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Longitudinal Analysis of Dietary Patterns in Chinese Adults from 1991 to 2009

Carolina Batis[1], **Daniela Sotres-Alvarez**[2], **Penny Gordon-Larsen**[1], **Michelle A. Mendez**[1], **Linda Adair**[1], and **Barry Popkin**[1]

[1]Department of Nutrition, and Carolina Population Center, University of North Carolina at Chapel Hill, Chapel Hill, NC

[2]Department of Biostatistics, University of North Carolina at Chapel Hill, Chapel Hill, NC

Abstract

Our aims were to identify the changes or stability in the structure of dietary patterns and the tracking, trends and factors related to the adherence of these patterns in China from 1991 to 2009. We used seven waves of the China Health and Nutrition Survey and included 9,253 adults with ≥3 waves complete. Diet was measured over a 3-day period with 24-hr recalls and a household food inventory. Using factor analysis in each wave we found that the structure of the two dietary patterns identified, remained stable over the studied period. The traditional southern pattern was characterized by high intake of rice, fresh leafy vegetables, low-fat red meat, pork, organ meats, poultry and fish/seafood and low intakes of wheat flour, corn/coarse grains; and the modern high-wheat pattern was characterized by high intake of wheat buns/breads, cakes/cookies/pastries, deep-fried wheat, nuts/seeds, starchy roots/tubers products, fruits, eggs/eggs products, soy milk, animal-based milk and instant noodles/frozen dumplings. Temporal tracking (maintenance of a relative position over time) was higher for the traditional southern, whereas adherence to the modern high-wheat had an upward trend over time. Higher income, education and urbanicity level were positively associated with both dietary patterns, but the association became smaller in the later years. These results suggest that even in the context of rapid economic changes in China; the way people chose to combine their foods remained relatively stable. However, the increasing popularity of the modern high-wheat pattern, a pattern associated with several energy-dense foods is cause of concern.

Keywords

patterns; factor analysis; China; longitudinal

Introduction

China is one of the countries with the most rapid increases in chronic diseases; overweight/obesity (BMI ≥25kg/m^2) prevalence among adults was 15% in 1992, 22% in 2002[(1)] and 33% in 2007-08[(2)]. Diabetes, hypertension and dyslipidaemia reached a prevalence of 10%, 27% and 65% respectively in 2007-08[(2)]. Due to the key role that diet plays in all of these chronic diseases, it is important to better understand the eating behavior of this population.

To whom correspondence should be addressed: Barry Popkin. Mailing address: Carolina Population Center, University of North Carolina, 123 W. Franklin St., Chapel Hill, NC 27516, Phone: (919) 966-1732, Fax: 919-966-9159, (popkin@unc.edu).

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Over the last two decades, many important changes in the diet of the Chinese population have been identified. Eating behaviors like snacking emerged and continue to grow, and cooking methods have also changed from predominantly steaming and boiling to frying[3, 4]. A marked increase in dietary diversity has also been observed, with more people consuming food from a higher number of food groups[5]. The intake of vegetables, fruits, cakes, and milk and other animal products like pork, poultry and eggs have increased; whereas the intake of cereals and tubers has decreased[6].

In addition to the study of number of meals, cooking methods or food group consumption, data-driven dietary pattern analyses, such as factor or cluster analysis, are also useful for studying diet. Dietary patterns more closely resemble actual eating behaviors because they consider multiple food groups instead of single food groups or nutrients, and they give insights into how people eat by identifying the foods that are eaten in combination[7-9]. Previous studies conducted in a Chinese National survey from 2002 have identified several dietary patterns like the “Yellow earth” or “traditional northern” pattern that is high in wheat, wheat products, maize, sorghum and tubers; the “green water” or “traditional southern” pattern high in rice, vegetables, seafood, pork and poultry; and the “western” or “new affluence” pattern high in beef, lamb, milk, cheese, yogurt, cakes, juices and nuts[10-12]. However to best of our knowledge, no longitudinal analysis of dietary patterns over time has been conducted in the Chinese population.

To fill this gap, we used measurements of dietary intake from seven occasions over the course of 18 years collected in the China Health and Nutrition Survey (CHNS). When examining dietary patterns over time there are two different dimensions one can look at, one is the changes or stability in the general structure of the dietary patterns (are foods combined differently in each year?), and another is the individuals’ level of adherence to each dietary pattern over time. Therefore, our aims were to first derive the dietary patterns independently at each point in time to determine whether the structure of dietary patterns have changed or remained stable. Secondly, we assessed the tracking, trends over time, and socio-demographic characteristics associated with the adherence to each dietary pattern.

METHODS

Study design and participants

The CHNS is an ongoing study with detailed income, employment, education, demographic, health, and diet information. The survey was designed to examine across space and time how economic and social changes are associated with a range of health behaviors. A multistage, random cluster process was used to draw the sample in 9 provinces. Survey protocols, instruments, and the process for obtaining informed consent for this study were approved by the institutional review committees of the University of North Carolina at Chapel Hill (UNC-CH) and the Chinese Institute of Nutrition and Food Safety (INFS), China Center for Disease Control and Prevention. Participants provided their written, informed consent. Additional details about the CHNS data are provided elsewhere[13].

Surveys were conducted in 1989, 1991, 1993, 1997, 2000, 2004, 2006 and 2009. We used data from 1991 to 2009 because in 1989 only adults aged 20-45 years were included. All waves of the CHNS obtained identical clinical, dietary and anthropometric data from each household member. We included all adults aged 18 to 65 years old at any wave with at least 3 waves with complete dietary data (N=9,253); from these 20% had all 7 waves of diet complete, 50% had 5 or more, and 75% had 4 or more waves of diet complete.

Dietary assessment and food grouping

The dietary assessment in the CHNS is a combination of three consecutive 24-hour recalls at the individual level and a food inventory at household level performed over the same three day period. The three consecutive days were randomly allocated to start from Monday to Sunday. For the food inventory, all available foods at the household (purchased, stored or home produced) were measured on daily basis with Chinese balance (1991-1997) or digital scales (2000-2009). The changes in the household food inventory as well as the wastage were used to estimate total household food consumption. For the 24-hour recall, trained interviewers recorded the types, amounts, type of meal and place of consumption of all food items consumed. For dishes prepared at home the amount of each dish was estimated from the household food inventory, based on the proportion of each dished the person reported to have consumed.

