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# Serum leptin concentrations in relation to dietary patterns in Chinese men and women

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## Abstract

*Objective:* The present study aimed to evaluate the independent associations between serum leptin concentration and dietary patterns in a Chinese population.
*Design:* A cross-sectional study.
*Setting:* Data obtained from the 2006 wave of the China Health and Nutrition Survey in Jiangsu Province, China.
*Subjects:* The sample contained 1061 Chinese adults (488 men and 573 women). BMI was calculated as a parameter of obesity. Factor analysis was used to derive dietary patterns. ANCOVA was performed to assess the associations between serum leptin concentration and the dietary patterns.
*Results:* Four dietary patterns were derived: Western, High-wheat, Traditional and Hedonic. The Western pattern (rich in meat, milk and cake) was significantly associated with a higher level of serum leptin in men and women, both in an unadjusted model (both *P* for trend $<0{\cdot}001$) and after adjusting for sex, age, income, total energy intake, physical activity, smoking status and BMI (*P* for trend $=0{\cdot}007$ for men and *P* for trend $<0{\cdot}001$ for women). The other three dietary patterns were not significantly associated with serum leptin after adjustment. Sensitivity analysis showed there was an interaction between age and the Western pattern in relation to leptin level. An interaction also existed between current smoking status and the Western pattern.
*Conclusions:* Serum leptin concentration was positively associated with the Western dietary pattern in a Chinese population independent of BMI, energy intake and other factors.

**Keywords**
Leptin
Dietary patterns
Factor analysis
China

Leptin is a 16 kDa protein hormone encoded by the obese (*ob*) gene and is secreted predominantly by adipocytes. It plays a key role in the regulation of food intake, energy expenditure and body weight[1–3]. Data indicate that leptin is the afferent signal in a negative feedback loop that maintains constancy of adipose tissue mass. A loss of body fat (starvation) leads to a decrease in leptin, which in turn leads to a state of positive energy balance (food intake > energy expenditure). Conversely, an increase in adiposity leads to an increase in leptin level, which results in negative energy balance (food intake < energy expenditure). Leptin acts centrally to decrease food intake and modulate glucose and fat metabolism[3]. In animal studies, leptin is found to play a role in Fe homeostasis[4]. People with the same BMI do not have the same risk for developing obesity-related diseases such as type 2 diabetes. So the composition of the diet is expected to be an important explanatory variable for leptin levels independent of energy balance.

The association between diet or nutrients and leptin has been explored in a few studies[5–11], but the results were inconsistent. Previous studies have found associations between leptin and different diets, including a high-fat (high-energy) diet[12], a fish-rich diet[7], sucrose intake[8], soup and dietary fibre intake[10] and a high-legume, low-glycaemic-index diet[11]. However several other studies[5,13] reported no impact of diet on leptin level. Inconsistent findings may be explained in part by limitations in the single nutrient/food approach in traditional nutritional epidemiological research.

In light of the complexity of diets consumed by free-living individuals, there is increasing interest in assessment of the overall diet by dietary pattern analysis[14,15]. However, to our knowledge, there are only two studies[16,17] which have examined the relationship between diet pattern as a whole and leptin level. The study results were inconsistent although both of them

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were performed in the USA. Fung *et al.*[16] reported a significant positive correlation between the Western pattern and leptin, whereas Ganji *et al.*[17] found leptin was not related to dietary patterns in a representative sample of the US population.

The relationship between leptin and dietary patterns in other populations remains largely unknown. Based on the data of the 2006 wave of the China Health and Nutrition Survey (CHNS) in Jiangsu Province, we aimed to examine whether serum leptin concentration was associated with dietary patterns, independently of BMI and other confounders, in a Chinese population.

## Participants and methods

### *Participants*

Data used in the present study were derived from the 2006 wave of the CHNS in Jiangsu. The CHNS is a nationwide, ongoing, open cohort designed to evaluate the effects of health, nutrition and family planning on population health and nutritional status under economic transformation in China, initiated in 1989. More detailed information was described elsewhere[18]. Jiangsu was the only province that collected blood samples in that project in the 2006 wave. The study sample was drawn from six areas (Suzhou, Yangzhou, Shuyang, Taixing, Haimen and Jinhu) by a multistage random cluster process. In total, sixteen villages and townships within the counties and eight urban and suburban neighbourhoods within the cities were selected randomly. The study protocol in the province was approved by the review board in the Jiangsu Provincial Center for Disease Control and Prevention. All participants provided written informed consent. The response rate was 91·3 %.

