Original Article

Dietary patterns, dietary lead exposure and hypertension in the older Chinese population

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Background and Objectives: With rapid population ageing and an increasing rate of hypertension in China, this study aims to examine the association between dietary patterns, dietary lead and hypertension among older Chinese population. **Methods and Study Design:** We analysed the 2009 China Health and Nutrition Survey data (2,634 individuals with dietary and hypertension measurement data, aged ≥60 years). Dietary data were obtained using 24 hour-recall over three consecutive days. Dietary lead intake is based on a published systematic review of food lead concentration and dietary lead exposure in China. Factor analysis was used to identify dietary patterns. Poisson regression and multinomial logistic regression models were used to explore the association between dietary patterns and hypertension. **Results:** The prevalence of hypertension was 47.0% in men and 48.9% in women. Traditional dietary pattern (high intake of rice, pork and vegetables) was significantly inversely associated with known hypertension. In the fully adjusted model, compared with the lowest quartile of traditional dietary pattern, the highest quartile had a lower risk of known hypertension, with Relative Risk Ratio=0.69 (95% CI: 0.50; 0.95). However, associations between modern dietary pattern and hypertension differed by urbanization; an inverse, positive and null association was seen in low, medium and high urbanization. Additionally, dietary lead showed a significant positive association with hypertension and known hypertension. **Conclusions:** Policies that facilitate and promote healthy diets, and the availability of healthy foods particularly at the regional and local levels, are important for the prevention of hypertension.

Key Words: dietary patterns, dietary lead exposure, hypertension, older Chinese, factor analysis

INTRODUCTION

Hypertension is the most common preventable risk factor for cardiovascular and cerebrovascular diseases.[1] In China, the prevalence of hypertension has increased by 60% over the last 30 years.[2] Hypertension is more common in older people with both prevalence and severity increasing with age.[3] Data from the 2007-2008 China National Diabetes and Metabolic Disorder Study shows that the prevalence of hypertension for people aged 65 years or over is 56.5%, which is much higher than for people in younger age groups.[4] Additionally, people who live in urban areas have a higher prevalence of hypertension than those living in rural areas.[2,4]

The dramatic increase in the prevalence of hypertension in China is due largely to lifestyle changes, such as overconsumption of dietary fat,[5] dietary salt and reduction in physical activity.[4] Dietary changes can reduce blood pressure and lower the risk of blood pressure related complications.[6] Previous studies have found that changing dietary behaviours can lower blood pressure.[7,8] The Dietary Approaches to Stop Hypertension program shows that consuming foods that contain decreased amounts of total and saturated fats and cholesterol can reduce the blood pressure substantially in both people with or without high blood pressure.[7] Moreover, previous studies have demonstrated the link between environmental lead exposure, hypertension and cardiovascular diseases.[9,10] However, there are extremely few epidemiological studies on the links between dietary lead exposure and hypertension.

There is increasing interest in exploring the association between dietary pattern and hypertension in China,[11,12] however studies of diet and nutrition among older Chinese population are scarce.[5] As China's population ages

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rapidly,[13] and the prevalence of hypertension increases with age,[3] it is important to conduct epidemiological studies that examine the association between dietary pattern and hypertension. The evidence can help health professionals and policy makers to develop a dietary policy and interventions aimed at preventing the high prevalence of chronic diseases among the older population in China. The aim of this study is to assess the association between dietary pattern and hypertension. In additional, the dietary lead intake in the Chinese population is extremely high. With the potential of an association between lead exposure and hypertension, we also examined the association between dietary lead exposure and hypertension.

METHODS

China Health and Nutrition Survey (CHNS)

CHNS is an ongoing, open cohort longitudinal survey of nine waves (1989-2011). The survey uses a multistage random-cluster sampling process to select samples from nine provinces across China.[14] From the 2000 survey, the selection of the nine provinces in the CHNS was made to maximize the variation in geography, economic development and health indicators.[15] Detailed study design and sample collection procedure has been described in the previous study.[14] The present study includes 2,634 participants aged ≥60 years, for whom dietary and hypertension measurement data were available in 2009.

Survey protocols, instruments, and the process for obtaining informed consent for CHNS were approved by the institutional review committees of the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety, China Centre for Disease Control and Prevention. All participants have given their written informed consent. The University of Newcastle, Australia approved the use of the data for this study (Approval Number: H-2013-0360).

Dietary assessment and food grouping

Detailed dietary data collection has been described elsewhere.[14] Dietary assessment was based on a combination of data collected at the individual level, and a food inventory was taken at the household level. Household food consumption was determined by weighing all food consumed by the household over three consecutive days from Monday to Sunday. Household food consumption was determined by examining changes in the food inventory from the beginning to the end of each day, in combination with a weighing and measuring technique. All foods remaining after the last meal, before initiation of the survey, were weighed and recorded. All purchases, as well as home produced foods, were recorded. Wasted foods were estimated when weighing was not possible. At the end of the survey, all remaining food was again weighed and recorded. To collect individual dietary data, each household member was asked to report all food consumed over the previous 24 h for each of the three days, whether at home or away from home. Interviewers recorded the types and amounts of food consumed at each meal during the previous day. The amount of food in each dish was estimated from the household inventory, and the proportion of each dish consumed was reported by each person.

