

Original Article:

Association between food patterns and metabolic syndrome in China

* Z. Shi^{1,2}, X. Hu¹, B. Yuan¹, G. Hu³, X. Pan¹, Y. Dai¹, G. Holmboe-Ottesen⁴, J. Byles²

Abstract:

The objective of this paper is to investigate the association between a vegetable rich food pattern and the metabolic syndrome among Chinese adults. A cross-sectional household survey of 2849 men and women aged 20 years and over was undertaken in 2002 in Jiangsu Province (response rate 89.0%). Nine hundred fifty six participants free from metabolic syndrome in 2002 participated in a follow up survey in 2007. At baseline, food intake was assessed by food frequency questionnaire. Factor analysis was used to identify food patterns. Food intake was measured by food weighing plus consecutive individual 3 day food records. Height, weight and any individual components of the metabolic syndrome were measured both in 2002 and 2007. The prevalence of metabolic syndrome by the modified ATP III definition was 12.9% in men and 19.6% in women. A four-factor solution explained 30.5% of the total variance in food frequency intake. The 'vegetable rich' food pattern (whole grains, fruits and vegetables) was positively associated with vegetable oil and energy intake in both genders. Prevalence of metabolic syndrome increased across the quartiles of 'vegetable rich' food pattern. After adjusting for socio-demographic and other three distinct food patterns, the 'vegetable rich' pattern was independently associated with metabolic syndrome at baseline. Compared with the lowest quartile (Q1) of 'vegetable rich' pattern, the highest quartile (Q4) had a higher risk of metabolic syndrome (men: odds ratio [OR]: 1.68, 95% confidence interval [CI] 1.02-2.79; women: OR: 1.75, 95%CI 1.17-2.62). The 'vegetable rich' food pattern was also positively associated with incident metabolic syndrome among women in 2007. The healthfulness of 'vegetable rich' food pattern is dependent on variety and amounts of other foods used and total intake of energy and various nutrients.

Key words: Food pattern, Metabolic Syndrome, Chinese

¹Jiangsu Provincial Center for Disease Control and Prevention, Nanjing, China

²Research Center for Gender, Health and Ageing, Hunter Medical Research Institute, The University of Newcastle, Australia

³Pennington Biomedical Research Center, Louisiana State University System, Baton Rouge, U.S.A.

⁴Section of Preventive Medicine and Epidemiology, Department of General Practice and Community Medicine, University of Oslo, Norway.

***Corresponding Author:**

Zumin Shi MD, PhD

Nutrition and Food borne Disease Prevention, Jiangsu Provincial Center for Disease Control and Prevention, 172 Jiangsu Road, Nanjing 210009, P. R. China.

E-mail: zumins@vip.sina.com

Introduction:

The metabolic syndrome is characterized by a clustering of cardiovascular risk factors, including abdominal obesity, raised blood pressure and glucose concentration, and dyslipidaemia (1, 2). The syndrome is associated with the development of diabetes and cardiovascular diseases (3-8). Obesity, especially central obesity, has been proposed as an important mechanism underlying metabolic syndrome (2).

China is undergoing rapid nutrition transition. There has been a rapid increase in the prevalence of obesity during the past decade (9). Changes in diet and physical activity are associated with this epidemic (10). The reported prevalence of metabolic syndrome range from 3.2 to 17.8% in different studies in China (11-13) depending on urban – rural residency and socio-economic status. The prevalence rates are lower than in the Western population. The rapid increase in the prevalence of obesity may

however suggest that the prevalence of metabolic syndrome will increase in the future.

Generally, the Chinese diet is characterized by a high intake of vegetables and other plant foods, and thus the intake of carbohydrates and fiber is high. Even with the on-going nutrition transition, the average intake of vegetables is still higher than in the Western countries. At a national level, the mean intake of vegetables is 276 g/day in 2002, which is 40 g/day less than twenty years before (14). Understanding the immediate causes of the rapid increase in the prevalence of non-communicable chronic disease is of importance.

In Western countries, a fruit and vegetable rich food pattern, as identified by factor analysis, is protective to many chronic diseases including diabetes, obesity, cancer, as well as metabolic syndrome (15-22). Similar fruit and vegetable food patterns are found in the Chinese population and are related to anemia and mortality (23, 24). However, no study has reported the association between such pattern and metabolic syndrome. The objective of the present study is to investigate the cross-sectional and longitudinal associations between 'vegetable rich' food pattern derived from factor analysis and the association to metabolic syndrome as defined by the ATP III and IDF in Chinese adults.

