Prevalence of Hyperuricemia and Its Correlations With Other Diseases in The Pearl River Delta, Guangdong Province, China

Weiqi Liu  
Huadu Maternal and Child Health Care Hospital

Shaoling Wang  
Taishan People's Hospital

Weiling Liu (✉ lw18104@hotmail.com)  
Chancheng Centre Hospital  https://orcid.org/0000-0001-7192-5295

Huichun Tong  
Boai Hospital of Zhongshan

Jianmin Yuan  
Humen Hospital

Zhenning Zou  
Shenzhen Maternity & Child Health Hospital

Jianwen Liu  
Huiyang Sanhe Hospital

Donghai Yang  
Sanzhao Town Health Center Jinwan District

Zhongxing Xie  
Second People's Hospital of Zhaoqing

Research

Keywords: Hyperuricemia, Uric acid, Prevalence, Pearl River Delta, Risk

DOI: https://doi.org/10.21203/rs.3.rs-108422/v1

License: This work is licensed under a Creative Commons Attribuition 4.0 International License. Read Full License
Abstract

Background: Hyperuricemia (HUA) has become the most common and serious public health problem worldwide. In China, the prevalence of HUA in the Pearl River Delta (PRD) region of Guangdong Province has not been extensively investigated. Therefore, this study investigated the prevalence of HUA and its related factors among people aged 20–99 years in nine cities in the PRD.

Methods: We selected 6491 health check participants from 9 cities in the PRD and collected participants’ anthropometric and biochemical test results for a cross-sectional study. We included 6491 participants and assessed their blood pressure (BP), body mass index (BMI), total cholesterol (TC), triglycerides (TG), glucose (Glu) and serum uric acid (UA) to analyze the regional prevalence of HUA and its related factors. HUA was indicated when fasting serum UA level was > 420 μmol/L in men and > 360 μmol/L in women.

Results: Overall prevalence of HUA in our cohort was 34.05%; prevalence was higher in men than in women (41.53% vs 26.14%, \( P < 0.000 \)). Characteristics associated with HUA were hypertension (odds ratio (OR), 5.506; 95% confidence interval (CI), 4.402–6.889), higher body mass index (BMI; OR: 1.746; 95% CI: 1.560–1.954), age 31–40 years (OR: 0.829; 95% CI: 0.706–0.973), age 61–70 years (OR: 1.434; 95% CI: 1.194–1.722) and age > 71 years (OR: 1.742; 95% CI: 1.397–2.173). In all subjects, serum UA was positively correlated with Glu, TG and TC. After we adjusted for age, BMI and BP, multivariate logistic-regression analysis showed that HUA risk factors were high TC (OR: 1.770; 95% CI: 1.459–2.147) and TG (OR: 1.961; 95% CI: 1.632–2.357) in men; and high Glu (OR: 1.508; 95% CI: 1.084–2.099), TC (OR: 1.341; 95% CI: 1.084–1.660) and TG (OR: 1.680; 95% CI: 1.290–2.187) in women.

Conclusion: The prevalence of HUA was relatively high in the PRD of Guangdong Province. Relevant governmental bodies should focus on early diagnosis, early treatment and early intervention.

Background

Gout is a crystal-associated arthropathy caused by monosodium urate (MSU) deposition, which is directly related to hyperuricemia (HUA) caused by decreased serum uric acid (UA) excretion. Serum UA is the final product of the body's intake of purine-rich foods or the catabolism of inner core protein. The xanthine and hypoxanthine produced by purine are converted into UA by the enzymatic reaction of xanthine oxidase (XO) [1]. When serum UA exceeds its saturation level in blood or tissue fluid, serum urate crystals can form and be deposited in the joints, inducing local inflammation and tissue destruction, which is called gout. HUA is fasting serum UA > 420 μmol/L in healthy men and 360 μmol/L in healthy women who consume a normal purine diet [2] and has been recognized as an important cause of gout [3]. Studies have shown that the prevalence of HUA across different races is 2.6–36% [4–6] and that of gout is 0.03–15.3% [7, 8]; in recent years, the prevalence of gout has significantly increased and trended [9, 10]. Liu et al. reported that the overall prevalence of HUA in China was 13.3% [3]. More and more evidence shows that HUA and gout are independent risk factors for chronic kidney disease (CKD), hypertension,
cardiovascular (CV) and cerebrovascular diseases and diabetes, as well as independent predictors of premature death [11].

With continuous in-depth research on the function of serum UA, the influence thereof on clinical diagnosis of diseases has become more and more extensive. In a study on serum UA and cardiovascular disease (CVD) in 5926 subjects, Fang et al. found that increased serum UA level is positively correlated with CVD mortality and that increased blood UA level is an independent risk factor for CVD [12]. Magnoni et al. found a relationship between serum UA and adverse CV events in 1548 patients and that serum UA concentration is closely related to hospital mortality in patients with acute coronary syndrome (ACS) [13]. Biscaglia et al. showed that UA can penetrate the cell membrane, which has a destructive effect on the physiological activities and oxidative metabolism of cells, causing an inflammatory reaction [14]. Lee et al. found a relationship between blood UA levels and acute respiratory distress syndrome (ARDS). In that study, ARDS patients in the low-serum UA group experienced significant clinical improvement, and low serum UA levels were significantly associated with ARDS survival rate. However, patients with ARDS in the normal- and high-serum UA groups mostly died of sepsis. Low serum UA level could therefore be a prognostic marker in ARDS for determining risk of death during hospitalization [15]. At the same time, an increase in serum UA results in vascular endothelial damage; meanwhile, cell proliferation leads to glomerular proliferation and sclerosis [16], increases oxidative stress (OS), promotes platelet activation and vascular smooth-muscle cell (VSMC) proliferation and increases the release of pro-inflammatory substances such as interleukins, ultimately leading to renal damage [17, 18].

The Pearl River Delta (PRD) is located in Guangdong Province, China. Its coastal location means its economy is relatively developed, with many entertainment venues; people there often consume high-fat diets that include seafood, alcohol and meat. In recent years, the number of patients with CVD has increased significantly in the PRD. Most studies in cardiology have confirmed that diseases such as dyslipidemia, diabetes, alcoholism and hypertension are risk factors for CVD [19–21], but few have focused on determining the prevalence and epidemiological characteristics of HUA in the PRD. In order to obtain more epidemiological data on chronic diseases and CV risk factors in the PRD and improve medical and health conditions there, in this study we investigated the prevalence of HUA and its related factors in people aged 20–99 years in nine cities of this region.

