Three plant- and animal-based dietary patterns and their relationship to serum uric acid levels

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Research Article

Keywords: Plant-based diet, animal-based diet, dietary pattern, serum uric acid, hyperuricemia

Posted Date: May 22nd, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2950411/v1

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Abstract

Background

Dietary patterns play an important role in the development of hyperuricemia and gout, but evidence for the association between different kinds of plant-based and animal-based dietary patterns and individual serum uric acid levels is scarce and inconsistent.

Methods

We analyzed data from the sixth wave of the China Health and Nutrition Survey. The plant-based diet of 7,806 participants was determined using three consecutive 24-hour dietary recalls, and latent profile analysis was used to identify dietary patterns among participants. Serum uric acid levels were analyzed using the enzymatic colorimetric method. The association between intakes of different types of dietary pattern and individual serum uric acid levels was analyzed using linear regression analysis, after adjusting for confounding variables.

Results

We identified three types of plant-based dietary patterns, namely, low tuber starches and vegetable plant-based diet (LTVP), high cereal, tuber starches and vegetable plant-based diet (HCTVP), and high legume and fruit plant-based diet (HLFP). We also identified three types of animal-based dietary patterns, namely, high milk and egg animal-based diet (HMiEA), low egg and fish animal-based diet, and high meat and fish animal-based diet (HMeFA). Significant coefficients for participant serum uric acid levels were observed for the HCTVP diet ($\beta = -0.022, P = 0.031$) and HMeFA diet ($\beta = 0.061, P < 0.001$). The median intake of foods in the HCTVP diet was as follows: cereals and cereal products, 444.83 g/d; tubers and starch products, 166.67 g/d; dried legumes and legume products, 8.33 g/d; vegetables and vegetable products, 333.33 g/d; and fruits and fruit products, 0 g/d. The median intake of foods in the HMeFA diet was as follows: meat and meat products, 73.33 g/d; poultry and poultry products, 0 g/d; milk and milk products, 0 g/d; eggs and egg products, 26.67 g/d; and fish, shellfish, and mollusks, 180.00 g/d.

Conclusion

We showed that individual serum uric acid levels (1) might decrease under the plant-based HCTVP diet, (2) might increase under the animal-based HMeFA diet, (3) might not decrease under the plant-based HLFP diet, and (4) might not increase under the animal-based HMiEA diet. Further studies are needed to confirm these associations.

Background
Serum uric acid has been found to be associated with the incidence and progression of hyperuricemia, gout, chronic kidney disease, hypertension, cardiovascular events, diabetes, rheumatoid arthritis, and obesity [1–7]. Individual serum uric acid levels are related to dietary purine consumption and uric acid excretion in urine. Uric acid is a product of exogenous and endogenous purine nucleic acid and metabolism of adenine and guanine (8). In humans with normal excretion function, individual serum uric acid levels are associated with dietary adenine and guanine consumption. Moreover, serum uric acid levels are related to the activity of deaminase, nucleotidase, phosphorylase, xanthine oxidase, and guanine deaminase which are involved in the metabolism of adenine and guanine [8]. The activity of these enzymes is also associated with diet. Thus, it is important to better understand the relationship between diet and serum uric acid levels.

In particular, dietary intervention is now recognized as a possible modifiable factor in preventing hyperuricemia [9]. According to previous studies, high intakes of protein, lipids and fructose and low intakes of glucose are most common in patients with hyperuricemia [10–16]. After adjustment for demographic characteristics, a positive association has been found between carbohydrate and lipid intake and serum uric acid levels [17]. Additionally, it has been reported that Vitamin D deficiency increases the risk of hyperuricemia, with a pooled odds ratio of 1.496 (95% confidence interval − 1.141, 1.963) [18]. Some previous studies have shown that plant-based foods like legumes and fruits are negatively correlated with individual serum uric acid levels, whereas animal-based foods like meats, animal giblets, and fish are positively correlated with the serum uric acid level [19, 20]. However, because humans do not consume single plant-based foods, it is necessary to understand the role of multiple classes of plant-based and animal-based foods in serum uric acid levels.

Understanding an individual’s diet is essential to lowering their serum uric acid levels [21]. However, preliminary studies have tended to focus on a single or several plant-based or animal-based foods. Therefore, developing a holistic approach to integrate classes of foods is needed. In contrast to these single-food studies, dietary patterns can reflect the overall effect of a plant-based or animal-based diet. To the best of our knowledge, there are only a few studies investigating the relationship of different types of plant-based or animal-based dietary patterns with individual serum uric acid levels, with limited comparisons between these dietary patterns. The objective of this study was to examine the relationship between different plant- or animal-based dietary patterns and individual serum uric acid levels. This research will help in designing a targeted dietary pattern to regulate serum uric acid levels among individual patients.