Methodology

In 2002, China launched a national study on nutrition and health. The data presented in this article is based on a subsample from Jiangsu province, one of the economically booming areas in China with a population of 73.6 million. The rural sample was selected from six counties (Jiangyin, Taicang, Suining, Jurong, Sihong and Haimen). From each of the six counties, three towns were randomly selected. The urban sample was selected from two prefecture capital cities (Nanjing and Xuzhou). From each prefecture city, three streets were randomly selected. The six counties and two prefecture cities represented a geographically and economically diverse population. In each town/street, two villages/neighbourhoods were further randomly selected. In each village/neighbourhood 30 households were randomly selected. All members of the households were invited to take part in the study. Written consents were obtained from all the participants. In the study presented here, we analyzed only data for adults aged 20 years and

over. The response rate was 89.0% in 2002. In 2007, a 5-year follow up survey was done (25). In 2007, only 1682 participants could be identified, 1492 of them participated in the study, and 1175 had fasting blood samples taken. There were 956 participants without metabolic syndrome at baseline who finished the follow up.

Measurement

Participants were interviewed in their homes by trained health workers using a pre-coded questionnaire. Interviews took approximately two hours to complete and included questions on diet, socio-demographic information, medical history, cigarette smoking, physical activity, and other lifestyle factors. Smoking was assessed by asking about the frequency of daily cigarette smoking. Drinking was assessed by asking about the frequency and amount of alcohol/wine intake. Income level was assessed by questions on family income and number of persons in the household and categorized into three groups: 'low' : <1999 Yuan/person; 'medium': 2000-4999 Yuan/person; and 'high': >5000 Yuan/person. Education was recorded into three categories based on six educational levels in the questionnaire: 'Low': illiteracy, primary school; 'Medium': junior middle school; 'High': high middle school or higher. Occupation was recorded into manual or non-manual based on a question with 12 occupational categories. Active commuting (walking or cycling to and from work) and leisure-time physical activity were both categorized into three groups: none, 1-30 minutes/day, and more than 30 minutes/day.

In the baseline survey, diet during the past year was investigated by a series of detailed questions about usual frequency and quantity of intake of 33 foods/food groups and beverages. The list of foods was further collapsed into 25 foods/food groups in the analysis because of low intake of some items. Portion size for each food was established by reference to food models. Subjects were asked to recall the frequency of consumption of individual food items (number of times/day, /week, /month, /year) and the estimated portion size, using local weight units [liang (50g)] or natural units (cups). Intake of foods were converted into grams per week and were used in the further analysis. The food frequency questionnaire has been validated (26, 27) and reported to be a useful method for the collection of individual food consumption information in face-to-face interviews.

Dietary patterns were identified by factor analysis, using standard principal component analysis method. In brief, factors were rotated with an orthogonal (varimax) rotation to improve interpretability and minimize the correlation between the factors. The number of factors retained from each food classification method was determined by eigenvalue (>1), scree plot, factor interpretability and the variance explained by each factor. Labelling of the factors was primarily descriptive and based on our interpretation of the pattern structures.

Participants were assigned pattern-specific factor scores. Scores for each pattern were calculated as the sum of the products of the factor loading coefficients and standardized weekly intake of each food associated with that pattern. Only foods with factor loadings of >0.20 and <-0.20 were included in calculation of pattern scores, because these items represent the foods most strongly related to the identified factor.

Nutrient and vegetable oil intakes were also measured by food weighing plus consecutive individual 3 day food records. Food consumption data were analyzed using the Chinese Food Composition Table (28). Energy intake was compared with Chinese Recommended Nutrient Intakes (RNIs).

At the study site, health workers measured height, weight, blood pressure, and waist circumference (WC). Blood pressure was measured by mercury sphygmomanometer on the right upper arm of the subject, who was seated for 5 min before the measurement. Blood pressure was measured twice and the mean of these two measurements was used in the analyses. Height was measured without shoes and weight was measured with light clothing. Body mass index (BMI) was calculated as weight in kilograms divided by the square of the height in meters. WC was measured at midway between the inferior margin of the last rib and the iliac crest in a horizontal plane.

Both in baseline and follow-up survey, all the participants were invited to take a fasting blood sample. The blood samples were analyzed for plasma glucose in the local centres for disease control and prevention. Part of the blood specimens were processed at the examination centre and shipped to a central clinical laboratory in Beijing where the specimens were stored at -70°C until laboratory assays could be

done. Plasma glucose was measured with a modified hexokinase enzymatic method. Concentrations of total cholesterol, high-density lipoprotein (HDL)-cholesterol, and triglycerides were assessed enzymatically with commercially available reagents.

Definition of the metabolic syndrome

Modified National Cholesterol Education Program ATP-III Criteria (2). Affected individuals should meet three or more of the following conditions: Waist Circumference (WC) ≥ 90 cm in men or ≥ 80 cm in women; triglyceride level ≥ 150 mg/dl (1.7 mmol/l) or specific treatment for this lipid abnormality; HDL-cholesterol < 40 mg/dl (1.03 mmol/l) in men or < 50 mg/dl (1.29 mmol/l) in women or specific treatment for this lipid abnormality; blood pressure $\geq 130/85$ mmHg or using antihypertensive treatment; and fasting plasma glucose (FPG) ≥ 100 mg/dl (5.6 mmol/l) or previously diagnosed type 2 diabetes.