The food groups were based on a food system developed specifically for the CHNS and the Chinese Food Composition Table.[16] Initially, 33 food groups were included. As some food items were consumed by less than 5% of participants, food intakes were further collapsed into 27 food groups based on similarity of nutritional profiles. The 27 food groups are: rice, wheat flour and wheat noodles, wheat buns and bread, corn and coarse grains, deep-fried wheat, starchy roots and tubers, pork, red meat, organ meat, processed meats, poultry and game, fish and seafood, milk, eggs and egg products, fresh legumes, legume products, dried legumes, fresh vegetables-non-leafy, fresh vegetables- leafy, pickled or canned vegetables, dried vegetables, cakes, fruits, nuts and seeds, beer, liquor and fast food.

Heavy metal contamination in food is of great concern in China. Different heavy metal affects health differently, e.g. cadmium mainly affects kidneys; environmental lead is known to affect blood pressure.[17,18] Thus in the study we only focused the association between dietary lead and blood pressure. We calculated dietary lead intake based on a published systematic review of food lead concentration and dietary lead exposure in China.[18] Salt intake from household food consumption data was used to supplement the individual dietary data. Individual salt consumption was calculated according to the total amount of salt consumed in the household, divided by the number of individuals per household, and was then adjusted for the proportion of the household energy intake by each individual, details have been described in our previous study.[19]

Mean consumption of each food group per day was calculated from dietary data as liang (Chinese ounce, 1 liang=50 g). For alcoholic beverages, soft drink and tea, mean consumption was calculated from the adults' questionnaire in CHNS. Respondents were asked 'do you drink any kind of alcoholic beverage (beer or liquor)?', and were asked further questions on drinking frequency, types and quantity consumed in a week. Also, participants were asked 'do you normally drink tea?' and 'do you drink soft drinks or sugared fruit drinks?' Further questions on drinking frequency and number of cups consumed per day (a cup is approximately 240 mL) were asked. Energy intake was calculated by CHNS based on the Chinese Food Composition Table.[20]

Outcome and hypertension definition

After at least a 10 min rest, trained examiners measured the blood pressure on the right arm in the sitting position using a mercury sphygmomanometer according to a standard protocol.[21] The blood pressure was measured three times and the average of the three readings was calculated as the blood pressure value.[21] Hypertension was defined by combining a systolic blood pressure (SBP) ≥140 mmHg and/or diastolic blood pressure (DBP) ≥90 mmHg[22] or taking anti-hypertensive medication.[23] Known hypertension was identified by the question "has a doctor ever told you that you suffer from high blood pressure?" Newly diagnosed hypertension was defined as SBP ≥140 mmHg and/or DBP ≥90 mmHg but with no use of anti-hypertensive medication.

Assessment of sociodemographic and lifestyles factors

The adult's questionnaire in CHNS provided data on each participant's background information, health history, physical measurement, and health-related behaviours. We used participants' age, gender, education, marital status, work status, smoking, alcohol intake, physical activities and urbanization as covariates in this study.

Education level as indicated in the questionnaire was allocated to one of four categories, namely illiterate; low: primary school; medium: junior middle school, and high: high middle school or higher. Marital status was categorized as married or other, based on five categories in the questionnaire: married; never married; divorced; widowed; separated. Work status was divided into two categories (no paid work/ paid work). Smokers were identified as people who have at least one cigarette per day (Yes/ No), based on the question 'how many cigarettes do you smoke per day?' Drinking was allocated into two categories (Yes/No), with the question 'last year, did you drink beer or any other alcoholic beverage?' Participants were asked the amount of time spent at different types of physical activities per week.[14] We calculated the Metabolic Equivalent of Task (MET) based on the Compendium of Physical Activities 2011.[24] Four types of physical activities were involved to calculate the MET, which were domestic activity (e.g. buying food, cooking); occupational activity (e.g. light, moderate and heavy); transportation activity (e.g. walking to/from work) and leisure activity (e.g. martial arts). Based only on absolute threshold of population and/or population density, the urbanization index was uses instead of urban/rural measurement. Urbanization is defined by a multidimensional, twelve-component urbanisation index, which captures population density and physical, social, cultural and economic environments in CHNS. Details has been described elsewhere.[5]

Statistical analysis

Exploratory factor analysis was used to identify dietary patterns using the principal component analysis method in STATA/SE 13.1 (STATA, StataCorp, USA). The 27 food groups were included in the factor analysis. Dietary patterns were identified based on the eigenvalue (>1), scree plot, factor interpretability and the variance explained (>5%). Factors were rotated with varimax to improve the interpretability of factors and minimize the correlation between factors. Factor loadings of >|0.20| represent the foods which most strongly related to the identified factor.