The food groups included in our analysis were based on a food grouping system developed specifically for the CHNS by researchers from UNC-CH and INFS[5], this system separates foods into nutritional and behavioral meaningful food groups. We did not include alcoholic beverages, because it was mostly consumed by males, with very low consumption for females. Further description of the food group classification that we used can be found in Supplemental Table 1.

Statistical analysis

Because in each wave we included subjects that were 18 to 65 y old, it was possible for subjects to be excluded at certain waves (e.g. a subject 64 y old in 2000 would be excluded in 2004 and after, or a subject aged 14 y old in 1991 would be included only when he became 18 in 1993). This exclusion criterion resulted in younger subjects at the later waves. In addition, the proportion of subjects in the sample residing in the North region increased since 2000. This was because in 1997 a province in the North was unable to participate and a substitute province was included in the study; and in 2000 both the original and the substitute provinces were included again. Therefore, all analyses were adjusted by geographical region and age in 1991(equivalent to adjusting by birth year), so that the dietary trends found over time were not related to these sample distribution changes in age and region.

Most food groups had a high proportion of non-consumers; possibly due to the fact that diet intake was measured over a 3-day period. Therefore, we categorized consumption as binary (non-consumers vs. consumers) for food groups with <25% of consumers in all waves; and otherwise as a three-level variable (non-consumers, consumers below or above the estimated median using all waves).

We performed exploratory factor analysis for categorical variables using the robust weighted least square estimator in Mplus 6.1 (Muthén & Muthén, Los Angeles, California) at each wave. Factor analysis on ordinal variables is performed with a polychoric correlation matrix. Conceptually, ordinal variables have an underlying continuous normally distributed variable, so thresholds for the levels of the categorical variables are estimated. These thresholds are normal z scores corresponding to the cumulative proportion of subjects in each category [i.e. for a binary variable (non-consumers vs. consumers) with a 0.87 proportion of non-consumers, the threshold between the two categories would be equal to the corresponding normal z-score 1.13].[14, 15]

Food groups with ≤5% of consumers in all waves were not included in the factor analysis. These food groups are uninformative because of their intake's lack of variability in the population, and also they could produce bivariate tables with empty cells and affect the polychoric correlation.

Based on eigenvalues >1, inspection of the scree plot, and interpretability, we retained two dietary patterns in each wave. Factors were rotated with the varimax procedure, because this method seeks to maximize the variability among the loadings in each factor and hence gives simpler and more easily interpreted factors[16]. To evaluate the similarity of the factor loadings across all waves in each dietary pattern, we estimated a coefficient of congruence between each pair of waves. The coefficient of congruence is an index of factor similarity and is estimated as $\Sigma x_i y_i / \sqrt{\Sigma y_i^2 \Sigma x_i^2}$ where x_i and y_i are factor loadings of food group i(i=1,...,n) on factor x and y (i.e. x=dietary pattern 1 in 1991 and y=dietary pattern 1 in 1993). A coefficient of congruence ranges from −1 to 1, a value between 0.85 and 0.94 indicates that the factors are fairly similar, and a value higher than 0.95 indicates that the two factors can be consider equal[17].

Because we found similarity in the factor loadings across all waves, we computed applied scores as many studies with longitudinal dietary patterns have done previously[18-21]. The factor loadings from year 2000 were used to calculate the factor scores in all other waves, we used the loadings of all food groups included in the dietary pattern analysis, regardless if the loading was high or not. We chose year 2000 because it was the midpoint of the observed period, the loadings were close to the mean of the loadings of all other wave, and therefore most representative of the entire period. Because this applied score measures the same dietary pattern across time, it allows meaningful temporal comparisons. In order to estimate the scores with the procedure implemented by Mplus 6.1 (similar to the regression method, but with an iterative technique for categorical variables[22]) we performed a confirmatory factor analysis in each wave specifying the factor loadings and thresholds estimated from year 2000. Because thresholds are z scores of the intake variables and they are involved in the estimation of the score, it is important that they are not year-specific; therefore we also fixed them to the estimates of year 2000.

Pearson correlation coefficients of the factor scores between each pair of waves were computed to assesses the tracking (maintenance of a relative position or rank over time) of each dietary pattern. Additionally we estimated a single tracking coefficient for the entire period. In a longitudinal model, the value of the score of one wave is regressed simultaneously on the scores of all other waves; the coefficient is standardized so that it can represent a correlation coefficient[23]. This coefficient can be interpreted as the average correlation between one wave and all the other waves. We first standardized the dietary pattern score independently in each wave and then performed a Generalized Estimating Equations to account for the repeated measures (with unstructured working correlation matrix and robust estimation of standard errors). Because our sample size was the largest in 2000, we regressed the standardized dietary pattern scores of wave 2000 on the standardized dietary pattern scores of all other waves. We tested for interactions of this tracking coefficient with gender, age, income and region. We present stratified results and specified when the p value of the interaction term was less than 0.10.

$$Y_{it} = \beta_0 + \beta_1 Y_{it2000} + \beta_2 t + \beta_3 X_{it} + \beta_4 Y_{it2000} {}^* X_{it} + \varepsilon_{it}$$

Where Y_{it} is the standardized dietary pattern score for subject i at wave t (1991, 1993, 1997, 2004, 2006 and/or 2009), Y_{it2000} is the standardized dietary pattern score for subject i at wave 2000, β_1 is the tracking coefficient, and X is gender, age, income or region.

We computed factor score means over time, adjusted by age and region, to look at trends in each dietary pattern. Finally, multiple linear regressions with each factor score as the outcome and socio-demographic variables as the predictors were performed independently in each wave, the clustering at the household level was accounted for in the estimation of the variance. Except for the factor analysis, all other analyses were conducted in Stata 12.1 (StataCorp, College Station, TX).

