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ORIGINAL RESEARCH

Burden of Metabolic Syndrome Among a Low-Income Population in China: A Population-Based Cross-Sectional Study

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Introduction: Metabolic syndrome (MetS) is a chronic and complex disease associated with all-cause mortality, cardiovascular disease, and type 2 diabetes. The present study aimed to evaluate the prevalence of MetS and its risk factors among middle-aged and older adults in low-income, low-education rural areas with a high incidence of stroke.

Methods: This cross-sectional study of the general population was performed from April 2019 to June 2019 in rural areas of Tianjin, China. All eligible residents aged ≥ 45 years and without active malignant tumors, hepatic failure, and severe renal disease underwent routine medical examinations, which included a questionnaire, physical examination, and routine blood and biochemical tests. The modified International Diabetes Federation criteria for the Asian population was used to identify patients with MetS.

Results: A total of 3175 individuals (44.8% men, 55.2% women) were included in the final analysis. The prevalence of MetS was 52.8%, with higher prevalence in women than in men (62.4%and 40.9%, respectively). Of the five MetS components, high blood pressure and abdominal obesity were the two most prevalent in both women and men, accounting for 89.3% and 62.0%, respectively, followed by elevated fasting plasma glucose, low high-density lipoprotein cholesterol, and elevated triglycerides. Multivariate logistic regression analysis revealed the following traits to be risk factors for MetS: female sex, self-reported smoking, self-reported snoring, high body mass index, high waist-to-hip ratio, and high serum urate level.

Conclusion: The prevalence of MetS was quite high in rural areas with a low-income, low-education population. Implementing preventive and therapeutic interventions based on these risk factors is essential to prevent metabolic abnormalities.

Keywords: metabolic syndrome, epidemiology, risk factors, population-based, cross-sectional study

Introduction

Non-communicable diseases (NCDs) are the leading cause of death globally.[1] One of the most common NCDs is metabolic syndrome (MetS), a disorder characterized by obesity, insulin resistance, hypertension, and hyperlipidemia.[1] MetS can lead to the development of diseases including type 2 diabetes (T2DM), cardiovascular disease, nonalcoholic steatohepatitis, and cancer.[2,3]

Received: 5 June 2022
Accepted: 16 August 2022
Published: 3 September 2022

Characterized by a cluster of interconnected cardiometabolic risk factors, including obesity, dyslipidemia, hypertension, and impaired glucose tolerance,[4] MetS contributes to the development of coronary diseases, stroke, T2DM, and premature mortality.[5] Previous research has shown that adults residing in rural China had a higher prevalence of MetS than urban adult residents in the United States.[6] In addition, previous study reported that the prevalence of MetS in rural areas worldwide ranges from 2.45% to 39.70%.[6]

Despite the differing prevalence of MetS that depend on the various criteria used in different definitions, as well as the composition of the population studied, including sex, age, and ethnicity,[7] the prevalence of MetS is alarmingly high, and a vast proportion of the population with MetS is at high risk of developing cardiovascular diseases and type 2 diabetes.[8] Longer lifespans in China have accompanied a rapid increase in per-capita income, a rising proportion of the elderly, and progressive Westernization of lifestyle,[9] and the lower socioeconomic status associated with the presence of MetS in a rural population in China.[10] Accordingly, the resulting persistent increase in the prevalence of MetS in rural areas calls for further evaluation of modifiable risk factors for MetS.

We previously demonstrated a high incidence of stroke in rural areas in China, with an age-standardized incidence of first-ever stroke per 100,000 person-years of up to 318.2 in 2012 and an incidence of stroke that increased annually by 6.5% overall from 1992–2012.[11] Considering the burgeoning epidemic of stroke worldwide, especially in rural areas of China, as well as the fact that MetS is a risk factor for stroke,[12,13] early recognition of MetS risk factors and prompt intervention to curb disease progression is imperative. Therefore, the present study aimed to evaluate the prevalence of MetS among middle-aged and older adults in a low-income, low-education population in rural areas with a high incidence of stroke and identify potential risk factors for the development of MetS.

Methods and Materials

Study Population

This population-based cross-sectional study was derived from The Tianjin Brain Study, which is an ongoing longitudinal cohort study in Tianjin, China. Briefly, the Tianjin Brain Study is a population-based stroke surveillance project including 14,251 participants from 18 administrative villages in the Yangjinzhuang township of Ji country in Tianjin, China.[14] The 95% local residents were farmers with relatively low levels of income and education. The main source of income was grain production, and the residents had an annual per capita income of <\$100 in 1991 and <\$1000 in 2010.[15] 100% of the population eats rice and wheat flour as staple food.

The study recruited all adults at least 45 years of age who resided in the villages between April and June 2019. In this study, all qualified residents who lived in this township more than five years were the potential participants. Exclusion criteria were age < 45 years, active malignant tumors, hepatic failure, and severe renal disease (defined as an estimated glomerular filtration rate of < 30 mL/min/1.73 m^2). All eligible participants underwent routine medical examinations, which included a questionnaire, physical examination, and routine blood and biochemical tests.

