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Reproducibility and validity of dietary patterns identified using factor analysis among Chinese populations

Xin Hong[1], Qing Ye[1], Zhiyong Wang[1], Huafeng Yang[1], Xupeng Chen[1,2], Hairong Zhou[1,2], Chenchen Wang[1,2], Wenjie Chu[2], Yichao Lai[3], Liuyuan Sun[4], Youfa Wang[5] and Fei Xu[1,2]*

[1]*Department of Non-communicable Disease Prevention, Nanjing Municipal Center for Disease Control & Prevention, 2, Zizhulin, Nanjing 210003, People's Republic of China*

[2]*Department of Epidemiology and Biostatistics, School of Public Health, Nanjing Medical University, Nanjing 211166, People's Republic of China*

[3]*Department of Non-communicable Disease Prevention, Qinhuai District Center for Disease Control & Prevention, Nanjing 210029, People's Republic of China*

[4]*Department of Non-communicable Disease Prevention, Liuhe District Center for Disease Control & Prevention, Nanjing 211500, People's Republic of China*

[5]*Department of International Health, Bloomberg School of Public Health, Johns Hopkins Global Center for Childhood Obesity, Johns Hopkins University, Baltimore, MD 21205, USA*

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Abstract

In the present study, we evaluated the reproducibility and validity of dietary patterns among Chinese adult populations. A random subsample of 203 participants (aged 31–80 years) from a community-based nutrition and health survey was enrolled. An eighty-seven-item FFQ was administered twice (FFQ1 and FFQ2) 1 year apart; four 3 consecutive day, 24-h dietary recalls (24-HDR, as a reference method) were performed between the administrations of the two FFQ every 3 months. Dietary patterns from three separate dietary sources were derived using factor analysis based on twenty-eight predefined food groups. Comparisons between dietary pattern scores were made by using Pearson's or intraclass correlation coefficients (ICC), cross-classification analysis, weighted κ statistic and Bland–Altman plots; the four major dietary patterns identified from FFQ1, FFQ2 and 24-HDR were similar. Regarding reproducibility, ICC for z-scores between FFQ1 and FFQ2 were all >0·6 for dietary patterns. The 'animal and plant protein' pattern had the highest ICC of 0·870. For validity, the adjusted Pearson's correlation coefficients for dietary pattern z-scores between two FFQ and the mean of four 3 consecutive day 24-HDR ranged from 0·387 for the 'Chinese traditional' pattern to 0·838 for the 'animal and plant protein' pattern. More than 75 % of the participants were classified into the same or adjacent quartile, and <5 % were misclassified into opposite quartiles. The weighted κ ranged from 0·259 to 0·680. Bland–Altman plots indicated that no significant deviation was found between two dietary assessment methods. Our findings indicate a good reasonable reproducibility and a reasonable validity of dietary patterns derived by factor analysis in China.

Key words: **Reliability: Validity: Dietary patterns: Factor analyses: China**

Epidemiological studies have suggested that dietary pattern analysis is a useful method for studying the role of diet in relation to health outcomes or disease risk. Dietary pattern analysis has been used increasingly as an alternative method to traditional analysis because it takes into account the diet's overall effects, reflecting more closely the real-world habits[1,2].

The following three main approaches have been used to define dietary patterns: factor analysis, cluster analysis and dietary indices. Factor analysis is a multivariate statistical reduction technique that aggregates specific food groups based on analyses of the correlation–covariance matrix of a number of food items[3]. The continuous nature of factor analysis has been seen to be advantageous over other methods[4]. Factor analysis was therefore commonly used to derive dietary patterns.

However, several subjective or arbitrary decisions can be made during factor analysis, including the consolidation of food items into food groups, the number of factors to extract, the method of rotation and the labelling of the components[5]. Furthermore, dietary patterns can be population specific, such that it is essential to identify dietary patterns in a specific study population of interest[1,6], such as the Chinese population. In the past two decades, China has experienced a significant

Abbreviations: 24-HDR, 24-h dietary recalls; FA, factor analysis; ICC, intraclass correlation coefficients; LOA, limits of agreement; m24-HDR, mean of four 3 consecutive day 24-HDR; mFFQ, mean of two FFQ.

* **Corresponding author:** F. Xu, email frankxufei@163.com

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nutrition transition from the traditional Chinese diet to a Western diet pattern, with an increase in consumption of red meats, eggs and oils and a decrease in fruit and vegetable intakes.

Most dietary pattern studies have used FFQ to estimate dietary intakes, as they are easy to administer, comparatively inexpensive, and they can assess long-term dietary habits in large populations. However, FFQ are sensitive to the diverse lifestyle, eating habits and dietary preferences in the population concerned[7]. Dietary recalls may be superior to FFQ and have been frequently used as a reference method in many Chinese validation studies[8–10]. To date, some foreign studies[11–18] have been conducted to examine the validity of dietary patterns derived from FFQ using factor analysis. Unfortunately, no similar studies have been reported in China, with different culture-specific dietary habits.

The purpose of the present study was to examine the reproducibility and validity of dietary patterns derived from factor analysis among Chinese populations. The reproducibility was assessed by comparing the dietary pattern scores between two FFQ administered 1 year apart, and the validity was assessed by comparing the dietary pattern scores between FFQ and 24-h dietary recalls (24-HDR) as a reference method at 3-month intervals during the period of 1 year.

Methods

Study population

The present study was conducted using a subsample of the community-based, cross-sectional, nutrition and health survey in Nanjing, the capital of Jiangsu Province of China. The detailed study recruitment methods have been described previously[19]. In brief, a multi-stage random sampling method was adopted. First, we randomly selected two districts (one urban and one suburban). Next, three streets/towns from each chosen district were randomly selected. Finally, one community from each chosen street/town was randomly selected. This resulted in a total number of six communities. Of 2030 participants of the nutrition and health survey, a random sample of 250 members was invited to participate in the present study. Sample size of the present study was calculated according to subjects per food group ratios of 7:1[18]. Inclusion criteria were as follows: local resident for at least 5 years, aged 30 years or above, free of chronic non-communicable diseases requiring a special diet and not on a weight-reduction diet. Among the 250 selected residents, 248 were eligible to participate and 223 agreed to take part in the survey (response rate: 89·9 %).