Sensitivity Analysis

In order to corroborate that the dietary patterns obtained at each wave were not affected by the sample changes in geographical region and age, we computed inverse probability weights and included them in the factor analysis. We fitted two logistic regressions, one to predict the probability of being in each wave, and another to predict the probability of being in each wave conditional on region and age in 1991. Then, stabilized weights were estimated as the ratio of these two probabilities. Applying these weights is an alternative to standardization[24]. We found that the dietary patterns were very similar to the ones we found in our original analysis; the difference between the factor loadings of the two analyses was below 0.08 in all food groups. Similarly, to assess if changes in energy intake over time affected the dietary patterns, we created inverse probability weights to standardize the patterns by total energy intake in addition to region and age. We found that this standardization did not affect meaningfully the composition of the dietary patterns.

In addition, because subjects coming from the same households were more likely to consume the same type of food groups, we repeated the analysis using only a single member per household (selected randomly, n=4,837). We found that the dietary patterns did not change meaningfully; all loadings had a difference below 0.08. Also, the correlation coefficients between scores remained basically unchanged (all differences in the coefficients were below 0.03).

RESULTS

There was a dramatic increase in the prevalence of overweight from 1991 to 2009 and in the proportion of the sample classified as medium and high income over the same period, which paralleled changes in urbanization. The proportion of smokers declined over time in males, and remained low in females (Table 1).

The mean total energy intake increased by 267 kJ/d (64 kcal/d) from 1991 to 2009 (Table 2). In general, it can be seen that the diversity of diet increased over time, the mean number of food groups consumed increased over time and for most of the food groups the percentage of consumers also increased. The only food groups with a decline in the percentage of consumers from 1991 to 2009 were: wheat flour, dried legumes, pickled/salted/canned vegetables, and low-fat red meat. In contrast, starchy roots/tubers products, fresh leafy vegetables, dried vegetables and organ meats remained with a stable percentage of consumers over time (difference $\leq$ 1 point between 1991 and 2009). In addition, all food groups that had an increase in the percentage of consumers, also had an increase in the amount consumed (g/per capita), except for rice, corn/coarse grains and starchy roots/tubers where even if the percent consumers increased, the g/capita actually decreased over time (data not shown).

The following food groups had ≤5% of consumers in all waves (data not shown): deep-fried rice/legumes, dried fruit, preserved fruit with added sugar, seaweed, processed meats, dairy products, sweetened dairy products, Western-style fast-food, salty snacks, ready-to-eat cereals/porridge, calorically-sweetened beverages, and low-caloric beverages. Overall, these modern-type foods, over a 3-day period, were not yet widely consumed by 2009.

Using factor analysis on a total of 29 food groups (excluding food groups with ≤5% of consumers) we identified two dietary patterns, which we called “traditional southern” and “modern high-wheat”. These dietary patterns, despite the increase in the diversity of diet, remained fairly similar (Table 3). The coefficient of congruence between each pair of waves was generally higher than 0.84, it was only below this value between 1991-2009, 1993-2009 and 1997-2009 for the traditional southern (0.74, 0.78 and 0.81 respectively); and between 1991-2006 and 1991-2009 for the modern high-wheat (0.80 and 0.80) (data not shown). In table 3 we present the coefficients of congruence between each wave and wave 2000. Across time, the traditional southern dietary pattern was positively associated with the intake of rice, fresh leafy vegetables, low-fat red meat, low- and high-fat pork, organ meats, poultry and fish/seafood and inversely associated with wheat flour, corn/coarse grains. Interestingly, the loadings of rice, wheat flour and corn/coarse grains markedly declined over time, which was not related to the percentage of consumers (as seen above, of these food groups only wheat flour had a decrease in the percentage of consumers). These decreases in the factor loadings represent that the influence or importance of these food groups in the traditional southern dietary pattern was decreasing over time. The second dietary pattern, modern high-wheat was positively associated, across time, with the intake of wheat buns/breads, cakes/cookies/pastries, deep-fried wheat, nuts/seeds, starchy roots/tubers products, fruits, eggs/eggs products, soy milk and animal-based milk. In the earlier years this pattern was associated with high-fat red meat, high-fat pork, organ meats and poultry/game. In 1991 and 1993 there were no consumers of instant noodles/frozen dumplings, so this food group was not included in the factor analysis in these years, but when these foods began to be consumed in 1997, they became prominent in the modern high-wheat dietary pattern.

Because overall we found similarity in dietary pattern structure over time, we computed applied scores and hence the rest of the results refer to these applied scores. The tracking coefficient of factor scores between wave 2000 and all other was considerably higher for the traditional southern pattern compared to the modern high-wheat pattern; 0.71 vs. 0.55 respectively (Table 4). This means that the tracking of the traditional southern pattern was higher, or in other words that individuals maintained their relative position over time. However, the tracking in the traditional southern pattern decreased over time, between 1991 and 1993 the person correlation coefficient was 0.79, whereas in more recent years, between a similar 2 or 3 years interval the correlations were lower (0.71 for 2004-2006 and 0.67 for 2006-2009). Interestingly we found that the tracking varied importantly by sociodemographic variables. The tracking was much higher in the Central region, particularly for the traditional southern. The tracking coefficient was also slightly higher among the younger (traditional southern) and those with lower income (both patterns), whereas it did not varied by gender.

The mean dietary pattern score increased over time for both dietary patterns, however the slope was considerably higher for the modern high-wheat pattern (Figure 1A). To understand how much of the increase in both scores was related to the increase in diet diversity, we adjusted the scores by number of food groups consumed (Figure 1B). After adjustment, the traditional southern pattern had a flat trend over time, and the modern high-wheat had only a slight increase. This means that for the modern high-wheat pattern, in order to increase the score while holding the number of food groups constant, individuals were either substituting other foods with food groups related to this pattern or had a higher consumption of these.