Of the 4222 residents who met the inclusion criteria, 3182 eligible individuals enrolled in this study, with the response rate of 75.4%. After excluding seven residents with missing data (including physical examination results and biochemical parameters), 3175 participants were finally included in this study (Figure 1).

This study was approved by the Ethics Committee of the Tianjin Medical University General Hospital and complies with the Declaration of Helsinki. All participants provided written informed consent.

Data Collection and Identification of Risk Factors

Anthropometric Measurements

Personal information, including demographic characteristics (sex, age, education level, household income), personal/family medical history (coronary heart disease and stroke), and lifestyle factors (cigarette smoking, alcohol consumption, physical activity, and snoring) information were obtained through a specific questionnaire administered by trained researchers in person. Snoring status was ascertained based on the participants' self-report and as assisted by family members. History of coronary heart disease and stroke were based on medical records.

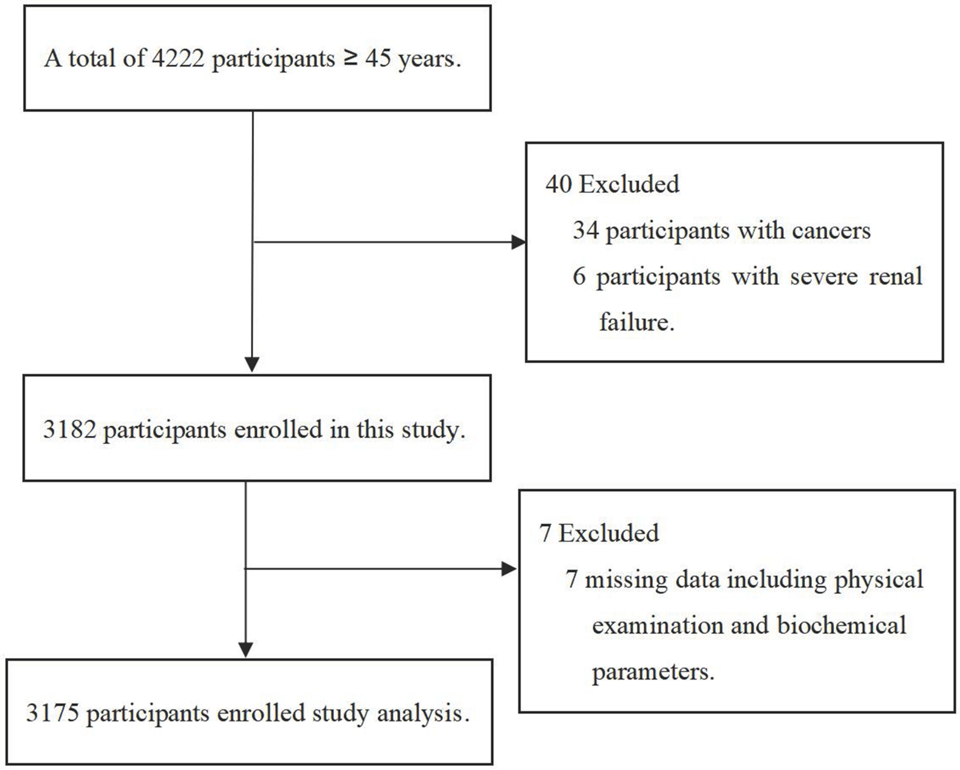

Figure 1 Flowchart of object selection. Of the 4222 residents who met the inclusion criteria, 3182 eligible individuals enrolled in this study, with the response rate of 75.4%. Finally, 3175 participants were included in this study after excluding seven residents with missing data.

Physical Examinations

Height, body weight, and hip and waist circumference (WC) were measured using a height scale and tape measure by trained staff. Blood pressure (BP) was measured using an electronic sphygmomanometer (HEM-741 C; Omron, Tokyo, Japan) a total of three times with the participant in a seated position at least 30 minutes after consumption of coffee, tea, and alcohol; cigarette smoking; and strenuous exercise. The mean values were used for analysis. Waist-to-hip ratio (WHR) was calculated as WC (cm) divided by the hip circumference (cm).

