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Prevalence of hyperuricemia and its correlates in rural Northeast Chinese population: from lifestyle risk factors to metabolic comorbidities

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Abstract The increasing trend of hyperuricemia in urban areas of China has been noted in the past decade. However, the prevalence of hyperuricemia in rural China has not been extensively investigated. We aimed to estimate the prevalence and risk factors of hyperuricemia and the associated comorbidities in rural Northeast China. This survey was conducted from July 2012 to August 2013. In this study, a total of 11,576 residents from the rural Northeast China were randomly selected and examined. Hyperuricemia was defined as serum uric acid ≥416 μmol/l in men and ≥357 μmol/l in women. Data regarding the demographic and lifestyle characteristics and the blood biochemical indexes of these participants were collected by well-trained personnel. The prevalence of hyperuricemia was 10.9 % and was more prevalent in men than in women (15.0 vs. 7.3 %, $P<0.001$). Multivariate logistic regression models revealed that besides age, hyperuricemia in men was associated with ethnic minority [OR (95 %): 0.683 (0.472,0.989)], physical activity [moderate, OR (95 %): 0.716 (0.596,0.859); high, OR (95 %): 0.527 (0.354,0.786)], current smoking [OR(95 %):1.380 (1.179,1.616)], and current drinking [OR(95 %):0.705 (0.603,0.825)], while in women was only associated with ethnic minority [OR(95 %):0.485 (0.262,0.896)]. After adjusting for possible confounders, hyperuricemia was related to different subtypes of cardiometabolic comorbidities in both gender like abdominal obesity,

general obesity, hypertriglyceridemia, hypertension, hypercholesterolemia, and low HDL-C. Besides, in women only, hyperuricemia was related to diabetes and high LDL-C. Hyperuricemia was common among residents living in rural Northeast China especially among men. Ethnic minority, physical activity, current smoking, and drinking contributed to hyperuricemia in this population.

Keywords Comorbidities · Hyperuricemia · Prevalence · Risk · Rural

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Introduction

Epidemiologic studies show that hyperuricemia has become a common metabolic disorder worldwide in recent decades [1]. According to the National Health and Nutrition Examination Survey conducted in the USA, the prevalence of hyperuricemia during 2007–2008 was 21.1 % in men and 21.6 % in women [2]. This high incidence of hyperuricemia in developed countries may be related to the epidemic occurrence of overweight and obesity, as well as the Western diet rich in purine, alcohol, meat consumption, and soft drinks [3, 4]. With a more open policy and economic development in China, westernization has became common not only in urban but also in rural areas [5]. Dietary patterns play a key role in hyperuricemia. The prevalence of hyperuricemia is increasing in some cities in China, such as Shanghai (6.79 vs. 22.52 % for men, 3.65 vs. 15.32 % for women) [6, 7]. Moreover, the prevalence of hyperuricemia in urban areas of China like Guangdong (23.43 % for men and 11.77 % for women), Beijing (25.74 % for men and 10.52 % for women), and Hainan (27.30 % for men and 15.33 % for women) are very close to levels in developed countries [2, 8, 9].

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Previous studies have demonstrated that an association exists between serum uric acid levels and hypertension, chronic kidney disease (CKD), heart failure, metabolic syndrome, obesity, and cardiovascular events [10]. In China, studies have investigated the possible relationship between hyperuricemia and other metabolic comorbidities [11, 12]. However, most of the studies were conducted in urban areas of China. As far as we know, few studies have focused on determining the prevalence and epidemiological features of hyperuricemia in rural areas of China. A nationwide population-based survey conducted in 2005 found that 57.01 % of Chinese residents lived in rural areas. Therefore, we performed the present study to estimate the prevalence of hyperuricemia and its risk factors in rural Northeast China and to evaluate the independent effects of hyperuricemia on different cardiac metabolic comorbidities in a large sample size of a rural population from 2012 to 2013.

Subjects and methods

Study population

Liaoning Province is located in Northeast China. From January 2012 to August 2013, a representative sample of participants aged ≥35 years was selected to characterize the prevalence, incidence, and natural history of cardiovascular risk factors in rural areas of Liaoning Province. The study adopted a multi-stage, stratified, random-cluster sampling scheme. In the first stage, three counties (Dawa, Zhangwu, and Liaoyang County) were selected from the eastern, southern, and northern regions of Liaoning province. In the second stage, one town was randomly selected from each county (for a total of three towns). In the third stage, 8–10 rural villages from each town were randomly selected (for a total of 26 rural villages). Participants who were pregnant or had malignant tumors or mental disorders and had severe psychiatric disturbances, hepatic failure, or end-stage renal failure were excluded from the study. All the eligible permanent residents aged ≥35 years from each village were invited to attend the study (a total of 14,016 participants). Of those, 11,956 participants agreed and completed the study to give a response rate of 85.3 %. The study was approved by the Ethics Committee of China Medical University (Shenyang, China). All procedures were performed in accordance with ethical standards. Written consent was obtained from all participants after they had been informed of the objectives, benefits, medical items, and confidentiality agreement regarding their personal information. For participants who were illiterate, we obtained written informed consent from their proxies. In this report, we used only the data from participants who completed the study, which provided a final sample size of 11,576 (5359 men and 6217 women).