Participants were assigned a pattern-specific factor score, which was calculated as the sum of the products of the factor loading coefficients and standardized daily intake of each food associated with that pattern. Factor loadings were included in the calculation of pattern scores.

Factor scores were divided into four quartiles based on their distributions in each stratum. Poisson regression models were used to examine the associations between dietary patterns and hypertension. Multinomial logistic regression models were used to examine the association between each dietary pattern and different blood pressure status groups (normal, known hypertension and newly diagnosed hypertension). Forest plots[25] were used to show the association between blood pressure status groups and each dietary pattern, stratified by three urbanization levels.

RESULTS

Sample characteristics are shown in Table 1. Among the 2634 participants, the overall prevalence of hypertension was 47.0% in men and 48.9% in women (p=0.33). Average DBP and SBP were similar between men and women, with a median DBP of 80 mmHg for both men and women, and a median SBP of 130 mmHg for men and 131 mmHg for women. Significant differences were found between men and women in their physical activity, marital status, work status, education level, smoking status, and DBP ($p \leq 0.01$).

Two dietary patterns were identified by factor analysis. Two factors explained 14.9% of the variance in intake. The traditional dietary pattern (Eigenvalue=2.25) loaded heavily on rice, pork, vegetables and fish (factor loading >0.3), and inversely loaded on wheat flour and wheat buns (factor loading <-0.50). The modern dietary pattern (Eigenvalue=1.75) was characterised by high intake of fruit, milk, fast food, nuts and cakes (factor loading >0.3), and inversely on rice and wheat flour (factor loading < -0.2).

After adjusting for socioeconomic status factors, smoking, physical activity, dietary salt, and lead intake (model 4), there were no significant associations between dietary patterns and hypertension (Table 2a). Results from the fully adjusted multinomial logistic regression model (model 4, Table 2b) show that traditional dietary pattern was inversely associated with known hypertension (Table 2b), the Relative Risk Ratios (RRRs) across quartiles were 1, 0.82 (95% CI: 0.62; 1.10), 0.81 (95% CI: 0.61; 1.09) and 0.69 (95% CI: 0.50; 0.95), respectively (p for trend=0.05). No significant associations were found between dietary patterns and newly diagnosed hypertension.

Table 3 shows the association between dietary salt/lead intake and hypertension in the fully adjusted model (model 4). Average dietary intake was 8.5 g/day for salt and 74.4 μg/day for lead. There is no significant difference in risk of hypertension between quartiles of dietary salt consumption (p>0.05). Dietary lead intake was positively associated with hypertension and known hypertension, but not in the newly diagnosed hypertension. Compared with the lowest quartile, the PRs in the highest quartile was 1.15 (95% CI: 1.01; 1.31) for hypertension, and RRR of 1.61 (95% CI: 1.15; 2.27) for the known hypertension.

After adjusting for urbanization levels (Table 2, model 2), PRs and RRRs decreased by 10% for the traditional dietary pattern, and the association between hypertension and the modern dietary pattern was no longer statistically significant in either the hypertension or known hypertension. This implies that urbanization is a potential confounding or matching variable. Therefore, data was stratified by urbanization levels for further analysis.

Figure 1 shows the association between each dietary pattern and blood pressure status, stratified by three urbanization levels. There were inverse associations between a traditional dietary pattern and all hypertension groups across the three urbanization levels. However, the associations between modern dietary pattern and hyper-

Table 1. Characteristics of study participants (n=2,634)

Factor	Men	Women	*p* value
n (%)	1246 (47.3)	1388 (52.7)	
Age, median (IQR)	67.0 (63.0; 74.0)	68.0 (63.0; 74.0)	0.13
Physical activity (MET), median (IQR)	85.1 (62.8; 134.9)	103.0 (80.9; 134.8)	<0.001*
Marital status, n (%)			
Married	1061 (85.6)	906 (65.8)	<0.001*
Others†	178 (14.4)	471 (34.2)	
Work status, n (%)			
No paid work	824 (66.3)	1093 (79.0)	<0.001*
Paid work	419 (33.7)	290 (21.0)	
Urbanization level, n (%)			
Low	443 (35.6)	460 (33.1)	0.35
Medium	404 (32.4)	453 (32.6)	
High	399 (32.0)	475 (34.2)	
Education level, n (%)			
Illiteracy	163 (13.2)	608 (44.1)	<0.001*
Low	558 (45.1)	523 (37.9)	
Medium	268 (21.7)	140 (10.2)	
High	248 (20.0)	108 (7.8)	
Smoking status, n (%)			
No	684 (54.9)	1298 (93.5)	<0.001*
Yes	562 (45.1)	90 (6.5)	
Alcohol drinking, n (%)			
No	920 (73.8)	1082 (78.0)	0.01
Yes	326 (26.2)	306 (22.1)	
DBP, median (IQR)	80.0 (71.7; 90.0)	80.0 (70.7; 88)	0.01*
SBP, median (IQR)	130.0 (118.7; 144.7)	130.7 (119.3; 146.0)	0.13
Blood pressure status, n (%)			
Normal	642 (51.5)	691 (49.8)	0.009
Known hypertension	275 (22.1)	374 (27.0)	
Newly diagnosed	329 (26.4)	323 (23.3)	