**Methods**

**Study subjects**

From June 2018 to December 2019, we randomly selected 6491 outpatients aged 20–99 years from health checkups in nine PRD cities: Dongguan, Foshan, Guangzhou, Huizhou, Jiangmen, Shenzhen, Zhaoqing, Zhongshan and Zhuhai. In all subjects, we measured blood pressure (BP), including systolic BP (SBP) and diastolic BP (DBP); height; weight; total cholesterol (TC); triglycerides (TG); glucose (Glu); and serum UA. We excluded patients with mental-health problems; malignant tumors; peritoneal dialysis as a result of severe liver or kidney failure; artificial extracorporeal liver support; hemodialysis; and
pregnancy. This study was approved by the Ethics Committee of Huadu District Maternal and Child Health Hospital, Guangzhou, China. All participants gave informed consent after having been informed about the objectives and benefits of our study.

**Laboratory measurements**

We collected blood samples from all study subjects in the morning when their stomachs were empty, taking 5 mL of venous blood using a vacuum blood collection tube at room temperature. This sample was immediately centrifuged at 3000 rpm for 10 min. No hemolysis was found in any specimen. All specimens were tested within 4 h using an automatic biochemical analyzer. We determined UA, fasting plasma glucose (FPG), TC and TG using the enzymatic method.

**Definitions**

According to the *Chinese Adult Dyslipidemia Prevention and Control Guidelines* [22], TC ≥ 6.22 mmol/L (240 mg/dL) and TG ≥ 2.26 mmol/L (200 mg/dL) are considered elevated levels, while the American Diabetes Association's (ADA's) *Standards of Medical Care in Diabetes* guide [23] considers FPG ≥ 7 mmol/L (126 mg/dL) an elevated level. Body mass index (BMI) is calculated by dividing body weight (kg) by height squared (m²). According to an earlier report [24], low BMI is < 24 kg/m², and high BMI is ≥ 24 kg/m². The definition of hypertension is SBP ≥ 140 mmHg and/or DBP ≥ 90 mmHg, based on the 2018 *Chinese Guidelines for Prevention and Treatment of Hypertension* [25]. Different guidelines specify different levels of serum UA for the diagnosis of HUA [26]. In this study, we diagnosed HUA when serum UA was > 420 μmol/L in men and > 360 μmol/L in women.

**Statistical analysis**

For all statistical analyses, we used SPSS version 17.0 (IBM Corp., Armonk, NY, USA) and STATA version 16.0 (StataCorp., College Station, TX, USA), and we created graphs used GraphPad Prism 5 (GraphPad Software, Inc., San Diego, CA, USA). Continuous variables are represented by means and standard deviations (SDs); categorical variables are expressed as numbers and percentages. Depending on data type, we used Student's *t* test, the Kruskal–Wallis test or the χ² test for data analysis. Simple correlation and multiple linear regression were used to analyze relationships between serum UA and cardiometabolic risk factors. Multiple logistic-regression analysis was used to determine the factors affecting HUA, and odds ratios (ORs) and 95% confidence intervals (95% CIs) were used to quantify the relationships. *P* < 0.05 was considered statistically significant.

**Results**

**Baseline information of subjects from the Pearl River Delta**

Table 1 shows anthropometric and serum biochemical characteristics of subjects in the PRD. Age, BMI, SBP, DBP, Glu, TC, TG and UA were significantly higher overall in men than in women; there was no
significant between-sex difference in TC. Age, BMI, SBP, DBP, Glu, TC, TG and UA were significantly higher in subjects with HUA than in those without. In Dongguan, age, BMI, SBP, DBP, Glu, TC, TG and UA were significantly higher in men than in women, and all eight factors were significantly higher in patients with HUA than without. In Foshan, men had significantly lower TC and UA than women, while age, BMI, SBP, DBP, Glu, TC, TG and UA were significantly higher in subjects with HUA than in those without. In Guangzhou, men had significantly higher age, DBP, TC and UA than women, while BMI, SBP, DBP, TG and UA were significantly higher in patients with than without HUA. In Huizhou, BMI, SBP, DBP, TG and UA were significantly higher in men than in women; female patients were significantly older than male ones; and BMI, SBP, DBP, TC, TG and UA were significantly higher in hyperuricemic than in non-hyperuricemic patients, who were significantly older than the hyperuricemic ones. In Jiangmen City, Glu, TG and UA were significantly higher in men than in women; BMI, SBP, DBP, TG and UA were significantly higher in subjects with than without HUA. In Shenzhen, TC, TG and Glu were significantly lower in men than in women, and BMI, SBP, DBP, Glu, TC, TG and UA were significantly higher in hyperuricemic than in non-hyperuricemic patients. In Zhaoqing City, BMI, Glu, TG and UA were significantly higher in men than in women, while age, BMI, SBP, DBP, Glu, TC, TG and UA were higher in subjects with HUA than in those without. In Zhongshan City, age, DBP, Glu, TC, TG and UA were significantly higher in men than in women; BMI, SBP, DBP, Glu, TC, TG and UA were significantly higher in patients with than without HUA. In Zhuhai, age, BMI, Glu and UA were significantly higher in men than in women, while the reverse was true of TC; also, age, BMI, SBP, DBP and UA were significantly higher in hyperuricemic than in non-hyperuricemic subjects.