The Ethics Board of Nanjing Municipal Center for Disease Control and Prevention reviewed and approved the study protocol, and written informed consent was obtained from each participant before inclusion.

Study design

The study design with time frame is shown in Fig. 1. The study stared in June 2014 and ended in May 2015. Each participant completed the same FFQ twice – the first FFQ (FFQ1) was administrated at baseline and the second FFQ (FFQ2) was administrated 1 year later; four 3 consecutive day 24-HDR were collected between the administrations of the two FFQ every 3 months during a period of 1 year (a total of twelve 24-HDR). The first 3 consecutive day 24-HDR was performed 1 month after FFQ1, and the last 3 consecutive day 24-HDR was performed 1 month before FFQ2. We excluded participants who failed to provide two completed FFQ (*n* 6), did not complete four 3-d 24-HDR (*n* 9) or had extreme values for total energy intake (<2092 kJ/d (<500 kcal/d) or >20 920 kJ/d (>5000 kcal/d), *n* 5). Finally, 203 subjects (81·9 %) were included in the data analysis.

Dietary assessment

A semi-quantitative FFQ was used to estimate habitual dietary intakes over the previous year. The reproducibility and validity of the FFQ used in this study have been published elsewhere[19]. The FFQ included eighty-seven food items and

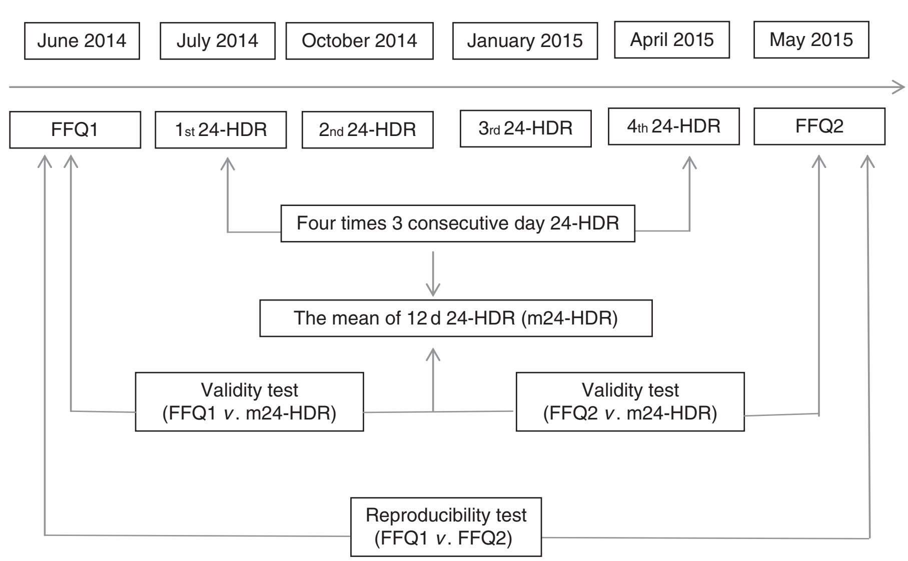

Fig. 1. Study design and time frame used in the present study. 24-HDR, 24-h dietary recalls; m24-HDR, mean of four 3 consecutive day 24-HDR.

twelve food categories (grains and products; red meat (pork, beef, mutton); poultry meat; fish and shrimp; eggs; dairy products; soya-based foods; vegetables; fruits; beverages; alcohol; snacks/desserts), which covered 90 % of the commonly consumed foods in Nanjing. For each food item, participants were asked to recall the frequency of consumption (daily, weekly, monthly, annually or never) and the amount of consumption each time in a common unit of weight in China (1 liang = 50 g) or in millilitre over the past 12 months. For seasonal vegetables and fruits, participants were asked to recall how often they ate these foods during the season. Individual consumption of food items was converted to grams per day for further analysis.

Owing to the small number of subjects (*n* 203) relative to the number of food items, and to reduce the complexity of the data, we collapsed the initial eighty-seven food items into twenty-eight predefined food groups (Appendix 1). The grouping scheme was based on the similarity of nutrient profiles or culinary usage among the foods[13,20].

In total, four 3 consecutive day (including 2 weekdays and 1 weekend day in a usual week) 24-HDR were collected at intervals of 3 months during the 1-year period. Each participant was asked to provide the name and amount of all foods consumed during the previous 24 h. If the previous day was a special day, such as feast or travel days, food consumption of the day before the 24 h was recorded or another day was chosen to interview the participant by telephone. The amounts of different food items that were mixed in one dish were recorded, respectively. The recalled food items were assigned to the corresponding food groups as defined by the FFQ. The *Chinese Food Composition Tables*[21] were used to estimate the intake of energy (kJ/d (kcal/d)) and key nutrients from each food group consumed by 24-HDR. All values obtained for key nutrient intake were adjusted for total energy intake using the regression residual method[22]. The mean of four 3 consecutive day 24-HDR (m24-HDR) data was used as the standard to measure the validity of the FFQ.

Trained interviewers from the local Center for Disease Control and Prevention administered the two FFQ and four 3-d 24-HDR by face-to-face interviews. All diet information were collected and checked after completion. Any implausible or ambiguous information would be further verified and obtained from the participants. Each participant had the same interviewer during the study period.

Dietary pattern analysis

Exploratory factor analysis (FA) was used to identify major dietary patterns based on a set of twenty-eight predefined food groups; FA was performed separately for FFQ1, FFQ2 and m24-HDR food groups. Factors were rotated with varimax rotation to maintain uncorrelated factors and enhance interpretability. A combined evaluation of the eigenvalues, scree plot test and factor interpretability was used in determining the number of retained factors[11,23]. Factor loadings were interpreted as correlation coefficients between food groups and dietary patterns. Food groups with positive loadings contributed to the dietary pattern, and food groups with negative loadings were inversely associated with the dietary pattern. Food groups with absolute factor loadings ≥0·30 were considered as significantly contributing to the pattern[24]. The patterns were labelled according to food groups with high loadings in each dietary pattern. The sum of the squares of the respective factor loadings over all retained factors represented the percentage of variance that was explained by the final factors. Factor scores for each pattern were calculated as the sum of the products of the factor loading coefficients and the standardised daily intake of each food group[24].