**Materials and methods**

**Study population**

Study participants were from the sixth wave of the China Health and Nutrition Survey in which blood and urine samples were tested for the first time. A detailed description of the study protocol is provided in previous publications [22, 23]. We excluded participants with incomplete data (including demographic
characteristics, diet, biomarkers, and lifestyle characteristics such as smoking and physical activity), as well as those aged below 18 years [24].

The survey was approved by the ethics committee of the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention.

**Dietary consumption assessment**

Three consecutive days of 24-hour dietary recalls were used to collect information regarding participants’ food consumption. Then, we identified five types of plant-based foods and five types of animal-based foods with intakes of > 10 g per day and calculated the nutrients in each food, according to the Chinese Food Composition Tables (Table 1). For each type of food, two parts were calculated. One part was unprocessed food (such as cereals), and the other part was processed food (such as cereal products).

**Serum uric acid level assessment**

Fasting blood samples were taken from participants, stored at −86°C, and then analyzed under stringent quality control in the national central lab. The serum uric acid levels were analyzed using the enzymatic colorimetric method. Details of the biomarker analysis methods and quality control standards are presented in a previous publication (*Manual for Specimen Collection and Processing*) [25].

**Measurements of covariates**

The other variables in the study were demographic characteristics including age, sex, marital status, education level, registered residence type, body mass index (BMI) and lifestyle factors including smoking and physical activity. We classified smoking status into as none, ever smoker, and current smoker. Physical activity was calculated for all activities within 1 week, and the metabolic equivalent of each task per week was calculated [26, 27]. Sedentary time was calculated for all sitting time within 1 week. We considered four types of physical activity in the study: domestic activities, occupational activities, transportation activities, and leisure activities [28].

**Statistical analysis**

The variables are presented as mean (standard deviation), range, or median (25th percentile, 75th percentile) for continuous variables, and the proportions of the total for categorical variables. We used the t-test, F test, and \( \chi^2 \) test to determine differences in the distribution of serum uric acid levels according to demographic characteristics. The Mann–Whitney U test was used to determine differences in the distribution of foods and nutrient intakes according to dietary patterns. The Bonferroni test was used in post hoc multiple comparisons. We used Pearson or Spearman correlation method to analyze the correlations between variables. Latent profile analysis (LPA) was used to identify the association between dietary patterns and individual serum uric acid levels by subgroup. The details of fit indices of LPA are shown in Tables 2 and 3. Linear regression analyses was used to explore the associations between dietary pattern and serum uric acid levels. Both an unadjusted model and adjusted model were applied in the
analyses. The adjusted model controlled for demographic characteristics and lifestyle characteristics. Significance was based on two-sided tests, and the confidence interval was 95%.

Results

Demographic characteristics

A total of 7,806 participants (4,180 female, 53.54% and 3,626 male, 46.45%) aged 18–94 years with average age 50 (15) years were included in the study. Among all participants, 70.52% were from rural areas, and 88.39% had an education level of high school or below. Participants were from communities with an average urban index of 66.83 (19.40). Participants’ average BMI and physical activity range were 23.36 (3.47) kg/m2 and 0–31,830.00, respectively. The details of food intake, nutrient intake, and serum uric acid levels among participants are shown in Tables 4 and 5.

The correlation of participants’ serum uric acid levels with BMI and urban index were all positive, with correlation coefficients $r = 0.092$ and $r = 0.185$ ($P < 0.001$), respectively. The correlation of participants’ serum uric acid levels with the physical activity was negative, with correlation coefficient $r = -0.023$ ($P = 0.040$). Participants who were older, male, separated, from urban areas, ever smokers, and those with higher education levels had significantly higher serum uric acid levels ($P < 0.01$). See Table 1 for details.