Table 1 Anthropometric and serum biochemical characteristics of subjects in the Pearl River Delta, Guangdong Province, China
| Variable                  | Age          | BMI          | SBP          | DBP          | Glu          | TC           | TG           | UA           |
|--------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Dongguan                 |              |              |              |              |              |              |              |              |
| Male (n = 504)           | 46.19 ± 9.29 | 24.57 ± 2.03 | 126.93 ± 12.62 | 86.03 ± 8.76 | 5.36 ± 1.52 | 5.24 ± 0.97 | 2.09 ± 1.80 | 393.49 ± 86.02 |
| Female (n = 266)         | 35.05 ± 11.38 | 24.15 ± 2.04 | 123.57 ± 1.65 | 83.75 ± 8.28 | 4.78 ± 0.95 | 4.78 ± 0.89 | 1.26 ± 0.83 | 282.58 ± 62.46 |
| Hyperuricemia (n = 217)  | 47.71 ± 10.59 | 25.14 ± 1.99 | 130.72 ± 14.09 | 90.43 ± 8.51 | 5.30 ± 1.16 | 5.29 ± 0.98 | 2.33 ± 1.52 | 470.41 ± 10.59 |
| Non-Hyperuricemia (n = 553) | 41.41 ± 11.54 | 24.15 ± 2.00 | 123.83 ± 11.08 | 83.21 ± 7.84 | 5.11 ± 1.45 | 5.00 ± 0.95 | 1.60 ± 0.83 | 309.96 ± 62.56 |
| Foshan                   |              |              |              |              |              |              |              |              |
| Male (n = 361)           | 58.90 ± 16.62 | 24.30 ± 2.00 | 126.39 ± 12.31 | 85.87 ± 8.98 | 5.91 ± 2.12 | 5.42 ± 1.28 | 1.86 ± 1.64 | 419.87 ± 103.24 |
| Female (n = 460)         | 60.79 ± 14.63 | 24.39 ± 2.14 | 126.29 ± 12.85 | 86.50 ± 8.68 | 5.91 ± 1.93 | 5.72 ± 1.17 | 1.55 ± 0.77 | 355.81 ± 96.68 |
| Hyperuricemia (n = 368)  | 60.98 ± 15.73 | 24.95 ± 2.04 | 129.57 ± 13.68 | 89.14 ± 8.76 | 5.77 ± 1.43 | 5.72 ± 1.20 | 1.90 ± 1.37 | 469.10 ± 82.34 |
| Non-Hyperuricemia (n = 453) | 59.13 ± 15.38 | 23.86 ± 1.98 | 123.70 ± 10.99 | 83.85 ± 8.13 | 6.03 ± 2.38 | 5.48 ± 1.25 | 1.52 ± 1.09 | 314.82 ± 60.16 |
| Gangzhou                 |              |              |              |              |              |              |              |              |
| Male (n = 164)           | 44.02 ± 10.74 | 24.24 ± 2.04 | 126.01 ± 12.03 | 85.43 ± 8.25 | 5.05 ± 1.04 | 4.96 ± 0.96 | 1.76 ± 1.24 | 377.95 ± 75.37 |
| Female (n = 439)         | 40.10 ± 10.36 | 24.18 ± 2.02 | 124.48 ± 11.77 | 83.43 ± 8.31 | 4.87 ± 0.71 | 4.88 ± 0.93 | 1.23 ± 1.08 | 290.79 ± 72.05 |
| Hyperuricemia (n = 108)  | 40.45 ± 10.82 | 24.93 ± 2.14 | 129.72 ± 13.35 | 88.74 ± 8.46 | 4.98 ± 0.76 | 5.05 ± 0.90 | 1.91 ± 1.53 | 439.68 ± 62.08 |
| Non-Hyperuricemia (n = 495) | 41.32 ± 10.56 | 24.04 ± 1.96 | 123.84 ± 11.24 | 82.93 ± 7.94 | 4.90 ± 0.82 | 4.87 ± 0.94 | 1.26 ± 1.01 | 287.18 ± 57.49 |
| Huizhou                  |              |              |              |              |              |              |              |              |
| Male (n = 654)           | 36.63 ± 11.59 | 24.71 ± 2.04 | 127.92 ± 12.92 | 87.34 ± 8.97 | 5.40 ± 1.21 | 5.36 ± 1.07 | 1.82 ± 1.65 | 454.67 ± 104.28 |
| Female (n = 343)         | 40.56 ± 12.42 | 24.39 ± 11.88 | 125.74 ± 5.36 | 85.42 ± 1.18 | 5.23 ± 0.97 | 1.07 ± 0.76 | 318.94 ± 84.68 |
|                | Male       | Female      | Male       | Female      |
|----------------|------------|-------------|------------|-------------|
| Hyperuricemia  | 36.15 ± 11.94 | 39.86 ± 11.82** | 46.68 ± 14.84 | 45.53 ± 13.80 |
| Non-Hyperuricemia | 129.48 ± 13.43 | 124.78 ± 11.24** | 125.02 ± 12.56 | 123.59 ± 11.57 |
|                | 89.73 ± 8.66 | 83.54 ± 8.21** | 84.93 ± 8.71 | 83.44 ± 8.02 |
|                | 5.37 ± 0.93 | 5.40 ± 1.43  | 5.72 ± 1.80 | 5.42 ± 1.41# |
|                | 5.46 ± 1.07 | 5.16 ± 0.97** | 5.44 ± 1.02 | 5.55 ± 1.09 |
|                | 1.83 ± 1.50 | 1.28 ± 1.35** | 1.73 ± 1.71 | 1.16 ± 0.86## |
|                | 499.14 ± 81.93 | 314.01 ± 60.07** | 375.71 ± 78.87 | 279.91 ± 62.98## |

**Shenzhen**

|                | Male       | Female      | Male       | Female      |
|----------------|------------|-------------|------------|-------------|
| Hyperuricemia  | 35.98 ± 7.95 | 36.91 ± 11.49 | 36.55 ± 11.12 | 37.11 ± 11.40 |
| Non-Hyperuricemia | 129.98 ± 13.56 | 124.25 ± 11.20* | 125.38 ± 11.38 | 124.15 ± 11.74 |
|                | 83.66 ± 8.33** | 83.08 ± 8.15** | 83.83 ± 8.24 | 84.57 ± 8.93 |
|                | 5.34 ± 1.03 | 5.04 ± 0.74** | 4.91 ± 0.35 | 5.25 ± 1.06# |
|                | 5.39 ± 1.11 | 4.78 ± 0.90* | 4.67 ± 0.79 | 4.95 ± 1.02## |
|                | 1.60 ± 1.04 | 0.93 ± 0.72## | 0.85 ± 0.63 | 1.12 ± 0.88## |
|                | 440.78 ± 89.56 | 280.13 ± 49.91## | 291.43 ± 58.19 | 288.89 ± 61.72 |