The full sample size of our study was 1422. We excluded participants with any of the following conditions: (i) age < 18 years (*n* 81); (ii) no information on dietary intake and leptin (*n* 185); (iii) implausible daily energy intake (<2092 kJ/d or >16 736 kJ/d (<500 kcal/d or >4000 kcal/d) for women; <2092 kJ/d or >17 573 kJ/d (<500 kcal/d or >4200 kcal/d) for men) based on the Chinese context[19] (*n* 46); (iv) known diabetes (*n* 40); and (v) pregnant (*n* 3) and lactating (*n* 6) women. Consequently, 1061 participants (488 men and 573 women) remained for analysis.

### *Dietary assessment*

A validated semi-quantitative FFQ[20] was used to collect dietary intake information by a face-to-face interview, which was only used in Jiangsu in the 2006 CHNS. Participants were asked to recall their usual frequency and quantity of intake of thirty-three food groups and beverages during the previous year with a series of detailed questions. Intake of each food item was calculated by multiplying the reported frequency of the food by estimated portion size of the food per time. Intakes of foods were converted into g/d for further analysis. Total energy and nutrients were computed by using the Chinese Food Composition Table[21].

### *Blood sampling and analysis*

Blood was collected by venepuncture from participants after an overnight fast. The fasting status was verbally confirmed by participants before the blood sampling. All blood samples were collected in three vacuum tubes and processed within 3 h. All specimens were then shipped to the Jiangsu Provincial Center for Disease Control and Prevention and were stored at −70° C for later laboratory testing. Serum leptin concentrations were measured using the Linco Human Leptin ELISA Kit (Linco Research, St. Charles, MO, USA), the sensitivity of which was 0·5–100 ng/ml. The average intra- and inter-assay CV were 4·7 % and 7·2 %, respectively.

### *Other parameters*

Anthropometric data were measured by trained health workers following standard protocols. Weight in light clothing and without shoes was measured to the nearest 0·1 kg and height was measured to the nearest 0·1 cm. BMI was calculated as weight (kg)/height squared ($m^2$). Physical activities including domestic, occupational, transportation and leisure-time physical activity were assessed in terms of metabolic equivalent (MET) hours per week (MET-h/week) to account for both intensity and time spent on activities[22]. Income was estimated by family annual income per capita. It was categorized as low (<5000 Yuan), medium (5000–10 000 Yuan) and high (>10 000 Yuan). Current smoking status was classified as a dichotomous variable (yes/no).

### *Statistical analysis*

Dietary patterns were identified by factor analysis using a principal component analysis method. Cheese was excluded due to no consumption by our study participants. Some food items were aggregated into food groups, mainly according to macronutrient composition and culinary use: i.e. tofu was a proportional aggregation of tofu, dried bean curd and soyabeans according to protein content; pickled vegetables were the total of preserved vegetables, pickled vegetables, *kimchi* and Chinese sauerkraut; beverages represented juice and other soft drinks. As a result, twenty-six foods/food groups were entered into the final analysis.

The PROC FACTOR procedure in SAS was used to perform the analysis. The number of factors retained was determined by consideration of the eigenvalue (>1·25), scree plot, factor interpretability and the variance explained (>5 %) by each factor. The factors retained were then rotated with an orthogonal rotation (‘Varimax’ option in SAS) to improve interpretability and minimize the correlation between the factors[23]. From these analyses, a four-factor solution was selected. A factor score was then calculated for each participant for each of the four factors, as the sum of the products of the factor loading coefficient and standardized daily intake of each food/food group associated with that pattern. The participants were then categorized into quartiles of factor score for each dietary pattern (quartiles 1 and 4 represented low and high adherence, respectively, to each pattern). Labelling of the factors was primarily descriptive and based on our interpretation of the pattern structures.

Because the distribution of leptin was highly skewed to the right, natural logarithmic transformation was used in all analyses. The resulting geometric means are therefore presented. ANCOVA was used to determine if serum leptin concentration differed across quartiles of different dietary patterns after adjusting for sex, age, income, total energy intake, physical activity, smoking status and BMI. Associations between serum leptin concentration (log-transformed) and the four dietary pattern scores as continuous variables were also assessed by multivariate regression analysis and partial Pearson correlation analysis. In addition, sensitivity analysis was further performed between leptin and the Western dietary pattern after controlling for potential confounding effects by other factors. A $P$ value less than 0·05 was considered statistically significant. All statistical analyses were conducted using the statistical software package SAS version 8·1.