†Other marital status includes divorced; widowed; separated and never married.
*$p \leq 0.01$.

tension differed by urbanization: an inverse, positive and null association was seen in low, medium and high urbanization.

Post hoc analysis

The association between modern dietary pattern and hypertension varied by urbanization levels (Figure 1), which may imply that food compositions of the modern dietary pattern were different in each of the three urbanization levels. Thus we performed additional factor analysis to identify dietary patterns for low urbanization level. Compared with the factor analysis results across all three urbanization levels, we found different food compositions of modern dietary pattern in low urbanization levels. Figure 2 shows modern dietary pattern components and factor loadings between the three urbanization levels and the low urbanization level. Fast food and processed meat were loaded heavily across three urbanization levels, but less positively loaded in the low urbanization level. Dried vegetables and legume products were positively loaded across three urbanization level, but inversely loaded in the low urbanization level. By contrast, fresh legumes and non-leafy vegetables were inversely loaded across the three urbanization levels, but had a high positive loading in the low urbanization level. Starches were loaded heavily in the low urbanization level, while much less positively loaded across the three urbanization levels.

Table 4 shows the intake of food groups in the modern dietary pattern, across the three urbanization levels and in the low urbanization level. Processed products (fast food, processed meat, dried vegetables and legume products) across the three urbanization levels had higher average intake than in the low urbanization levels. Q4 had significantly higher intake of fresh legumes and non-leafy vegetables than Q1 in the low urbanization level (*p* for trend <0.001), while higher quartile had lower intake than lower quartiles across the four quartiles was found across the three urbanization levels, with no significant difference found (*p* for trend >0.05). Although starches intakes in Q4 were significantly higher than Q1 (*p* for trend <0.001) in both groups, the mean starches intake in the low urbanization level was higher across the four quartiles than that across three urbanization levels.

DISCUSSION

In this cross-sectional study, we found that the traditional Chinese dietary pattern was inversely associated with known hypertension. Dietary lead was significantly positively associated with hypertension and known hypertension. Stratified analysis illustrates the different pictures for the modern dietary pattern in three urbanization levels, with people living in the low urbanization level having a different dietary pattern compared with other urbanization levels.

Our results show that the prevalence of overall hypertension in older Chinese people was extremely high (47.0% for men and 48.9% of women). We also found large differences between the overall prevalence of hyper-

Table 2. Prevalence ratios (PRs) / relative risk ratio (RRRs) and 95% confidence interval (CI) for traditional and modern dietary pattern

