the general Dutch population. *Am J Clin Nutr* **77**, 1156–1163.
8. Shimazu T, Kuriyama S, Hozawa A *et al.* (2007) Dietary patterns and cardiovascular disease mortality in Japan: a prospective cohort study. *Int J Epidemiol* **36**, 600–609.
9. Terry P, Hu FB, Hansen H *et al.* (2001) Prospective study of major dietary patterns and colorectal cancer risk in women. *Am J Epidemiol* **154**, 1143–1149.
10. Kim MK, Sasaki S, Sasazuki S *et al.*; Japan Public Health Center-based Prospective Study Group (2004) Prospective study of three major dietary patterns and risk of gastric cancer in Japan. *Int J Cancer* **110**, 435–442.
11. Terry P, Suzuki R, Hu FB *et al.* (2001) A prospective study of major dietary patterns and the risk of breast cancer. *Cancer Epidemiol Biomarkers Prev* **10**, 1281–1285.
12. Nkondjock A, Krewski D, Johnson KC *et al.* (2005) Dietary patterns and risk of pancreatic cancer. *Int J Cancer* **114**, 817–823.
13. Fung TT, Schulze M, Manson JE *et al.* (2004) Dietary patterns, meat intake, and the risk of type 2 diabetes in women. *Arch Intern Med* **164**, 2235–2240.
14. Newby PK, Muller D, Hallfrisch J *et al.* (2004) Food patterns measured by factor analysis and anthropometric changes in adults. *Am J Clin Nutr* **80**, 504–513.
15. Okubo H, Sasaki S, Murakami K *et al.*; Freshmen in Dietetic Courses Study II Group (2008) Three major dietary patterns are all independently related to the risk of obesity among 3760 Japanese women aged 18–20 years. *Int J Obes (Lond)* **32**, 541–549.
16. Okubo H, Sasaki S, Horiguchi H *et al.* (2006) Dietary patterns associated with bone mineral density in premenopausal Japanese farmwomen. *Am J Clin Nutr* **83**, 1185–1192.
17. Touvier M, Niravong M, Volatier JL *et al.* (2009) Dietary patterns associated with vitamin/mineral supplement use and smoking among women of the E3N-EPIC cohort. *Eur J Clin Nutr* **63**, 39–47.
18. Hu FB, Rimm E, Smith-Warner SA *et al.* (1999) Reproducibility and validity of dietary patterns assessed with a food-frequency questionnaire. *Am J Clin Nutr* **69**, 243–249.

19. Khani BR, Ye W, Terry P *et al.* (2004) Reproducibility and validity of major dietary patterns among Swedish women assessed with a food-frequency questionnaire. *J Nutr* **134**, 1541–1545.
20. Togo P, Heitmann BL, Sorensen TI *et al.* (2003) Consistency of food intake factors by different dietary assessment methods and population groups. *Br J Nutr* **90**, 667–678.
21. Crozier SR, Inskip HM, Godfrey KM *et al.* (2008) Dietary patterns in pregnant women: a comparison of food-frequency questionnaires and 4 d prospective diaries. *Br J Nutr* **99**, 869–875.
22. Sasaki S, Yanagibori R & Amano K (1998) Self-administered diet history questionnaire developed for health education: a relative validation of the test-version by comparison with 3-day diet record in women. *J Epidemiol* **8**, 203–215.
23. Sasaki S, Yanagibori R & Amano K (1998) Validity of a self-administered diet history questionnaire for assessment of sodium and potassium: comparison with single 24-hour urinary excretion. *Jpn Circ J* **62**, 431–435.
24. Sasaki S, Ushio F, Amano K *et al.* (2000) Serum biomarker-based validation of a self-administered diet history questionnaire for Japanese subjects. *J Nutr Sci Vitaminol* **46**, 285–296.
25. Okubo H, Sasaki S, Hirota N *et al.* (2006) The influence of age and body mass index on relative accuracy of energy intake among Japanese adults. *Public Health Nutr* **9**, 651–657.
26. Murakami K, Sasaki S, Takahashi Y *et al.* (2008) Reproducibility and relative validity of dietary glycaemic index and load assessed with a self-administered diet-history questionnaire in Japanese adults. *Br J Nutr* **99**, 639–648.
27. Ogawa K, Tsubono Y, Nishino Y *et al.* (2003) Validation of a food-frequency questionnaire for cohort studies in rural Japan. *Public Health Nutr* **6**, 147–157.
28. Ministry of Health, Labour, and Welfare of Japan (2008) *The National Health and Nutrition Survey in Japan, 2005*. Tokyo: Ministry of Health and Welfare (in Japanese).
29. Science and Technology Agency (2005) *Standard Tables of Food Composition in Japan*, fifth revised and enlarged edition. Tokyo: Printing Bureau of the Ministry of Finance (in Japanese).
30. Willett WC (1998) *Nutritional Epidemiology*, 2nd ed. New York: Oxford University Press.
31. Kim J-O & Mueller CW (1978) *Factor Analysis: Statistical Methods and Practical Issues*. Thousand Oaks, CA: Sage Publications Inc.
32. Bland JM & Altman DG (1986) Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* **1**, 307–310.
33. Livingstone MBE & Black AE (2003) Markers of the validity of reported energy intake. *J Nutr* **133**, 895S–920S.
34. Moeller SM, Reedy J, Millen AE *et al.* (2007) Dietary patterns: challenges and opportunities in dietary patterns research an Experimental Biology workshop, April 1, 2006. *J Am Diet Assoc* **107**, 1233–1239.
35. Okubo H, Sasaki S, Murakami K *et al.*; Freshmen in Dietetic Courses Study II Group (2007) Dietary patterns associated with functional constipation among Japanese women aged 18 to 20 years: a cross-sectional study. *J Nutr Sci Vitaminol* **53**, 232–238.