Original Article

# Associations between anthropometric parameters (body mass index, waist circumference and waist to hip ratio) and newly diagnosed hyperuricemia in adults in Qingdao, China: A cross-sectional study

Yun-yun Wang MS[1†], Lin Li MS[2†], Jing Cui PhD[3], Fan Yin MS[3], Fan Yang MS[1], Dong-min Yuan MS[4], Hua-lei Xin MS[3], Lei Zhang PhD[5], Wei-guo Gao PhD[5], Jian-ping Sun PhD[3]

[1]*School of Public Health, Qingdao University, Qingdao, China*
[2]*Qingdao Women and Children's Hospital, Qingdao, China*
[3]*Qingdao Centers for Disease Control and Prevention/Qingdao Institute for Preventive Medicine, Qingdao China*
[4]*School of Public Health and Management, Weifang Medical University, Weifang, China*
[5]*Qingdao Endocrine and Diabetes Hospital, Qingdao, China*
[†]*These authors contributed equally in this manuscript*

**Background and Objectives:** To evaluate the association between anthropometric parameter of obesity and newly diagnosed hyperuricemia (HUA) in a general Chinese population. **Methods and Study Design:** A population-based cross-sectional survey included 9 615 participants (3777 men and 5838 women) aged 35-74 years in 2006 and 2009 in Qingdao, China. The multivariate linear regression was used to assess the linear associations between anthropometric parameter of obesity [body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR)] and serum uric acid. The logistic regression model was performed to estimate the associations between BMI, WC, WHR and newly diagnosed HUA. **Results:** The prevalence of newly diagnosed HUA was higher in men than in women (19.46% vs 11.34%, $p<0.05$). Multivariate liner regression showed that BMI, WC and WHR were positively correlated with serum uric acid. Multivariate logistic regression revealed that being overweight [men, odds ratios (OR): 1.69, 95% confidence intervals (95% CI): 1.37-2.08; women, OR: 1.67, 95% CI: 1.34-2.09] and obese (men, OR: 3.01, 95% CI: 2.38-3.79; women, OR: 2.91, 95% CI: 2.31-3.67) were significantly associated with a higher risk of newly diagnosed HUA. Abdominal obesity (WC: men, OR: 2.26, 95% CI: 1.88-2.73; women, OR: 1.96, 95% CI: 1.61-2.39; WHR: men, OR: 1.91, 95% CI: 1.61-2.26; women, OR: 1.39, 95% CI: 1.16-1.67) were associated with an increased risk of newly diagnosed HUA. **Conclusions:** This study demonstrated that BMI, WC and WHR were positively correlated with serum uric acid in both genders. Meanwhile, overweight, obese and abdominal obesity were associated with increased risk of newly diagnosed HUA.

**Key Words: hyperuricemia, body mass index, waist circumference, waist-to-hip ratio, obesity**

## INTRODUCTION

Hyperuricemia (HUA) is pathological condition induced by too much production or under-excretion of uric acid, the final oxidation product of purine nucleotide metabolism in the urine. The current studies revealed that HUA could induce the chronic diseases, such as diabetes mellitus, hypertension, dyslipidemia, atherosclerotic cardiovascular disease, metabolic syndrome.[1-5] For all these above factors, HUA not only adversely affect the quality of life but also promote the development of gout.[6] The increasing prevalence of HUA in men and in women has become a major public health problem worldwide.[7] A cohort study from the National Kidney Disease Surveillance Programme revealed that prevalence of HUA significantly increased from 19.7% to 25.0% in Irish men and from 20.5% to 24.1% in Irish women from 2006 to 2014.[8] A cross-sectional study from the Korea National Health and Nutrition Examination Survey showed that the age-standardized prevalence of HUA in the general adults was 11.4% (17.0% in men and 5.9% in women) in 2016.[9] As a large developing country, the prevalence of HUA is continually increasing. In mainland China, a recent meta-

**Corresponding Author:** Dr Jian-ping Sun, Qingdao Centers for Disease Control and Prevention/Qingdao Institute for Preventive Medicine, Qingdao, China, 266033.
Tel: 86-532-85623919
Email: qdcdcsjp@126.com
Manuscript received 09 July 2020. Initial review completed 12 August 2020. Revision accepted 21 September 2020.
doi: 10.6133/apjcn.202012_29(4).0011

analysis of 16 provinces, municipalities, and autonomous regions showed that the prevalence of HUA was 13.3% (19.4% in men and 7.9% in women) from 2000 to 2014.[10] Nevertheless, a retrospective study including 32 623 males and 26 451 females showed that the overall prevalence of HUA was as high as 19.87% in Lanzhou from 2015 to 2018.[11]

Recent epidemiological studies showed that HUA are closely associated with obesity.[12-15] Simultaneously, obesity is the underlying cause for the development of HUA. Body mass index (BMI), waist circumference (WC) and Waist-to-Hip ratio (WHR) are simple and effective anthropometric parameter for classifying obesity and abdominal obesity. As we all known, HUA is closely associated with obese and abdominal obesity, there are few and controversial data about the association of all anthropometric parameter (BMI, WC and WHR) and the onset of HUA. A cross-sectional study including 5300 men and 6135 women aged ≥35 years in Liaoning Province, China showed that overweight and obesity with metabolically healthy were strong associations with HUA, except in females with metabolically healthy overweight.[14] Moreover, a cross-sectional study with 7632 adult subjects from the China Health and Nutrition Survey 2009 revealed that visceral adiposity index was significant association with HUA in metabolic health and obesity phenotypes in the Chinese population.[12] However, few data on the association between anthropometric parameter of obesity and newly diagnosed HUA are available in eastern coastal China. Hence, this study was to examine the association between different anthropometric parameter of obesity and HUA among general adults of a community-based health-promoting program in Qingdao, China.