To examine how the trends in the scores were translated into changes in dietary intake, we estimated the percentage of consumers among those in the 4th highest quartile of the scores of each dietary pattern in each wave (Table 5). The trends in consumption seen in the entire sample (i.e. increases in most of the food groups) are equally found in subjects with high scores for either pattern. However, the increase in percentage of consumers in the food groups positively related the modern high-wheat pattern, among the followers of this pattern, is dramatic. For example from 1991 to 2009 wheat buns/breads increased from 7 to

67%; cakes/cookies/pastries, 8 to 24%; deep-fried wheat 23 to 51%; fruits, 25 to 55%; soy milk, 6 to 44%; and instant noodles/frozen dumplings, 0 to 36%. This large increase in consumption of key food groups associated with the modern high-wheat dietary pattern can explain the upward trend observed in the score of this pattern. While we only present food groups relevant for the dietary patterns in Table 5, we also examined food groups excluded from the dietary pattern analysis due to low proportion of consumers (not shown), we found that none of these food groups had a higher percent of consumers in one of the dietary patterns, with the exception of deep-fried rice/legumes (traditional southern: 5-6% of consumers in the 4^{th} highest quartile, versus 1-2% of consumers in the modern high-wheat dietary pattern).

Finally, we run multiple linear regressions in each wave and looked at how socio-demographic factors were related to the traditional southern and modern high-wheat dietary patterns (Table 6). Geographical region was strongly associated with the traditional southern pattern, with lower scores in the central and north compared to the south. Interestingly the score difference between regions decreased over time, mainly due a slight increase over time in the North and Central region and a slight decrease in the score in the South. Urbanicity was strongly associated with the modern high-wheat pattern, with higher scores among those living in more urbanized areas. Males had a slightly higher score for traditional southern pattern and slightly lower score for modern high-wheat compared to females. Higher education, income, urbancity level, and alcohol intake were associated with higher scores in both dietary patterns, however the strength of the association decreased over time. Adjusting by number of food groups consumed did not affect the estimates, although differences for education, income and urbanicity level were largely attenuated (data not shown).

DISCUSSION

In this longitudinal study that included 7 waves of diet data over the course of 18 years (from 1991 to 2009), we derived two dietary patterns using factor analysis: a traditional southern pattern characterized by rice, vegetables, meat, poultry and fish; and a modern high-wheat pattern characterized by wheat products, nuts, fruits, eggs, milk and instant noodles/frozen dumpling. Despite the rapid increase in diet diversity, the structure of these two dietary patterns remained stable over time, meaning that the type of foods the population chose to eat in combination has not changed. However, compared to the traditional southern pattern, the scores of the modern high-wheat pattern had lower tracking and steeper upward trend over time, indicating that this pattern is more dynamic and is becoming more popular over time. Higher education, income and urbanicity level were all related to higher scores in both patterns, but the difference in pattern scores between these socio-economic groups became smaller over time, reflecting that this dietary pattern become more widely consumed.

Although this is the first study to assess longitudinal trends in dietary patterns over time in China, previous studies have looked at dietary patterns at one point. Whereas our findings differ from studies in specific urban areas, such as studies in Shanghai[25-28], they are most similar to findings in nationally representative samples, such as the China National Nutrition and Health Survey. Previously identified patterns are “yellow earth” or “traditional northern” high in wheat products, maize or sorghum and tubers; “green water” or “traditional southern” high in rice, vegetables, seafood, pork and poultry; and “Western” high in beef, fruit, eggs, poultry, seafood, tofu, milk, cake, fruit juice, beverages and nuts.[11, 12] Our “traditional southern” pattern is comparable to the one previously described. However, our “modern high-wheat” pattern could be considered as a combination of the “traditional northern” and “Western” patterns that these previous studies have found. This is reasonable because even in these studies, a considerably high intake of wheat, fried-wheat and other cereals was observed in the “Western” pattern. In addition, in the Jiangsu province a pattern similar to our “modern high-wheat” was found, in which the western-type pattern was also related to fried-wheat and cakes[29]. Taken all together, it is clear that the regional tradition and availability of wheat in the North and rice in the South is still a main driver in Chinese's food selection. It is interesting that wheat-patterns are more likely characterized by intake of more varied and western-type foods. Possibly, compared to rice, there is a wider range of foods that can be prepared with wheat, and a wider range of foods that can accompany a wheat-based food, therefore facilitating the incorporation of new foods among subjects used to consuming wheat.

Even if the general structure of both dietary patterns remained stable over time, the tracking or in other words the stability of the relative position of each subject's factor score between time points was higher for the traditional southern pattern than for the modern high-wheat, particularly in the South and Central region. This is comparable to a study in Japan[30], where among the prudent, traditional and westernized patterns, the traditional had the highest tracking among men. The degree of tracking that we found in the traditional southern pattern in the entire sample was remarkably high, the correlation coefficient between scores from 18 years apart (1991-2009) was 0.68, which is similar to what other studies in the US[31], Sweden[32] and Japan[30] have found but in only one year apart (0.56 to 0.77). In studies with 4 or 10 years apart in England[20] and Sweden[33], correlation coefficients have been found to be around 0.30 to 0.52. It is possible that the tracking was lower in the modern high-wheat because of the introduction of new food groups (e.g. instant noodles/frozen dumplings) and/or and rapid increase in the intake of the food groups associated with this dietary pattern. Noteworthy, the high tracking of the traditional southern pattern was actually driven by the Central region, whereas the South and North region had tracking coefficients comparable to those of the modern high-wheat pattern. The Central region had the lowest level of adherence to the traditional southern pattern, and the highest level of adherence to the modern high-wheat, and still for both patterns it was the region with the highest degree of tracking. Further research could explore the reasons of why the stability of the dietary patterns is higher in this region.

In this study we confirmed that the increase in diet diversity previously observed in 1989 to 1997[5], is a phenomenon still going on through 2009. Factor scores would be affected by diet diversity because they are similar to a weighted sum of several food groups, so with the exception of food groups with negative loadings, it is expected that the higher the number of food groups consumed, to a lesser or greater extent the higher the factor score. Therefore in the context of increasing diet diversity, the absolute factor scores trend over time represents the degree of adherence to a certain pattern as well as the overall number of food groups consumed. An alternative is to adjust by number of food groups consumed, because the only way to increase the factor score while holding the number of food groups consumed constant is to substitute with food groups related to the diet pattern and/or to increase the amount consumed of these food groups. In our results we found that in comparison with the traditional southern pattern, the modern high-wheat had a higher increase over time, and that even after adjusting by number of food groups consumed, the modern high-wheat pattern showed an upward trend. A clear illustration of this trend is the remarkable changes in the diets of those following this pattern (subjects with scores in the highest quartile of their year); although the increase in food groups such as fruits and soy-milk is beneficial, the sharp increase in items like cakes/cookies/pastries, deep-fried wheat or instant noodles is worrisome. Indeed the adherence of this pattern might be associated with overweight and obesity, we found that for the entire follow-up period one unit increase in the modern high-wheat pattern was associated with a BMI ≥23 kg/m^2 (Odds Ratio=1.27, 95% CI 1.24 to 1.30), whereas the traditional southern was inversely associated (Odds Ratio=0.94, 95% CI 0.92 to 0.97) (data not shown). In addition, it is of public health importance that with time, the modern high-wheat pattern seems to be becoming more available to all urban/rural, income, and education groups.