Statistical analyses

The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy (>0·6) and Bartlett's test of sphericity ($P < 0·05$) were used to determine the data suitability for FA. Three methods were used to examine the reliability and validity of dietary patterns.

First, the reproducibility and validity were assessed by comparing dietary pattern scores between FFQ1 and FFQ2, and between two FFQ and m24-HDR, respectively, using Pearson's or intraclass correlation coefficients (ICC), cross-classification analysis and weighted κ (*Kw*) statistic. Cross-classification (quartiles method) analysis was conducted to classify the participants into same, adjacent, one quartile apart or opposite quartiles. The inter-rater agreement of the two assessment methods was analysed by *Kw*. ICC > 0·4 indicated good agreement[25]. Pearson's correlation coefficients of 0·5–0·7 were considered good[26]. Values of *Kw* >0·4 indicated moderate agreement[26].

Second, a Bland–Altman plot was constructed to assess the agreement of dietary pattern scores between different dietary sources. The plots showed the difference between each individual's *z*-scores derived from the mean of two FFQ (mFFQ) and m24-HDR (mFFQ – m24-HDR) against their averages ((mFFQ + m24-HDR)/2)[27]. The mean differences and the 95 % limits of agreement (LOA, calculated as mean differences ±1·96 SD) were used to summarise agreement at the population level.

Third, Pearson's correlation coefficients were used to compare energy-adjusted nutrient intakes estimated by m24-HDR with dietary pattern scores derived from FFQ and m24-HDR.

All statistical analyses were performed using SPSS software version 20.0 (IBM) and MedCalc version 11.4. All tests were two-tailed, and a *P* value <0·05 was considered statistically significant.

Results

Study sample characteristics

Among 203 participants, about 48·8 % were males and 92·2 % were married. Their mean age was 50·4 (SD 12·2) years (range 31–80 years); the mean BMI was 23·1 (SD 2·8) kg/m^2; and 79·5 % had educational qualification of junior high school or above. The proportion of current smokers and drinkers was 22·0 and 28·8 %, respectively. There were no differences in baseline characteristics between the subsample (*n* 203) and the entire population (*n* 2030) (Appendix 2).

Table 1. Factor-loading matrix for four major dietary patterns* identified from FFQ1, FFQ2 and the mean of four 3 consecutive day 24-HDR (m24-HDR) in the subsamples (*n* 203)

	FFQ1				FFQ2				m24-HDR			
Food groups	Animal and plant	Nuts and sweets	Chinese traditional	Beverage and alcohol	Animal and plant	Nuts and sweets	Chinese traditional	Beverage and alcohol	Animal and plant	Nuts and sweets	Chinese traditional	Beverage and alcohol
Poultry meats	0·767†	0·045	−0·246	0·313†	0·841†	0·032	−0·050	0·217	0·630†	0·012	−·021	0·360†
Fish and shrimp	0·748†	−0·014	−0·048	0·115	0·807†	0·014	−0·020	0·058	0·656†	−0·002	0·046	0·098
Bean curd	0·727†	−0·034	0·045	0·016	0·762†	0·051	0·003	0·096	0·347†	−0·241	0·245	0·132
Dry vegetables	0·720†	0·206	0·093	−0·088	0·761†	0·032	0·099	−0·115	0·732†	0·207	0·070	−0·249
Livestock meats	0·706†	0·075	−0·259	0·273	0·717†	0·132	0·072	0·049	0·600†	−0·317†	0·162	0·108
Dry bean	0·666†	−0·017	0·273	−0·316†	0·804†	0·088	0·108	0·006	0·728†	0·112	−·013	−0·145
Other soyabean products	0·642†	0·166	0·197	−0·171	0·655†	0·106	0·084	−0·046	0·437†	0·074	0·251	−0·223
Eggs	0·594†	0·259	0·070	0·268	0·659†	0·246	0·207	0·215	0·653†	0·020	−0·019	0·116
Fresh fruits	0·381†	0·362†	0·109	0·066	0·590†	0·141	0·334†	0·031	0·519†	0·215	0·251	−0·006
Low-fat dairy products	0·318†	0·304†	0·164	0·005	0·415†	0·448†	0·082	0·168	0·313†	0·122	−0·310	0·091
Tea or coffee	0·310†	−0·019	−0·160	−0·045	0·282	−0·071	−0·156	−0·090	0·264	−0·060	−0·092	0·294
Nuts	0·033	0·750†	0·059	−0·065	0·010	0·673†	0·168	0·025	0·181	0·369†	0·001	0·108
Sweets and desserts	−0·021	0·743†	0·044	0·023	0·056	0·749†	0·006	0·271	0·140	0·564†	0·221	0·260
Snacks	0·098	0·666†	−0·020	−0·028	0·053	0·489†	0·188	−0·173	0·051	0·361†	0·097	0·058
Other grains and products	0·113	0·377†	0·580†	−0·067	0·039	0·146	0·670†	−0·039	0·079	0·334†	0·353†	−0·137
Potatoes	0·129	0·301†	0·579†	0·125	0·072	0·060	0·695†	0·075	−0·024	0·096	0·386†	−0·060
Fresh vegetables	0·163	0·143	0·552†	−0·028	0·250	0·066	0·430†	−0·216	−0·036	−0·067	0·493	−0·217
Fried food	0·032	−0·143	0·519†	0·223	−0·060	−0·038	0·574†	0·300†	0·004	0·078	0·437†	0·201
High-fat dairy products	0·359†	0·002	0·482†	0·199	0·286	−0·071	0·466†	0·374†	0·069	0·307†	0·486†	0·068
Wheat and products	0·019	0·383†	0·440†	−0·027	0·060	0·074	0·620†	−0·070	0·165	−·048	0·419†	0·053
Rice and products	0·236	−0·292	0·418†	0·132	0·321†	−0·306†	0·454†	−0·035	0·071	−0·262	0·511†	0·257
Pickled vegetables	−0·158	−0·236	0·330†	−0·228	−0·156	–	0·513†	−0·081	−0·085	−0·248	0·544†	−0·037
Sodas	0·024	−0·003	0·120	0·592†	−0·031	0·102	−0·027	0·702†	−0·086	0·073	0·055	0·460
Juice	0·103	0·034	−0·020	0·558†	0·058	0·103	−0·091	0·718†	−0·081	0·272	0·171	0·507
Beer	0·011	−0·162	−0·073	0·465†	0·042	−0·258	−0·077	0·532†	0·067	0·137	0·125	0·591
Wine	0·089	−0·033	0·312†	0·392†	0·086	−0·189	0·269	0·418†	0·179	−·072	−0·106	0·344
Processed meats	0·017	0·020	0·063	0·369†	0·011	0·169	0·051	0·560†	−0·069	−0·126	0·059	0·363
Liquor	−0·068	−0·180	0·079	0·306†	−0·075	−0·365†	0·077	0·313†	0·020	−0·516†	−0·120	0·375
Eigenvalue	4·990	2·571	2·489	1·943	5·946	2·006	2·640	2·890	3·905	2·160	1·889	1·759
Variance explained (%)	16·6	8·6	8·3	6·5	19·8	6·7	8·8	9·6	13·0	7·2	6·3	5·9
Total variance (%)	40·0				44·9				32·4			