Data collection and measurements

Data were collected during a single visit to the clinic by cardiologists and trained nurses using a standard questionnaire in a face-to-face interview. Before the survey was performed, we invited all eligible investigators to attend an organized training session. The training included the purpose of this study, how to administer the questionnaire, the standard method of measurement, the importance of standardization, and the study procedures. A strict test was administered after this training, and only those who scored perfectly on the test were accepted as investigators in this study. During data collection, our inspectors had further instructions and support.

Data regarding the demographic characteristics, lifestyle risk factors, dietary habits, family income, and family history of chronic diseases were obtained during the interview using the standardized questionnaire. The study was guided by a central steering committee with a subcommittee for quality control. Educational level was assessed as completion of primary school or less, middle school, or high school and higher. Self-reported sleep duration (including nocturnal and nap duration) was obtained from the questionnaire. The responses were categorized into four groups: ≤7, 7–8, 8–9, and >9 h/day. Family income was classified as ≤5000, 5000–20,000, and >20,000 CNY/year.

According to American Heart Association protocol, blood pressure (BP) was measured three times at 2-min intervals after at least 5 min of rest using a standardized automatic electronic sphygmomanometer (HEM-907; Omron), which had been validated according to the British Hypertension Society protocol [13]. The participants were advised to avoid caffeinated beverages and exercise for at least 30 min before the measurement. During the measurement, the participants were seated with their arms supported at the level of the heart. The mean of three BP measurements was calculated and used in all analyses.

Weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, with the participants wearing light weight clothing and without shoes. Waist circumference (WC) was measured at the umbilicus using a non-elastic tape (to the nearest 0.1 cm), with the participants standing at the end of normal expiration. Body mass index (BMI) was calculated as the weight in kilograms divided by the square root of the height in meters.

Fasting blood samples were collected in the morning after at least 12 h of fasting. Blood samples were obtained from an antecubital vein into Vacutainer tubes containing ethylenediaminetetraacetic acid (EDTA). Fasting plasma glucose (FPG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglycerides (TGs), and other routine blood biochemical indexes were analyzed enzymatically using an autoanalyzer. All

laboratory equipments were calibrated, and blinded duplicate samples were used for these analyses.

Definitions

Hyperuricemia was defined as serum uric acid ≥416 μmol/l in men and ≥357 μmol/l in women according to guidelines [14]. According to JNC-7 report [15], prehypertension was defined as not being on antihypertensive medication and having a systolic blood pressure (SBP) of 120–139 mmHg or diastolic blood pressure (DBP) of 80–89 mmHg. Hypertension was defined as SBP≥140 mmHg and/or DBP≥90 mmHg and/or use of antihypertensive medications. BMI were categorized into 3 groups as normal (BMI <25 kg/m^2), overweight (25≤ BMI <30 kg/m^2), and obesity (BMI ≥30 kg/m^2), according to the World Health Organization (WHO) criteria [16]. Abdominal obesity was defined as WC≥88 cm for females and WC≥102 cm for males [17]. Dyslipidemia was defined according to the National Cholesterol Education Program-Third Adult Treatment Panel (ATP III) criteria [18]. High TC was defined as TC≥6.21 mmol/L(240 mg/dL). Low HDL-C was defined as HDL-C<1.03 mmol/L (40 mg/dL). High LDL-C was de fined as LDL-C≥4.16 mmol/L (160 mg/dL). High TG was defined as≥2.26 mmol/L (200 mg/dL). Diabetes mellitus was diagnosed according to the WHO criteria [19]: FPG≥7 mmol/L (126 mg/dL) and/or being on treatment for diabetes.

Physical activity included occupational and leisure time physical activity. A detailed description of the methods for assessing physical activity has been presented elsewhere [20, 21]. Occupational and leisure time physical activity were merged and regrouped into the following three categories: (1) low—subjects who reported light levels of both occupational and leisure time physical activity; (2) moderate—subjects who reported moderate or high levels of either occupational or leisure-time physical activity; and (3) high—subjects who reported a moderate or high level of both occupational and leisure time physical activity.