International Diabetes Federation (IDF) criteria (1). Affected individuals should meet the criterion of WC ≥ 90 cm in men or ≥ 80 cm in women plus two or more of the following four factors: triglyceride level ≥ 150 mg/dl (1.7 mmol/l) or specific treatment for this lipid abnormality; HDL-C < 40 mg/dl (1.03 mmol/l) in men or < 50 mg/dl (1.29 mmol/l) in women or specific treatment for this lipid abnormality; blood pressure $\geq 130/85$ mmHg or using antihypertensive treatment; and FPG ≥ 100 mg/dl (5.6 mmol/l) or previously diagnosed type 2 diabetes.

Statistical analyses

Factor scores were divided into quartiles, implying increased intake from quartile 1 to quartile 4. Chi square test was used to compare difference between categorical variables. Logistic regression was used to determine the association between food patterns and the risk of metabolic syndrome adjusted for age, income, education, occupation, commuting and leisure-time physical activity, smoking, and alcohol drinking. All the analyses were performed by using STATA 9.

Results

The data set contained 1308 men and 1541 women in 2002. About 80% of the participants had an education level of primary or junior school. The mean age was 47.0 years (SD 14.5).

Mean BMI were 23.4 for men and 23.6 for women.

Table 1 Factor loadings^a for 4 food patterns among adults in Jiangsu China (n= 2849)

| Factor 1: 'Traditional' | | Factor 2: 'Macho' | | Factor 3: 'Sweet tooth' | | Factor 4: 'Vegetable rich' | |
|--------------------------|----------------|---------------------|----------------|-------------------------|----------------|----------------------------|----------------|
| Food or food group | Factor loading | Food or food group | Factor loading | Food or food group | Factor loading | Food or food group | Factor loading |
| Rice | 0.81 | Poultry | 0.56 | Cake | 0.60 | Whole grains | 0.54 |
| Fresh vegetables | 0.57 | Beer | 0.53 | Juice | 0.58 | Fruits | 0.49 |
| Pork | 0.37 | Beef, lamb | 0.46 | Beverage ^c | 0.48 | Pickled vegetables | 0.46 |
| Fish | 0.21 | Deep fried products | 0.45 | Milk | 0.48 | Tofu | 0.44 |
| Root vegetables | -0.32 | Pork | 0.44 | Yogurt | 0.44 | Fresh vegetables | 0.37 |
| Wheat flour ^b | -0.78 | Liver | 0.43 | Beef, lamb | 0.30 | Root vegetables | 0.34 |
| | | Alcohol | 0.43 | Nut | 0.26 | Milk | 0.31 |
| | | Eggs | 0.38 | Poultry | 0.25 | Eggs | 0.30 |
| | | Fish | 0.26 | Fruits | 0.23 | Fish | 0.24 |
| | | Nuts | 0.23 | Pickled vegetables | -0.20 | Wheat flour | 0.23 |
| | | Fruits | 0.22 | Alcohol | -0.27 | Milk powder | 0.22 |
| | | Tofu | 0.22 | | | Beer | -0.21 |

a Factor loadings are equivalent to simple correlation between the food items and the factor. Higher loadings (absolute value) indicate that the food shares more variance with that factor. The sign of the loading determines the direction of the relationship of each food to the factor item. Food groups with absolute values <0.20 are excluded from the table for simplicity. Only one food item (cheese) is missing due to low factor loading.

b Wheat flour includes noodles and steamed dumplings.

c Beverage includes soft drinks, coffee and tea.

The prevalence of metabolic syndrome by modified ATP III definition was 12.9% in men and 19.6% in women. During 5-year follow-up, out of the 956 participants free of metabolic syndrome at baseline, 141 had developed metabolic syndrome by IDF's definition.

Four food patterns were obtained by factor analysis (Table 1). Factor 1 ('macho') was characterised by various kinds of animal foods and alcohol, i.e. foods commonly eaten by men. The 'traditional' pattern (factor 2) loaded heavily on rice and fresh vegetable and inversely on wheat flour. Factor 3 ('sweet tooth') contained cake, milk, yogurt and drinks, and more women than men could be associated to this pattern. Factor 4 ('vegetable rich' pattern) included whole grains, fruits, root vegetables, fresh and pickled vegetables, milk, eggs and fish. The four

factors explained 30.5% of the variance in intake (10.6%, 8.6%, 5.9% and 5.4% for factor 1 to factor 4 respectively).