## METHODS

### *Study population*

In 2006 and 2009, a community-based health-promoting program, which adopted four-stage stratified clustering sampling strategy, was conducted in Qingdao, China. A sample of general adults aged 35-74 years old and living locally at least 5 years was surveyed in this program. Among the 12100 individuals who received an invitation to participate this survey, 10465 participants finished surveys with a response rate of 86.5% (87.8% in 2006 and 85.2% in 2009) (Figure 1). The community-based health-promoting program was considered representative of a larger population in China. The participants were included in this cross-sectional study: (1) newly diagnosed HUA, (2) no missing data for parameter of obesity (BMI, WC, WHR) and uric acid, (3) the participants without severe disability and able to communicate properly. The participants were excluded from this cross-sectional study: (1) 119 participants with diagnosed HUA, (2) 251 participants without parameter of obesity (BMI, WC, and WHR), (3) 737 participants without uric acid. Finally, 9615 participants (3777 men and 5838 women) were included in current analysis. This cross-sectional study was approved by Qingdao Municipal Center for Disease Control and Prevention and all participants signed informed consent.

### *Data collection*

Information on demographics, socioeconomics and lifestyle factors were collected from standardized questionnaire by trained doctors and nurses through a face-to-face interview. Educational attainment were defined into school years ≤9 y and >9 y. Marital status were recorded into unmarried (single, divorced, and widowed) or married (married and cohabiting).Personal monthly income were categorized into ≤599 Chinese Yuan (CNY), 600-1999 CNY, and ≥2000 CNY. The criteria for smoking status was determined as non-smokers (including ex-smokers and non-smokers) and current smokers (smoking daily regardless of the amount, type of smoke), and alcohol status were grouped into non-drinkers (including ex-drinkers, rare drinkers, and non-drinkers) and current drinker (drinking frequently regardless of type and amount of alcohol).

Height and weight were obtained from each participant using calibrated digital scales and height gage. BMI was calculated as weight (kg) dividing by height squared ($m^2$). WC was measured to the nearest 0.1 cm at the midpoint between the lower rib margin and the iliac crest. HC was measured to the nearest 0.1 cm at the maximal horizontal girth between the waist and the thigh. WHR was calculated as WC (cm) divided by HC (cm). Venous blood samples were collected from the participant using anticoagulant tube in the morning after an 8-10 overnight fast. The blood samples were transported to the central laboratory in the cold chain state within 24 hours after centrifugation. Serum uric acid were assessed using enzymatic methods with Olympus automatic biochemical analyzer.

### *Variable definitions*

BMI, WC, WHR were defined according to the Working Group on Obesity in China. Participants within BMI category were stratified according to standard classifications: underweight (BMI <18.5 $kg/m^2$), normal weight (18.5-23.9 $kg/m^2$), overweight (24.0-27.9 $kg/m^2$), and obese (≥28 $kg/m^2$). Participants within WC category were divided into two categories according to standard classifications of Chinese sex specific cutoffs: normal (<85.0 cm for males and <80.0 cm for females); abdominal obesity (≥85.0 cm for males and ≥80.0 cm for females). Participants within WHR category were defined into two categories according to standard classifications of Chinese sex specific cutoffs: normal (<0.90 for males and <0.85 for females) and abdominal obesity (≥0.90 for males and ≥ 0.85 for females).[16]

According to the WHO criteria, participants within BMI category were stratified according to standard classifications: underweight (BMI <18.5 $kg/m^2$), normal weight (18.5-24.9 $kg/m^2$), overweight (25.0-29.9 $kg/m^2$), and obese (≥30.0 $kg/m^2$). Participants within WC category were divided into two categories: normal WC (<94.0 cm for males and <80.0 cm for females) and abdominal obesity (≥94.0 cm for males and ≥80.0 cm for females). Participants within WHR category were defined into two categories: normal WHR (<1.00 for males and <0.85 for females) and abdominal obesity (≥1.00 for males and ≥0.85 for females).[17]