## Results

Table 1 shows the basic characteristics of our study sample. Of the 1061 participants, 46·0 % were men. The mean age was 50·9 (SD 14·7) years in men and 48·8 (SD 14·1) years in women. There was no difference in BMI, physical activity and income between men and women. Smokers accounted for 53·5 % in men and 2·1 % in women. Men had a higher intake of total energy and a much lower leptin level than women ($P < 0·001$).

Four dietary patterns were identified by factor analysis. Rotated factor loadings and the label for each pattern are shown in Table 2. These patterns were as follows:

1. Factor 1 (Western), characterized by animal foods, milk, cake, etc.
2. Factor 2 (High-wheat), which had higher loadings for wheat, whole grains and beef/lamb and had negative loadings for rice, fresh vegetables and aquatic products.
3. Factor 3 (Traditional), which had higher loadings for eggs, tofu, organ meat, pickled vegetables, etc.
4. Factor 4 (Hedonic), which had higher loadings for beer, wine, alcohol, tubers and fresh vegetables, etc.

In total the four factors explained 29·8 % of the variance in dietary intake (9·4 %, 8·5 %, 6·4 % and 5·5 %, respectively).

Information about the patterns in relation to energy and nutrient intakes was described in detail in another article[24]. In brief, the Western, Traditional and Hedonic patterns were positively associated, while the High-wheat pattern was negatively associated, with total energy intake. The intakes of protein, fat, Zn, Se and vitamin C increased, while those of carbohydrate, dietary fibre and Mg decreased, across increasing quartile of the Western pattern. Intakes of all aforementioned nutrients (except fat, vitamin C and Zn) increased across quartiles of the High-wheat pattern. All aforementioned nutrients were positively associated with the Traditional pattern except vitamin C. The Hedonic pattern was positively related to intakes of all macronutrients and micronutrients mentioned above, except dietary fibre.

The geometric mean serum leptin concentrations across quartiles of each dietary pattern in the study participants are presented in Table 3. The Western pattern

**Table 1** Sample characteristics of 1061 Chinese men and women in the 2006 China Health and Nutrition Survey in Jiangsu Province, China

| | Men | | Women | | All | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| Participants (*n*) | 488 | | 573 | | 1061 | |
| Leptin (ng/ml)* | 1·4 | 0·07 | 8·2 | 0·04 | 3·7 | 0·05 |
| Age (years) | 50·9 | 14·7 | 48·8 | 14·1 | 49·6 | 14·4 |
| BMI (kg/m$^2$) | 23·4 | 3·5 | 23·4 | 3·7 | 23·4 | 3·6 |
| Physical activity (MET-h/week) | 167·1 | 121·5 | 165·5 | 114·5 | 166·2 | 117·6 |
| Total energy intake (kJ/d) | 10 478 | 3032 | 8951 | 2840 | 9653 | 3026 |
| Total energy intake (kcal/d) | 2504 | 725 | 2139 | 679 | 2307 | 723 |
| Smoking (%)† | 53·5 | | 2·1 | | 25·8 | |
| Annual income (Yuan per capita) (%) | | | | | | |
| Low (<5000) | 34·0 | | 36·8 | | 35·5 | |
| Medium (5000–10 000) | 36·1 | | 34·7 | | 35·4 | |
| High (>10 000) | 29·9 | | 28·5 | | 29·1 | |

MET, metabolic equivalent.
Values are presented as mean and standard deviation unless otherwise indicated.
*Geometric mean and standard error.
†Based on 482 men and 564 women.

**Table 2** Rotated factor loadings for four dietary patterns among 1061 Chinese men and women in the 2006 China Health and Nutrition Survey in Jiangsu Province, China