Table 1 Participants’ demographic characteristics and the distribution of serum uric acid levels ($n=7806$)
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N(N%)</th>
<th>Serum uric acid level (mg/mL)</th>
<th>Mean (SD)</th>
<th>t/F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-59 years</td>
<td>5627 (72.08)</td>
<td>5.09 (1.86)</td>
<td></td>
<td>7.131</td>
<td>0.001</td>
</tr>
<tr>
<td>60- years</td>
<td>2179 (27.91)</td>
<td>5.39 (4.56)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>4180 (53.54)</td>
<td>4.48 (1.36)</td>
<td></td>
<td>39.152</td>
<td>0.001</td>
</tr>
<tr>
<td>Male</td>
<td>3626 (46.45)</td>
<td>5.96 (1.89)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marital status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unmarried</td>
<td>445 (5.70)</td>
<td>5.46 (2.31)</td>
<td></td>
<td>4.202</td>
<td>0.002</td>
</tr>
<tr>
<td>Married</td>
<td>6625 (84.87)</td>
<td>5.15 (1.77)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Divorced</td>
<td>79 (1.01)</td>
<td>5.00 (1.48)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Widowed</td>
<td>609 (7.80)</td>
<td>5.18 (1.52)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separated</td>
<td>48 (0.61)</td>
<td>5.64 (1.57)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12.000</td>
</tr>
<tr>
<td>Illiterate/primary</td>
<td>3443 (44.11)</td>
<td>5.06 (1.67)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle school/high school</td>
<td>3457 (44.29)</td>
<td>5.18 (1.75)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Above</td>
<td>906 (11.61)</td>
<td>5.58 (2.27)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Registered resident type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.572</td>
</tr>
<tr>
<td>Urban</td>
<td>2301 (29.48)</td>
<td>5.39 (1.94)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>5505 (70.52)</td>
<td>5.08 (1.71)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>257.677</td>
</tr>
<tr>
<td>None</td>
<td>5400 (69.18)</td>
<td>4.88 (1.70)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ever</td>
<td>255 (3.27)</td>
<td>5.91 (1.62)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>2151 (27.56)</td>
<td>5.83 (1.81)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Latent profiles of dietary patterns**

We examined latent profiles of participants’ plant-based dietary patterns. The LPA model fitting parameters are listed in Table 2. Model fit information for the five different models is listed, ranging from Profile 2 to Profile 5. In terms of the Lo–Mendell–Rubin likelihood ratio (LMRT) and bootstrap likelihood ratio (BLRT), P-values for the Profile 2 and Profile 3 models were both <0.05 (statistically significant).
Profile 3 had lower Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values compared with Profile 2. The entropy in Profile 3 was 0.937 > 0.800. We found that the accuracy of classification was greater than 90.00% [29]. The Profile 3 model was better than the other models in this study.

Table 2 Fit indices for Profile 2 through 5 models

<table>
<thead>
<tr>
<th>Profiles</th>
<th>LogL</th>
<th>AIC</th>
<th>BIC</th>
<th>aBIC</th>
<th>Entropy</th>
<th>LMRT</th>
<th>BLRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>-236220.541</td>
<td>472473.082</td>
<td>472584.485</td>
<td>472533.640</td>
<td>0.954</td>
<td>0.018</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>3</td>
<td>-234906.914</td>
<td>469857.828</td>
<td>470011.006</td>
<td>469941.095</td>
<td>0.935</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>4</td>
<td>-233765.886</td>
<td>467587.773</td>
<td>467782.727</td>
<td>467693.749</td>
<td>0.937</td>
<td>0.435</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>5</td>
<td>-232925.060</td>
<td>465918.121</td>
<td>466154.851</td>
<td>466046.806</td>
<td>0.933</td>
<td>0.115</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

The latent profiles of participants’ animal-based dietary patterns were examined. The LPA model fitting parameters are listed in Table 3. The model fit information for the five different models is listed, ranging from Profile 2 to Profile 5. In terms of the LMRT and BLRT, $P$-values for the Profile 2 and Profile 3 models were both <0.05 (statistically significant). Profile 3 had lower AIC and BIC values compared with Profile 2. The entropy in Profile 3 was 0.968 > 0.800. The accuracy of classification was greater than 90.00% [29]. The Profile 3 model was better than the other models in this study.

Table 3 Fit indices for Profile 2 through 5 models

<table>
<thead>
<tr>
<th>Profiles</th>
<th>LogL</th>
<th>AIC</th>
<th>BIC</th>
<th>aBIC</th>
<th>Entropy</th>
<th>LMRT</th>
<th>BLRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>-201762.416</td>
<td>403556.832</td>
<td>403668.234</td>
<td>403617.389</td>
<td>0.999</td>
<td>0.321</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>3</td>
<td>-200530.816</td>
<td>401105.632</td>
<td>401258.811</td>
<td>401188.899</td>
<td>0.968</td>
<td>0.047</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>4</td>
<td>-199170.235</td>
<td>398396.470</td>
<td>398591.424</td>
<td>398502.445</td>
<td>0.966</td>
<td>0.483</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>5</td>
<td>-198071.225</td>
<td>396210.449</td>
<td>396447.179</td>
<td>396339.134</td>
<td>0.957</td>
<td>0.426</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Food and nutrient intake in different latent profiles of dietary patterns

The food and nutrient intakes for each identified profile of plant-based dietary patterns are shown in Tables 4 and 5.