The key strength of our study is the several repeated measures of diet in the same subjects, which allows us to assess for the first time the stability and tracking of dietary patterns in the Chinese population. Even though there were changes in our sample because not all the subjects had the 7 waves of diet complete, we believe our comparisons between years were not affected by this, not only because all subjects were present for at least three waves but also because we adjusted all of our results by age and geographical region.

A limitation in our study was that the diet measurement only captured three consecutive days of intake. Though the advantages of this method are important because the diet measurement is very detailed and precise, and the same method can remained constant over time, a disadvantage for this analysis is that the intake of important food groups that in this country are still only episodically consumed could not be captured. Items like dairy products, candies/other high-sugar foods, western-style fast food, salty snacks or calorically-sweetened beverages had a very low proportion of consumers in a 3-day period and hence we were not able to include these in our factor analysis. Therefore, we do not exclude the possibility that a new, separate western pattern emerged within the studied period, and we were not able to identify it.

In line with this, another important limitation common to all countries, is that the number of foods available in the food supply exceeds by far the number of those available in food composition tables. In the US for example, there are over 85,000 uniquely formulated products in the food system, whereas national food composition tables only have around 7,600 unique foods[(34)]. China has the world's fastest growth in supermarkets[(35)], and our survey, because of the inability to keep up with the rapidly changing food supply landscape, is unable to capture all the changes in intake, particularly of processed packaged foods. In addition, our dietary assessment, focuses on the measurement of foods at the ingredient and not at the dish level, this is very advantageous because recipes vary considerably between households[(5)] and few mixed dishes are available in the Chinese food composition table, however we miss this important behavioral aspect of diet, and important changes in dish selection might be going on.

In sum, to the best of our knowledge, this is the first study to assess the stability and tracking over time of dietary patterns in the Chinese population. We found that the way foods are eaten in combination has not changed much between 1991 and 2009. The degree of adherence to a traditional southern pattern has remained unchanged and there was remarkable inter-individual consistency in the Central region in the intake of foods related to this pattern. On the other hand, the modern high-wheat pattern has become more prominent in the population and there was more within-subject variation in their adherence level. The trend observed in this modern high-wheat pattern may as well reflect the global influence and economic rise of the last decades in China. Close attention should be given to this pattern because it is associated with many energy-dense foods that may affect diet quality. So far, the northern part of the country and subjects with better socio-economic position or in urban areas are more prone to follow this pattern, but it seems that the reach of this pattern is extending towards the general population. Among the followers of this modern high-wheat pattern, a willingness to diversify dietary intake and increase the intake of equally healthful foods like fruits was evident; therefore great opportunity also lies in the promotion of healthy foods and in the efforts to increase their intake in this population.

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Supplementary Material

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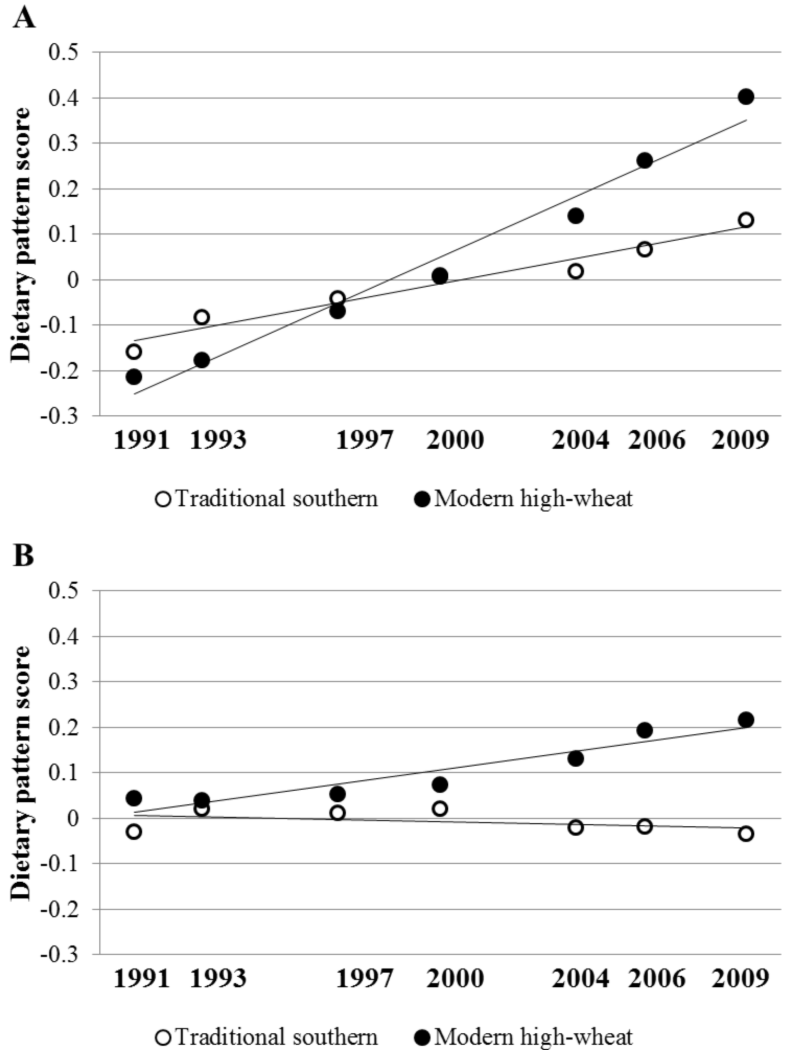

FIGURE 1.