	PRs and 95% CI				
	Q1	Q2	Q3	Q4	*p* for trend
Hypertension					
Intake of traditional dietary pattern					
Model 1	1	0.94 (0.84; 1.05)	0.97 (0.87; 1.08)	0.91 (0.81; 1.02)	0.41
Model 2	1	0.87 (0.78; 0.97)	0.91 (0.82; 1.02)	0.89 (0.80; 1.02)	0.21
Model 3[a]	1	0.88 (0.79; 0.99)	0.93 (0.83; 1.04)	0.91 (0.81; 1.02)	0.32
Model 4	1	0.88 (0.79; 0.99)	0.92 (0.82; 1.04)	0.87 (0.77; 0.99)	0.08
Intake of modern dietary pattern					
Model 1	1	1.04 (0.93; 1.17)	1.12 (1.00; 1.25)	1.18 (1.05; 1.31)	0.01
Model 2	1	1.00 (0.88; 1.12)	1.04 (0.92; 1.16)	1.07 (0.95; 1.21)	0.61
Model 3[b]	1	0.99 (0.88; 1.12)	1.04 (0.92; 1.17)	1.04 (0.92; 1.19)	0.99
Model 4	1	1.00 (0.88; 1.12)	1.02 (0.90; 1.15)	1.01 (0.89; 1.15)	0.67
	RRRs and 95% CI				
Blood pressure status[†]					
Intake of traditional dietary pattern					
Model 1					
Normal	1	1	1	1	
Known	1	0.97 (0.74; 1.26)	0.93 (0.71; 1.21)	0.81 (0.62; 1.06)	0.49
Newly diagnosed	1	0.74 (0.57; 0.97)	0.88 (0.68; 1.14)	0.77 (0.59; 1.01)	0.17
Model 2					
Normal	1	1	1	1	
Known	1	0.78 (0.59; 1.03)	0.77 (0.58; 1.02)	0.74 (0.56; 0.98)	0.15
Newly diagnosed	1	0.67 (0.51; 0.89)	0.81 (0.62; 1.06)	0.77 (0.59; 1.01)	0.19
Model 3[a]	1				
Normal	1	1	1	1	
Known	1	0.80 (0.61; 1.06)	0.81 (0.61; 1.08)	0.76 (0.57; 1.01)	0.24
Newly diagnosed	1	0.70 (0.53; 0.93)	0.83 (0.63; 1.10)	0.76 (0.58; 1.01)	0.16
Model 4					
Normal	1	1	1	1	
Known	1	0.82 (0.62; 1.10)	0.81 (0.61; 1.09)	0.69 (0.50; 0.95)	0.05
Newly diagnosed	1	0.69 (0.52; 0.92)	0.80 (0.60; 1.07)	0.71 (0.52; 0.97)	0.07
Intake of modern dietary pattern					
Model 1					
Normal	1	1	1	1	
Known	1	1.33 (0.99; 1.76)	1.75 (1.33; 2.30)	2.00 (1.52; 2.63)	<0.001
Newly diagnosed	1	0.93 (0.72; 1.21)	0.92 (0.71; 1.20)	0.98 (0.75; 1.28)	0.64
Model 2					
Normal	1	1	1	1	
Known	1	1.20 (0.90; 1.61)	1.42 (1.06; 1.91)	1.43 (1.05; 1.95)	0.24
Newly diagnosed	1	0.88 (0.68; 1.15)	0.88 (0.67; 1.17)	0.99 (0.73; 1.34)	0.77
Model 3[b]					
Normal	1	1	1	1	
Known	1	1.21 (0.89; 1.63)	1.42 (1.05; 1.92)	1.39 (1.01; 1.91)	0.40
Newly diagnosed	1	0.88 (0.67; 1.15)	0.88 (0.66; 1.17)	0.92 (0.67; 1.27)	0.39
Model 4					
Normal	1	1	1	1	
Known	1	1.20 (0.89; 1.62)	1.35 (1.00; 1.83)	1.28 (0.92; 1.77)	0.69
Newly diagnosed	1	0.88 (0.67; 1.16)	0.84 (0.63; 1.20)	0.86 (0.63; 1.19)	0.26

[†]Number of participants in three groups is as below: Normal: n=1333, known: n=649 and newly diagnosed: n=652.
Model 1 crude model; Model 2 adjusted for age, gender, marital status, work status, urbanization levels and education level; Model 3[a] adjusted for smoking, alcohol drinking, physical activity, modern diet pattern, energy, salt and model 2. Model 3[b] adjusted for smoking, alcohol drinking, physical activity, traditional diet pattern, energy, salt and model 2. Model 4 adjusted for lead exposure and model 3.

tension and the prevalence of known hypertension. The prevalence of hypertension known to patients was 24.6% for men and 29.3% for women, which was half the prevalence of overall hypertension, suggesting public awareness of hypertension is low. A Chinese study in Shandong Province reported similar findings, showing that while 43.8% of the population had hypertension, only 26.2% were aware of their hypertension.[26] Although the awareness of hypertension has improved significantly during the past decade,[27] further action is needed to increase the public's knowledge of hypertension, because of the high prevalence of hypertension among the older Chinese population. Improving awareness of hypertension can promote the control and treatment of blood pressure, and help reduce the risk of cardiovascular and cerebrovascular diseases.[1]

The inverse association of a traditional dietary pattern and hypertension might be explained by the high consumption of vegetables, fish and legumes, as these food have been shown to lower blood pressure.[7] The food

Table 3. The association between salt/lead intake and hypertension†

	PRs, RRRs and 95% CI				p for trend
Hypertension	Q1	Q2	Q3	Q4	
Salt‡	1	0.91 (0.81; 1.03)	1.04 (0.93; 1.16)	1.03 (0.91; 1.15)	0.43
Lead§	1	1.11 (0.99; 1.25)	1.02 (0.90; 1.16)	1.15 (1.01; 1.31)	0.05
Blood pressure status					
Known					
Salt	1	0.81 (0.61; 1.07)	1.12 (0.84; 1.48)	0.98 (0.73; 1.30)	0.70
Lead	1	1.57 (1.18; 2.10)	1.32 (0.97; 1.80)	1.61 (1.15; 2.27)	0.03
Newly diagnosed					
Salt	1	0.86 (0.65; 1.13)	1.07 (0.80; 1.42)	1.03 (0.78; 1.37)	0.16
Lead	1	0.99 (0.75; 1.32)	0.93 (0.69; 1.25)	1.15 (0.83; 1.59)	0.22

RR: Prevalence Ratios; RRR: Relative Risk Ratios.
†Final model adjusted for age, gender, marital status, work status, urbanization levels, education level, smoking, alcohol drinking, physical activity, traditional diet pattern, modern dietary pattern and energy.
‡Average intake of salt across quartiles was: 3.0, 5.7, 8.0 and 17.5 g/day.
§Average intake of lead across quartiles was: 43.6, 63.0, 80.3 and 109.6 μg/day.