Dietary patterns were assessed by having participants recall the foods they had eaten during the previous year. The questionnaire included questions regarding the average consumption of several food items per week. The reported consumption was quantified approximately in terms of grams per week. Vegetable consumption was assessed on the following scale: rarely=3, <1000 g=2, 1000–2000 g=1, ≥2000 g=0, and meat consumption, including red meat, fish, and poultry was assessed on the following scale: rarely=0, <250 g=1, 250–500 g=2, and ≥500 g=3. A special diet score (vegetable consumption score plus meat consumption score) was calculated for each participant (range 0–6). Higher values of the diet score indicated higher meat consumption, lower vegetable consumption, and greater adherence to a Westernized diet,

while lower values indicate adherence to the Chinese diet. Similar methods for calculating a diet score can be found in the ATTICA study [22].

Statistical analysis

Descriptive statistics were calculated for all the variables, including continuous variables (reported as mean values and standard deviations) and categorical variables (reported as numbers and percentages). The differences between the hyperuricemia and non hyperuricemia groups were evaluated using the Student's t test, ANOVA, non-parametric test, or the χ^2 test, as appropriate. Multivariate logistic regression analyses were used to identify independent factors of hyperuricemia, and odds ratios (ORs) and corresponding 95 % confidence intervals (CIs) were calculated. All the statistical analyses were performed using SPSS version 17.0 software, and P values less than 0.05 were considered to be statistically significant.

Results

Baseline characteristics of study population

Table 1 provides the baseline characteristics of the study subjects. Current smoking and drinking were more common in men than in women. Age, weight, height, SBP, DBP, serum uric acid, serum creatinine, serum glucose, sleep duration, and dietary score levels were significantly higher for men than for women, with no significant differences in HDL cholesterol and triglycerides. Women compared to men had a lower educational level (primary school or below), were less physically active, and had a lower family income (≤5000 CNY/year), with no significant difference in ethnic composition.

Prevalence of hyperuricemia in different gender and age groups

The overall prevalence of hyperuricemia was 10.9 % (data not shown) for subjects >35 years of age. The serum uric acid level was higher for men than for women (333.7±83.5 vs. 255.8±67.8 μmol/L, P<0.001), and the prevalence of hyperuricemia was greater in men than in women (15.0 vs.7.3 %, P<0.001). For men, the prevalence of hyperuricemia decreased with age (35–45 years: 18.2 %; 45–55 years: 15.3 %; 55–65 years: 12.7 %; >65 years: 14.5 %). For women, the prevalence of hyperuricemia increased with age (35–45 years: 4.0 %; 45–55 years: 5.5 %; 55–65 years: 9.4 %; >65 years: 12.6 %) (Fig. 1).

Table 1 Demographic, anthropometric, and plasma biochemical characteristics of subjects in rural Liaoning Province of Northeast China

Characteristics	Men (n=5359)	Women (n=6217)	Hyperuricemia (n=1256)	Non-hyperuricemia (n=10320)	Total (n=11576)
Clinical variables					
Age (years)	54.4±10.8	53.4±10.4*	54.7±11.0	53.7±10.5#	53.8±10.6
Weight (kg)	68.6±11.1	60.3±10.1*	70.6±12.5	63.3±10.9*	64.1±11.4
Height (cm)	166.4±6.3	155.6±6.1*	163.3±8.5	160.3±8.1*	160.6±8.2
BMI (Kg/m^2)	24.7±3.5	24.9±3.8	26.4±3.8	24.6±3.6*	24.8±3.7
SBP (mmHg)	143.7±22.6	140.2±24.0*	146.0±23.5	141.3±23.4*	141.8±23.5
DBP (mmHg)	83.8±11.8	80.6±11.5*	86.1±12.8	81.6±11.5*	82.1±11.8
Biochemical variables					
Total cholesterol (mmol/L)	5.2±1.0	5.3±1.1*	5.6±1.3	5.2±1.1*	5.2±1.1
LDL cholesterol (mmol/L)	2.9±0.8	3.0±0.8*	3.1±0.9	2.9±0.8*	2.9±0.8
HDL cholesterol (mmol/L)	1.4±0.4	1.4±0.3	1.3±0.4	1.4±0.4*	1.4±0.4
Triglycerides (mmol/L)	1.7±1.7	1.6±1.3	2.5±2.4	1.5±1.3*	1.6±1.5
Serum uric acid (μmol/l)	333.7±83.5	255.8±67.8*	452.1±68.0	272.4±63.3*	291.9±84.9
Serum creatinine (mmol/L)	79.7±20.0	65.4±19.9*	85.9±44.3	70.3±15.4*	72.0±21.2
Serum glucose (mmol/L)	6.0±1.7	5.9±1.6#	6.0±1.5	5.9±1.7#	5.9±1.6
Current smoking status (yes)	3058 (57.1)	1030 (16.6)*	494 (39.3)	3594 (34.8)#	4088(35.3)
Current drinking status (yes)	2435 (45.4)	183 (2.9)*	425 (33.8)	2193 (21.3)*	2618 (22.6)
Diet score	2.5±1.1	2.1±1.1*	2.4±1.2	2.3±1.1#	2.3±1.1
Sleep duration (h/d)	7.4±1.6	7.1±1.7*	7.2±1.7	7.3±1.7	7.3±1.7
Ethnicity		0.325		0.003	
Han	5073 (94.7)	5898 (94.9)	1211 (96.4)	9760 (94.6)	10971 (94.8)
Others[a]	286 (5.3)	319 (5.1)	45 (7.4)	560 (5.4)	605 (5.2)
Education		<0.001		0.012	
Primary school or below	2233 (41.7)	3532 (56.8)	631 (50.2)	5134 (49.7)	5765 (49.8)
Middle school	2513 (46.9)	2205 (35.5)	480 (38.2)	4238 (41.1)	4718 (40.8)
High school or above	613 (11.4)	480 (7.7)	145 (11.5)	948 (9.2)	1093 (9.4)
Physical activity		<0.001		0.068	
Low	1209 (22.6)	2233 (35.9)	408 (32.5)	3034 (29.4)	3442 (29.7)
Moderate	3853 (71.9)	3628 (58.4)	784 (62.4)	6697 (64.9)	784 (64.6)
High	297 (5.5)	356 (5.7)	64 (5.1)	589 (5.7)	653 (5.6)
Family income (CNY/year)		0.009		0.729	
≤5000	720 (13.4)	721 (11.6)	165 (13.1)	1276 (12.4)	1441 (12.4)
5000–20,000	2872 (53.6)	3437 (55.3)	677 (53.9)	5632 (54.6)	6309 (54.5)
>20,000	1767 (33.0)	2059 (33.1)	414 (33.0)	3412 (33.1)	3826 (33.1)