**Zhaoqing**

|                | Male       | Female      | Male       | Female      |
|----------------|------------|-------------|------------|-------------|
| Hyperuricemia  | 48.75 ± 14.26 | 44.91 ± 12.39 | 47.10 ± 13.71 | 44.91 ± 12.39 |
| Non-Hyperuricemia | 129.98 ± 13.56 | 126.24 ± 12.57 | 127.93 ± 12.34 | 126.24 ± 12.57 |
|                | 89.40 ± 8.49 | 85.88 ± 8.90 | 87.03 ± 8.48 | 85.88 ± 8.90 |
|                | 5.34 ± 1.03 | 5.15 ± 0.88# | 5.44 ± 1.55 | 5.25 ± 1.07 |
|                | 5.39 ± 1.11 | 5.21 ± 1.07 | 5.27 ± 0.91 | 5.21 ± 1.07 |
|                | 1.60 ± 1.04 | 1.33 ± 0.85## | 1.83 ± 1.28 | 1.33 ± 0.85## |
|                | 461.36 ± 71.95 | 330.66 ± 77.33## | 440.78 ± 89.56 | 330.66 ± 77.33## |

**Zhongshan**
|                      | Male (n = 512) | Female (n = 467) | Hyperuricemia (n = 403) | Non-Hyperuricemia (n = 576) |
|----------------------|----------------|------------------|-------------------------|---------------------------|
| BMI                  | 43.64 ± 12.74  | 41.74 ± 12.91    | 42.52 ± 13.24           | 42.89 ± 12.58             |
| SBP                  | 24.47 ± 2.06   | 24.40 ± 2.03     | 24.95 ± 2.00            | 24.08 ± 2.00              |
| DBP                  | 126.22 ± 12.87 | 125.29 ± 12.44   | 129.69 ± 13.76          | 123.03 ± 12.07            |
| Glu                  | 86.86 ± 8.79   | 85.43 ± 8.84     | 89.39 ± 9.02            | 83.92 ± 7.98              |
| TC                   | 5.71 ± 2.32    | 5.21 ± 1.31      | 5.56 ± 2.17             | 5.41 ± 1.72               |
| TG                   | 126.22 ± 12.87 | 125.29 ± 12.44   | 129.69 ± 13.76          | 123.03 ± 12.07            |
| UA                   | 5.45 ± 1.11    | 5.24 ± 1.10      | 5.50 ± 1.20             | 5.25 ± 1.35               |
| Glu                  | 1.84 ± 1.82    | 1.35 ± 2.47      | 1.97 ± 1.82             | 1.34 ± 1.35               |
| TC                   | 421.05 ± 104.80| 339.30 ± 92.42   | 482.12 ± 78.44          | 312.04 ± 57.37            |
| TG                   | 5.71 ± 2.32    | 5.45 ± 1.11      | 5.50 ± 1.20             | 5.25 ± 1.35               |
| UA                   | 1.84 ± 1.82    | 1.35 ± 2.47      | 1.97 ± 1.82             | 1.34 ± 1.35               |
| Glu                  | 421.05 ± 104.80| 339.30 ± 92.42   | 482.12 ± 78.44          | 312.04 ± 57.37            |
| TC                   | 5.71 ± 2.32    | 5.45 ± 1.11      | 5.50 ± 1.20             | 5.25 ± 1.35               |
| TG                   | 1.84 ± 1.82    | 1.35 ± 2.47      | 1.97 ± 1.82             | 1.34 ± 1.35               |
| UA                   | 421.05 ± 104.80| 339.30 ± 92.42   | 482.12 ± 78.44          | 312.04 ± 57.37            |
| Glu                  | 5.71 ± 2.32    | 5.45 ± 1.11      | 5.50 ± 1.20             | 5.25 ± 1.35               |
| TC                   | 1.84 ± 1.82    | 1.35 ± 2.47      | 1.97 ± 1.82             | 1.34 ± 1.35               |
| TG                   | 421.05 ± 104.80| 339.30 ± 92.42   | 482.12 ± 78.44          | 312.04 ± 57.37            |
| UA                   | 5.71 ± 2.32    | 5.45 ± 1.11      | 5.50 ± 1.20             | 5.25 ± 1.35               |
| Glu                  | 1.84 ± 1.82    | 1.35 ± 2.47      | 1.97 ± 1.82             | 1.34 ± 1.35               |
| TC                   | 421.05 ± 104.80| 339.30 ± 92.42   | 482.12 ± 78.44          | 312.04 ± 57.37            |
| TG                   | 5.71 ± 2.32    | 5.45 ± 1.11      | 5.50 ± 1.20             | 5.25 ± 1.35               |
| UA                   | 1.84 ± 1.82    | 1.35 ± 2.47      | 1.97 ± 1.82             | 1.34 ± 1.35               |

**BMI** body mass index, **SBP** systolic blood pressure, **DBP** diastolic blood pressure, **Glu** glucose, **TC** total cholesterol, **TG** triglycerides, **UA** uric acid, #P < 0.05, ##: P < 0.001, male vs female; *P < 0.05; **P < 0.001, hyperuricemic group vs non-hyperuricemic group

**Prevalence of hyperuricemia and serum uric acid levels in different cities**

Overall prevalence of HUA in the PRD was 34.05%. Prevalence ranged from high to low in Huizhou, Foshan, Zhaoqing, Zhongshan, Zhuhai, Dongguan, Shenzhen, Guangzhou and Jiangmen, with respective
rates of 50.75%, 44.82%, 43.14%, 41.16, 36.06%, 28.18%, 20.17%, 17.91% and 7.78%. There were significant differences in HUA prevalence between different cities (Fig. 1), as well as statistically significant differences in serum UA levels between different cities (Fig. 2). Shenzhen had the lowest serum UA level, while Huizhou City had the highest.

**Prevalence of hyperuricemia across different sexes and age groups**

Serum UA level was higher in men than in women overall (406.19 ± 104.43 vs 315.92 ± 86.64 μmol/L; \( P < 0.001 \)). Across different age groups, serum UA level was significantly higher in men than in women (Fig. 3). Overall prevalence of HUA in men was higher than in women (41.53% vs 26.14%, \( P < 0.000 \)), and the disease's prevalence was significantly higher in men than in women < 60 years, but there was no significant difference between men and women after the age of 60 (Fig. 4).