There were significant differences in intake of fruits, vegetables, whole grains, animal foods, milk, and fish across quartiles of 'vegetable rich' food pattern (Table 2). A clear increasing trend of intake of energy, protein, carbohydrate, and fat was seen across quartiles of intake of the 'vegetable rich' food pattern from low to high. Men in the highest quartile of 'vegetable rich' pattern consumed 160 kcal/day more than those in the lowest quartile; the corresponding figure in women was 240 kcal/day. Among women aged 31-45, the energy intake difference between Q4 and Q1 of Vegetable rich food pattern was 360 kcal/day (data not shown).

Table 2: Food, nutrient intakes and metabolic syndrome components across quartiles of vegetable rich food pattern at baseline in Chinese adults (n=2849)^a

| | Intake of 'vegetable rich' food pattern quartiles (Men, n=1308) | | | | | | | | | Intake of 'vegetable rich' food pattern quartiles (Women, n=1541) | | | | | | | | |
|--------------------------------|--|----|------|----|------|----|------|----|-------------|--|----|------|----|------|----|------|----|-------------|
| | Q1 | | Q2 | | Q3 | | Q4 | | | Q1 | | Q2 | | Q3 | | Q4 | | |
| | Mean | SE | Mean | SE | Mean | SE | Mean | SE | P for trend | Mean | SE | Mean | SE | Mean | SE | Mean | SE | P for trend |
| Fresh vegetables (g/day) | 204 | 9 | 259 | 9 | 266 | 9 | 317 | 9 | <0.001 | 178 | 8 | 235 | 8 | 266 | 8 | 304 | 8 | <0.001 |
| Fruits (g/day) | 31 | 4 | 45 | 4 | 69 | 5 | 105 | 5 | <0.001 | 28 | 4 | 46 | 4 | 70 | 4 | 121 | 4 | <0.001 |
| Rice (g/day) | 367 | 10 | 337 | 10 | 269 | 10 | 246 | 10 | <0.001 | 315 | 9 | 276 | 8 | 243 | 8 | 220 | 8 | <0.001 |
| Wheat flour (g/day) | 79 | 10 | 114 | 10 | 197 | 10 | 253 | 10 | <0.001 | 56 | 9 | 118 | 8 | 141 | 8 | 180 | 8 | <0.001 |
| Whole grain (g/day) | 2 | 1 | 2 | 1 | 6 | 1 | 27 | 1 | <0.001 | 1 | 1 | 3 | 1 | 6 | 1 | 22 | 1 | <0.001 |
| Root vegetables (g/day) | 7 | 1 | 11 | 1 | 16 | 1 | 29 | 1 | <0.001 | 6 | 1 | 12 | 1 | 17 | 1 | 28 | 1 | <0.001 |
| Animal foods (g/day) | 70 | 3 | 61 | 4 | 69 | 4 | 77 | 4 | 0.026 | 48 | 3 | 43 | 3 | 54 | 3 | 63 | 3 | <0.001 |
| Fish (g/day) | 23 | 2 | 28 | 2 | 31 | 2 | 44 | 2 | <0.001 | 19 | 2 | 21 | 2 | 28 | 2 | 46 | 2 | <0.001 |
| Milk (g/day) | 2 | 3 | 3 | 3 | 23 | 3 | 39 | 3 | <0.001 | 1 | 3 | 4 | 3 | 15 | 3 | 48 | 3 | <0.001 |
| Energy (kcal/day) | 2549 | 37 | 2534 | 37 | 2630 | 39 | 2710 | 30 | <0.001 | 2003 | 31 | 2126 | 31 | 2131 | 30 | 2243 | 31 | <0.001 |
| Protein (g/day) | 79 | 1 | 77 | 1 | 80 | 1 | 86 | 1 | <0.001 | 62 | 1 | 65 | 1 | 66 | 1 | 70 | 1 | <0.001 |
| Carbohydrate (g/day) | 331 | 6 | 347 | 6 | 360 | 6 | 365 | 6 | <0.001 | 280 | 5 | 310 | 5 | 302 | 5 | 314 | 5 | <0.001 |
| Fat (g/day) | 88 | 2 | 86 | 2 | 90 | 2 | 94 | 2 | 0.054 | 69 | 2 | 73 | 2 | 73 | 2 | 78 | 2 | 0.003 |
| Fat energy percentage (%) | 31 | 1 | 31 | 1 | 31 | 1 | 32 | 1 | 0.658 | 31 | 1 | 30 | 1 | 31 | 1 | 32 | 1 | 0.210 |
| Fat energy percentage >30% (%) | 57 | 3 | 51 | 3 | 51 | 3 | 56 | 3 | 0.188 | 55 | 3 | 49 | 3 | 50 | 3 | 55 | 3 | 0.228 |
| Fat distribution (%) | | | | | | | | | | | | | | | | | | |
| Plant foods | 61 | 1 | 67 | 1 | 71 | 1 | 69 | 1 | <0.001 | 62 | 1 | 70 | 1 | 71 | 1 | 70 | 1 | <0.001 |