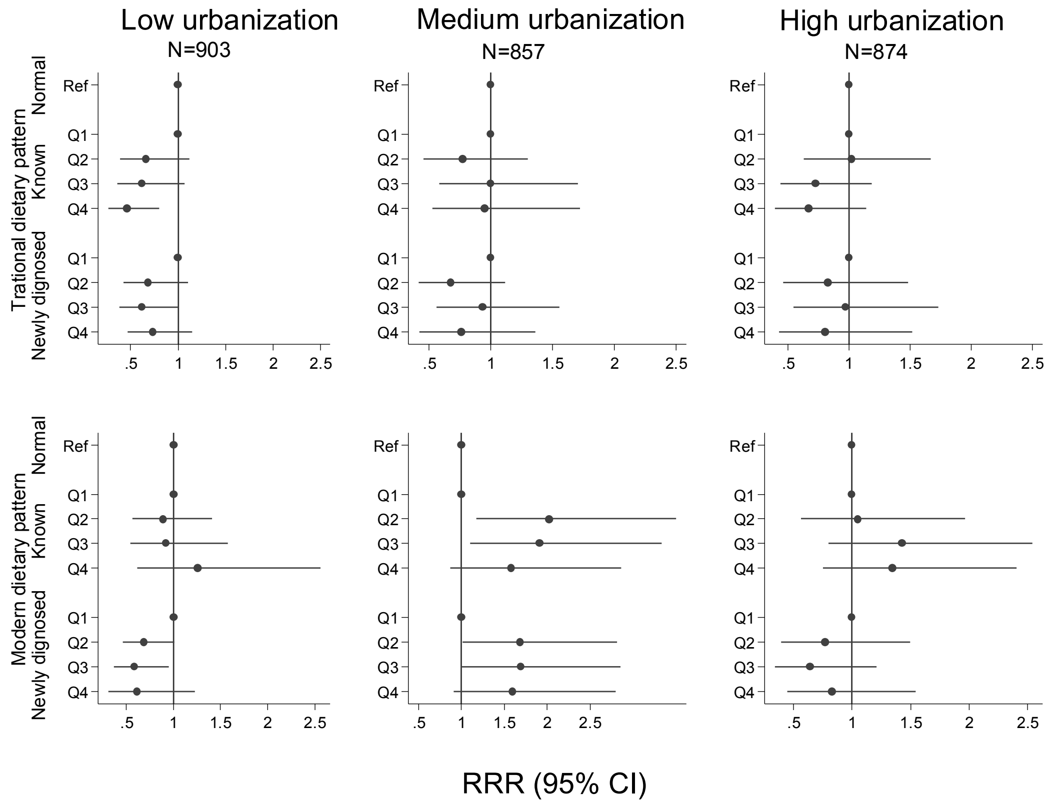

Figure 1. The association between dietary patterns and blood pressure status, stratified by low, medium and high urbanization levels. Figures were adjusted for age, gender, marital status, work status, urbanization levels, education level, smoking, physical activity, alcohol drinking, salt, lead and energy

groups contained in the traditional dietary pattern in the present study are similar in other Asian countries, and are considered to be a heathy diet to prevent hypertension.[28] A Japanese traditional diet, characterised by high consumption of vegetables, fruit, fish, pork and soybeans, shares many of the same food items as our traditional dietary pattern, which also found an inverse association with blood pressure.[28] We also found that rice consumption, as the staple food in the traditional dietary pattern, may contribute to a low risk of hypertension. A Chinese study also pointed out that a rice consumption of ≥401 g/day was associated with 42% less risk of hypertension compared to a rice consumption of <200 g/day, which is consistent with our results.[29] A modern dietary pattern, high in processed meat, fast food and dairy, is positively associated with hypertension, which is consistent with previous studies in the Chinese population.[12]

Rapid industrialization and urbanization in China has led to a higher incidence of food contamination.[18] In our study the average dietary lead intake was 74.4 μg/day. The Total Diet Study conducted by the Chinese government also showed that the daily dietary lead intake is high, estimated to be 86.3 μg/day in 1990; 81.5 μg/day in 1992; 81.1 μg/day in 2000 and 50.5 μg/day in 2007. The dietary exposure to lead was 1.438; 1.358; 1.352 and 0.842 μg/kg bw/day using a default body weight (bw) of 60 kg for the general population. The dietary intake of lead in China is much higher than in other countries,[18,30] e.g. in Canada