**Correlated factors and hyperuricemia**

Table 2 shows the relationships between variables and HUA. Multivariable logistic-regression analysis showed that hypertension (OR: 5.506; 95% CI: 4.402–6.889); higher BMI (OR: 1.746; 95% CI: 1.560–1.954); and the age ranges of 31–40 years (OR: 0.829; 95% CI: 0.706–0.973), 61–70 years (OR: 1.434; 95% CI: 1.194–1.722) and > 71 years (OR: 1.742; 95% CI: 1.397–2.173) were correlated with HUA in our subjects. Men were more likely to suffer from HUA before age 70, while women were more likely to develop it after age 51. Therefore, BMI and hypertension were risk factors for HUA.

**Table 2** Multiple-regression analyses of HUA and associated factors in all subjects and between sexes
| Variables     | All     | All     | Male    | Male    | Female | Female |
|---------------|---------|---------|---------|---------|--------|--------|
|               | OR      | 95% CI  | OR      | 95% CI  | OR     | 95% CI |
| Age (years)   |         |         |         |         |        |        |
| ≤ 30          | 1       | (reference) | 1       | (reference) | 1     | (reference) |
| 31-40         | 0.829*  | 0.706-0.973 | 0.730*  | 0.589-0.903 | 1.013 | 0.782-1.313 |
| 41-50         | 0.874   | 0.740-1.033 | 0.714*  | 0.576-0.885 | 1.140 | 0.860-1.509 |
| 51-60         | 0.852   | 0.711-1.021 | 0.568** | 0.451-0.715 | 1.614* | 1.200-2.170 |
| 61-70         | 1.434** | 1.194-1.722 | 0.736*  | 0.569-0.954 | 2.911** | 2.224-3.810 |
| ≥ 71          | 1.742** | 1.397-2.173 | 1.030   | 0.761-1.393 | 3.311** | 2.387-4.593 |
| BMI           | 1.746** | 1.560-1.954 | 1.791** | 1.544-2.078 | 1.688** | 1.422-2.003 |
| Hypertension  | 5.506** | 4.402-6.889 | 5.719** | 4.194-7.798 | 5.279** | 3.812-7.309 |

*BMI* body mass index, *OR* odds ratio, *95% CI* 95% confidence interval, *P* < 0.05, **P* < 0.001 for the independent association between hyperuricemia and each factor.

Hyperuricemia and cardiometabolic index

Correlation results showed that serum UA was positively correlated with TC and TG in all subjects (Table 3). Serum UA of study subjects overall and of women was positively correlated with Glu, while men's serum UA was negatively correlated with Glu. Multiple linear-regression analysis (Table 4) showed that after adjustments for age, sex, BMI and hypertension, serum UA of all subjects was positively correlated with TC and TG and negatively correlated with Glu. After adjustment, serum UA in men was positively correlated with TC and TG and negatively correlated with Glu, while in women it was positively correlated with Glu, TC and TG. In subjects with high levels of Glu, TC and TG, serum UA was significantly higher than in normal subjects (Fig. 5), as was the prevalence of HUA (Fig. 6). After we adjusted for age, BMI and BP, multivariate logistic-regression analysis showed that high TC (OR: 1.770; 95% CI: 1.459–2.147) and TG (OR: 1.961; 95% CI: 1.632–2.357) were risk factors for HUA in men, while high Glu (OR: 1.508; 95% CI: 1.084–2.099), TC (OR: 1.341; 95% CI: 1.084–1.660) and TG (OR: 1.680; 95% CI: 1.290–2.187) were risk factors for HUA in women (Table 5).

**Table 3** Correlation between cardiometabolic risk factors and serum UA
| Variables | All  | Male  | Female |
|-----------|------|-------|--------|
|           | $r$  | $P$   | $r$  | $P$   |
| Glu       | 0.061| $< 0.001$ | -0.016 | 0.343 | 0.121 | $< 0.001$ |
| TC        | 0.134| $< 0.001$ | 0.153 | $< 0.001$ | 0.131 | $< 0.001$ |
| TG        | 0.224| $< 0.001$ | 0.199 | $< 0.001$ | 0.156 | $< 0.001$ |

*Glu* glucose, *TC* total cholesterol, *TG* triglycerides, $r$: correlation coefficient; $P$: $P$-value

**Table 4** Cardiometabolic risk factors associated with serum UA levels in multiple linear-regression analysis

| Variables | Model | All  | Male  | Female |
|-----------|-------|------|-------|--------|
|           | $\beta$-value | $P$ | $\beta$-value | $P$ | $\beta$-value | $P$ |
| Glu       | Model 1 | 0.911 | 0.284 | -3.894 | 0.000 | 5.538 | 0.000 |
|           | Model 2 | -1.217 | 0.117 | -3.279 | 0.002 | 2.080 | 0.069 |
| TC        | Model 1 | 6.990 | 0.000 | 10.605 | 0.000 | 6.396 | 0.000 |
|           | Model 2 | 7.018 | 0.000 | 10.429 | 0.000 | 1.712 | 0.238 |
| TG        | Model 1 | 14.299 | 0.000 | 11.536 | 0.000 | 7.551 | 0.000 |
|           | Model 2 | 9.461 | 0.000 | 10.536 | 0.000 | 6.904 | 0.000 |

*Glu* glucose, *TC* total cholesterol, *TG* triglycerides, Model 1: unadjusted; Model 2: adjusted for age, sex (male = 1, female = 2), body mass index and hypertension (normal = 0; abnormal = 1); $P$: $P$-value

**Table 5** Characteristics of biochemical indices in patients with and without HUA according to sex
Variables & Male (n = 3335) & Female (n = 3156) 

| Non-HUA (n = 1950) | HUA (n = 1385) | OR (95%CI) | Non-HUA (n = 2331) | HUA (n = 825) | OR (95%CI) |
|-------------------|----------------|------------|-------------------|----------------|------------|
| High Glu          | 8.10%          | 6.86%      | 0.674 (0.503–0.901) | 4.46%          | 9.82%*     | 1.508 (1.084–2.099) |
| High TC           | 13.90%         | 23.25%*    | 1.770 (1.459–2.147) | 15.66%         | 25.33%*    | 1.341 (1.084–1.660)  |
| High TG           | 15.03%         | 27.51%*    | 1.961 (1.632–2.357) | 7.81%          | 15.39%*    | 1.680 (1.290–2.187)  |

Adjusted for age, BMI and blood pressure.