| | | | | | | | | | | | | | | | | | | |
|---|------|-----|------|-----|------|-----|------|-----|--------|------|-----|------|-----|------|-----|------|-----|--------|
| Animal foods | 39 | 1 | 33 | 1 | 29 | 1 | 31 | 1 | | 38 | 1 | 30 | 1 | 29 | 1 | 30 | 1 | <0.001 |
| Vegetable oil (g/day) | 42 | 2 | 44 | 2 | 48 | 2 | 48 | 2 | 0.038 | 33 | 1 | 39 | 1 | 40 | 1 | 42 | 1 | <0.001 |
| Energy>120%RNI (%) ^b | 19.2 | | 17.6 | | 24.5 | | 23.5 | | 0.094 | 11.5 | | 17.6 | | 15.0 | | 23.4 | | <0.001 |
| Sodium | 7197 | 230 | 6963 | 235 | 7022 | 243 | 6719 | 239 | 0.549 | 6126 | 188 | 6065 | 183 | 5931 | 178 | 5428 | 181 | 0.030 |
| Potassium | 1823 | 27 | 1762 | 28 | 1755 | 29 | 1902 | 28 | <0.001 | 1542 | 23 | 1528 | 23 | 1551 | 22 | 1568 | 22 | 0.644 |
| Diabetes ^c | 1.7 | | 4.5 | | 2.6 | | 5.3 | | 0.048 | 1.4 | | 3.7 | | 3.2 | | 5.9 | | 0.010 |
| IDF definition MetS | 6.2 | | 10.0 | | 9.5 | | 11.9 | | 0.087 | 16.9 | | 17.9 | | 15.4 | | 21.7 | | 0.128 |
| Modified ATP III MetS | 10.0 | | 13.3 | | 12.5 | | 15.9 | | 0.156 | 18.2 | | 19.5 | | 17.2 | | 23.3 | | 0.161 |
| Individual MetS components | | | | | | | | | | | | | | | | | | |
| IDF central obesity (WC: men>90 cm, women>80 cm) | 13.7 | | 20.7 | | 20.2 | | 23.8 | | <0.001 | 33.6 | | 37.4 | | 37.5 | | 44.0 | | 0.030 |
| Glucose (>5.6 mmol/l) | 10.8 | | 11.1 | | 6.8 | | 10.9 | | 0.218 | 9.6 | | 9.6 | | 8.7 | | 11.5 | | 0.544 |
| High triglycerides | 17.4 | | 16.7 | | 14.3 | | 14.1 | | 0.555 | 12.7 | | 12.0 | | 11.8 | | 11.6 | | 0.968 |
| Low HDL | 19.5 | | 22.2 | | 20.5 | | 25.3 | | 0.294 | 48.1 | | 44.9 | | 51.1 | | 49.4 | | 0.367 |
| High Blood pressure | 45.6 | | 46.4 | | 49.4 | | 47.2 | | 0.805 | 38.3 | | 37.4 | | 34.3 | | 40.7 | | 0.325 |
| High diastolic blood pressure | 22.5 | | 25.7 | | 24.1 | | 27.7 | | 0.091 | 20.9 | | 24.9 | | 23.5 | | 30.7 | | 0.052 |
| High systolic blood pressure | 26.8 | | 25.4 | | 23.8 | | 24.0 | | 0.978 | 25.2 | | 26.0 | | 23.0 | | 26.0 | | 0.245 |

a All values of food and nutrients intakes are adjusted for age. Intake of sodium is also adjusted for energy intake. Data are given as means (standard error [SE]) or percentages.

b RNI refers to Chinese reference nutrient intake

c Diabetes defined as fasting plasma glucose >7.0 mmol/l and known diabetes

The most common cooking fat consumed was vegetable oil (99.4%); the mean daily intake was 42g (45g in men, 39g in women). Significant differences in the mean intake of vegetable oil were seen among those having a 'vegetable rich' food pattern: from Q1 to Q4, the mean intakes were 42, 44, 48 and 48 g/day in men ($p=0.038$); and 33, 39, 40 and 42 g/day in women ($p<0.001$). The consumption of animal cooking fat was very low (all groups below 0.4g/day), and no difference was found in the consumption this type of fat across Vegetable rich food pattern quartiles (data not shown). Although there was a significant difference in the intake of fat across quartiles of Vegetable rich food pattern the fat energy percentage was similar.

A negative association between 'vegetable rich' food pattern and sodium intake was found in women; while a positive association between 'vegetable rich' food pattern and potassium intake existed in men.

In women, 23.4% of those in the highest quartile of 'vegetable rich' food pattern had a total energy intake of more than 120% of the RNI (reference nutrient intake), compared with 11.5% of the women in the lowest quartile ($p<0.001$). A similar but not significant trend was seen in men. Mean fat energy percentage was about 31% in most of the quartile groups, and half the sample had a fat energy percentage above 30% (Table 2).