* The test for suitability of factor analysis: the Kaiser–Meyer–Olkin measure of sampling adequacy was 0·734 for FFQ1, 0·806 for FFQ2 and 0·640 for m24-HDR, and *P* values for Bartlett's test of sphericity were all <0·001.
† The factor loadings were >0·30.

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Dietary patters identified in the two FFQ and mean of four 3 consecutive day 24-HDR

The KMO measure of sampling adequacy was 0·734 for FFQ1, 0·806 for FFQ2 and 0·640 for m24-HDR, and *P* values for Bartlett's test of sphericity were all <0·001. Using FA, four major dietary patterns were extracted from FFQ1, FFQ2 and m24-HDR (Table 1). These four derived patterns were relatively similar from three dietary sources. Factor 1, which loaded heavily on poultry meats, fish and shrimp, bean curd, livestock meats, dry bean and other soyabean products, was labelled the 'animal and plant protein' pattern. Factor 2, with high loadings for nuts, sweets and desserts and snacks, was labelled the 'nuts and sweets' pattern. Factor 3, which was rich in other grains and products, potatoes, fresh vegetables, fried food, high-fat dairy products, wheat and products, rice and products, and pickled vegetables, was labelled the 'Chinese traditional' pattern. Factor 4, characterised by higher intake of sodas, juice, beer, wine, processed meats and liquor, was labelled the 'beverage and alcohol' pattern. Overall, the total percentage of variance explained by the four patterns derived from FFQ1, FFQ2 and m24-HDR was 40·0, 44·9, 32·4 %, respectively. In addition, four similar dietary patterns were also identified in the overall samples (Appendix 3).

Correlations and agreement between dietary pattern z-scores

Regarding reproducibility, ICC for dietary pattern *z*-scores between FFQ1 and FFQ2 were >0·6 for all four patterns. The 'animal and plant protein' pattern had the highest ICC of 0·870 (Table 2). For validity, the adjusted Pearson's correlation coefficients for dietary pattern *z*-scores between two FFQ and m24-HDR ranged from 0·387 for the 'Chinese traditional' pattern to 0·838 for the 'animal and plant protein' pattern.

When the four dietary pattern scores were categorised into quartiles, the ranges of agreement rates for the same or adjacent quartile classifications were 75·6–95·5 %, when derived from the two FFQ and the m24-HDR. Extreme misclassification into opposite quartiles was <5·0 % (Table 3). The *Kw* ranged from 0·259 to 0·680.

The Bland–Altman plots of all dietary patterns are presented in Fig. 2–5. The mean agreement between the dietary pattern *z*-scores derived from the mFFQ and the m24-HDR were not significantly different from zero in all comparisons. The mean differences were 0·0 (95 % LOA −1·03, 1·04) for the 'animal and plant protein' pattern, − 0·0 (95 % LOA −1·7, 1·6) for the 'nuts and sweets' pattern, −0·1 (95 % LOA −2·0, 1·8) for the 'Chinese traditional' pattern and −0·2 (95 % LOA −1·9, 1·5) for the 'beverage and alcohol' pattern between mFFQ and m24-HDR.

Correlations between dietary pattern z-scores and nutrient intakes

Correlations between energy-adjusted nutrient intakes from the dietary recalls and dietary pattern scores derived from FFQ1, FFQ2 and m24-HDR are shown in Table 4. The majority of statistically significant correlations were consistent for the FFQ and m24-HDR. In particular, the 'animal and plant protein' pattern was positively correlated with intakes of protein, carbohydrates, fibre, vitamin A, retinol, thiamine, riboflavin, niacin, vitamin E, Ca, P, K, Mg, Fe, Zn, Se and Cu, and was negatively correlated with intakes of total fat and cholesterol. In contrast, the 'Chinese traditional' pattern was negatively correlated with intakes of vitamin A, carotene, niacin, vitamin C, Ca, P, Na, Zn and Mn. The 'beverage and alcohol' patterns were positively correlated with intakes of total fat and cholesterol and negatively correlated with intakes of retinol, thiamine and Se.