*Glu glucose, TC total cholesterol, TG triglycerides, Non-HUA non-hyperuricemic, HUA hyperuricemic, OR odds ratio, 95% CI 95% confidence interval; *P < 0.001

**Discussion**

This study was based on health examination data of adults in nine cities of the PRD. We collected and used easily available anthropometric and blood biochemical indicators—including age, BMI, SBP, DBP, Glu, TC, TG and UA—to analyze the risk of HUA. Clinicians can use our results to identify high-risk groups at an early stage and alert patients with risk factors for HUA after routine physical examination, so that these patients can pay more attention to their health, reduce the occurrence of HUA through appropriate health management and reduce adverse outcomes of HUA such as metabolic syndrome and gout.

Overall prevalence of HUA in this representative population sample from the PRD was 34.05%. The prevalence of the disease varied greatly by city, highest in Huizhou (50.75%) and lowest in Jiangmen (7.78%). HUA is significantly higher in the PRD region than in other regions of China [27], which could be due to the region's geographical location and related urban lifestyle. First, the PRD is the centerpiece of China's reform and opening up; its economy is relatively developed. Studies have shown that HUA is more common in economically developed areas [27, 28]. Second, the PRD is located along the coast, where seafood has become a must-have for entertaining guests at the table. Studies have shown a positive correlation between seafood consumption and HUA [29]. Finally, as the iconic food of the PRD, the Chinese soup Laohuoliangtang has become a staple of family life, but it also has more purine content, as its boiling time is longer [30]; therefore, Laohuoliangtang might be another cause of HUA. In addition, wine culture, meat and other dietary choices might increase the risk of HUA [31]. More men had HUA than women among our subjects (41.53% vs 26.14%), and prevalence in both sexes was higher than previously reported [28]. In men, the prevalence of HUA was less affected by age changes, while in women it increased with age. Men had a higher risk of HUA before age 70, while women had a higher risk thereof after age 51, which might be related to the influence of female sex hormone levels on serum UA.
Mumford et al. [32] studied the fluctuation of blood UA during the menstrual cycle in healthy young women and found that it is highest in the follicular phase and lowest in the luteal phase, inversely proportional to estrogen and progesterone; it is also positively correlated with follicle-stimulating hormone (FSH). Sumino et al. [33] analyzed serum UA levels of postmenopausal Japanese women on an estrogen + progesterone replacement regimen and found that the average serum UA level of women in the HUA group decreased significantly after treatment, while this change was not observed in women in the normal UA group. At the same time, the third United States National Health and Nutrition Examination Survey showed average serum UA level in women increases after menopause, but postmenopausal women receiving hormone replacement therapy (HRT) had lower serum UA levels [34].

We found that hypertension, high BMI, hyperglycemia and hyperlipidemia were risk factors for HUA in the PRD. In recent years, the prevalence of hypertension and HUA has shown an upward trend. Hypertension is a common and highly prevalent [35] chronic disease that can increase the risk of death from CVDs. Serum UA can activate the renin–angiotensin system (RAS), damage renal blood vessels and lead to elevated BP [36]. Studies have demonstrated a dose–response relationship between serum UA level and relative risk (RR) of hypertension [37]; Grayson et al. reported that for every 1 mg/dL increase in UA level, the pooled RR for incident hypertension after adjusting for potential confounding was 1.13 [38]. At the same time, long-term use of diuretics in hypertensive patients causes the body's blood volume to decrease and UA reabsorption to increase. Microvascular disease in patients with hypertension inhibits metabolism of UA in renal tubules; in addition, severe intrarenal arteriosclerosis in hypertensive patients leads to increased reabsorption of UA in the proximal convoluted tubules. Therefore, hypertension and HUA can mutually affect each other. People with high serum UA levels are prone to hypertension, and hypertensive patients often have elevated serum UA levels. As a standard for body weight and degree of health, BMI has been widely used to assess population health. The results of this study in PRD residents showed that higher BMI was a risk factor for HUA. Other studies have shown that obesity and hypertension are important independent risk factors for HUA and gout [39]. Liu [40] and other studies have proven that being underweight is associated with the prevalence of HUA. Among overweight or obese individuals, young people are more likely to develop HUA than elderly ones. Compared with people at normal weights, women are more likely to develop HUA with weight gain than men are. We found that levels of serum UA in hyperglycemic and hyperuricemic PRD residents were significantly higher than in non-hyperuricemic subjects. The risk of HUA in women with hyperglycemia was significantly higher than in men with hyperglycemia. Young et al. [41] found that gout might be independently associated with increased diabetes risk, and the degree of association is significantly greater in women than in men. Studies have shown that in high-risk middle-aged subjects with impaired Glu tolerance, UA and changes thereto double one's changes of developing type 2 diabetes [42]. At the same time, UA and changes thereto are closely related to changes in Glu and insulin levels. This could be due to hyperinsulinemia's effect on renal tubular function; as insulin-mediated Glu disposal decreases, so does UA clearance. Therefore, decreased UA excretion can lead to HUA [43]. We also found that PRD residents with hyperlipidemia had a significantly higher risk of HUA than those without. Men with hyperlipidemia were more likely to develop HUA than women with hyperlipidemia. Studies have shown [44] that high TG levels
can lead to a significant increase in the occurrence density of HUA, and TG is an independent risk factor for HUA. This could be due to TG causing disorder of free fatty acid metabolism. The increase in TG leads to an increase in free fatty acid production, accelerates the decomposition of adenosine triphosphate (ATP) and leads to an increase in UA, the final product of purine metabolism [45]. At the same time, Chen et al. [46] found that hypertriglyceridemic waist (HTGW) is closely related to hyperuricemia; therefore, the HTGW phenotype might be a marker for identifying high-risk groups of hyperuricemia.