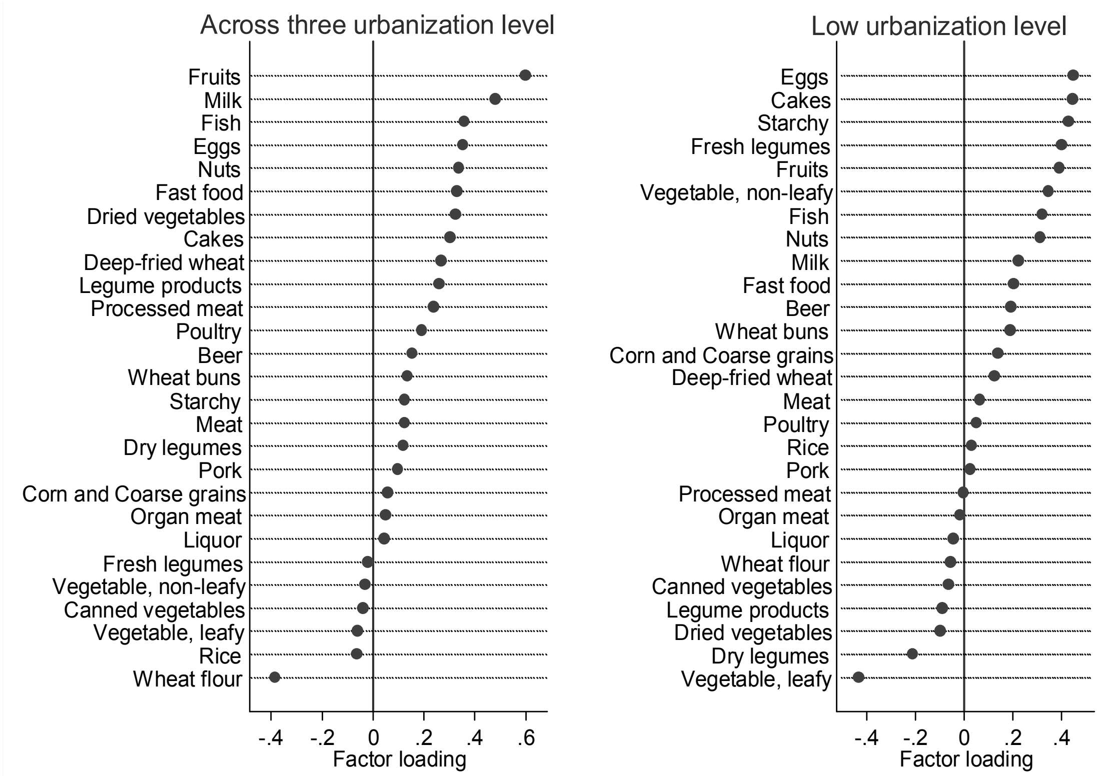

Figure 2. Modern dietary pattern components and factor loadings between three urbanization levels and low urbanization level

Table 4. Food intakes across qualities of several food groups for modern dietary pattern, by across urbanization level and in low urbanization level

Food items (Liang per day)	Intake of modern dietary pattern quartiles (Q)								*p* for trend
	Q1		Q2		Q3		Q4		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Across three urbanization levels									
Fast food	0.01	0.11	0.13	0.50	0.45	0.86	0.94	1.75	<0.001
Processed meat	0.003	0.03	0.03	0.15	0.06	0.25	0.15	0.50	<0.001
Dried vegetables	0.007	0.05	0.01	0.07	0.07	0.22	0.16	0.40	<0.001
Legume products	0.61	0.91	0.82	1.22	1.11	1.37	1.57	1.85	<0.001
Starchy	0.65	1.05	0.90	1.33	1.01	1.64	1.10	1.43	<0.001
Fresh legumes	0.82	1.48	0.98	1.57	0.93	1.50	0.82	1.17	0.45
Vegetable, non-leafy	2.77	2.85	2.63	2.48	2.65	2.34	2.69	2.29	0.30
Energy (kcal per day)	2018	1279	1880	720	2091	1482	2268	1578	<0.001
Low urbanization level									
Fast food	0.01	0.09	0.07	0.35	0.22	0.70	0.31	1.33	<0.001
Processed meat	0.02	0.12	0.04	0.24	0.06	0.55	0.02	0.14	0.11
Dried vegetables	0.04	0.23	0.02	0.09	0.03	0.14	0.008	0.06	0.004
Legume products	1.00	1.36	0.77	1.54	0.73	1.17	0.66	1.13	0.04
Starchy	0.31	0.64	0.71	1.01	1.18	1.35	1.87	2.24	<0.001
Fresh legumes	0.31	0.64	0.52	0.82	1.10	1.28	2.31	2.81	<0.001
Vegetable, non-leafy	1.60	1.75	2.98	2.45	4.03	2.65	4.59	3.30	<0.001
Energy (kcal per day)	1881	944	2192	1847	2146	826	2359	675	<0.001