Intake of vegetables was significantly associated with intake of vegetable oil. The regression coefficient was 0.40 (95%CI 0.08-0.71) in men and 0.57 (95%CI 0.25-0.89) in women (data not shown).

A clear increasing trend in the prevalence of central obesity and diabetes was found across quartiles of 'vegetable rich' food pattern from low to high in both genders in the baseline sample. The same trend was found in the prevalence of metabolic syndrome (Table 2). In both genders, there was also a trend of increasing prevalence of high diastolic blood pressure across quartiles of 'vegetable rich' food pattern. According to the modified ATP III definition, the prevalence of metabolic syndrome across quartiles of Vegetable rich food pattern was 10.0, 13.3, 12.5 and 15.9% in men, 18.2, 19.5, 17.2 and 23.3% in women (table 2). No difference was found in lipid profiles by 'vegetable rich' food pattern.

In multivariate analysis, after adjusting for known risk factors of diabetes and other three food patterns, people in the second to fourth quartiles of 'vegetable rich' food pattern had higher risk of metabolic syndrome both according to the IDF and the modified ATP III definitions compared with the lowest quartile (Table 3). The OR of metabolic syndrome, comparing Q4 and Q1 'vegetable rich' pattern groups was 2.01 (95%CI 1.11-3.66) by IDF definition and 1.68 (95%CI 1.02-2.79) by modified ATP III definition in men, and 1.76 (95%CI 1.16-2.65) by IDF definition and 1.75 (95%CI 1.17-2.62) by modified ATP III definition in women. OR was 1.63(1.17-2.26) by IDF definition in men and women combined, and 1.54(1.13-2.10) by modified ATP III definition in men and women combined (Table 3). Additional adjustment for energy, fat, and fiber intake and excluding 51 participants with known diabetes, the OR of metabolic syndrome comparing Q4 and Q1 Vegetable rich food pattern groups was 1.48 (95%CI 1.05-2.09) by IDF definition and 1.40 (95%CI 1.01 -1.94) by modified ATP III definition in men and women combined (data not shown). 'Vegetable rich' food pattern was positively associated with three individual components of metabolic syndrome including central obesity, high blood pressure, and high blood glucose (fasting glucose >6.1 mmol/l or known diabetes). Stratified analyses showed no interaction in the risk of metabolic syndrome between 'vegetable rich' food pattern and smoking, gender, and high energy intake (data not shown).

The association between other food patterns and metabolic syndrome was analyzed using multivariate logistic regression. In the fully adjusted model (variables in Table 3 with additional adjustment of energy, fat, fiber intake and sex), there was a trend of negative association between 'traditional' pattern and metabolic syndrome: ORs of metabolic syndrome by IDF definition across quartiles were 1, 1.15 (0.80-1.65), 0.89 (0.56-1.33), and 0.71 (0.47-1.07) (p for trend 0.024) for 'traditional' pattern. There was no association between 'macho' food pattern and 'sweet tooth' pattern and metabolic syndrome. In the above full model, ORs for metabolic syndrome by IDF definition across quartiles were: 1, 0.91 (0.66-1.26), 1.01 (0.72-1.42), and 1.27 (0.88-1.82) (p for trend 0.206) for 'macho' food pattern; and 1, 0.82 (0.57-1.17), 0.86 (0.59-1.24), and 1.00 (0.68-1.46) (p for trend 0.876) for 'sweet tooth' pattern. Further excluding participants who reported having changed their

Table 3 Odds ratio for metabolic syndrome according to quartiles of intake of vegetable rich food pattern^a at baseline