**Conclusion**

Age, hypertension, BMI, hyperglycemia and hyperlipidemia among study participants in the PRD region were risk factors for HUA. The prevalence of HUA was relatively high in various PRD cities. Promotion of healthy lifestyles and eating habits; better detection and control of BMI, blood Glu and blood lipids; and targeted interventions for high-risk groups can reduce the risk of HUA.

**Limitation**

As this study collected only a small amount of data from nine cities in the PRD, this could have had a certain impact on the results. A more comprehensive reflection of the prevalence of HUA in the PRD requires further data collection.

**Abbreviations**

BMI: body mass index; BP: blood pressure; CI: confidence interval; DBP: diastolic blood pressure; Glu: glucose; HUA: hyperuricemic; Non-HUA: non-hyperuricemic; OR: odds ratio; PRD: Pearl River Delta; SBP: systolic blood pressure; TC: total cholesterol; TG: triglycerides; UA: uric acid

**Declarations**

**Ethics approval and consent to participate**

This study was approved by the Ethics Committee of Huadu District Maternal and Child Health Hospital, Guangzhou, China. All participants gave informed consent after having been informed about the objectives and benefits of our study.

**Consent for publication**

Not applicable.

**Availability of data and materials**

The datasets supporting the conclusions of this article are available from the authors on direct request.
Competing interests

The authors declare that they have no competing interests.

Funding

Not applicable.

Authors' contributions

Wq L and SW performed the experiments and collected data, analyzed the results and manuscript writing. HT, JY, ZZ, JL, DY, and ZX helped collected data and performing experiments. WL L designed and supervised this research, provided technical support and reviewed the paper. All authors approved and read the final manuscript.

Acknowledgements

Not applicable.

References

1. Maiuolo J, Oppedisano F, Gratteri S, Muscoli C, Mollace V. Regulation of uric acid metabolism and excretion. Int J Cardiol. 2016;213:8-14.

2. Huang X, Zhou Z, Liu J, Song W, Chen Y, Liu Y, Zhang M, Dai W, Yi Y, Zhao S. Prevalence, awareness, treatment, and control of hypertension among China's Sichuan Tibetan population: A cross-sectional study. Clin Exp Hypertens. 2016;38:457-63.

3. 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.

4. Zhu Y, Pandya BJ, Choi HK. Prevalence of gout and hyperuricemia in the US general population: the National Health and Nutrition Examination Survey 2007-2008. Arthritis Rheum. 2011;63:3136-41.

5. Uaratanawong S, Suraamornkul S, Angkeaw S, Uaratanawong R. Prevalence of hyperuricemia in Bangkok population. Clin Rheumatol. 2011;30:887-93.

6. Xia Y, Wu Q, Wang H, Zhang S, Jiang Y, Gong T, Xu X, Chang Q, Niu K, Zhao Y. Global, regional and national burden of gout, 1990-2017: a systematic analysis of the Global Burden of Disease Study. Rheumatology (Oxford). 2020;59:1529-38.

7. Mikuls TR, Saag KG. New insights into gout epidemiology. Curr Opin Rheumatol. 2006;18:199-203.

8. Richette P, Doherty M, Pascual E, Barskova V, Becce F, Castaneda J, Coyfish M, Guillo S, Jansen T, Janssens H, et al. 2018 updated European League Against Rheumatism evidence-based recommendations for the diagnosis of gout. Ann Rheum Dis. 2020;79:31-8.
9. Dehlin M, Jacobsson L, Roddy E. Global epidemiology of gout: prevalence, incidence, treatment patterns and risk factors. Nat Rev Rheumatol. 2020;16:380-90.

10. Ford ES, Li C, Cook S, Choi HK. Serum concentrations of uric acid and the metabolic syndrome among US children and adolescents. Circulation. 2007;115:2526-32.

11. Bardin T, Richette P. Impact of comorbidities on gout and hyperuricaemia: an update on prevalence and treatment options. BMC Med. 2017;15:123.

12. Fang J, Alderman MH. Serum uric acid and cardiovascular mortality the NHANES I epidemiologic follow-up study, 1971-1992. National Health and Nutrition Examination Survey. JAMA. 2000;283:2404-10.

13. Magnoni M, Berteotti M, Ceriotti F, Mallia V, Vergani V, Peretto G, Angeloni G, Cristell N, Maseri A, Cianflone D. Serum uric acid on admission predicts in-hospital mortality in patients with acute coronary syndrome. Int J Cardiol. 2017;240:25-9.

14. Biscaglia S, Ceconi C, Malagu M, Pavasini R, Ferrari R. Uric acid and coronary artery disease: An elusive link deserving further attention. Int J Cardiol. 2016;213:28-32.

15. Lee HW, Choi SM, Lee J, Park YS, Lee CH, Yim JJ, Yoo CG, Kim YW, Han SK, Lee SM. Serum uric acid level as a prognostic marker in patients with acute respiratory distress syndrome. J Intensive Care Med. 2019;34:404-10.

16. Hsu WL, Li SY, Liu JS, Huang PH, Lin SJ, Hsu CC, Lin YP, Tarng DC. High uric acid ameliorates indoxyl sulfate-induced endothelial dysfunction and is associated with lower mortality among hemodialysis patients. Toxins (Basel). 2017;9.

17. Mancia G, Grassi G, Borghi C. Hyperuricemia, urate deposition and the association with hypertension. Curr Med Res Opin. 2015;31 Suppl 2:15-9.

18. Nagano S, Takahashi M, Miyai N, Oka M, Utsumi M, Shiba M, Mure K, Takeshita T, Arita M. Association of serum uric acid with subsequent arterial stiffness and renal function in normotensive subjects. Hypertens Res. 2017;40:620-4.

19. Atherosclerosis Group GDoGPMA. Epidemiological study on plasma lipid among patients with cardiovascular disease in 9 cities of the Pearl River Delta region. Zhonghua Xin Xue Guan Bing Za Zhi. 2009;37:849-53 (In Chinese).

20. Huang Y, Cai X, Mai W, Li M, Hu Y. Association between prediabetes and risk of cardiovascular disease and all cause mortality: systematic review and meta-analysis. BMJ. 2016;355:i5953.

21. Ding W, Li T, Su Q, Yuan M, Lin A. Integrating factors associated with hypertensive patients' self-management using structural equation modeling: a cross-sectional study in Guangdong, China. Patient Prefer Adherence. 2018;12:2169-78.