Data are expressed as the mean±SD or as n (%)

SBP systolic blood pressure, *DBP* diastolic blood pressure, *BMI* body mass index, *LDL cholesterol* low-density lipoprotein cholesterol, *HDL* high-density lipoprotein cholesterol

[a] Including some ethnic minorities in China, such as Mongol and Manchu

* *P*<0.001; # *P*<0.05

Factors associated with hyperuricemia

Table 2 shows the multivariable logistic regression analysis of risk factors related to hyperuricemia in men and women. Increasing age was associated with an increased risk of hyperuricemia in women, but a decreased risk of hyperuricemia in men. Being from an ethnic minority was associated with a lower risk of hyperuricemia compared to being ethnic Han in both genders (men: OR: 0.683, 95 %CI: 0.472 to 0.989; women: OR: 0.485, 95 %CI: 0.262 to 0.896). Current male smokers were less likely to have hyperuricemia but current female smokers were not, while current male drinkers had a higher possibility to developing hyperuricemia than did current female drinkers. Moderate or high physical activity was found to be a protective factor for hyperuricemia (for moderate
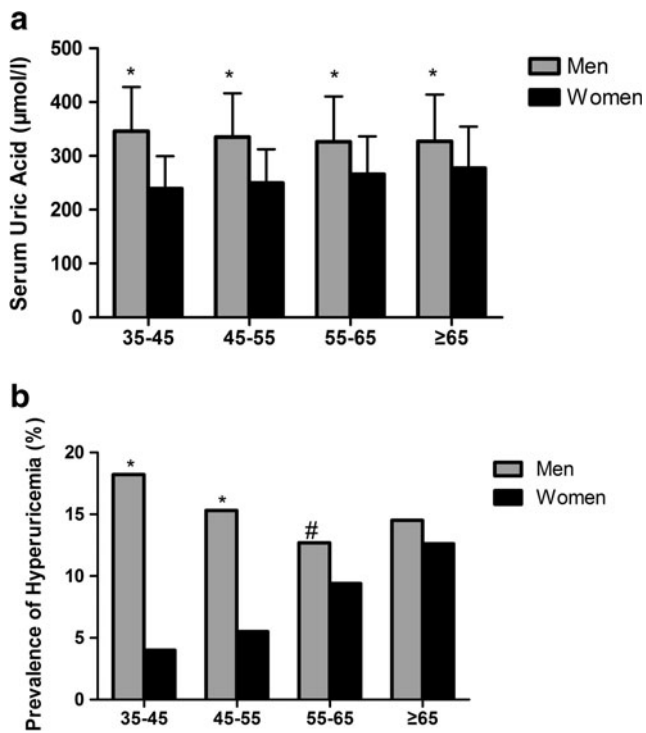
Fig. 1 Serum uric acid level and prevalence of hyperuricemia by age and sex. **a** Serum uric acid level, **b** prevalence of hyperuricemia. $^{\#}P<0.05$; $*P<0.001$