We found that participants with a Profile 2 dietary pattern had higher intake of cereals and cereal products, tuber starches and products, and vegetables and vegetable products than those with Profiles 1 and 3 ($P<0.001$). Participants with a Profile 3 dietary pattern had higher intakes of dried legumes and legume products, and fruit and fruit products than those with Profiles 1 and 2 ($P<0.001$). Participants with a
Profile 1 dietary pattern had lower intakes of tuber starches and products, and vegetables and vegetable products than those with Profiles 2 and 3 ($P < 0.001$). See Table 4 for details.

Participants with a Profile 1 dietary pattern had the highest intakes of vitamin A and calcium ($P < 0.01$). We also found that Profile 3 had the highest intake of energy, lipids, carbohydrate, protein, dietary fiber, thiamine, riboflavin, niacin, vitamin C, vitamin E, phosphorus, potassium, sodium, magnesium, iron, zinc, selenium, copper, and manganese ($P < 0.01$). Profile 2 had higher intakes of protein, lipids, thiamine, riboflavin, niacin, vitamin C, vitamin E, phosphorus, potassium, sodium, iron, zinc, selenium, copper, and manganese than Profile 1 ($P < 0.01$). See Table 5 for details.

The characteristics of the Profile 1 dietary pattern comprised the lowest intakes of tuber starches and products and of vegetables and vegetable products. The characteristics of the dietary pattern in Profile 2 showed higher intakes of cereals and cereal products, tuber starches and products, and vegetables and vegetable products. The characteristics of the dietary patterns in Profile 3 included the highest intake of dried legumes and legume products and fruit and fruit products. Based on the characteristics of these plant-based dietary pattern profiles, we denoted Profile 1–6 dietary patterns as the low tuber starches and vegetable plant-based diet (LTVP), high cereal, tuber starches, and vegetable plant-based diet (HCTVP), and high legume and fruit plant-based diet (HLFP), respectively. See Table 4 for details.

Table 4 Daily dietary food intakes in latent profiles of plant-based dietary patterns

<table>
<thead>
<tr>
<th>Food intakes</th>
<th>All</th>
<th>Latent Dietary Patterns ($P_{50}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$P_{25}$</td>
<td>$P_{50}$</td>
</tr>
<tr>
<td>Cereals and cereal products</td>
<td>283.330</td>
<td>366.670</td>
</tr>
<tr>
<td>Tubers starches and products</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dried legumes and legume products</td>
<td>0</td>
<td>33.330</td>
</tr>
<tr>
<td>Vegetables and vegetable products</td>
<td>200.000</td>
<td>300.000</td>
</tr>
<tr>
<td>Fruit and fruit products</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 5 Daily dietary nutrient intakes in latent profiles of plant-based dietary patterns
The intakes of foods and nutrients in each identified profile of animal-based dietary patterns are shown in Tables 6 and 7.

Participants with a Profile 1 dietary pattern had higher intakes of milk and milk products and eggs and egg products than those with Profile 2 and 3 dietary patterns ($P < 0.001$). Participants with a Profile 3 dietary pattern had higher intakes of meat and meat products and fish shellfish, and mollusks. Participants with
a Profile 2 dietary pattern had lower intakes of eggs and egg products, fish shellfish, and mollusks than those with Profiles 1 and 3 \((P < 0.001)\). See Table 6 for details.

Participants with a Profile 1 dietary pattern had the highest intakes of energy, carbohydrate, cholesterol, vitamin A, thiamine, riboflavin, vitamin C, calcium, phosphorus, potassium, sodium, and selenium \((P < 0.01)\). The Profile 3 dietary pattern had the highest intake of protein, lipids, niacin, vitamin E, magnesium, iron, zinc, copper, and manganese \((P < 0.01)\). See Table 7 for details.