Discussion

To our knowledge, the present study is perhaps the first one to assess the reproducibility and validity of dietary patterns identified by FA derived from FFQ in comparison with dietary recalls in a Chinese population. In a random subsample of 203 subjects, four major dietary patterns were identified using FA – that is, the 'animal and plant protein' pattern, the 'nuts and sweets' pattern, the 'Chinese traditional' pattern and the 'beverage and alcohol' pattern. These four derived patterns were qualitatively similar across three sources of dietary data obtained from the two FFQ and the means of twelve 24-HDR. For all dietary patterns, factor loadings of the FFQ and m24-HDR food groups were partly different. This might be due to methodological differences between dietary assessment methods[28,29], random statistical variation and different assessment periods as mentioned previously[12,13,15,17,18]. The patterns identified in the present study were similar to previous findings in China[30–32].

The correlations of the dietary pattern *z*-scores between FFQ1 and FFQ2 revealed good reliability, and the correlations of the dietary pattern *z*-scores between the two FFQ and the m24-HDR represented a reasonable comparative validity of four major dietary patterns derived by FA using the data of FFQ in a Chinese population. In this study, the 24-h recall

Table 2. Correlation coefficients for dietary pattern *z*-scores derived from FFQ1, FFQ2 and the mean of four 3 consecutive day 24-HDR (m24-HDR) in the subsamples (*n* 203)*

	Animal and plant	Nuts and sweets	Chinese traditional	Beverage and alcohol
FFQ1 *v.* FFQ2†	0·870	0·649	0·731	0·669
FFQ1 *v.* m24-HDR‡	0·838	0·440	0·387	0·440
FFQ2 *v.* m24-HDR‡	0·748	0·451	0·486	0·479

* All correlations were statistically significant ($P < 0·001$).
† Values were intraclass correlation coefficients.
‡ Values were Pearson's correlation coefficients adjusted for energy intake using the residual method.

Table 3. Percentage agreement and κ statistic for dietary pattern *z*-scores derived from FFQ1, FFQ2 and the mean of four 3 consecutive day 24-HDR (m24-HDR) in the subsamples (*n* 203)

	FFQ1 *v.* FFQ2					FFQ1 *v.* m24-HDR					FFQ2 *v.* m24-HDR				
Dietary patterns	Same quartile	Adjacent quartile	One quartile apart	Opposite quartile	*Kw*	Same quartile	Adjacent quartile	One quartile apart	Opposite quartile	*Kw*	Same quartile	Adjacent quartile	One quartile apart	Opposite quartile	*Kw*
Animal and plant	66·3	29·2	3·5	1·0	0·680	47·0	42·7	9·1	1·2	0·481	45·4	43·2	9·2	2·2	0·466
Nuts and sweets	42·4	37·5	15·6	4·5	0·340	35·7	40·5	19·5	4·3	0·283	36·8	42·7	18·4	2·1	0·379
Chinese traditional	52·2	39·0	7·8	1·0	0·576	32·4	43·8	19·5	4·3	0·282	36·8	45·4	15·6	2·2	0·355
Beverage and alcohol	50·2	37·6	7·8	4·4	0·527	35·1	40·5	19·6	4·8	0·259	36·8	38·9	19·4	4·9	0·295

Kw, weighted κ.

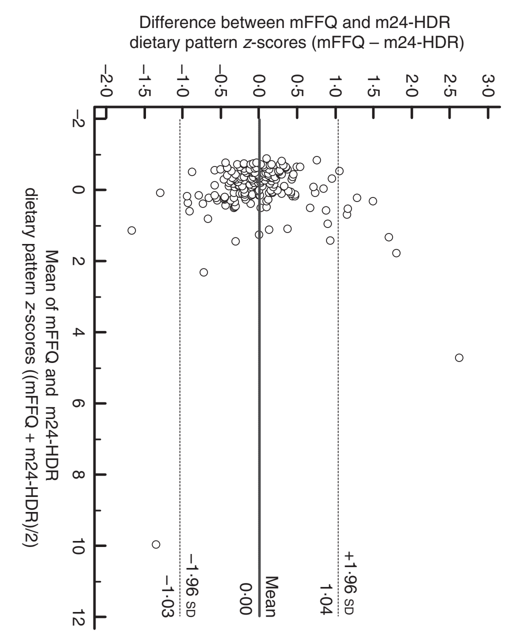

Fig. 2. Bland–Altman plots for 'animal and plant protein' pattern *z*-scores derived from the mean of two FFQ (mFFQ) and mean of four 3 consecutive day 24-HDR (m24-HDR).

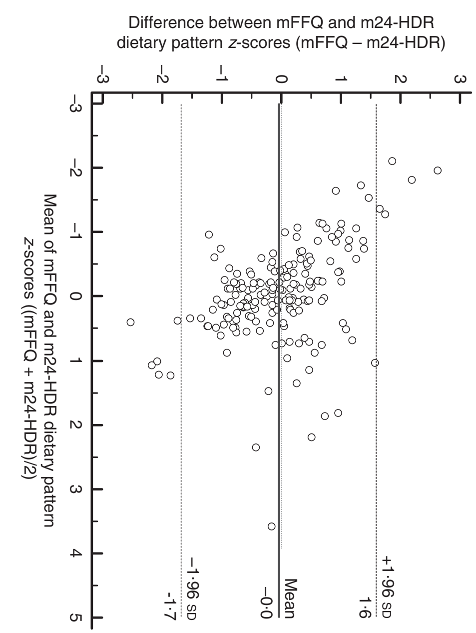

Fig. 3. Bland–Altman plots for 'nuts and sweets' pattern *z*-scores derived from the mean of two FFQ (mFFQ) and mean of four 3 consecutive day 24-HDR (m24-HDR).