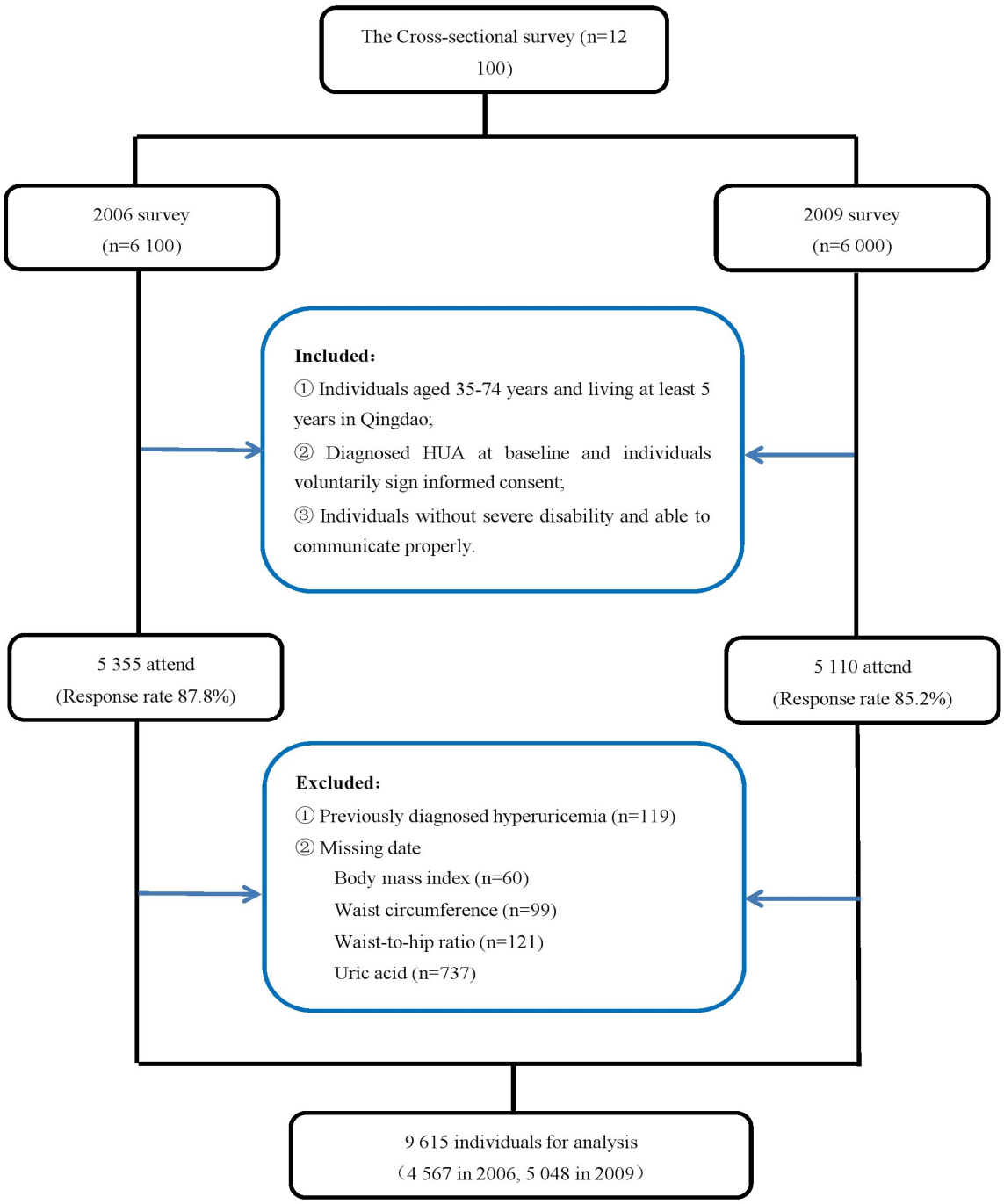


**Figure 1.** Flow chart of included and excluded participant in baseline analysis.

HUA was defined as fasting serum uric acid >420 μmol/L in men and >360 μmol/L in women.[18]

***Statistical analysis***

Continuous variables were presented as mean with standard deviations (SD), whereas categorical variables were expressed as number (percentage). T-test for continuous variable and Chi-squared test for categorical variables were performed to the difference between men and women. The multivariate linear regression was used to assess the linear association between serum uric acid and anthropometric parameter of obesity (BMI, WC, and WHR) in men and women. The logistic regression analysis was used to estimate the odd ratio (OR) and 95% Confidence intervals (CI) for the association between newly diagnosed HUA and each variable in men and women according to Chinese criteria of obesity. The adjusted variables included age, demographic factors (educational attainment, marital status, resident districts, personal monthly income), and lifestyle factors (smoking status and alcohol consumption) in multivariable logistic regression analysis. Sensitivity analysis was performed according to WHO criteria of obesity. All data analyses were performed using SPSS (version 23.0), and a $p<0.05$ was considered as statistically significant.

**RESULTS**

The baseline characteristics of the participants were

summarized in Table 1. Of 9615 participants, the men only accounted for 39.28%. The prevalence of newly diagnosed HUA was significantly higher in men (19.46%) than in women (11.34%) ($p$<0.05). Meanwhile, the men were likely to be older age, had a lower of unmarried and had higher percentage of school years >9 y, high personal monthly income, rural living, smoker, alcohol-drinker in comparison with the women ($p$ all <0.05). Additionally, the men were likely of lower mean of BMI, and higher mean of WC, WHR, uric acid in compared with the women ($p$ all <0.05).

The prevalence of HUA by categories of BMI, WC, and WHR was shown in Figure 2. The prevalence of newly diagnosed HUA was higher in overweight and obese compared with the normal weight participants in both gender according to the BMI category ($p$<0.05). Additional, a significantly higher prevalence of newly diagnosed HUA were observed in the abdominal obesity compared with the normal participants in both gender according to WC or WHR categories ($p$<0.05).

Multivariate liner regression of anthropometric parameters and uric acid was shown in Table 2. In both gender, BMI, WC and WHR were positively correlated with serum uric acid adjusted for age, educational attainment, personal monthly income, smoking status and alcohol consumption.

