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# Joint effects of serum uric acid and body mass index on risk of prehypertension in Chinese population

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ABSTRACT

*Background:* There are few data available on the association between serum uric acid (UA) and prehypertension when hypertension prevention efforts may be applicable.
*Methods:* We performed a cross-sectional study to evaluate risk of prehypertension and its association with serum UA and other confounding factors. Levels of serum UA, blood pressure, body mass index (BMI) and some related factors were detected.
*Results:* Participants with prehypertension had higher levels of serum UA and BMI. Compared to those with normotension, the multivariate-adjusted odds ratios [ORs, 95% confidence interval (CI)] for men with prehypertension were 1.33 (95% CI, 1.08–3.91) of serum UA and 1.21 (95% CI, 1.17–1.29) of BMI. In women, the ORs were 1.96 (95% CI, 1.21–3.46) and 1.28 (95% CI, 1.14–2.46), respectively. Increasing serum UA and BMI were associated with increased risk of prehypertension. Compared with the lowest quartiles, the highest serum UA and BMI quartiles entailed >4.4 times greater risk of prehypertension. In sex-specific analysis, OR was 2.41 (95% CI, 1.55–3.75) for men and 7.37 (95% CI, 4.16–13.0) for women.
*Conclusions:* Both high serum UA and high BMI are associated with risk of prehypertension. Individuals with higher serum UA and BMI simultaneously have a higher risk for prehypertension, especially for women.


## 1. Introduction

Hypertension is a common disease worldwide and a major risk factor for cardiovascular mortality. Untreated hypertension may lead to many serious health conditions, including stroke, hypertensive heart disease, coronary artery disease and kidney disease [1–3]. According to the Seventh Report of the Joint National Committee (JNC-7) guideline, prehypertension is defined as systolic blood pressure (SBP) ranging from 120 to 139 mm Hg and/or diastolic blood pressure (DBP) ranging from 80 to 89 mm Hg [4]. Early detection and treatment of prehypertension could effectively prevent hypertension occurrence and decrease cardiovascular disease (CVD) risk [5].

Uric acid (UA) is the final oxidation product of purine metabolism generated during enzymatic degradation of hypoxanthine and xanthine [6]. Several epidemiological studies indicated that elevated serum UA correlated with blood pressure and was an important risk factor for hypertension [7–9]. Recently, there are more and more evidences on the association between serum UA and prehypertension. A cross-section study found that higher serum UA levels were associated with prehypertension in US adults [10]. Bao et al. [11] reported that higher serum UA levels were also positively associated with prehypertension in Chinese population [12]. In addition, there was a study indicating that UA reduction rectifies prehypertension in obese adolescents [13].

Moreover, some studies show that several other factors involving age, body mass index (BMI), gender, fasting glucose (FPG), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), smoking and excessive alcohol intake may be associated with prehypertension risk [14–16].

## 2. Materials and methods

### 2.1. Study population

From January 2014 to June 2014, a total of 6731 healthy physical examinees who visited the Health Examination Center of the First Affiliated Hospital of Nanjing Medical University (Nanjing, China) were recruited. According to the check-up results, we excluded the people

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with hypertension, hyperuricemia, diabetes as well as other cardiovascular diseases, and the left 4615 participants were involved in this study.

### 2.2. Clinical measurement

Blood pressure was measured in the sitting position using a mercury sphygmomanometer by specialist hypertension nurses. The average of 3 readings was recorded. Prehypertension and normotension (SBP < 120 mm Hg and DBP < 80 mm Hg) were defined according to the JNC-7 criteria. Height and weight of all participants were measured using standardized equipment during each visit to calculate BMI. All blood samples were obtained from physical examinees in the morning after 12 h of fasting for measurement of serum UA, FPG, CHO and TG. All biochemical indices were detected by Olympus AU2700 automatic chemistry analyzer.

### 2.3. Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics Ver 20 and GraphPad Prism v5. The Kolmogorov–Smirnov test was used to determine whether the continuous variables were normally distributed. Parametric tests were used with normal distribution, whereas nonparametric tests were applied without normal distribution. Normally distributed variables were expressed as mean ± standard deviation, while those variables featured by non-normal distribution were expressed as medians with 25th and 75th percentiles. Statistical significance of difference among the groups was calculated by $\chi^2$-test for categorical variables and Student's *t*-test for continuous variables for normally distributed data and the Mann–Whitney test for the data distributed not normally. Correlation between blood pressure and serum UA as well as other parameters was evaluated using standard methods, such as the Pearson's or Spearman's test accordingly. One-way analysis of variance was used for comparison of mean values across the serum UA quartile groups. The adjusted odds ratio (OR) and 95% confidence interval (CI) were calculated to estimate the risk for prehypertension of single/combined status of serum UA and BMI, and quartiles of serum UA and BMI by logistic regression analyses. A 2-sided $p < 0.05$ was considered statistically significant.