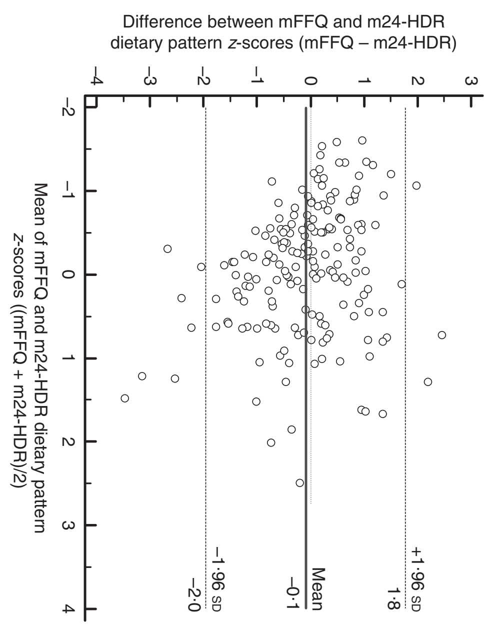

Fig. 4. Bland–Altman plots for 'Chinese traditional' pattern *z*-scores derived from the mean of two FFQ (mFFQ) and mean of four 3 consecutive day 24-HDR (m24-HDR).

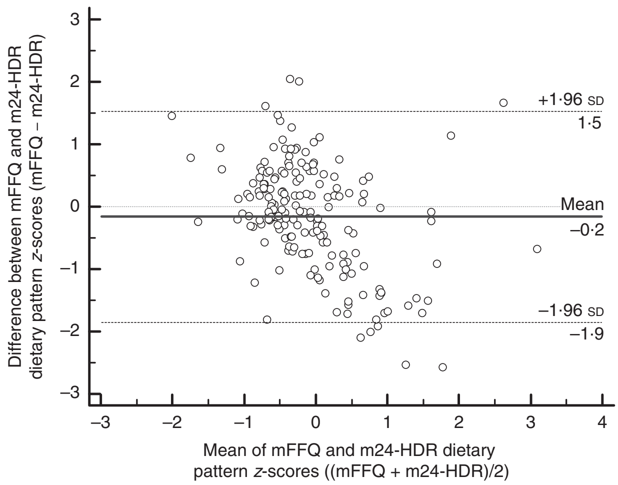

Fig. 5. Bland–Altman plots for 'beverage and alcohol' pattern z-scores derived from the mean of two FFQ (mFFQ) and mean of four 3 consecutive day 24-HDR (m24-HDR).

method was adopted as a reference method. For reducing the effect of difference in seasonal food availability and seasonal food preferences, twelve 24-HDR (one for 3-month intervals) were collected, which covered variability in food consumption during different seasons. Moreover, 3 consecutive day 24-HDR were administered for 2 weekdays and 1 weekend day in a usual week. Therefore, the influence of different diets between weekdays and weekends could be taken into consideration.

Although the methods of reproducibility and validity of dietary patterns were different, the obtained correlations in the present study were similar to those reported by other studies. In the first such study reported by Hu *et al.*[13] in 1999, the corrected correlations between the two FFQ and two 1-week diet records (DR) ranged from 0·45 to 0·74 for the prudent and the Western patterns among 127 US males. The correlations for the factor scores between the two FFQ were 0·70 for the prudent pattern and 0·67 for the Western pattern. In 879 Danish men and 927 Danish women[14], three (green, sweet and traditional) for men and two (green and sweet-traditional) patterns for women were identified in data from a FFQ and a 7-d DR, with corrected correlations ranging between 0·34 and 0·61. Khani *et al.*[15] provided results with uncorrected correlations ranging between 0·41 and 0·73 for healthy, Western and drinker patterns identified using a FFQ and four 1-week DR in a random subgroup of 362 Swedish women. The coefficients of reproducibility were 0·63 (healthy pattern), 0·68 (Western pattern) and 0·73 (drinker pattern). Among 585 pregnant women in the UK[16], the correlation coefficients ranged between 0·35 and 0·67 for the dietary patterns derived from a FFQ and a 4-d food diary. In a subsample of 244 men and 254 women in Japan[11], Pearson's correlation coefficients between the two FFQ ranged from 0·55 for the Western pattern in men and the prudent pattern in women to 0·77 for the traditional Japanese pattern in men. The corresponding values between 1-week DR and the FFQ ranged from 0·32 for the Western pattern in men to 0·63 for the traditional pattern in women. In 132 Iranian populations[17], the ICC between factors scores of the two FFQ were 0·72 for the traditional and 0·80 for the Western pattern, and corrected correlations between FFQ2 and twelve 24-HDR were 0·48 for the traditional and 0·75 for the Western pattern. Loy & Jan Mohamed[18] found that Pearson's correlation coefficients between FFQ and three 24-HDR for healthy and less-healthy patterns were 0·59 and 0·63, respectively, in 162 Malay pregnant women.

When the dietary pattern scores were classified into quartiles, a higher percentage of participants being classified into the same or adjacent quartile (>75 %) and a low percentage into opposite quartile (<5 %) were shown in four dietary patterns in the present study, which demonstrated moderate agreement and lower misclassification between two FFQ and m24-HDR. The weighted κ statistic, which overcame agreement by chance, depicted fair-to-good agreement for dietary patterns.

The Bland–Altman plot is a better method to illustrate the exact agreement between two different dietary assessment methods, which estimates the mean agreement and the 95 % LOA[27]. A wide LOA indicates that the potential for large differences between methods and agreement is considered poor. The mean agreement was approximately equal to 0 for four patterns between FFQ and m-24HR in this study. The 95 % LOA for four dietary patterns were acceptable, in accordance with the results of previous studies[12,16–18]. Although the 95 % LOA in the 'Chinese traditional' pattern was wider than those in other patterns, these differences were marginal.

The correlation coefficients, κ statistics and percentage of agreement were higher and the 95 % LOA were slight narrower for the 'animal and plant protein' pattern compared with the other three patterns; meanwhile, the percentage of misclassification was lower for the 'animal and plant protein' pattern than others. This may due to the fact that the 'animal and plant protein' pattern was rich in some usual food groups during 1 year (such as red meat, poultry meat, fish and shrimp, eggs, soya foods) and that the other three patterns included infrequent (nuts, sweets and desserts, and snacks in the 'nuts and sweets' pattern) or seasonal food groups (fresh fruits and vegetables in the 'Chinese traditional' pattern, and beer, wine and liquor in the 'beverage and alcohol' pattern).