Table 3 showed OR for newly diagnosed HUA in association to anthropometric parameters by univariate logistic regression. In both gender, overweight obese and abdominal obesity had a higher risk for newly diagnosed HUA compared with the normal participants. Besides, higher personal monthly income, current alcohol-drinking were significantly associated with increased risk for newly diagnosed HUA. For men, school years >9 was significantly associated with increased risk for newly diagnosed HUA, while higher age, rural living and current smoking were significantly associated with decreased risk for newly diagnosed HUA. For women, higher age and unmar-

**Table 1.** Baseline characteristics of the study population†

| Variable | Men (n=3777) | Women (n=5838) | $p$ value |
|---|---|---|---|
| Age, years | 51.8±11.0 | 50.9±10.3 | <0.001 |
| School years >9, n (%) | 1281 (34.1) | 1591 (27.4) | <0.001 |
| Unmarried, n (%) | 180 (4.81) | 353 (6.10) | 0.007 |
| Rural living, n (%) | 2535 (67.1) | 3471 (59.5) | <0.001 |
| Personal monthly income (CNY), n (%) | | | <0.001 |
| ≤599 | 1438 (39.4) | 2961 (52.9) | |
| 600-1999 | 1664 (45.6) | 2392 (42.8) | |
| ≥2000 | 546 (15.0) | 242 (4.33) | |
| Current smoking, n (%) | 1966 (52.4) | 156 (2.72) | <0.001 |
| Current alcohol-drinking, n (%) | 1606 (42.7) | 82 (1.41) | <0.001 |
| BMI (kg/m$^2$) | 25.2±3.44 | 25.6±3.71 | <0.001 |
| Normal weight, n (%) | 1428 (37.8) | 2008 (34.4) | <0.001 |
| Underweight, n (%) | 57 (1.51) | 68 (1.16) | |
| Overweight, n (%) | 1544 (40.9) | 2379 (40.8) | |
| Obese, n (%) | 748 (19.8) | 1383 (23.7) | |
| WC (cm) | 86.5±10.3 | 82.7±10.0 | <0.001 |
| Normal WC, n (%) | 1660 (44.0) | 2257 (38.7) | <0.001 |
| Abdominal obesity, n (%) | 2117 (56.1) | 3581 (61.3) | |
| WHR | 0.89±0.06 | 0.84±0.07 | <0.001 |
| Normal WHR, n (%) | 2100 (55.6) | 3235 (55.4) | 0.857 |
| Abdominal obesity, n (%) | 1677 (44.4) | 2603 (44.6) | |
| Uric acid (μmol/L) | 352±83.9 | 278±69.1 | <0.001 |
| Newly Diagnosed HUA, n (%) | 735 (19.5) | 662 (11.3) | <0.001 |

CNY: Chinese Yuan; BMI: body mass index; WC: waist circumference; WHR: waist-to-hip ratio; UA: uric acid; n, number.
†Data are expressed as mean ± standard deviations or n (%).

**Table 2.** Multivariate liner regression of anthropometric parameters and uric acid stratified for sex†

| | β (95% CI) | $p$ value |
|---|---|---|
| Men | | |
| BMI | 5.40 (4.61, 6.18) | <0.001 |
| WC | 1.73 (1.47, 2.00) | <0.001 |
| WHR | 196 (154, 239) | <0.001 |
| Women | | |
| BMI | 4.39 (3.92, 4.86) | <0.001 |
| WC | 1.46 (1.27, 1.64) | <0.001 |
| WHR | 104 (77.4, 132) | <0.001 |

BMI: body mass index; WC: waist circumference; WHR: waist-to-hip ratio.
†Multiple linear regression model after adjustment for age, educational attainment, personal monthly income, smoking status and alcohol consumption.