OR: 0.716, 95 %CI: 0.596 to 0.859; for high OR: 0.527, 95 %CI: 0.354 to 0.786)

Hyperuricemia and cardiometabolic comorbidities

As shown in Fig. 2, the overall mean serum uric acid level was significantly higher for subjects with metabolic disorders like general obesity (319.01±91.86 vs. 289.60±83.87), high TC (307.08±88.84 vs. 288.86±83.74), high TG (332.05±92.81 vs. 283.46±80.62), low HDL-C (318.10±90.98 vs. 287.98± 83.23), high LDL-C (301.56±88.15 vs. 291.09±84.56), impaired fasting glucose (IFG) (300.13±91.26 vs. 290.93± 84.06), and hypertension (301.79±87.78 vs. 281.52± 80.436), as was the prevalence of hyperuricemia. On multivariate analysis shown in Table 3, hyperuricemia was a risk factor for abdominal obesity, general obesity, hypertension, hypertriglyceridemia, diabetes, hypercholesterolemia, low HDL-C, and high LDL-C in both genders except for high LDL-C and diabetes in men (Fig. 3).

Discussion

The present study found that the prevalence of hyperuricemia in a rural Northeast Chinese population was 10.9 %. Men had a significantly higher incidence of hyperuricemia than women had (15.0 vs. 7.3 %, $P<0.001$). In addition, men and women

had different risk factors and different associated comorbidities. Hyperuricemia in men was associated with age, ethnicity, physical activity, and current smoking and drinking, while in women hyperuricemia was only related to age and ethnicity.

With a more open policy and economic development, dietary patterns have changed remarkably during the past decades. A previous study demonstrated that the traditional Chinese diet has become westernized. Grain consumption has been decreasing, and animal food, fried food, and fast food, which is full of purine, has been markedly increasing [22]. As a result, common health problems in China are now similar to those in Western countries, e.g., metabolic syndrome, obesity, and diabetes. The prevalence of these metabolic disorders was high in our study: abdominal obesity (3.9 % for men, 24.8 % for women), hypertension (53.9 % for men, 48.7 % for women), and low HDL-C (16.1 % for men, 18.4 % for women).

Moreover, the prevalence of hyperuricemia in urban areas of China has increased and is now very close to that in developed countries. Huang and colleagues reported that 39.18 % of men and 30.18 % of women suffer from hyperuricemia in Fujian province [23]. In addition, hyperuricemia is prevalent in many developed cities in China like Beijing (25.74 % for men, 10.52 % for women), Chongqing (57.14 % for men, 12.73 % for women), and Tibet (34.53 % for men, 13.70 % for women) [8, 24, 25]. However, most of the previous studies were carried out in urban areas of China. Few studies reported on the prevalence and epidemiological features of hyperuricemia because measuring serum uric acid was not included in the regular health examination in rural areas. A survey of a total population of 4683 rural adults in Java reported that the prevalence of hyperuricemia was 24.3 % [26]. Our study estimated that 10.5 % of rural residents had hyperuricemia, which was lower than that in the urban cities in China and rural areas outside of China. Residents who live in urban areas have quite a different life style than those of rural residents. They live a more sedentary life, with fewer physical activities, and a more westernized diet. The above may partially count for the lower prevalence of hyperuricemia in rural areas. Our findings are consistent with those of other studies that concluded that men have a higher possibility of hyperuricemia than women have [27]. This result is in line with the most recent study also conducted in Northern and Northeastern China with the same results of a higher prevalence of hyperuricemia in men than in women (men vs. women, 21 vs. 7.9 %; $P<0.0001$) [28]. Previous studies have observed that women compared with men have a significantly lower serum uric concentration [8, 24, 25]. This could be due to the decreasing fractional excretion of urate by the kidneys and a substantial increase in body mass during male adolescence, contributing to an increase in uric acid levels. During early adolescence, girls weigh more than their male peers, resulting in slightly higher serum uric acid levels in girls. However,