Examining nutrient profiles is a useful way to compare dietary patterns from different dietary methods. Nutrient intakes are informative because they describe the product of a dietary pattern. As expected, correlations of our study were weaker between the FFQ and the m24-HDR; however, the directions of associations were consistent.

A major strength of the present study was the fact that there were no differences in baseline characteristics between the subsample in the present study and the entire population in the cross-sectional nutrition and health study; four similar dietary patterns were also identified in the overall sample. Therefore, as the subsample in the reproducibility and validity study were representative, the results can be generalised to the entire population. In addition, a high recruitment rate (81·9 %) and detailed data collected by trained interviewers were included.

There are several limitations to the present study. First, the sample size was relative small (*n* 203), which might have led to inadequate study power. However, some studies[18,33] have

Table 4. Pearson's correlation coefficients between dietary pattern scores and energy-adjusted nutrient intakes from the mean of four 3 consecutive day 24-HDR (m24-HDR) in the subsamples (*n* 203)

	Animal and plant protein pattern			Nuts and sweets pattern			Chinese traditional pattern			Beverage and alcohol pattern		
Nutrient intakes	FFQ1	FFQ2	m24-HDR	FFQ1	FFQ2	m24-HDR	FFQ1	FFQ2	m24-HDR	FFQ1	FFQ2	m24-HDR
Protein	0·280*	0·359*	0·443*	0·004	−0·004	−0·040	−0·151*	−0·129	0·002	0·001	−0·007	0·143
Total fat	−0·605*	−0·632*	−0·736*	0·103	0·043	0·040	−0·018	−0·016	0·154*	0·184*	0·166*	0·170*
Carbohydrates	0·235*	0·318*	0·376*	0·132	0·097	0·077	−0·095	0·045	0·120	0·005	−0·008	0·082
Fibre	0·135	0·225*	0·292*	−0·019	−0·022	−0·041	−0·146*	−0·099	−0·054	−0·026	−0·046	0·042
Cholesterol	−0·694*	−0·631*	−0·826*	0·102	0·039	0·023	−0·092	−0·017	0·017	0·140*	0·141*	0·166*
Vitamin A	0·140*	0·227*	0·293*	−0·032	−0·031	−0·051	−0·159*	−0·201*	−0·090	−0·027	−0·043	0·134
Carotene	0·114	0·205*	0·265*	−0·038	−0·035	−0·058	−0·160*	−0·207*	−0·094	−0·034	−0·054	0·125
Retinol	0·655*	0·579*	0·773*	0·139*	0·093	0·156*	−0·002	0·022	0·024	−0·189*	−0·253*	0·130
Thiamine	0·369*	0·420*	0·515*	0·045	−0·112	−0·399*	−0·045	0·084	0·176*	−0·290*	−0·207*	−0·220*
Riboflavin	0·294*	0·370*	0·460*	0·002	−0·012	−0·027	−0·121	−0·114	−0·023	0·067	0·068	0·133
Niacin	0·225*	0·319*	0·391*	−0·037	−0·048	−0·139	−0·197*	−0·238*	−0·049	0·019	−0·014	0·234*
Vitamin C	0·087	0·171*	0·207*	−0·016	0·025	−0·027	−0·305*	−0·381*	−0·317*	0·018	0·019	0·460*
Vitamin E	0·210*	0·290*	0·373*	0·046	0·033	0·048	−0·097	−0·050	−0·014	0·009	−0·001	0·066
Ca	0·188*	0·273*	0·334*	−0·018	0·002	−0·047	−0·156*	−0·177*	−0·068	−0·006	0·007	0·085
P	0·404*	0·480*	0·560*	0·037	0·026	−0·060	−0·156*	−0·053	0·068	0·038	0·035	0·115
K	0·183*	0·276*	0·340*	−0·026	−0·030	−0·064	−0·157*	−0·142*	−0·044	−0·018	−0·039	0·099
Na	−0·059	−0·040	−0·037	−0·134	−0·083	−0·236*	−0·118	−0·487*	−0·514*	−0·095	−0·055	0·077
Mg	0·176*	0·261*	0·337*	−0·005	−0·010	−0·038	−0·139*	−0·126	−0·036	−0·009	−0·023	0·086
Fe	0·162*	0·252*	0·321*	−0·024	−0·027	−0·077	−0·164*	−0·004	0·003	−0·021	−0·040	−0·064
Zn	0·263*	0·348*	0·429*	−0·007	−0·017	−0·075	−0·159*	−0·146*	−0·010	0·017	−0·001	0·151*
Se	0·652*	0·677*	0·799*	0·146*	0·088	0·091	−0·079	−0·023	0·103	−0·137*	−0·138*	−0·187*
Cu	0·156*	0·241*	0·311*	0·002	−0·002	−0·026	−0·132	−0·131	−0·033	−0·018	−0·023	0·086
Mn	0·115	0·206*	0·267*	−0·037	−0·036	−0·060	−0·157*	−0·250*	−0·173*	−0·035	−0·055	0·099

* $P < 0·05$.

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suggested that the generally accepted sample size is seven participants per food group for FA. Second, in the absence of an absolute gold standard for dietary assessment, we chose dietary recalls as a reference method. This method was advantageous in its ability to collect actual intake on specific days. However, dietary recalls might also be subject to recall bias, erroneous recording and potential changes in eating behaviour, leading to over-estimating or under-estimating food intake. Therefore, we attempted to minimise weakness by checking dietary recalls by following-up incomplete or ambiguous information directly with respondents. Moreover, four 3 consecutive day 24-HDR were shown to be sufficient to capture seasonal variations in food intake. Third, the analysis of reproducibility and validity was confined to adults aged 31–80 years. It is unclear whether our findings can be applied to children, adolescents and younger adults. Finally, the total variance explained by the four dietary patterns derived from FFQ1, FFQ2 and m24-HDR was 40·0, 44·9, 32·4 %, respectively, suggesting the existence of minor dietary patterns, which were less interpretable and highly variable; therefore, they were not presented in this study.