| Factor 1: Western | | Factor 2: High-wheat | | Factor 3: Traditional | | Factor 4: Hedonic | |
|---|---|---|---|---|---|---|---|
| Food/food group | Factor loading | Food/food group | Factor loading | Food/food group | Factor loading | Food/food group | Factor loading |
| Milk | 0·52 | Whole grains | 0·75 | Eggs | 0·55 | Beer | 0·60 |
| Pork | 0·51 | Wheat | 0·75 | Tofu | 0·52 | Wine | 0·41 |
| fruits | 0·50 | Beef/lamb | 0·24 | Aquatic products | 0·49 | Low alcohol | 0·39 |
| Cake | 0·50 | Aquatic products | −0·32 | Poultry | 0·45 | Tubers | 0·31 |
| Soyabean milk | 0·49 | Fresh vegetables | −0·43 | Organ meat | 0·40 | Fresh vegetables | 0·29 |
| Fried wheat | 0·44 | Rice | −0·68 | Pickled vegetables | 0·33 | Fried wheat | 0·28 |
| Poultry | 0·44 | | | Nuts | 0·24 | Beverage | 0·28 |
| Yoghurt | 0·44 | | | High alcohol | 0·22 | Pork | 0·27 |
| Beverages | 0·38 | | | Fruits | 0·22 | High alcohol | 0·27 |
| Aquatic products | 0·37 | | | Milk powder | 0·21 | Cake | −0·21 |
| Tubers | 0·29 | | | Beverage | −0·22 | Milk | −0·24 |
| Beef/lamb | 0·27 | | | | | | |
| Organ meat | 0·23 | | | | | | |

Foods/ food groups with absolute values of factor loadings <0·20 are excluded from the table for simplicity.

**Table 3** Serum leptin concentration (ng/ml) according to quartile (Q) of each dietary pattern in 1061 Chinese men and women in the 2006 China Health and Nutrition Survey in Jiangsu Province, China

| | Unadjusted | | | | | | Adjusted* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Men | | Women | | All | | Men | | Women | | All | |
| Dietary pattern | Mean† | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| Western | | | | | | | | | | | | |
| Q1 | 0·8 | 0·1 | 5·4 | 0·1 | 2·0 | 0·1 | 1·2 | 0·1 | 5·7 | 0·1 | 2·7 | 0·1 |
| Q2 | 1·6 | 0·1 | 8·8 | 0·1 | 4·5 | 0·1 | 1·7 | 0·1 | 8·8 | 0·1 | 4·3 | 0·1 |
| Q3 | 2·0 | 0·1 | 9·2 | 0·1 | 4·5 | 0·1 | 1·4 | 0·1 | 8·7 | 0·1 | 4·0 | 0·1 |
| Q4 | 2·2 | 0·1 | 11·0 | 0·1 | 5·0 | 0·1 | 1·8 | 0·1 | 10·7 | 0·1 | 4·8 | 0·1 |
| *P* for trend | <0·001 | | <0·001 | | <0·001 | | 0·007 | | <0·001 | | <0·001 | |
| High-wheat | | | | | | | | | | | | |
| Q1 | 1·3 | 0·1 | 6·8 | 0·1 | 2·9 | 0·1 | 1·7 | 0·1 | 7·1 | 0·1 | 3·8 | 0·1 |
| Q2 | 1·8 | 0·1 | 8·9 | 0·1 | 4·1 | 0·1 | 1·5 | 0·1 | 9·0 | 0·1 | 4·0 | 0·1 |
| Q3 | 2·0 | 0·1 | 9·7 | 0·1 | 4·9 | 0·1 | 1·5 | 0·1 | 9·6 | 0·1 | 4·1 | 0·1 |
| Q4 | 1·1 | 0·1 | 8·2 | 0·1 | 3·5 | 0·1 | 1·3 | 0·1 | 7·9 | 0·1 | 3·5 | 0·1 |
| *P* for trend | 0·005 | | 0·052 | | 0·001 | | 0·505 | | 0·081 | | 0·344 | |
| Traditional | | | | | | | | | | | | |
| Q1 | 1·5 | 0·2 | 7·8 | 0·1 | 4·3 | 0·1 | 1·4 | 0·1 | 8·3 | 0·1 | 3·7 | 0·1 |
| Q2 | 1·2 | 0·1 | 9·6 | 0·1 | 3·7 | 0·1 | 1·5 | 0·1 | 8·6 | 0·1 | 3·7 | 0·1 |
| Q3 | 1·7 | 0·1 | 8·8 | 0·1 | 3·9 | 0·1 | 1·6 | 0·1 | 8·9 | 0·1 | 4·2 | 0·1 |
| Q4 | 1·5 | 0·1 | 7·4 | 0·1 | 3·3 | 0·1 | 1·5 | 0·1 | 7·6 | 0·1 | 3·7 | 0·1 |
| *P* for trend | 0·446 | | 0·197 | | 0·290 | | 0·859 | | 0·550 | | 0·411 | |
| Hedonic | | | | | | | | | | | | |
| Q1 | 3·2 | 0·2 | 9·8 | 0·1 | 6·8 | 0·1 | 2·0 | 0·1 | 8·7 | 0·1 | 4·4 | 0·1 |
| Q2 | 1·5 | 0·2 | 7·7 | 0·1 | 4·5 | 0·1 | 1·6 | 0·1 | 8·3 | 0·1 | 3·9 | 0·1 |
| Q3 | 1·1 | 0·1 | 7·8 | 0·1 | 3·2 | 0·1 | 1·3 | 0·1 | 8·0 | 0·1 | 3·6 | 0·1 |
| Q4 | 1·3 | 0·1 | 7·7 | 0·1 | 2·0 | 0·1 | 1·4 | 0·1 | 8·1 | 0·1 | 3·6 | 0·1 |
| *P* for trend | <0·001 | | 0·144 | | <0·001 | | 0·060 | | 0·858 | | 0·137 | |