Table 2 Multiple regression analyses of hyperuricemia and associated factors

Variables	Men		Women	
	OR (95 %CI)	P-value	OR (95 %CI)	P value
Age (years)				
35–44	1.000 (reference)		1.000 (reference)	
45–54	0.808 (0.661,0.988)	0.038	1.328 (0.961,1.836)	0.086
55–64	0.609 (0.490,0.757)	<0.001	2.198 (1.586,3.046)	<0.001
≥65	0.666 (0.510,0.869)	0.003	3.124 (2.157,4.525)	<0.001
Ethnicity				
Han	1.000 (reference)		1.000 (reference)	
Others[a]	0.683 (0.472,0.989)	0.043	0.485 (0.262,0.896)	0.021
Education				
Primary school or below	1.000 (reference)		1.000 (reference)	
Middle school	0.914 (0.768,1.088)	0.311	0.812 (0.634,1.040)	0.099
High school or above	1.123 (0.870,1.448)	0.373	1.191 (0.810,1.750)	0.373
Physical activity				
Low	1.000 (reference)		1.000 (reference)	
Moderate	0.716 (0.596,0.859)	<0.001	0.914 (0.741,1.127)	0.400
High	0.527 (0.354,0.786)	0.002	1.223 (0.819,1.826)	0.324
Family income (CNY/year)				
≤5000	1.000 (reference)		1.000 (reference)	
5000–20,000	0.988 (0.777,1.255)	0.918	1.162 (0.856,1.578)	0.334
>20,000	0.965 (0.744,1.252)	0.791	1.190 (0.848,1.670)	0.315
Current smoking status	0.705 (0.603,0.825)	<0.001	0.892 (0.686,1.160)	0.395
Current drinking status	1.380 (1.179,1.616)	<0.001	1.351 (0.801,2.279)	0.259
Sleep duration (hours/day)				
≤7	1.000 (reference)		1.000 (reference)	
7–8	0.904 (0.755,1.083)	0.272	0.873 (0.688,1.107)	0.262
8–9	1.502 (0.846,1.307)	0.649	0.794 (0.572,1.101)	0.167
>9	0.771 (0.574,1.037)	0.085	1.097 (0.753,1.599)	0.631
Diet score (per 1 unit)	1.033 (0.962,1.109)	0.378	0.947 (0.867,1.035)	0.229

OR odds ratio, *95 % CI* 95 % confidence interval, *CNY* China Yuan (1CNY=0.161 USD)

[a] Including some ethnic minorities in China, such as Mongol and Manchu

*$P<0.05$ for the independent association between hyperuricemia and each factor after adjusting for the remaining factors

during mid-adolescence, boys tend to be heavier, with higher uric acid levels, compared to girls, which is partially associated with androgen levels that promote kidney uric acid reabsorption [29]. In addition, men in our study had a significantly higher rate of current drinking than did the women (45.4 vs. 2.9 %). Studies confirm that alcohol consumption increases the demands on purine elimination resulting in hyperuricemia [10].

Many risk factors for hyperuricemia have been described, e.g., age, gender, diet, and others. In our study, we found that men and women had different risk profiles. The hyperuricemia prevalence decreased with increasing age for men, while in women, older age seemed to result in a higher risk of hyperuricemia. This is consistent with a previous study also conducted in China [30]. The mechanism of the decreasing trend