(0.13 µg/kg bw/day), Australia (0.12-0.13 µg/kg bw/day) and Lebanon (0.14 µg/kg bw/day). Lead levels are especially high in plant foods (such as vegetables and cereals).[18] Lead is a toxic contaminant, which can affect virtually all human body systems, including the blood, cardiovascular, renal, endocrine, gastrointestinal, immune and reproductive systems.[18] In this present study, we found a significant association between dietary lead and hypertension. Furthermore, the dietary lead intake was associated with known hypertension, but not associated with newly diagnosed hypertension. It may be explained by the possible changes of diet after diagnosis of hypertension. Further studies are needed to explore to what degree these changes on diet affects dietary lead exposure. Although population studies have demonstrated the link between environmental lead exposure, hypertension and cardiovascular diseases,[9,10] there are no epidemiological studies on dietary lead exposure and hypertension. More epidemiological studies need to be conducted in the future to further examine these associations.

Based on the factor loadings (Figure 2) and actual food intake across quartile of dietary patterns (Table 4), it can be speculated that fresh legumes, starches and non-leafy vegetables were most likely the key components that inversely associated with hypertension, while processed products (including processed meat and fast food) were most likely the key components that were positively associated with hypertension. Soybean sprouts, peas and mung bean sprouts were included in the group of fresh legumes in the present study. Previous epidemiological studies show that fresh legumes have a major role in the dietary prevention of hypercholesterolemia and hypertension,[31] and starch intake is also inversely related to blood pressure.[32] Vegetables are naturally high in fibre, and dietary fibre has a protective effect in hypertension. A meta-analysis examining the association between dietary fibre and blood pressure shows that increasing fibre intake can contribute to hypertension prevention.[33] The main mechanism may be that dietary fibre reduces the glycaemic index of food, thereby attenuating the insulin response. Insulin plays a role in blood pressure regulation, and dietary fibre can enhance insulin sensitivity and improve vascular endothelial function.[33] Processed foods are major contributors to dietary salt intake and salt intake may be the main reason for the positive association between processed products and hypertension.[34] However, in our study we only measured cooking salt at home. Salt in the processed food was not calculated. The association between salt intake and hypertension may be masked by eating out and the consumption of processed food. Salt must be reduced in commercially processed products in China to avoid excess salt intake by the Chinese population.[35]

Our results show that urbanization level is a confounding variable in the association between dietary patterns and hypertension. This could be partly explained by the different food composition in modern dietary pattern, probably due to disparity of food access and availability in the different urbanization levels in China. For example, it is common for people who live in an area of low urbanization to grow their own food, which can reduce reliance on fast and processed food.[36] The government needs to consider regulations and policies that encourage healthy diets by using available local and regional healthy food in the prevention of hypertension. Moreover, the main impact of dietary lead on human health is principally through accumulation in food, mainly in vegetables grown on contaminated soil. To reduce the dietary lead intake, the government should take effective measures to control food lead contamination in China.

Some limitations need to be addressed in the present study. One of the limitations of the present study is the cross-sectional design, which means we cannot make an etiological link between dietary patterns and hypertension. Although strong associations were found between salt intake and hypertension in previous studies, failure to find a statistically significant association may be due to the cross-sectional design and our study population which had a particular focus on the older population. Although cooking methods may have an effect on the prevalence of hypertension, they were not considered in the present study. Surprisingly, no significant associations were found between dietary patterns and newly diagnosed hypertension, which may be due to the low number of participants reducing the study power. In addition, although blood lead level should be also included in the analysis, blood lead data was not available in the CHNS.

Furthermore, two dietary pattern explained 14.9% of the variance in intake seems low. However, the variance explained by the derived factors depended on the number of food groups entered in the factor analysis. Also, in contrast to the other studies using FFQ based food intake data, we used data from 3-day food records. It was expected that the variation of food intake would be greater than those FFQ based data.

In conclusion, the significance of the study findings is that dietary patterns and dietary lead are associated with hypertension in the older Chinese population. Food quality and safety is an issue that needs to be reinforced by the Chinese government. Condiments, in particular excess added salt in the processed product, need to be further controlled to help prevent hypertension. Excess dietary lead intake also indicates the importance of food safety in prevention of hypertension. Further longitudinal studies need to be undertaken to evaluate these associations. In addition, health professionals can use the evidence of these associations between dietary pattern and hypertension to give appropriate dietary advice based on food access and availability at the regional and local level, in order to reduce the risk of hypertension in the older Chinese population.

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