## 3. Results

### 3.1. Study population

The 4615 participants included 2406 men aged 49.4 ± 14.8 years and 2209 women aged 48.4 ± 13.3 years. Among them, the respective prevalence of normotension and prehypertension was 56.8% and 43.2% in men and 54.6% and 45.4% in women. Background parameters of participants according to blood pressure status were shown in Table 1. In gender-specific analysis, serum UA and BMI were significantly higher in prehypertension than in normotension for men ($p = 0.012$, $p < 0.0001$, respectively) and women ($p < 0.0001$, $p < 0.0001$, respectively). And TG was higher in women with prehypertension ($p = 0.038$). However, we didn't find significant difference in other indexes (e.g. age, smoking history, alcohol consumption and FPG as well as CHO) in gender-specific analyses ($p > 0.05$).

### 3.2. Correlation analysis

Table 2 shows the relationship between blood pressure and various characteristics. Pearson's test was performed for normally distributed data (e.g., age, BMI, CHO and serum UA), while Spearman's test was performed for the data (e.g. FPG and TG) distributed not normally and for categorical variables (e.g. smoking status and alcohol consumption), respectively. Both SBP and DBP increased significantly and progressively with increasing serum UA ($r = 0.135$, $p = 0.039$ and $r = 0.086$, $p < 0.0001$, respectively) and BMI ($r = 0.15$, $p < 0.0001$ and $r = 0.179$, $p < 0.0001$, respectively) in men, and there were also positive correlation between blood pressure and serum UA ($r = 0.185$, $p < 0.0001$ and $r = 0.157$, $p < 0.0001$, respectively), and BMI ($r = 0.325$, $p < 0.0001$ and $r = 0.258$, $p < 0.0001$, respectively), as well as age ($r = 0.394$, $p < 0.0001$ and $r = 0.155$, $p < 0.0001$, respectively) in women. In multiple linear regression analysis, we assessed the potential confounding factors (age, smoking status, alcohol consumption, BMI, FPG, CHO, TG, and serum UA) for prehypertension. In this model, we found that BMI had a significant correlation with SBP and DBP in men ($\beta = 0.146$, $p < 0.0001$ and $\beta = 0.167$, $p < 0.0001$, respectively). Moreover, serum UA was positively correlated with DBP ($\beta = 0.051$, $p = 0.014$), but there was no correlation between serum UA and SBP ($\beta = 0.005$, $p = 0.797$) in men. In women, both BMI and serum UA had a significant correlation with SBP ($\beta = 0.283$, $p < 0.0001$ and $\beta = 0.093$, $p < 0.0001$, respectively) and DBP ($\beta = 0.221$, $p < 0.0001$ and $\beta = 0.084$, $p < 0.0001$, respectively) (Table 3). According to the abovementioned two models, the main contribution to the variability in prehypertension was determined from serum UA and BMI in our study.

### 3.3. The ORs of various characteristics for prehypertension compared with normotension

Next, we evaluated the risk of prehypertension compared with normotension by calculating the ORs (95% CI) of various characteristics in Table 4. After adjustment for age, BMI, FPG, CHO, TG and serum UA as well as smoking status and alcohol consumption, the multivariate-

**Table 1**
Characteristics of subjects categorized by blood pressure status.

| Characteristics (n = 4615) | Men (n = 2406) | | | Women (n = 2209) | | |
|---|---|---|---|---|---|---|
| | Normotension | Prehypertension | *p*-Value | Normotension | Prehypertension | *p*-Value |
| | n = 1366 | n = 1040 | | n = 1206 | n = 1003 | |
| Age (years) | 49.1 ± 13.9 | 49.8 ± 15.2 | NS | 48.2 ± 12.8 | 48.8 ± 12.3 | NS |
| Body mass index (kg/m$^2$) | 23.1 ± 2.7 | 24.6 ± 2.9 | <0.0001 | 22.3 ± 2.9 | 24.3 ± 3.3 | <0.0001 |
| Smoking, currently (%) | 33.7 | 34.8 | NS | 19.4 | 20.5 | NS |
| Alcohol consumption (%) | 45.2 | 46.3 | NS | 34.2 | 35.1 | NS |
| SBP (mm Hg) | 108.7 ± 6.6 | 125.8 ± 7.3 | <0.0001 | 106.5 ± 7.2 | 125.9 ± 7.4 | <0.0001 |
| DBP (mm Hg) | 71.2 ± 5.1 | 79.7 ± 6.7 | <0.0001 | 69.5 ± 5.3 | 78.5 ± 7.3 | <0.0001 |
| Fasting glucose (mmol/l) | 5 (4.6–5.5) | 5 (4.7–5.6) | NS | 4.9 (4.1–5.2) | 4.9 (3.8–5.3) | NS |
| Cholesterol (mmol/l) | 5.0 ± 1.1 | 4.9 ± 0.9 | NS | 4.8 ± 1.0 | 4.8 ± 0.9 | NS |
| Triglyceride (mmol/l) | 1.4 (0.9–2.0) | 1.4 (0.9–1.9) | NS | 1.1 (0.9–1.7) | 1.3 (0.7–1.9) | 0.038 |
| Serum uric acid (μmol/l) | 373.1 ± 76.3 | 381.5 ± 86.6 | 0.012 | 275.2 ± 62.3 | 297.4 ± 70.2 | <0.0001 |

SBP, systolic blood pressure; DBP, diastolic blood pressure. Data are expressed as mean ± standard deviation or median (interquartile range). *p*-Value for comparison between normotension and prehypertension.