in hyperuricemia with increasing age in men is possibly due to the higher prevalence of current drinking and lack of physical activity among younger residents, while the increasing hyperuricemia prevalence with age for women may be related to menopause, causing changes in the endocrine system and estrogen levels [31]. In our study, we found that ethnic minorities had a relatively lower risk of hyperuricemia than did the Han, which was also demonstrated in other studies [32]. The relatively lower prevalence of hyperuricemia in ethnic minorities is possibly due to the low consumption of seafood and higher prevalence of current drinking [32]. Additionally, ethnic diversity may partially count for this discrepancy. Another interesting finding in our study is that current smoking was a protective factor for hyperuricemia in both genders but without statistical significance in women. This is consistent with
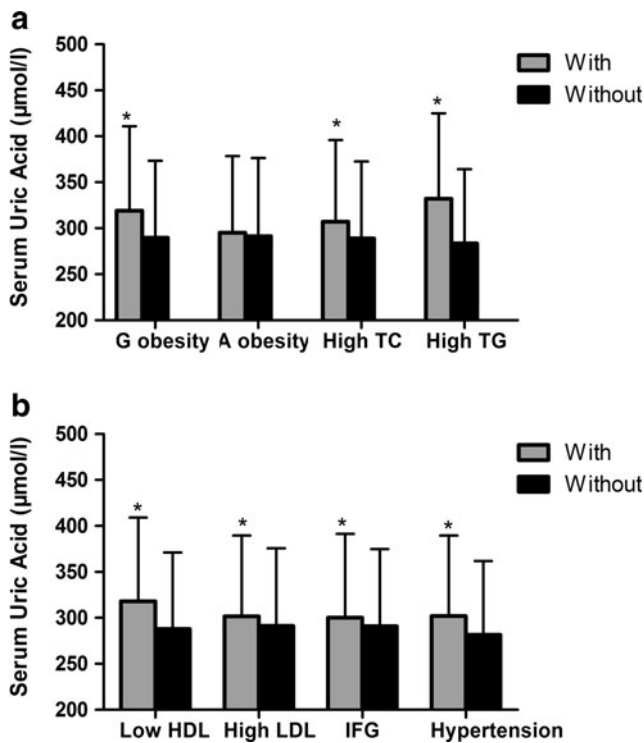
Fig. 2 Serum uric acid level with or without selected risk factors. *G obesity* general obesity, *A obesity* abdominal obesity, *IFG* increase fasting glucose. #*P*<0.05; *P*<0.001
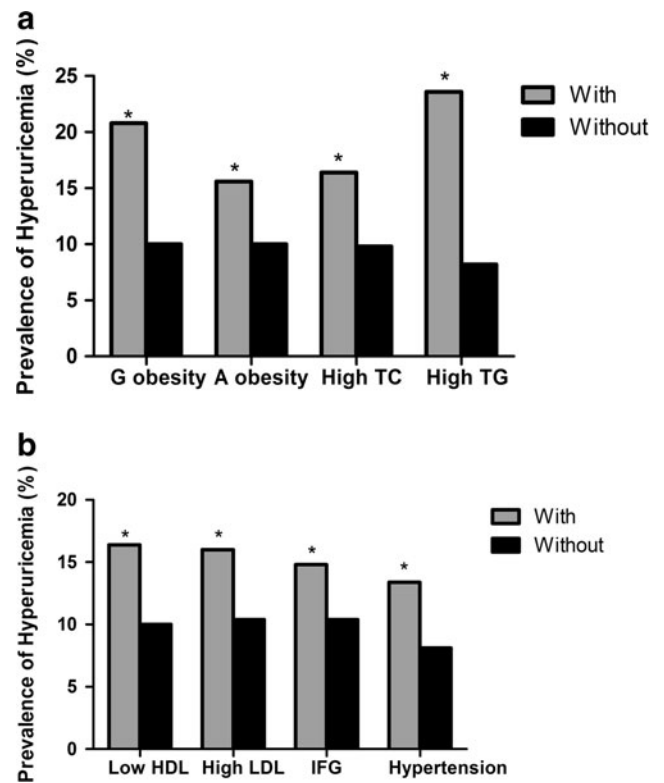
the findings in many other studies [33]. It has been suggested that smoking might suppress serum uric acid levels via the action of the superoxides found in cigarette smoke [33].

Fig. 3 Prevalence of hyperuricemia in selected risk factors. *G obesity* general obesity, *A obesity* abdominal obesity, *IFG* increase fasting glucose. #*P*<0.05; *P*<0.001

Some studies have confirmed that an inverse association exists between smoking and abdominal obesity and general obesity,

Table 3 Characteristics of subjects with and without hyperuricemia according to gender (*n*=11576)

	Men				Women			
	With HU *n*=805 (*n*,%)	Without HU *n*=4554 (*n*,%)	Total *n*=5359 (*n*,%)	OR (95 %CI)	With HU *n*=451 (*n*,%)	Without HU *n*=5766 (*n*,%)	Total *n*=6217 (*n*,%)	OR (95 %CI)
Abdominal obesity	69 (8.6)	140 (3.1)*	209 (3.9)*	2.800 (2.053,3.818)*	204 (45.2)	1335 (23.2)*	1539 (24.8)	2.779 (2.258,3.421)*
General obesity	107 (13.3)	246 (5.4)*	353 (6.6)*	2.510 (1.955,3.222)*	80 (17.7)	465 (8.1)*	545 (8.8)	3.013 (2.283,3.976)*
Hypertension	499 (62.0)	2392 (52.5)*	2891 (53.9)*	1.602 (1.357,1.892)*	296 (65.6)	2730 (47.3)*	3026 (48.7)	1.749 (1.398,2.188)*
High TG	282 (35.0)	657 (14.4)*	939 (17.5)	3.008 (2.531,3.575)*	192 (42.6)	876 (15.2)*	1068 (17.2)	3.643 (2.954,4.494)*
Diabetes	80 (9.9)	450 (9.9)	530 (9.9)	1.004 (0.776,1.300)	98 (21.7)	572 (9.9)*	670 (10.8)	2.164 (1.668,2.807)*
High TC	172 (21.4)	601 (13.2)*	773 (14.4)*	1.679 (1.381,2.042)*	142 (31.5)	1004 (17.4)*	1146 (18.4)	1.646 (1.312,2.066)*
Low HDL-C	179 (22.2)	686 (15.1)*	865 (16.1)*	1.574 (1.287,1.925)*	67 (14.9)	567 (9.8)#	634 (10.2)	1.577 (1.186,2.097)#
High LDL-C	64 (8.0)	266 (5.8)#	330 (6.2)*	1.337 (0.999,1.790)	76 (16.9)	469 (8.1)*	545 (8.8)	1.922 (1.446,2.555)*