| | Q1 | Q2 | Q3 | Q4 | P for trend |
|--|----|-----------------|-----------------|-----------------|-------------|
| Men | | | | | |
| IDF definition MetS | 1 | 2.09(1.15-3.81) | 1.76(0.95-3.28) | 2.01(1.11-3.66) | 0.056 |
| Modified ATP III MetS | 1 | 1.62(0.99-2.68) | 1.40(0.83-2.36) | 1.68(1.02-2.79) | 0.084 |
| Women | | | | | |
| IDF definition MetS | 1 | 1.38(0.92-2.08) | 1.20(0.79-1.82) | 1.76(1.16-2.65) | 0.019 |
| Modified ATP III MetS | 1 | 1.41(0.95-2.10) | 1.24(0.82-1.86) | 1.75(1.17-2.62) | 0.017 |
| Both genders^b | | | | | |
| IDF definition MetS | 1 | 1.50(1.08-2.09) | 1.25(0.89-1.76) | 1.63(1.17-2.26) | 0.017 |
| Modified ATP III MetS | 1 | 1.43(1.05-1.94) | 1.21(0.88-1.66) | 1.54(1.13-2.10) | 0.022 |
| Abnormal FPG | 1 | 1.17(0.82-1.67) | 0.87(0.59-1.27) | 1.09(0.75-1.57) | 0.964 |
| Central obesity | 1 | 1.48(1.15-1.90) | 1.43(1.11-1.85) | 1.76(1.37-2.27) | <0.001 |
| High triglycerides | 1 | 1.05(0.77-1.43) | 0.91(0.66-1.25) | 0.79(0.57-1.10) | 0.115 |
| Low HDL | 1 | 0.98(0.78-1.24) | 1.04(0.83-1.32) | 1.01(0.79-1.28) | 0.815 |
| High blood pressure | 1 | 1.17(0.92-1.48) | 1.24(0.97-1.58) | 1.33(1.04-1.70) | 0.022 |
| Glucose | | | | | |
| Glucose>7.0 and known diabetes | 1 | 3.04(1.49-6.21) | 2.24(1.05-4.76) | 3.44(1.68-7.02) | 0.004 |
| Glucose>6.1 and know diabetes | 1 | 2.10(1.30-3.42) | 1.34(0.79-2.28) | 2.21(1.35-3.62) | 0.016 |
| Glucose 5.6-6.1 excluding known diabetes | 1 | 0.60(0.35-1.04) | 0.59(0.34-1.01) | 0.41(0.22-0.76) | 0.004 |

a Odds ratio adjusted for age, gender, 'Traditional' food pattern, 'Macho' food pattern, and 'Sweet tooth' pattern, smoking (yes/no), and drinking (yes/no), education, occupation (manual/non-manual), income (low, medium, and high), active commuting (no, 1-30 minutes/day, >30 minutes/day), leisure time physical activity (no, 1-30 minutes/day, >30 minutes/day).

b Adjusted for gender in addition to other variables

diet to control blood glucose or blood lipids or who wanted to lose weight did not change the above associations (data not shown).

Table 4 shows the OR for incident metabolic syndrome by 'vegetable rich' food pattern comparing results from 2002 and 2007. A clear positive association between 'vegetable rich' food pattern and incident metabolic syndrome was observed among women but not men. Adjusting for energy intake attenuated the association.

Discussion

In this study, we found a positive association between a vegetable rich food pattern and metabolic syndrome among women both cross-sectionally within the 2002 survey and longitudinally relating this food pattern of 2002 to

metabolic syndrome in 2007. At baseline a positive association between this food pattern and metabolic syndrome was found among men. The 'vegetable rich' food pattern was also positively associated with high intake of energy, and intake of vegetables was highly associated with increased intake of vegetable oil.

The 'vegetable rich' food pattern identified by factor analysis was characterized by high intake of fruits, vegetables, whole grains, animal foods, and milk. The highest intake of 'vegetable rich' pattern corresponded to an intake of vegetables of around 300 g/day, which was about 100 g/day more than the lowest intake group. This intake level meets the WHO recommendation on intake of fruits and vegetables (29).

Table 4 Odds ratio for incident metabolic syndrome between 2002-2007 according to quartiles of intake of vegetable rich food pattern ^a

| | Q1 | Q2 | Q3 | Q4 | P for trend |
|---|------|-----------------|-----------------|-----------------|-------------|
| Both genders | | | | | |
| N | 305 | 279 | 198 | 174 | |
| No. of MetS new cases by IDF definition | 37 | 37 | 35 | 32 | |
| Rate | 12.1 | 13.3 | 17.7 | 18.4 | |
| OR (95%CI) | | | | | |
| Model 1 ^a | 1.00 | 1.15(0.69-1.91) | 1.58(0.94-2.68) | 1.70(0.97-2.95) | 0.030 |
| Model 1+ energy intake | 1.00 | 1.08(0.65-1.80) | 1.51(0.89-2.55) | 1.49(0.85-2.63) | 0.083 |
| Men | | | | | |
| N | 144 | 128 | 82 | 78 | |
| No. of MetS new cases by IDF definition | 13 | 6 | 4 | 7 | |
| Rate | 9.0 | 4.7 | 4.9 | 9.0 | |
| OR (95%CI) | | | | | |
| Model 1 ^a | 1.00 | 0.49(0.17-1.36) | 0.64(0.19-2.14) | 1.19(0.39-3.64) | 0.917 |
| Model 1+ energy intake | 1.00 | 0.51(0.18-1.43) | 0.63(0.18-2.15) | 1.15(0.37-3.53) | 0.975 |
| Women | | | | | |
| N | 161 | 151 | 116 | 96 | |
| No. of MetS new cases by IDF definition | 24 | 31 | 31 | 25 | |
| Rate | 14.9 | 20.5 | 26.7 | 26.0 | |
| OR (95%CI) | | | | | |
| Model 1 ^a | 1.00 | 1.58(0.86-2.91) | 2.39(1.27-4.47) | 2.12(1.09-4.14) | 0.009 |
| Model 1+ energy intake | 1.00 | 1.43(0.77-2.65) | 2.24(1.19-4.20) | 1.83(0.92-3.64) | 0.028 |

^a Odds ratio adjusted for age, gender, smoking (yes/no), and drinking (yes/no), education, occupation (manual/non-manual), income (low, medium, and high), active commuting (no, 1-30 minutes/day, >30 minutes/day), leisure time physical activity (no, 1-30 minutes/day, >30 minutes/day).