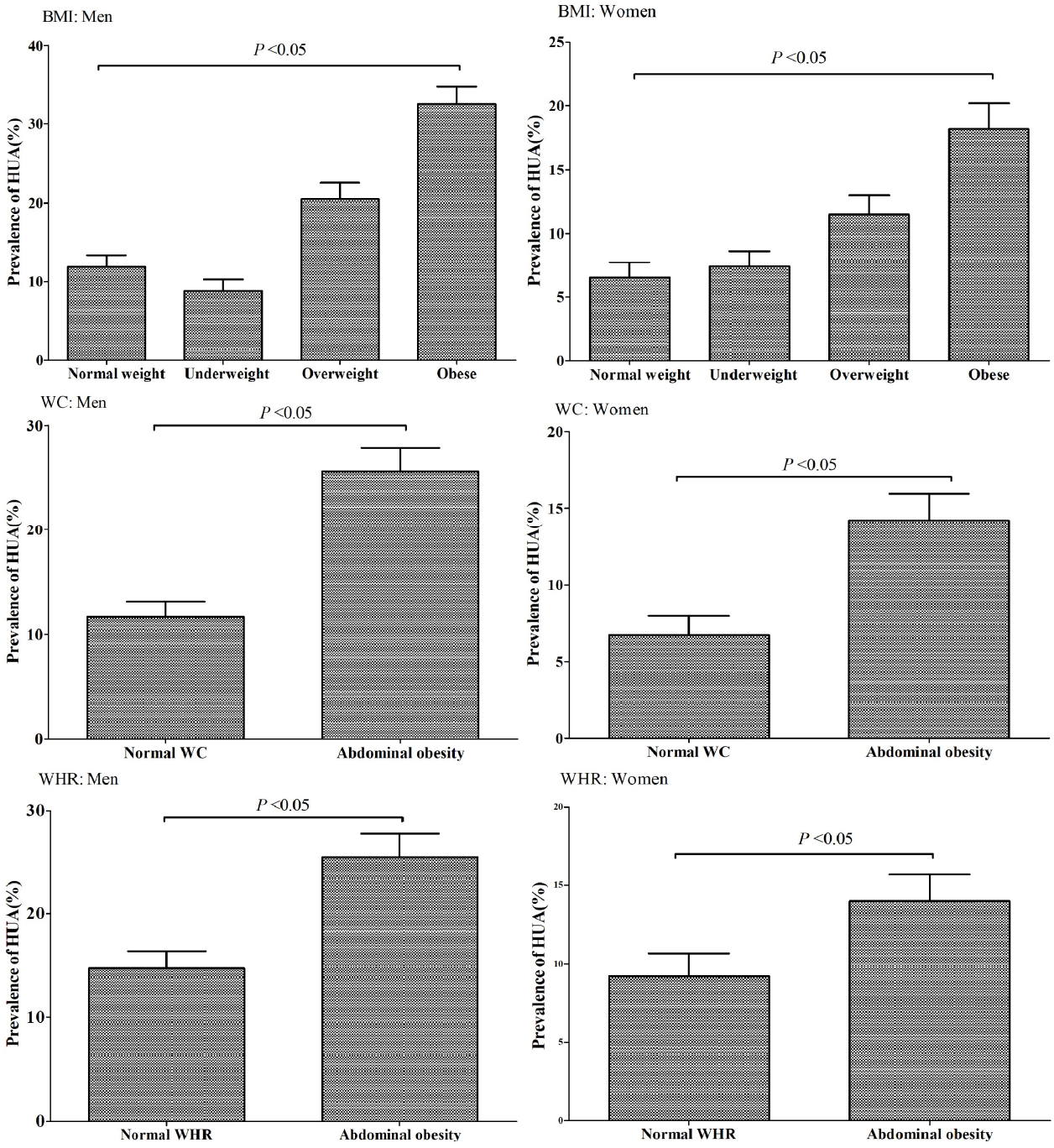


**Figure 2.** The prevalence (%) of hyperuricemia in men and women based on the body mass index (BMI), waist circumference (WC) and waist-to-hip ratio (WHR).

ried were significantly associated with increased risk for newly diagnosed HUA, while rural living was significantly associated with decrease risk for newly diagnosed HUA.

As shown in Table 4, multivariate logistic regression was performed to determine the association of BMI, WC and WHR with the prevalence of newly diagnosed HUA according to Chinese criteria. Overweight, obese and abdominal obesity were significantly associated with increased risk of newly diagnosed HUA compared with the normal participants in men after adjusted age, educational attainment, resident districts, personal monthly income, smoking status and alcohol-drinking status. Overweight, obese and abdominal obesity also showed significant association with newly diagnosed HUA compared with the normal participants in women after adjusted age, marital status, resident districts, personal monthly income and alcohol-drinking status.

Table 5 showed sensitivity analysis according to WHO criteria. According to WHO criterion, overweight, obese (according to BMI) and abdominal obesity (according to WC) were significantly associated with newly diagnosed HUA in men and women. While, abdominal obesity (according to WHR) was only significantly associated with newly diagnosed HUA in women.

## DISCUSSION

In this population-based cross-sectional study, the prevalence of newly diagnosed HUA was higher in overweight, obese and abdominal obesity participants compared with the normal weight in both gender. The linear regression showed that serum uric acid was positively correlated

**Table 3.** Odds ratio (95% confidence interval) for newly diagnosed HUA in association to anthropometric parameters by univariate logistic regression according to Chinese criteria

| | Men | | Women | |
|---|---|---|---|---|
| variable | OR (95% CI) | *p* value | OR (95% CI) | *p* value |
| BMI | | | | |
| Normal weight | 1.00 | | 1.00 | |
| Underweight | 0.71 (0.28, 1.81) | 0.474 | 1.14 (0.45, 2.88) | 0.786 |
| Overweight | 1.91 (1.56, 2.34) | <0.001 | 1.87 (1.50, 2.32) | <0.001 |
| Obese | 3.56 (2.85, 4.44) | <0.001 | 3.19 (2.55, 3.99) | <0.001 |
| WC | | | | |
| Abdominal obesity | 2.59 (2.17, 3.10) | <0.001 | 2.30 (1.90, 2.78) | <0.001 |
| WHR | | | | |
| Abdominal obesity | 1.99 (1.69, 2.34) | <0.001 | 1.60 (1.36, 1.89) | <0.001 |
| Age | 0.98 (0.97, 0.99) | <0.001 | 1.04 (1.03, 1.05) | <0.001 |
| School years >9 | 1.76 (1.50, 2.08) | <0.001 | 0.89 (0.74, 1.08) | 0.235 |
| Unmarried | 0.93 (0.63, 1.37) | 0.702 | 1.52 (1.13, 2.05) | 0.006 |
| Rural living | 0.66 (0.56, 0.78) | <0.001 | 0.72 (0.62, 0.85) | <0.001 |
| Personal monthly income (CNY) | | | | |
| ≤599 | 1.00 | | 1.00 | |
| 600～1999 | 1.46 (1.21, 1.76) | <0.001 | 1.21(1.03, 1.44) | 0.025 |
| ≥2000 | 2.26 (1.78, 2.86) | <0.001 | 1.11(0.73, 1.67) | 0.628 |
| Current smoking | 0.71 (0.60, 0.83) | <0.001 | 1.08(0.67, 1.76) | 0.746 |
| Current alcohol-drinking | 1.33 (1.13, 1.56) | 0.001 | 1.77(1.00, 3.11) | 0.049 |

BMI: body mass index; WC: waist circumference; WHR: waist-to-hip ratio; CNY: Chinese Yuan.