MET, metabolic equivalent.
*ANCOVA, adjusted for sex (only adjusted in all participants), age, income (low/medium/high), total energy intake (kJ/d, kcal/d), physical activity (MET-h/week), smoking status (yes/no) and BMI.
†Geometric mean.

was significantly associated with higher level of serum leptin in men and women, both in the unadjusted model (both *P* for trend <0·001) and after adjusting for sex, age, income, total energy intake, physical activity, smoking status and BMI (*P* for trend = 0·007 for men and *P* for trend <0·001 for women). The unadjusted serum leptin concentration differed significantly across the High-wheat pattern (positive association, *P* for trend = 0·005 for men and *P* for trend = 0·001 for all participants) and the Hedonic pattern (negative association, both *P* for trend <0·001) in separate analyses for men and all participants. However, such associations were no longer significant after adjustment for potential confounders. No association was found between the Traditional pattern and serum leptin.

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**Table 4** Stratified linear regression analysis between leptin level and the Western dietary pattern among 1061 Chinese men and women in the 2006 China Health and Nutrition Survey in Jiangsu Province, China

| | $\beta$ | SE | *P* value | *P* for interaction |
|---|---|---|---|---|
| Gender | | | | |
| Men (*n* 488) | 0·153 | 0·053 | 0·004 | 0·356 |
| Women (*n* 573) | 0·180 | 0·042 | <0·001 | |
| Age (years) | | | | |
| ≤40 (*n* 306) | 0·100 | 0·057 | 0·079 | 0·005 |
| >40 (*n* 755) | 0·204 | 0·044 | <0·001 | |
| BMI (kg/m$^2$) | | | | |
| <24 (*n* 611) | 0·180 | 0·054 | 0·001 | 0·803 |
| ≥24 (*n* 450) | 0·151 | 0·047 | 0·001 | |
| Current smoking status | | | | |
| No (*n* 776) | 0·143 | 0·039 | <0·001 | 0·010 |
| Yes (*n* 270) | 0·277 | 0·072 | <0·001 | |
| Total energy intake (kJ/d) | | | | |
| <9853 (*n* 551) | 0·127 | 0·052 | 0·015 | 0·555 |
| ≥9853 (*n* 510) | 0·170 | 0·046 | <0·001 | |
| Total energy intake (kcal/d) | | | | |
| <2355 (*n* 551) | 0·127 | 0·052 | 0·015 | 0·555 |
| ≥2355 (*n* 510) | 0·170 | 0·046 | <0·001 | |
| Physical activity (MET-h/week) | | | | |
| <147·3 (*n* 562) | 0·122 | 0·043 | 0·005 | 0·179 |
| ≥147·3 (*n* 499) | 0·239 | 0·054 | <0·001 | |

MET, metabolic equivalent.
Analysis was performed on log-transformed leptin concentration due to non-normality of the distribution. Total energy intake and physical activity level were dichotomized by their medians, respectively.
The models were adjusted for sex, age, income (low/medium/high), smoking status (yes/no), BMI, total energy intake (kJ/d, kcal/d) and physical activity (MET-h/week) simultaneously.

Further, serum leptin concentration was significantly related to the Western pattern as a continuous variable in men ($\beta = 0{\cdot}153$, $P = 0{\cdot}004$), women ($\beta = 0{\cdot}180$, $P < 0{\cdot}001$) and all participants ($\beta = 0{\cdot}170$, $P < 0{\cdot}001$) by multivariate regression analysis. In addition, partial correlation analysis also showed that the Western pattern was positively correlated with log-transformed leptin ($r = 0{\cdot}141$, $P = 0{\cdot}004$ for men and $r = 0{\cdot}188$, $P < 0{\cdot}001$ for women) after adjusting for all other potential confounders (data not shown).