22. Joint Committee for Developing Chinese guidelines on P, Treatment of Dyslipidemia in A. Chinese guidelines on prevention and treatment of dyslipidemia in adults. Zhonghua Xin Xue Guan Bing Za Zhi. 2007;35:390-419 (In Chinese).

23. American Diabetes A. Standards of medical care in diabetes-2018 abridged for primary care providers. Clin Diabetes. 2018;36:14-37.
24. Zhou B, Cooperator Meta-Analysis Group Of China Obesity Task F. Predictive values of body mass index and waist circumference to risk factors of related diseases in Chinese adult population. Zhonghua Liu Xing Bing Xue Za Zhi. 2002;23:5-10 (In Chinese).

25. Joint Committee for Guideline R. 2018 Chinese guidelines for prevention and treatment of hypertension-a report of the revision committee of Chinese guidelines for prevention and treatment of hypertension. J Geriatr Cardiol. 2019;16:182-241.

26. Manara M, Bortoluzzi A, Favero M, Prevete I, Scire CA, Bianchi G, Borghi C, Cimmino MA, D'Avola GM, Desideri G, et al. Italian Society of Rheumatology recommendations for the management of gout. Reumatismo. 2013;65:4-21.

27. Qiu L, Cheng XQ, Wu J, Liu JT, Xu T, Ding HT, Liu YH, Ge ZM, Wang YJ, Han HJ, et al. Prevalence of hyperuricemia and its related risk factors in healthy adults from Northern and Northeastern Chinese provinces. BMC Public Health. 2013;13:664.

28. Song P, Wang H, Xia W, Chang X, Wang M, An L. Prevalence and correlates of hyperuricemia in the middle-aged and older adults in China. Sci Rep. 2018;8:4314.

29. Miao Z, Li C, Chen Y, Zhao S, Wang Y, Wang Z, Chen X, Xu F, Wang F, Sun R, et al. Dietary and lifestyle changes associated with high prevalence of hyperuricemia and gout in the Shandong coastal cities of Eastern China. J Rheumatol. 2008;35:1859-64.

30. Han Z, Dai L, Yu X, Sun D, Cheng J. Effect of gas cooking on the nutrition and health benefits of Crucian Carp Soup. Modern Food Science and Technology. 2020;36:1-8 (In Chinese).

31. Hainer BL, Matheson E, Wilkes RT. Diagnosis, treatment, and prevention of gout. Am Fam Physician. 2014;90:831-6.

32. Mumford SL, Dasharathy SS, Pollack AZ, Perkins NJ, Mattison DR, Cole SR, Wactawski-Wende J, Schisterman EF. Serum uric acid in relation to endogenous reproductive hormones during the menstrual cycle: findings from the BioCycle study. Hum Reprod. 2013;28:1853-62.

33. Sumino H, Ichikawa S, Kanda T, Nakamura T, Sakamaki T. Reduction of serum uric acid by hormone replacement therapy in postmenopausal women with hyperuricaemia. Lancet. 1999;354:650.

34. Hak AE, Choi HK. Menopause, postmenopausal hormone use and serum uric acid levels in US women—the Third National Health and Nutrition Examination Survey. Arthritis Res Ther. 2008;10:R116.

35. Lewington S, Lacey B, Clarke R, Guo Y, Kong XL, Yang L, Chen Y, Bian Z, Chen J, Meng J, et al. The burden of hypertension and associated risk for cardiovascular mortality in China. JAMA Intern Med. 2016;176:524-32.

36. Perlstein TS, Gumieniak O, Hopkins PN, Murphey LJ, Brown NJ, Williams GH, Hollenberg NK, Fisher ND. Uric acid and the state of the intrarenal renin-angiotensin system in humans. Kidney Int. 2004;66:1465-70.

37. Zheng R, Yang T, Chen Q, Chen C, Mao Y. Serum uric acid concentrations can predict hypertension: a longitudinal population-based epidemiological study. Horm Metab Res. 2017;49:873-9.
38. Grayson PC, Kim SY, LaValley M, Choi HK. Hyperuricemia and incident hypertension: a systematic review and meta-analysis. Arthritis Care Res (Hoboken). 2011;63:102-10.

39. Choi HK, Atkinson K, Karlson EW, Curhan G. Obesity, weight change, hypertension, diuretic use, and risk of gout in men: the health professionals follow-up study. Arch Intern Med. 2005;165:742-8.

40. Liu DM, Jiang LD, Gan L, Su Y, Li F. Association between serum uric acid level and body mass index in sex- and age-specific groups in Southwestern China. Endocr Pract. 2019;25:438-45.

41. Rho YH, Lu N, Peloquin CE, Man A, Zhu Y, Zhang Y, Choi HK. Independent impact of gout on the risk of diabetes mellitus among women and men: a population-based, BMI-matched cohort study. Ann Rheum Dis. 2016;75:91-5.

42. Niskanen L, Laaksonen DE, Lindstrom J, Eriksson JG, Keinanen-Kiukaanniemi S, Ilanne-Parikka P, Aunola S, Hamalainen H, Tuomilehto J, Uusitupa M. Serum uric acid as a harbinger of metabolic outcome in subjects with impaired glucose tolerance: the Finnish Diabetes Prevention Study. Diabetes Care. 2006;29:709-11.

43. Facchini F, Chen YD, Hollenbeck CB, Reaven GM. Relationship between resistance to insulin-mediated glucose uptake, urinary uric acid clearance, and plasma uric acid concentration. JAMA. 1991;266:3008-11.

44. Hou YL, Yang XL, Wang CX, Zhi LX, Yang MJ, You CG. Hypertriglyceridemia and hyperuricemia: a retrospective study of urban residents. Lipids Health Dis. 2019;18:81.

45. Balasubramanian T. Uric acid or 1-methyl uric acid in the urinary bladder increases serum glucose, insulin, true triglyceride, and total cholesterol levels in Wistar rats. ScientificWorldJournal. 2003;3:930-6.

46. Chen S, Guo X, Dong S, Yu S, Chen Y, Zhang N, Sun Y. Association between the hypertriglyceridemic waist phenotype and hyperuricemia: a cross-sectional study. Clin Rheumatol. 2017;36:1111-9.