**Table 4.** Odds ratio (95% confidence interval) for newly diagnosed HUA in association to anthropometric parameter by multivariable logistic regression according to Chinese criteria

| | Men† | | Women‡ | |
|---|---|---|---|---|
| | OR (95% CI) | *p* value | OR (95% CI) | *p* value |
| BMI | | | | |
| Normal weight | 1.00 | | 1.00 | |
| Underweight | 0.70 (0.25, 1.97) | 0.493 | 1.08 (0.42, 2.76) | 0.873 |
| Overweight | 1.69 (1.37, 2.08) | <0.001 | 1.67 (1.34, 2.09) | <0.001 |
| Obese | 3.01 (2.38, 3.79) | <0.001 | 2.91 (2.31, 3.67) | <0.001 |
| WC | | | | |
| Abdominal obesity | 2.26 (1.88, 2.73) | <0.001 | 1.96 (1.61, 2.39) | <0.001 |
| WHR | | | | |
| Abdominal obesity | 1.91 (1.61, 2.26) | <0.001 | 1.39 (1.16, 1.67) | <0.001 |

BMI: body mass index; WC: waist circumference; WHR: waist-to-hip ratio.
†Men adjusted for age, educational attainment, resident districts, personal monthly income, smoking status and alcohol consumption.
‡Women adjusted for age, marital status, resident districts, personal monthly income and drinking.

with BMI, WC and WHR in both gender. The logistic regression showed that overweight, obese and abdominal obesity participants were significantly associated with HUA in both gender. Sensitivity analysis showed that the result of abdominal obesity (according to WHR) were slightly different in Chinese criteria and WHO criteria.

In our study, the prevalence of newly diagnosed HUA was significantly higher in men than that in women, which was consistent with current epidemiological studies in Korea[9] and China,[18] however, slightly different from Iran.[19] Those differences might be attributed to the ethnic background of particular region, dietary habit and estrogen. Residents in economically developed region consume more meat, seafood, and alcohol than residents elsewhere, therefore, the prevalence of hyperuricemia was higher than in other regions.[10] In addition, studies confirmed that high ingestion of purine sources and alcohol increases the demands on purine elimination resulting in HUA.[20] Moreover, estrogen and progesterone attenuate the post-transcriptional expression of the components of the urate reabsorption system and reduced the renal reabsorption of urate, and increased urate excretion into the urine.[21] However, few study reported the association between BMI, WC, WHR and the prevalence of HUA at present.

Some epidemiological studies of BMI, WC, WHR and HUA have been reported at present. A cross-sectional study involving 250 males and 237 females from 14 primary care clinics demonstrated that BMI correlated significantly with serum acid in both genders.[22] The cross-sectional study from both monozygotic and dizygotic twins also revealed that BMI was significantly correlation with uric acid after adjusted for genetic and familial environment factors in both genders.[23] The study including a random population sample of 94 male and 87 females aged 38-year-old reported that BMI and WHR were positive correlation with serum uric acid after adjusted potential confounders.[24] A cross-sectional study involving 1006 Chinese adults reported that BMI, WC, WHR was positively correlation with serum uric acid.[25] These findings

**Table 5.** Sensitivity analyses for newly diagnosed HUA according to WHO criteria

| | Men† | | Women‡ | |
|---|---|---|---|---|
| | OR (95% CI) | *p* value | OR (95% CI) | *p* value |
| BMI | | | | |
| Normal weight | 1.00 | | 1.00 | |
| Underweight | 0.65 (0.23, 1.83) | 0.413 | 1.06 (0.42, 2.69) | 0.910 |
| Overweight | 1.92 (1.60, 2.32) | <0.001 | 1.99 (1.63, 2.42) | <0.001 |
| Obese | 3.15 (2.38, 4.16) | <0.001 | 2.52 (2.74, 4.53) | <0.001 |
| WC | | | | |
| Abdominal obesity | 2.15 (1.79, 2.58) | <0.001 | 1.96 (1.61, 2.39) | <0.001 |
| WHR | | | | |
| Abdominal obesity | 1.15 (0.76, 1.74) | 0.504 | 1.39 (1.16, 1.67) | <0.001 |

BMI: body mass index; WC: waist circumference; WHR: waist-to-hip ratio.
†Men adjusted for age, educational attainment, resident districts, personal monthly income, smoking status and alcohol consumption.
‡Women adjusted for age, marital status, resident districts, personal monthly income and drinking.

were consistent with our cross-sectional study on BMI, WC, WHR and serum uric acid. In addition, Chen Y et al[14] reported that overweight and obesity with metabolically healthy had strong associations with HUA, except in females with metabolically healthy overweight. This finding was not consistent with our cross-sectional study on overweight, obesity and HUA. Meanwhile, the cross-sectional analysis involving 90047 Japanese adults and 14734 American adults found that higher BMI was associated with an increased prevalence of HUA both in Japan and U.S, which was consistent with our study on BMI and HUA.[26] So far, there are few studies on the association between WC, WHR and onset of HUA. Our present study revealed that abdominal obesity was positively associated with the prevalence of HUA. Some possible mechanisms may explain the relationship between HUA and obesity. Obesity may be connect to HUA involving two factors: overproduction of uric acid and poor excretion of uric acid. A study investigating the relationship between uric acid metabolism and fat distribution in 36 obese men reported that HUA was likely to affect by the difference in body fat distribution.[27] On the side, visceral fat accumulation causes plasma free fatty acid flow into the live and hepatic portal vein, which stimulates the synthesis of neutral fatty acids and activates the uric acid synthesis pathway.[23,28] Mendelian randomization analysis supports a causal effect between BMI and HUA in two large, prospective cohort studies in Denmark, which involving in 58072 participants and 10602 participant, respectively.[29] These mechanisms further confirmed our study on obesity and HUA.