Mean factor scores over time. Panel A: adjusted by geographical region and age in 1991. Panel B: additionally adjusted by number of food groups consumed. Difference between slopes was statistically significant ($p<0.01$) in both A and B.

Table 1

General characteristics of study sample by wave*

	1991	1993	1997	2000	2004	2006	2009	P for trend
N	5521	5732	6702	7410	6831	6488	5658	
Mean Age in 1991 (SE), years	37.3 (0.14)	36.8 (0.14)	35.0 (0.13)	33.5 (0.12)	32.2 (0.13)	31.7 (0.13)	30.7 (0.14)	<0.001
Geographical region†, %								
North	9.6	9.3	9.9	19.7	21.5	22.1	21.9	<0.001
Central	37.2	37.4	36.9	33.4	32.8	32.9	33.1	<0.001
South	53.2	53.3	53.1	46.9	45.7	45.0	45.0	<0.001
Male, %	50.2	49.8	49.7	49.1	48.5	47.8	48.3	0.002
Overweight (BMI ≥23 kg/m^2 (36)), %	32.9	35.4	43.2	50.6	52.4	54.3	56.7	<0.001
Education, %								
None	25.5	24.0	23.7	20.0	18.0	23.1	24.4	<0.001
Primary school	23.7	23.7	24.7	24.4	25.8	20.1	21.9	<0.001
≥Lower middle school	50.8	52.1	51.3	55.2	56.0	56.6	53.6	<0.001
Income‡, %								
Low	87.8	82.2	74.5	63.6	56.0	50.5	33.6	<0.001
Medium	7.5	13.0	19.8	27.9	28.9	30.2	33.2	<0.001
High	0.6	1.2	2.5	5.9	14.2	18.6	33.4	<0.001
Urbanicity §, %								
Low	72.8	67.9	57.6	49.3	45.9	40.7	32.7	<0.001
Medium	25.2	30.6	32.1	26.6	22.7	27.0	34.0	0.138
High	2.1	1.5	10.4	24.1	31.5	32.3	33.3	<0.001
Currently smoking, %								
Females	3.1	3.5	3.8	3.3	3.2	2.9	3.3	0.524
Males	69.8	67.9	64.5	63.6	60.8	58.5	58.6	<0.001
Alcohol intake >3 times/week, %								
Females	1.7	2.1	2.9	2.7	1.9	1.9	2.4	0.913
Males	25.6	29.9	30.2	32.1	31.9	31.7	31.7	<0.001

*All variables (except age in 1991 and geographical region) are adjusted by age in 1991 and geographical region.

†Estimated from per capita household income inflated to 2009, categories based on cutoff values of tertiles in 2009.

‡North: Heilongjiang and Liaoning provinces; Central: Shandong, Henan and Jiangsu; South: Hubei, Guizhou, Hunan and Guangxi.

§Estimated from urbanicity index, a multicomponent scale that considers population density, economic activity, modern markets, transportation, etc.(37), categories based on cutoff values of tertiles in 2009.

Table 2

Mean energy intake, number of food groups consumed and percentage of consumers for different food groups by wave*

	1991	1993	1997	2000	2004	2006	2009	P for trend
Energy (SE), kJ/day†	6585 (28)	6546 (27)	6429 (25)	6605 (24)	6623 (25)	6746 (26)	6855 (28)	<0.001
Number of food groups consumed (SE)	7.2 (0.04)	7.5 (0.04)	7.9 (0.03)	8.2 (0.03)	8.7 (0.03)	9.1 (0.03)	9.8 (0.04)	<0.001
Percentage of consumers, %								
Rice	84	84	87	88	87	87	90	<0.001
Wheat noodles	23	32	38	42	47	54	55	<0.001
Wheat flour	51	42	40	41	36	28	25	<0.001
Wheat buns, breads	3	12	13	15	28	34	37	<0.001
Cakes, cookies and pastries	3	4	3	3	6	8	8	<0.001
Deep-fried wheat	6	8	7	8	12	14	15	<0.001
Corn and coarse grains	21	23	22	22	24	23	26	<0.001
Starchy roots and tubers	41	39	41	37	44	45	50	<0.001
Fresh legumes	38	37	41	47	47	54	53	<0.001
Dried legumes	14	14	13	12	13	12	12	<0.001
Legume products	41	41	50	49	50	49	54	<0.001
Nuts and seeds	8	6	8	9	9	8	11	<0.001
Starchy roots and tubers products	9	9	11	11	11	8	9	0.126
Fresh vegetables, non-leafy	75	77	76	83	84	87	90	<0.001
Fresh vegetables, leafy	86	87	87	86	88	83	85	<0.001
Pickled, salted or canned vegetables	30	32	26	25	22	22	23	<0.001
Dried vegetables	9	11	9	9	7	8	10	0.005
Fruits	11	10	12	11	17	23	32	<0.001
Low-fat red meat	6	9	7	7	4	3	4	<0.001
High-fat red meat	4	5	8	8	12	13	10	<0.001
Low-fat pork	9	11	11	10	12	12	13	<0.001
High-fat pork	55	57	57	64	64	69	73	<0.001
Organ meats	9	9	9	10	9	8	10	<0.001
Poultry and game	11	12	16	18	18	18	24	<0.001
Eggs and eggs products	34	32	49	51	53	59	64	<0.001
Fish and seafood	32	32	34	34	36	37	42	0.382
Soy milk	2	2	2	4	5	10	12	<0.001
Animal-based milk	1	1	1	3	7	6	5	<0.001
Instant noodles and frozen dumplings	0	0	2	2	4	12	15	<0.001

*All variables are adjusted by age in 1991 and region, food groups with ≤5% of consumers in all waves not shown.