The characteristics of the Profile 1 dietary pattern included highest intakes of milk and milk products and eggs and egg products. The characteristics of the dietary patterns in Profile 2 included the lowest intakes of eggs and egg products and fish, shellfish, and mollusks. The characteristics of the dietary patterns in Profile 3 included the highest intakes of meat and meat products and fish, shellfish, and mollusks. Based on the characteristics of these animal-based dietary pattern profiles, we denoted the Profile 1–6 dietary patterns as the high milk and egg animal-based diet (HMiEA), low egg and fish animal-based diet (LEFA), and high meat and fish animal-based diet (HMeFA), respectively. See Table 6 for details.

**Table 6 Daily dietary food intakes in latent profiles of animal-based dietary patterns**

<table>
<thead>
<tr>
<th>Food intakes</th>
<th>All (P_{25})</th>
<th>All (P_{50})</th>
<th>All (P_{75})</th>
<th>HMiEA (P_{50})</th>
<th>LEFA (P_{50})</th>
<th>HMeFA (P_{50})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat and meat products</td>
<td>16.670</td>
<td>60.000</td>
<td>108.330</td>
<td>66.670</td>
<td>60.000</td>
<td>73.330</td>
</tr>
<tr>
<td>Poultry and poultry products</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Milk and milk products</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>222.000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Eggs and egg products</td>
<td>0</td>
<td>20.000</td>
<td>48.330</td>
<td>40.000</td>
<td>20.000</td>
<td>26.670</td>
</tr>
<tr>
<td>Fish shellfish and mollusc</td>
<td>0</td>
<td>0</td>
<td>50.000</td>
<td>28.330</td>
<td>0</td>
<td>180.000</td>
</tr>
</tbody>
</table>

**Table 7 Daily dietary nutrient intakes in latent profiles of animal-based dietary patterns**
Relationship between individual serum uric acid levels and dietary patterns

There was no significant difference in participants’ serum uric acid levels according to different types of plant-based dietary patterns ($F = 1.176, P > 0.05$). We found a significant difference in serum uric acid levels between different types of animal-based dietary patterns ($F = 32.792, P < 0.001$). Participants who followed an HMeFA diet (participants’ mean serum uric acid 5.82mg/mL) had higher serum uric acid
levels than those who had an HMiEA diet (participants’ mean serum uric acid 5.12) and LEFA diet (participants’ mean serum uric acid 5.12) \(P<0.01\).

Table 8 shows the association between the plant/animal-based dietary pattern and participants’ serum uric acid levels. In the unadjusted model, significant coefficients for serum uric acid levels were observed for the HEMA diet \(\beta = 0.027, \ P = 0.018\) and the HMeFA diet \(\beta = 0.089, \ P < 0.001\). Furthermore, in the adjusted model, significant coefficients for participants’ serum uric acid levels were observed for the HCTVP diet \(\beta = -0.022, \ P = 0.031\) and HMeFA diet \(\beta = 0.061, \ P < 0.001\).

### Table 8. Association between dietary patterns and serum uric acid levels

<table>
<thead>
<tr>
<th></th>
<th>Serum uric acid level</th>
<th>Plant-based dietary pattern</th>
<th>Animal-based dietary pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LTVP</td>
<td>HCTVP</td>
</tr>
<tr>
<td>Model I†</td>
<td>(\beta)</td>
<td>0.017</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(P)</td>
<td>0.252</td>
<td>-</td>
</tr>
<tr>
<td>Model II‡</td>
<td>(\beta)</td>
<td>-</td>
<td>-0.022</td>
</tr>
<tr>
<td></td>
<td>(P)</td>
<td>-</td>
<td>0.031</td>
</tr>
</tbody>
</table>

† Pattern HCTVP and LEFA was the reference. ‡ Pattern LTVP and LEFA was the reference. Pattern HCTVP and LEFA was the reference Model I was unadjusted model. Model II was adjusted for gender, age, marital status, education level, registered resident type, urban index, BMI, smoking and physical activity.

### Discussion

In the present cross-sectional study, we assessed the effect of different plant/animal-based dietary pattern on individual serum uric acid levels in Chinese adults. We found a positive correlation between the HCTVP dietary pattern, and a negative correlation between the HMeFA dietary pattern, and individual serum uric acid levels.