Some studies revealed controversial results in different criteria of obesity. Hence, sensitivity analysis was performed according to WHO criteria of obesity in this study. In our present study, sensitivity analysis found that different criteria for obesity had an impact on the results. According to WHO criteria of obesity, we found that abdominal obesity (WHR category) were not significantly associated with newly diagnosed HUA in men. We suggested that the association between newly diagnosed HUA and obesity was influenced in men by the adopted criteria.

There are some main strengths in the current study. Our cross-sectional study enrolled a large and representative sample with sufficient statistical power in general adults from east coast China. Secondly, the classification of obesity was adopted the Guidelines from the Working Group on Obesity in China, which was more suitable Chinese adults. Thirdly, the association between BMI, WC, WHR and HUA was further explored based on single indictors about anthropometric parameter of obesity and HUA. Simultaneously, this current study suffered several potential limitations. First, this cross-sectional study cannot warrant a causal relationship between obesity and newly diagnosed HUA. Second, the current study was from two cross-sectional studies in 2006 and 2009, which may influence the effect of BMI, WC, WHR and newly diagnosed HUA. Thirdly, this current study collected from a community-based health-promoting program, and some variables, such dietary habits, history of cardiovascular disease, physical exercise, and the detail of smoking and alcohol status, were not collected. Furthermore, the information of drug use, which affected uric acid levels, also were not collected. These information may have an impact on the association between anthropometric parameter of obesity (BMI, WC and WHR) and newly diagnosed HUA. Therefore, further studies are required to establish the potential mechanism between obesity and HUA in humans.

## *Conclusion*

In conclusion, BMI, WC and WHR were positively correlated with serum uric acid in both gender. Simultaneously, overweight, obese and abdominal obesity were associated with increased risk of newly diagnosed HUA. Hence, the prospective study about potential mechanism are demanded for further explored between obesity and HUA etiology.

## ACKNOWLEDGEMENTS

We also thank the participants, primary care doctors, and nurses who participated in this survey.

## AUTHOR DISCLOSURES

The authors declare that they have no conflict of interest. This study was funded by World Diabetes Foundation (WDF05–108 and WDF07–308), Qingdao Science & Technology department program (19-6-1-5-nsh) and Qingdao Outstanding Health Professional Development Fund.