†conversion factor 1 kcal = 4·184 kJ

Table 3

Factor loadings for dietary patterns derived with Exploratory Factor Analysis at each wave

	Traditional southern dietary pattern							Modern high-wheat dietary pattern						
	1991	**1993**	**1997**	**2000**	**2004**	**2006**	**2009**	**1991**	**1993**	**1997**	**2000**	**2004**	**2006**	**2009**
Rice	**0.87**	**0.87**	**0.73**	**0.56**	**0.76**	**0.64**	**0.50**	−0.09	**−0.25**	**−0.25**	**−0.41**	−0.20	**−0.28**	**−0.30**
Wheat noodles	**0.30**	**0.27**	**0.28**	0.13	0.13	0.01	−0.17	0.04	−0.06	−0.12	−0.08	−0.09	−0.17	−0.22
Wheat flour	**−0.80**	**−0.82**	**−0.86**	**−0.66**	**−0.59**	**−0.67**	**−0.50**	0.13	0.12	0.03	0.26	0.05	0.00	0.15
Wheat buns, breads	−0.07	−0.12	**−0.30**	**−0.27**	**−0.53**	**0.44**	**−0.49**	**0.33**	**0.40**	**0.39**	**0.40**	**0.37**	**0.48**	**0.45**
Cakes, cookies and pastries	0.00	−0.08	−0.16	0.03	−0.05	0.11	0.11	**0.31**	**0.48**	**0.53**	**0.51**	**0.57**	**0.53**	**0.41**
Deep-fried wheat	−0.18	**−0.28**	−0.17	−0.15	**−0.37**	−0.12	−0.08	**0.46**	**0.70**	**0.57**	**0.71**	**0.63**	**0.76**	**0.74**
Corn and coarse grain	**−0.84**	**−0.78**	**−0.76**	**−0.65**	**−0.64**	**−0.53**	**−0.35**	−0.18	−0.03	−0.06	**0.28**	0.08	0.19	0.28
Starchy roots and tubers	−0.17	−0.17	−0.12	−0.13	−0.21	−0.19	**−0.27**	−0.08	−0.04	−0.17	−0.01	−0.04	0.20	0.15
Fresh legumes	−0.01	0.07	0.02	−0.04	0.03	−0.11	−0.20	0.04	0.07	0.00	−0.01	0.00	0.20	0.04
Dried legumes	−0.02	−0.03	−0.04	−0.03	0.00	0.03	0.23	0.04	−0.01	−0.17	−0.07	−0.14	−0.15	0.05
Legume products	0.17	0.08	0.19	0.18	0.10	0.11	0.14	0.24	0.18	0.17	0.16	0.19	0.14	0.10
Nuts and seeds	−0.06	0.01	0.06	0.15	0.07	0.14	0.21	**0.42**	**0.33**	0.24	**0.26**	**0.28**	**0.34**	**0.30**
Starchy roots and tubers products	**−0.30**	−0.19	−0.18	−0.05	−0.18	−0.09	−0.11	**0.30**	**0.32**	**0.26**	**0.26**	**0.24**	**0.28**	**0.26**
Fresh vegetables, non-leafy	0.07	0.05	−0.05	−0.05	−0.04	−0.11	−0.13	−0.08	−0.17	−0.13	−0.09	0.03	0.11	0.02
Fresh vegetables, leafy	**0.25**	0.21	0.22	0.22	0.21	**0.32**	**0.46**	0.12	0.06	0.23	0.05	0.12	−0.05	−0.06
Pickled, salted or canned vegetables	**0.28**	0.15	0.21	**0.25**	0.16	0.12	0.17	0.07	−0.07	0.01	−0.02	0.00	0.08	0.01
Dried vegetables	0.03	0.01	0.21	0.09	0.31	0.24	0.33	0.16	0.16	**0.25**	0.16	**0.25**	0.07	0.18
Fruits	−0.09	−0.03	0.05	0.19	0.05	0.13	0.08	**0.43**	**0.57**	**0.46**	**0.35**	**0.56**	**0.55**	**0.44**
Low−fat red meat	**0.31**	**0.50**	**0.40**	**0.48**	**0.33**	**0.47**	**0.38**	**0.40**	**0.25**	**0.28**	0.20	0.12	0.03	0.12
High-fat red meat	−0.05	0.09	0.06	0.24	0.13	**0.28**	**0.27**	**0.37**	**0.37**	**0.46**	0.24	**0.36**	0.22	**0.29**
Low-fat pork	**0.32**	**0.40**	**0.26**	**0.32**	**0.49**	**0.30**	**0.35**	**0.25**	**0.30**	0.12	0.06	0.11	−0.10	−0.01
High-fat pork	**0.32**	**0.36**	**0.44**	**0.48**	**0.27**	**0.34**	**0.43**	**0.49**	**0.34**	**0.44**	**0.25**	**0.32**	0.18	0.10
Organ meats	**0.40**	**0.49**	**0.39**	**0.53**	**0.32**	**0.43**	**0.48**	**0.45**	**0.32**	**0.46**	0.24	**0.37**	0.18	0.13
Poultry and game	**0.31**	**0.40**	**0.32**	**0.53**	**0.34**	**0.49**	**0.48**	**0.44**	**0.44**	**0.47**	**0.25**	**0.40**	0.19	0.18
Eggs and eggs products	0.01	0.03	−0.08	0.05	−0.08	−0.03	−0.16	**0.48**	**0.45**	**0.42**	**0.38**	**0.39**	**0.37**	**0.30**
Fish and seafood	**0.34**	**0.39**	**0.37**	**0.48**	**0.45**	**0.46**	**0.43**	**0.44**	**0.33**	**0.41**	0.19	**0.34**	**0.26**	0.24
Soy milk	−0.19	−0.13	−0.05	−0.05	−0.27	−0.06	0.01	**0.55**	**0.79**	**0.58**	**0.72**	**0.69**	**0.76**	**0.78**
Animal-based milk	−0.06	0.04	−0.14	0.12	0.05	0.14	0.17	**0.64**	**0.68**	**0.56**	**0.58**	**0.67**	**0.53**	**0.49**

	Traditional southern dietary pattern							Modern high-wheat dietary pattern						
	1991	**1993**	**1997**	**2000**	**2004**	**2006**	**2009**	**1991**	**1993**	**1997**	**2000**	**2004**	**2006**	**2009**
Instant noodles and frozen dumplings	NA	NA	−0.13	0.03	−0.12	0.10	−0.03	NA	NA	**0.47**	**0.40**	**0.27**	**0.41**	**0.44**
Percent variation in food groups intake explained	0.12	0.12	0.11	0.10	0.10	0.10	0.09	0.11	0.13	0.12	0.10	0.11	0.11	0.10
Coefficient of congruence with wave 2000	0.89	0.93	0.93	1.00	0.90	0.97	0.89	0.86	0.95	0.92	1.00	0.95	0.94	0.96

NA; not applicable

Factor loadings ≥|0.25| are in bold numbers.