Adjusted for age, serum creatinine, current smoking and current drinking, ethnicity, education, physical activity, family income, sleep duration, and diet score. Hypertension, systolic blood pressure≥140 mmHg, and/or diastolic blood pressure≥90 mmHg and/or use of antihypertensive medications. General obesity, body mass index≥30 Kg/m², abdominal obesity, waist circumference ≥88 cm for men, and waist circumference ≥102 cm for women. High TC, TC≥6.21 mmol/L, low HDL-C, HDL-C<1.03 mmol/L, high LDL-C, LDL-C≥4.16 mmol/L. High TG, TG≥2.26 mmol/L (200 mg/dL); diabetes, FPG≥7 mmol/L; and/or being on treatment for diabetes

BMI body mass index, *HDL-C* high-density lipoprotein cholesterol, *LDL-C* low-density lipoprotein cholesterol, *high TC* hypercholesterolemia, *high TG* hypertriglyceridemia

*P<0.001; #P<0.05

which have been proven to be risk factors for hyperuricemia [34]. We further investigated the association between current smoking and obesity and found that current smoking men had a lower prevalence of abdominal obesity (2.8 vs. 5.3 %) and general obesity (5.2 vs. 8.4 %) than noncurrent male smokers. However, this relationship did not exist among women. Our study also found that current drinking increased the risk of hyperuricemia in men. However, current drinking did not correlate with the prevalence of hyperuricemia in women in our study because only 2.9 % of the women were current drinkers. Previous epidemiological studies based mainly on cross-sectional observations or interventions have confirmed a causal relationship between alcohol consumption and hyperuricemia [35]. Furthermore, one 6-year prospective study in Japan also confirmed that habitual alcohol intake significantly contributed to the development of hyperuricemia, regardless of type of alcoholic beverage consumed [36]. We estimated that there was an inverse association between hyperuricemia and physical activity in our study. Many other studies have reached the same conclusion [37]. Some studies have demonstrated that physical activity might decrease serum uric acid excretion and accelerate purine degradation, while others have claimed that insulin sensitivity mediated the relationship between physical activity and serum uric acid [37, 38].

In the past decade, several studies have confirmed that serum uric acid is related to traditional cardiovascular risk factors, including diabetes, metabolic syndrome, hypertension, and dyslipidemia [39]. The effect of hyperuricemia on adverse cardiometabolic profiles varied in many epidemiologic studies of different ethnic groups. Our study found that hyperuricemia was a risk factor for hypertriglyceridemia, general obesity, abdominal obesity, hypertension, diabetes, hypercholesterolemia, high LDL-C, and low HDL-C. The relationship between hyperuricemia and cardiovascular diseases like hypertension, dyslipidemia, and obesity has been demonstrated by previous epidemiologic studies [40, 41]. On the one hand, a recent meta-analysis of 8 prospective cohort studies provided strong evidence that a high level of serum uric acid was independent of other risk factors, especially metabolic syndrome, for developing type 2 diabetes in middle and older aged people [42]. On the other hand, Wang SF and colleagues reported that hyperuricemia was associated with increased risk of hypertension in both males [OR(95 %CI):1.680(1.110–2.543)] and females [OR(95 %CI):1.065 (1.012–1.118)] [43]. Moreover, studies in cell culture and animal models have explored possible mechanisms that might explain the relationship. The possible mechanisms have been studied extensively, e.g., renin-angiotensin-aldosterone-dependent arteriolopathy, inhibition of neuronal nitric oxide synthase, endothelial dysfunction leading to reduced insulin-stimulated nitric oxide-induced vasodilatation, and inflammatory and oxidative changes [39, 44–46].

The present study has several limitations. First, our study was a cross-sectional study, which restricted the interpretation of the observed associations in terms of cause and effect. Longitudinal studies are required for further investigation of these findings. Second, the prevalence of hyperuricemia was based on a single assessment of blood samples, which may introduce error. In addition, although the researchers had been trained according to a standardized measurement protocol, measurements at a single visit might lead to incorrect values for the anthropometric indexes. Finally, in our study, we did not enroll residents <35 years of age. Finally, in our study, we did not evaluate insulin resistance which was in a core component in the pathophysiology of the metabolic syndrome.

In summary, our population-based study reports the latest prevalence of hyperuricemia in rural Northeast China. The prevalence of hyperuricemia among men was twice that of women. Men and women exhibited different risk profiles and had different adverse comorbidities. With economic development and the population aging, hyperuricemia will lead to increased health-care costs in rural China. It is urgent for the Chinese government to pay more attention to finding ways to halt or reduce the burden of hyperuricemia.

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