## REFERENCES

1. Liu J, Tao L, Zhao Z, Mu Y, Zou D, Zhang J, Guo X. Two-year changes in hyperuricemia and risk of diabetes: A five-

year prospective cohort study. J Diabetes Res. 2018;2018: 905720. doi: 10.1155/2018/6905720.
2. Ali N, Mahmood S, Islam F, Rahman S, Haque T, Islam S et al. Relationship between serum uric acid and hypertension: a cross-sectional study in Bangladeshi adults. Sci Rep. 2019; 9:9061. doi: 10.1038/s41598-019-45680-4.
3. Song P, Zha M, Yang X, Xu Y, Wang H, Fang Z, Yang X, Xia W, Zeng C. Socioeconomic and geographic variations in the prevalence, awareness, treatment and control of dyslipidemia in middle-aged and older Chinese. Atherosclerosis. 2019;282:57-66. doi: 10.1016/j. atherosclerosis.2019.01.005.
4. Sloop GD, Bialczak JK, Weidman JJ, St Cyr JA. Uric acid increases erythrocyte aggregation: Implications for cardiovascular disease. Clin Hemorheol Microcirc. 2016;63: 349-59. doi: 10.3233/ch-152023.
5. Kim IY, Han KD, Kim DH, Eun Y, Cha HS, Koh EM, Lee J, Kim H. Women with metabolic syndrome and general obesity are at a higher risk for significant hyperuricemia compared to men. J Clin Med. 2019;8. doi: 10.3390/ jcm8060837.
6. Scire CA, Manara M, Cimmino MA, Govoni M, Salaffi F, Punzi L et al. Gout impacts on function and health-related quality of life beyond associated risk factors and medical conditions: results from the KING observational study of the Italian Society for Rheumatology (SIR). Arthritis Res Ther. 2013;15:R101. doi: 10.1186/ar4281.
7. Li Q, Li X, Kwong JS, Chen H, Sun X, Tian H, Li S. Diagnosis and treatment for hyperuricaemia and gout: a protocol for a systematic review of clinical practice guidelines and consensus statements. BMJ Open. 2017; 7:e014928. doi: 10.1136/bmjopen-2016-014928.
8. Kumar AUA, Browne LD, Li X, Adeeb F, Perez-Ruiz F, Fraser AD, Stack AG. Temporal trends in hyperuricaemia in the Irish health system from 2006-2014: A cohort study. PLoS One. 2018;13:e0198197. doi: 10.1371/journal.pone. 0198197.
9. Kim Y, Kang J, Kim GT. Prevalence of hyperuricemia and its associated factors in the general Korean population: an analysis of a population-based nationally representative sample. Clin Rheumatol. 2018;37:2529-38. doi: 10.1007/ s10067-018-4130-2.
10. Liu R, Han C, Wu D, Xia X, Gu J, Guan H, Shan Z, Teng W. Prevalence of hyperuricemia and gout in mainland China from 2000 to 2014: A systematic review and meta-analysis. Biomed Res Int. 2015;2015:762820. doi: 10.1155/2015/ 762820.
11. Yang WX, Ma Y, Hou YL, Wang YB, You CG. Prevalence of hyperuricemia and its correlation with serum lipids and blood glucose in physical examination population in 2015 - 2018: a retrospective study. Clin Lab. 2019;65. doi: 10. 7754/Clin.Lab.2019.190338.
12. Dong H, Xu Y, Zhang X, Tian S. Visceral adiposity index is strongly associated with hyperuricemia independently of metabolic health and obesity phenotypes. Sci Rep. 2017;7: 8822. doi: 10.1038/s41598-017-09455-z.
13. Ishizaka N, Ishizaka Y, Toda A, Tani M, Koike K, Yamakado M, Nagai R. Changes in waist circumference and body mass index in relation to changes in serum uric acid in Japanese individuals. J Rheumatol. 2010;37:410-6. doi: 10. 3899/jrheum.090736.
14. Chen Y, Zhang N, Sun G, Guo X, Yu S, Yang H, Zheng L, Sun Y. Metabolically healthy obesity also has risk for hyperuricemia among Chinese general population: A cross-sectional study. Obes Res Clin Pract. 2016;10(Suppl 1):S84-s95. doi: 10.1016/j.orcp.2016.03.008.
15. Cai Z, Xu X, Wu X, Zhou C, Li D. Hyperuricemia and the metabolic syndrome in Hangzhou. Asia Pac J Clin Nutr. 2009;18:81-7.
16. Disease control CM. Chinese Guidelines on Overweight and Obesity Prevention and Control in Adults: Beijing: People's Medical Publishing House; 2006.
17. World Health Organization. Waist circumference and waist-hip ratio: report of a WHO expert consultation. Geneva: WHO; 2011.
18. Multidisciplinary Expert Task Force on Hyperuricemia and Related Diseases. Chinese multidisciplinary expert consensus on the diagnosis and treatment of hyperuricemia and related diseases. Chin Med J (Engl). 2017;130:2473-88. doi: 10.4103/0366-6999.216416.
19. Einollahi B, Einollahi H, Rostami Z. Elderly renal transplant recipients and renal dysfunction: a risk factor for hyperuricemia. Exp Clin Transplant. 2011;9:376-80.
20. Gustafsson D, Unwin R. The pathophysiology of hyperuricaemia and its possible relationship to cardiovascular disease, morbidity and mortality. BMC Nephrol. 2013;14:164. doi: 10.1186/1471-2369-14-164.
21. Takiue Y, Hosoyamada M, Kimura M, Saito H. The effect of female hormones upon urate transport systems in the mouse kidney. Nucleosides Nucleotides Nucleic Acids. 2011;30:113-9. doi: 10.1080/15257770.2010.551645.
22. Al-Arfaj AS. Hyperuricemia in Saudi Arabia. Rheumatol Int. 2001;20:61-4. doi: 10.1007/s002960000076.
23. Tanaka K, Ogata S, Tanaka H, Omura K, Honda C, Hayakawa K. The relationship between body mass index and uric acid: a study on Japanese adult twins. Environ Health Prev Med. 2015;20:347-53. doi: 10.1007/s12199-015-0473-3.
24. Cigolini M, Targher G, Tonoli M, Manara F, Muggeo M, De Sandre G. Hyperuricaemia: relationships to body fat distribution and other components of the insulin resistance syndrome in 38-year-old healthy men and women. Int J Obes Relat Metab Disord. 1995;19:92-6.
25. Yu XL, Shu L, Shen XM, Zhang XY, Zheng PF. Gender difference on the relationship between hyperuricemia and nonalcoholic fatty liver disease among Chinese: An observational study. Medicine (Baltimore). 2017;96:e8164. doi: 10.1097/md.0000000000008164.
26. Kuwabara M, Kuwabara R, Niwa K, Hisatome I, Smits G, Roncal-Jimenez CA et al. Different risk for hypertension, diabetes, dyslipidemia, and hyperuricemia according to level of body mass index in Japanese and American subjects. Nutrients. 2018;10. doi: 10.3390/nu10081011.
27. Matsuura F, Yamashita S, Nakamura T, Nishida M, Nozaki S, Funahashi T, Matsuzawa Y. Effect of visceral fat accumulation on uric acid metabolism in male obese subjects: visceral fat obesity is linked more closely to overproduction of uric acid than subcutaneous fat obesity. Metabolism. 1998;47:929-33. doi: 10.1016/s0026-0495(98) 90346-8.
28. Ali N, Perveen R, Rahman S, Mahmood S, Rahman S, Islam S et al. Prevalence of hyperuricemia and the relationship between serum uric acid and obesity: A study on Bangladeshi adults. PLoS One. 2018;13:e0206850. doi: 10. 1371/journal.pone.0206850.
29. Palmer TM, Nordestgaard BG, Benn M, Tybjærg-Hansen A, Davey Smith G, Lawlor DA, Timpson NJ. Association of plasma uric acid with ischaemic heart disease and blood pressure: mendelian randomisation analysis of two large cohorts. BMJ. 2013;347:f4262. doi: 10.1136/bmj.f4262.