Table 4

Tracking of dietary patterns.

	Traditional Southern						Modern High-wheat					
Pearson correlation coefficients of factor scores between waves*												
	1991	1993	1997	2000	2004	2006	1991	1993	1997	2000	2004	2006
1993	0.80						0.63					
1997	0.79	0.81					0.55	0.61				
2000	0.73	0.76	0.76				0.52	0.56	0.57			
2004	0.74	0.77	0.74	0.72			0.52	0.57	0.56	0.56		
2006	0.73	0.76	0.72	0.70	0.72		0.49	0.52	0.52	0.53	0.62	
2009	0.69	0.72	0.71	0.68	0.67	0.67	0.46	0.48	0.48	0.48	0.56	0.59
Tracking coefficient of factor scores between wave 2000 and all other waves†												
All	0.71						0.55					
South region	0.44						0.38					
Central region	0.77‡						0.47‡					
North region	0.40‡						0.43‡					
Male	0.72						0.54					
Female	0.71						0.56					
Age <35	0.73						0.56					
Age 35-49	0.70‡						0.55					
Age ≥50	0.71‡						0.53					
Low income	0.72						0.55					
Medium income	0.67‡						0.51‡					
High income	0.68‡						0.48‡					

*Pearson correlation coefficients were estimated between all available subjects for each pair of waves, therefore sample size for each coefficient is different. Sample size ranges from n=2888 (1991-2009) to n=5884 (2000-2004)

†Sample size n=7410

‡p-value for interaction term <0.10

Table 5

Mean energy intake, number of food groups consumed and percentage of consumers for relevant food groups, among those in the 4th highest quartile of the factor score in each dietary pattern and year.*

	Traditional southern			Modern high-wheat		
	1991	**2000**	**2009**	**1991**	**2000**	**2009**
Energy (SE), kJ/day†	6947 (54)	7272 (46)	7430 (53)	7158 (57)	7140 (48)	7667 (56)
Number of food groups consumed (SE)	8.4 (0.07)	9.4 (0.06)	10.7 (0.07)	9.1 (0.07)	10.9 (0.06)	12.9 (0.07)
Percentage of consumers, %						
Rice	**100**	**100**	**100**	67	82	84
Wheat flour	**9**	**7**	**4**	82	61	35
Wheat buns, breads	3	5	15	**7**	**33**	**67**
Cakes, cookies and pastries	3	3	9	**8**	**12**	**24**
Deep-fried wheat	5	4	9	**23**	**31**	**51**
Corn and coarse grains	**1**	**2**	**4**	38	37	42
Nuts and seeds	10	12	16	**17**	**17**	**22**
Starchy roots and tubers products	6	11	7	**21**	**19**	**16**
Fresh vegetables, leafy	**97**	**95**	**96**	87	88	88
Fruits	13	19	40	**25**	**26**	**55**
Low-fat red meat	**16**	**19**	**9**	9	12	6
High-fat red meat	5	15	18	**9**	**16**	**18**
Low-fat pork	**18**	**20**	**24**	8	11	15
High-fat pork	**87**	**91**	**93**	75	82	83
Organ meats	**27**	**29**	**25**	13	19	14
Poultry and game	**30**	**44**	**50**	18	31	33
Eggs and eggs products	37	55	64	**57**	**77**	**83**
Fish and seafood	**60**	**65**	**68**	42	48	56
Soy milk	1	2	8	**6**	**15**	**44**
Animal-based milk	2	3	7	**4**	**11**	**18**
Instant noodles and frozen dumplings	0	2	14	**0**	**8**	**36**

*All variables are adjusted by age in 1991 and region, numbers in bold are for relevant food groups in each dietary pattern (loadings ≥|0.20| in all waves), food groups not relevant for any dietary pattern are not shown.

†conversion factor 1 kcal = 4·184 kJ

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Table 6

Factor score differences by sample characteristics in each wave

	Traditional southern			Modern high-wheat		
	1991	2000	2009	1991	2000	2009
Age in 1991, 10 years increment	0.01	−0.02*	−0.04*	0.02*	0.01	−0.02
Region						
Central vs. South	−1.07*	−0.83*	−0.77*	0.61*	0.72*	0.67*
North vs. South	−0.85*	−0.78*	−0.65*	0.60*	0.38*	0.60*
Male vs. female	0.03	0.07*	0.05*	−0.07*	−0.06*	−0.08*
Education						
Primary school vs. none	0.13*	0.11*	0.06*	0.11*	0.08*	0.06*
≥Lower middle school vs. none	0.15*	0.09*	0.04	0.23*	0.20*	0.19*
Income						
Medium vs. Low	0.27*	0.24*	0.11*	0.06*	0.11*	0.05
High vs. Low	0.17	0.35*	0.22*	0.22*	0.18*	0.18*
Urbanicity						
Medium vs. Low	0.26*	0.24*	0.20*	0.49*	0.38*	0.38*
High vs. Low	0.08	0.45*	0.43*	0.78*	0.61*	0.72*
Smoking vs. non-smoking	−0.05	−0.03	0.02	0.02	−0.01	0.01
Alcohol intake						
≥3 times/wk vs. <3 times/wk	0.16*	0.08*	0.06*	0.08*	0.10*	0.06*
N	4,785	6,172	5,553	4,785	6,172	5,553
Score mean	−0.16	0.01	0.13	−0.16	0.05	0.47
Score range (min, max)	−2.3, 2.4	−2.4, 2.3	−2.5, 2.2	−1.5, 2.3	−1.6, 2.6	−1.6, 3.0
Score SE	0.009	0.008	0.009	0.009	0.008	0.009

* p<0.05; score differences based on a multiple linear regression that included all variables shown in table