Food weighing plus consecutive individual 3 day food records were used in the present study to assess nutrient intake. Therefore, the method provides a more accurate estimate of individual intake than 24 h food records over one day only.

A positive association between intake of 'vegetable rich' food pattern and intake of energy was found. This association was opposite to what has been found in studies from Western countries (16, 30, 31) and this is the first study to report such association. In general, individuals in the highest quartile of 'vegetable rich' pattern consumed about 200 kcal/day more than the lowest group. In some groups this difference reached 360 kcal/day. Disparity in vegetable oil intake explained part of this difference. Although the mean energy percentage from fat was about 31% which is close to the WHO recommendation of 30% (29), more than half of the sample exceeded this figure in all Vegetable rich food pattern groups. The fact that we found no differences in energy percentage from fat across quartiles of the healthy pattern may suggest that the total energy intake is the most important factor explaining the association.

The average intake of vegetable oil in China was 33g/day in 2002, while this figure was only 22 g/day in 1992 and 18 g/day in 1982 (14). Compared with the national mean, our data showed a higher mean intake of vegetable oil (42 vs 33g/day). This difference could be due to the better economic situation in the region, which is ranked as one of the best in China. Our results showed that the use of animal cooking fat was rare. The high intake of edible fats attracts the concern of health workers and researchers (14, 32). Due to the limitation of the study, we do not have information on saturated fat intake. However, the proportion of saturated fat is probably below 10% of the total energy intake as observed in another study from China (33).

Increased intake of the 'vegetable rich' pattern was found to be positively associated with risk of central obesity in the study. The OR of central obesity for comparing Q4 and Q1 of healthy pattern was 1.76 (95%CI 1.37-2.27). High intake of vegetable rich food was associated with high energy intake, probably due to the high proportion of energy coming from fat, which is known to affect obesity prevalence (34, 35). In our study, a large proportion of the participants had energy intake more than 120% of RNI.

A positive association between vegetable rich food pattern and blood pressure was found. This association could not be explained by intake of sodium or potassium. A negative association between 'vegetable rich' food pattern and intake of sodium was found in women, while a positive association between vegetable rich food pattern and potassium intake was found in men. Vegetable rich food pattern was significantly associated with blood glucose. The directions of this association were different according to different cut-off levels used and needs further study.

The strong association between vegetable rich food pattern and central obesity needs special attention because abdominal adiposity is associated with risk of metabolic syndrome (13), and mortality risk in Chinese population (36, 37). It could be the basis of the association between Vegetable rich food pattern and metabolic syndrome in our sample. In the sample we did not find any association between Vegetable rich food pattern and lipids abnormality.

The benefits of intake of vegetables are well documented and WHO recommends 400-500 grams fruits and vegetables a day (29). Most of the findings on the association between intake of fruits and vegetables and obesity are from Western countries. Literature on the health benefits of intake of vegetables in China is limited. In Shanghai Women's Healthy study, a food pattern characterized by high vegetable intake shows no reduction in mortality, while a fruit-rich diet was related to lower mortality (24). Our results are partly consistent with these findings. Vegetable cooking methods in China differ from those of the Western countries. In China, oil is used for cooking vegetables; the usual method is stir-frying. Eating raw vegetable is not common, thus the intake of vegetables is associated with high intake of energy. In the present study, a positive association between intake of vegetables and vegetable oil was observed. If the nutrition transition in China continues, it may imply that the proportion of total energy coming from fat will continue to increase, leading to even more obesity in the future. A trend of negative association between traditional food pattern and metabolic syndrome was found cross-sectionally. Further research is needed.

The null association between 'vegetable rich' food pattern in 2002 and incident metabolic

syndrome among men in 2007 could be due to the small number of incident cases caused by the small number of participants who finished the follow up. However, in the gender combined multivariate model, there was a significant positive trend between 'vegetable rich' food pattern and metabolic syndrome. The association was attenuated till non-significant after adjusting for energy intake. This suggests that the association could be partly explained by energy intake.

In conclusion, intake of 'vegetable rich' food pattern was associated with metabolic syndrome in Chinese adults. This association can be linked to the high intake of energy due to liberal use of vegetable oil for cooking vegetables. A high vegetable diet may not be protective if the energy/fat content is high.

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