Moreover, a sensitivity analysis was done by stratifying the participants into different groups and examining the difference in the associations between leptin level and the Western dietary pattern. The results were based on linear regression analysis on different strata. It showed there was an interaction between age and the Western pattern. The association between the Western pattern and leptin was stronger among persons whose age was >40 years than among their younger counterparts ($\beta$ coefficient: 0·204 *v.* 0·100, *P* for interaction = 0·005). Also, there was an interaction between current smoking status and the Western pattern. The association between the Western pattern and leptin was much stronger among smokers than among non-smokers ($\beta$ coefficient: 0·277 for smokers *v.* 0·143 for non-smokers, *P* for interaction = 0·010). No interaction was found between dietary patterns and gender, BMI, total energy intake and physical activity (Table 4).

## Discussion

Using the data of the 2006 wave of the CHNS in Jiangsu Province, we derived four dietary patterns in our population by factor analysis: Western, High-wheat, Traditional and Hedonic. Further, we found that serum leptin concentration was significantly and positively associated with the Western pattern in both Chinese men and women independently of BMI, energy intake and other factors, while it was not associated with the other three dietary patterns.

The Western pattern derived in the present study is somewhat similar to the 'macho' pattern identified from a different study sample in the same province but with very low absolute value of loadings of alcohol[25]. Moreover, our Western pattern is also largely similar to the 'Western pattern' observed in other studies using factor analysis[15,16,23,26], characterized by higher intakes of animal food, high-fat dairy products, cake, sugared beverages and fried wheat.

A significant positive association between leptin and the Western pattern found in our study is quite similar to Fung *et al.*'s observations[16] among white US men. However, it is inconsistent with another study done by Ganji *et al.*, who found leptin was not related to dietary patterns in a representative sample of the US population[17]. Different outcomes may result from different sample characteristics (sex, age, ethnicity and other demographics), cultural and dietary habits, and also from different potential confounders adjusted.

A positive association between leptin and the Western pattern in our study was not unexpected. It may be explained by some unhealthy and healthy components in the Western pattern. These may include higher intakes of fat and energy, and lower intake of dietary fibre. Cooling *et al.* observed that participants consuming a high-fat (high-energy) diet had significantly higher concentrations of plasma leptin than participants consuming a low-fat diet[12]. Wang *et al.* reported that plasma leptin levels were significantly elevated in the saturated fat group compared with low-fat controls[27]. Dietary fibre intake negatively correlated with plasma leptin concentration in Japanese adults[10]. In addition, a higher Western pattern score was also correlated to less physical activity in our study (data not shown). Physical activity may have too remarkable an impact on serum leptin to be eliminated by adjustment in the model. It is generally the main way for a person's energy expenditure, which indirectly regulates leptin[3,28].

Interaction between age, current smoking status and the Western pattern was observed in our study. The result that the association was stronger among the middle-aged and elderly may be explained by the possibility that their regulation function of leptin is relatively weaker than that of young people. The association between the Western pattern and leptin was much stronger among smokers than among non-smokers. This may be due to the fact that smoking was independently and inversely associated with serum leptin concentration in the present study. Smokers had a lower level of leptin than non-smokers, which may increase the sensitivity of leptin response to the Western pattern. Underlying mechanisms concerning such a hypothesis still need further research. In China, smoking is inversely related to general obesity[29].

Our study results indicate that dietary patterns are independently associated with leptin levels, which may potentially regulate the risk of developing obesity-related diseases such as type 2 diabetes and CVD among the population. The use of dietary pattern analysis for exploring the associations with leptin has several advantages over the single nutrient or food approach. Interactions and intercorrelations between nutrients as well as small effects from single nutrients may be detected. It closely links to tangible dietary advice[15]. The present study is the first to report such results in a Chinese population, to our knowledge. The findings may be more reliable since we adjusted for potential confounders in the model. However, we cannot infer a causal relationship by using observed association. 'Reverse causation' or other possibilities may exist due to the cross-sectional nature of our study.

In conclusion, we found that serum leptin concentration was associated with the Western dietary pattern in Chinese men and women, independently of BMI, energy intake and other factors. More studies are needed to figure out a clearer linkage between leptin and dietary patterns in different populations.

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