In conclusion, our study indicated a good reproducibility and a reasonable validity of the major dietary patterns identified by FA using data from a FFQ and dietary recalls among Chinese populations, suggesting that FFQ data provided useful information on dietary patterns. Dietary pattern might be used in nutrition epidemiology as a complementary approach to traditional analysis and is appropriate to examine the diet–disease association.

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The authors declare that there are no conflicts of interest.

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Appendix 1

The twenty-eight food groups used in the dietary pattern analysis

Food groups	Food items
1. Rice and products	White rice, millet, porridge, rice flour
2. Wheat and products	Noodle, dumpling, bread, steamed bread, wonton, twist bread
3. Potatoes	Potatoes, Chinese yam, sweet potato, taro
4. Other grains and products	Sorghum, maize
5. Fried food	Deep-fried dough sticks, deep-fried dough cake, other fried food
6. Livestock meats	Beef, steak, lamb, pork, meatballs, meatloaf, ham
7. Poultry meats	Chicken, duck, goose
8. Processed meats	Sausage, bacon, hot dogs
9. Fish and shrimp	Carp, grass carp, silver carp, herring, shrimp
10. Eggs	Eggs
11. High-fat dairy products	Butter, cheese, whole milk, whole yogurt, ice cream
12. Low-fat dairy products	Low-fat milk, reduced-fat (medium) milk, low-fat yogurt fat yogurt
13. Bean curd	Bean curd
14. Dry beans	Red bean, green beans, black beans, soyabean, bean curd
15. Other soyabean products	Bean sprouts, soya chicken, bean curd sheet, soyabean milk
16. Fresh vegetables	Spinach, cucumber, Chinese cabbage, lettuce, broccoli, greens, celery, water spinach, shepherd purse, carrots, tomatoes, onion, eggplant, yellow squash, mushrooms, green pepper
17. Pickled vegetables	Pickled vegetables
18. Dry vegetables	Dried mushroom, dried black fungus, kelp, laver
19. Fresh fruits	Oranges, bananas, apples, strawberries, grapes, peaches, pears, kiwifruit, melons, watermelon
20. Juice	Fruit or vegetable juice
21. Sodas	Cola, other carbonated beverage
22. Tea or coffee	Red or green tea, coffee
23. Beer	Beer, regular or light
24. Liquor	Liquor
25. Wine	Red or white wine
26. Sweets and desserts	Candy, cookie, chocolate, brownies, cake, pie, pastry
27. Nuts	Peanut, walnut, melon seed, cashew, other nuts
28. Other snacks	Potato chips or maize chips, crackers, popcorn

Appendix 2

Comparison of participants in the reliability and validity study with those in the cross-sectional survey
(Mean values and standard deviations)

	Subsample (*n* 203)		Total sample (*n* 2030)		
Variables	Mean	SD	Mean	SD	*P*
Age at recruitment (years)	50·4	12·2	51·5	12·3	0·224
BMI (kg/m^2)	23·1	2·8	23·5	3·1	0·077
Sex (%)					0·639
Male	48·8		50·5		
Female	51·2		49·5		
Marriage (%)					0·259
Married	92·2		89·7		
Unmarried/divorced/widowed	7·8		10·3		
Education (%)					0·080
Primary school and lower	20·5		28·2		
Junior high school	32·2		32·2		
Senior high school	24·4		20·6		
College and higher	22·9		19·0		
Occupation (%)					0·157
Manual labourers	42·4		46·2		
Service staff	6·8		6·5		
Mental labourers	25·9		19·4		
Others	24·9		28·0		
Current smokers (%)					0·918
Yes	22·0		22·3		
No	78·0		77·7		
Current drinkers (%)					0·202
Yes	28·8		24·7		
No	71·2		75·3		

Appendix 3

Factor-loading matrix for the four major dietary patterns* identified using factor analysis in the overall samples (*n* 2030)

Food groups	Animal and plant protein	Nuts and sweets	Chinese traditional	Beverage and alcohol
Poultry meats	0·739†	0·072	0·015	0·286
Fish and shrimp	0·656†	0·038	0·124	0·198
Bean curd	0·365†	−0·016	0·232	0·363†
Dry vegetables	0·300†	0·214	0·262	−0·164
Livestock meats	0·724†	0·098	0·010	0·246
Dry bean	0·576†	0·196	0·016	0·084
Other soyabean products	0·460†	0·231	−0·031	0·141
Eggs	0·474†	0·022	0·103	−0·115
Fresh fruits	0·503†	0·231	0·020	−0·216
Low-fat dairy products	0·359†	0·267	0·145	−0·277
Tea or coffee	0·228	0·092	0·001	0·067
Nuts	0·121	0·571†	0·113	−0·166
Sweets and desserts	0·054	0·458†	−0·106	0·014
Snacks	0·042	0·613†	0·019	−0·072
Other grains and products	0·142	−0·067	0·609†	−0·214
Potatoes	0·338†	−0·046	0·605†	0·020
Fresh vegetables	−0·254	−0·091	0·419†	0·225
Fried food	−0·104	−·006	0·466†	0·232
High-fat dairy products	0·188	0·116	0·399†	−0·299
Wheat and products	0·210	−0·053	0·427†	−0·036
Rice and products	0·130	−0·101	0·563†	−0·096
Pickled vegetables	−0·141	0·057	0·421†	0·031
Sodas	−0·028	0·196	0·033	0·562†
Juice	0·085	0·015	0·010	0·454†
Beer	0·007	0·044	−0·010	0·397†
Wine	0·159	0·099	0·038	0·380†
Processed meats	0·147	0·080	0·147	0·373†
Liquor	–	0·022	0·028	0·426†
Eigenvalue	3·378	1·864	2·493	1·820
Variance explained (%)	11·3	6·2	8·3	6·1
Total variance (%)		31·9		

* The test for suitability of factor analysis: the Kaiser–Meyer–Olkin measure of sampling adequacy was 0·702 for FFQ1 and *P* values for Bartlett's test of sphericity was <0·001.
† The factor loadings were >0·30.

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