Among the three plant-based dietary patterns, only the HCTVP diet might be beneficial for decreasing serum uric acid levels. The HCTVP diet (cereals, cereal products, tuber starches and products) is characterized by high intakes of carbohydrate and starch and lower intakes of protein and lipids. Our findings are consistent with those of previous studies. For instance, Johnston et al. investigated 20 healthy adults and reported that after 6 weeks’ consumption of a high carbohydrate diet, they observed a 22–30% decrease in individuals’ serum uric acid levels [30]. Another study among 12,765 adults in Australian and Tromso reported that higher consumption of carbohydrate and lower consumption of lipids were associated with decreased individual serum uric acid levels [31]. One possible reason for this finding might be that high carbohydrate intake could slow down the decrease in gluconeogenesis disorders, which decreases the pentose phosphate pathway and the serum uric acid level [32]. Another reason may be that
high carbohydrate foods like cereals contain high levels of glucose, which could increase the excretion of uric acid in the kidney and decrease the uric acid in serum [33].

The HCTVP diet (vegetables) was also characterized by a low intake of fructose foods. Previous studies have reported that fructose consumption is a risk factor of increased serum uric acid levels [34]. There are two possible mechanisms underlying this effect of fructose on serum uric acid. One is that fructose consumption would lead to the reactant aggregation of uric acid, and finally lead to increasing serum uric acid levels [35, 36]. The other mechanism is that fructose consumption might result in insulin resistance, which would increase gluconeogenesis disorders and the pentose phosphate pathway, finally leading to an increase in serum uric acid levels [37–39].

Thus, our findings suggested that only the plant-based HCTVP diet that comprised high intakes of cereals, tuber starches, and vegetables might have a positive impact on individual serum uric acid levels.

Of the three animal-based dietary patterns, only the HmeFA diet might be conducive to increasing the levels of individual serum uric acid. The HmeFA diet was characterized as having a high intake of purine foods (meats, meats products, fish, shellfish, and mollusks). Our findings are consistent with those of previous studies [40]. For instance, Choi et al. studied 14,809 adults over 20 years old and reported that higher levels of meat and seafood consumption were associated with higher serum levels of uric acid [41]. The reason is that uric acid is a product of purine metabolism in the body. If individuals consume a high-purine diet, their serum uric acid would be at a high level for a long time, which might cause damage to renal function, leading to a further rise in serum uric level.

The HmeFA diet was characterized as having a high intake of lipids. The mechanism underlying the lipid-related increase in uric acid is that high intakes of fatty acids can cause oxidative stress in the body and impair kidney function, which might cause serum uric levels to rise further [42]. Another characteristic of the HmeFA diet was a high intake of niacin. Our data are similar to those of previous studies. For instance, Kei and ElisafIt indicated that niacin treatment would lead to a side effect of hyperuricemia (incidence rate 14%) [43]. Another study showed that niacin treatment would decrease uric acid renal clearance, followed by an increase in serum uric acid level [44]. A possible mechanism underlying the effect of niacin on individual serum uric acid levels is that niacin would lead to hepatic insulin resistance and finally lead to increasing serum uric acid [45].

Thus, our findings suggested that only the animal-based HmeFA diet with high meat and fish consumption might have a negative impact in increasing individual serum uric acid levels.

There are several limitations in this study. First, the dietary data in this study were obtained from three consecutive 24-hour dietary recalls, which could yield measurement error versus non-consecutive and long-term recalls. Additionally, we used cross-sectional data; therefore, causal inference cannot be made.

**Conclusion**
We found a difference between different types of plant-based and animal-based dietary patterns in terms of effect on individual serum uric acid levels. Only the plant-based dietary pattern HCTVP and animal-based dietary pattern HMeFA influenced serum uric acid levels. Therefore, to reduce high levels of serum uric acid, following the HCTVP diet rather than the HLFP or LTVP dietary pattern is recommended; the HMeFA diet should be avoided. Future studies should be conducted to verify the proper amounts of nutrients and composition in specially designed dietary patterns.

Declarations

Authors’ contributions

Conceptualization, writing-original draft preparation, writing-review, visualization, supervision and re-editing were done by Danhui Mao. Methodology was done by Yangzilin Zhou and Honggang Li. Editing was done by Jing Feng. All authors have read and agreed to the published version of the manuscript.

Funding

This work was supported by the Doctorial Start-up Fund of Shanxi Medical University (SD2230, XD2139)

Acknowledgments

The authors appreciate the effort put in by individuals during the CHNS project’s data gathering period.

Availability of data and materials

The complete data can be found at https://www.cpc.unc.edu/projects/china.

Ethics approval and consent to participate

The survey obtained the approval of the ethics committee of the University of North Carolina at Chapel Hill (UNC-CH) and the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention.

Consent for publication

Not applicable.

Competing interests

All authors declare no competing interest

References