Biochemical Parameters

For routine blood and biochemical tests, 10 mL of blood were drawn from all patients. Fasted venous blood samples were obtained in the morning after the participants had fasted for at least 12 hours. Serum was obtained by centrifuging the sample at 3000 RPM for 10 minutes and then taking the supernatant. Blood tests for all patients were performed at the Laboratory Department of Jizhou District People's Hospital, which is a qualified laboratory center that meets the national standard. Blood biochemical indices including total cholesterol (TC: 2.58–5.17 mmol/L), triglyceride (TG: 0.56–1.70 mmol/L), low-density lipoprotein cholesterol (LDL-C< 3.12 mmol/L), high-density lipoprotein cholesterol (HDL-C> 1.04 mmol/L), fasting plasma blood glucose (FBG: 4.4–6.1 mmol/L), and serum uric acid (SUA) were analyzed at Guangzhou KingMed clinical laboratory in China. High SUA was defined as an SUA level ≥ 7.0 mg/dL (417 μmol/L) in men or ≥ 6.0 mg/dL (357 μmol/L) in women.[16]

Grouping and Definition of Variables

Education level was represented by three values: illiterate (without education), below high school (1–9 years), and high school (10–12 years). Household income was classified as < 2000, 2000–6000, and > 6000 yuan/year. Cigarette smoking was defined as smoking > 1 cigarette/day for ≥ 1 year and divided into never smoked, ever smoked, and currently smoked.[17] Alcohol consumption was defined as drinking > 30 mL of alcohol per week for ≥ 1 year and was categorized as never drinking, ever drinking, and current drinking.[18] Physical activity was defined as involvement in physical activity

≥ 2 days/week for ≥ 30 min/day. Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m^2) and included three categories: normal or underweight (BMI < 24 kg/m^2), overweight (24.00 kg/m^2 ≤ BMI < 28.00 kg/m^2), and obese (BMI ≥ 28.00 kg/m^2).[19]

Definitions of Metabolic Syndrome

According to the modified International Diabetes Federation criteria for the Asian population (2009), at least the following three conditions must be met to be defined as MetS:[20] (1) abdominal obesity (WC ≥ 90 cm in men and ≥ 80 cm in women); (2) elevated TG (TG ≥ 1.70 mmol/L or medications to treat hypertriglyceridemia); (3) low HDL-C (HDL-C < 1.03 mmol/L in men and < 1.3 mmol/L in women, or using medications to regulate HDL-C); (4) high BP (systolic BP [SBP] ≥ 130 mmHg or diastolic BP [DBP] ≥ 85 mmHg, or medications to treat hypertension); or (5) elevated fasting plasma glucose ([FPG] ≥ 5.6 mmol/L or on antidiabetic treatment).

Statistical Analysis

Continuous variables were described using the mean and standard deviation and were compared using Student's *t*-test; the distribution of these variables was assessed by the Kolmogorov–Smirnov test before performing Student's *t*-test. Categorical variables were described as frequency and percentage and were compared using Pearson's chi-squared test. Multivariate logistic regression was used to estimate the association between MetS and related factors by calculating the odds ratios (OR) and 95% confidence intervals (CIs) after adjustment for covariates with P <0.10 in the univariate analysis. We performed a sensitivity analysis for avoiding the effect of lifestyle intervention and medication on components of MetS among patients with the histories of coronary heart disease and/or stroke. Statistical analyses were conducted using IBM SPSS Statistics for Windows (version 25.0; IBM Corp, Armonk, NY, USA). All statistical tests were two-sided with a P value < 0.05 considered as significant.

Results

Demographic and Clinical Characteristics

Of the 3175 included individuals, 44.8% were men, and 55.2% were women. The mean age was 64 years. The 65-year and older age group accounted for 44.4%, the 55–64-year group accounted for 44.4%, and the 45–54-year group accounted for 14.5%. Altogether, 90% of the participants had ≤ 10-year education level; 73.5% had 1–9 year education, and 17.6% were illiterate. Moreover, 97% of the participants were of low and middle income, with household incomes less than 6000 yuan. In addition, 95.7% of women and 26.8% of men were never smokers and 98.0% and 46.7%, respectively, never drank alcohol. More than half of both men and women participated in physical activity and had self-reported snoring behavior. Furthermore, individuals with obesity, high SUA, and cardiovascular diseases accounted for 25.7%, 14.4%, and 16.1%, respectively. (Table 1).

Prevalence of MetS and Its Components

The total prevalence of MetS in this study was 52.8%, and the prevalence was higher in women (62.4%) than in men (40.9%). Individuals with two and three MetS components comprised the highest proportion, while those with five components comprised the lowest proportion. Among single MetS components, the major component was high BP (89%), followed by abdominal obesity (62.0%), elevated FBG (47.7%), low HDL-C level (33.7%), and elevated TG level (35.1%). Moreover, the values of MetS components, including abdominal obesity, low HDL-C level, and elevated TG level in women, seemed to be higher than those in men (Table 2).

Risk Factors for MetS

In general, participants with MetS were more likely to be female, older, non-smokers, and non-drinkers. Moreover, these individuals were more likely to have a history of self-reported snoring, overweight and obesity, and high SUA level. Higher levels of BMI, WHR, SUA level, LDL-C were also found in participants with MetS than in those without MetS (all P < 0.05; Table 3).

Table 1 Characteristics of Study Participants by Sex

Category	Men	Women	Total
Total	1425 (44.8)	1752 (55.2)	3175 (100)
Age, means (SD), years	65.14 (7.91)	63.32 (7.88)	64.13 (7.94)
Age group, n (%):			
45~54 years	161 (11.3)	298 (17.0)	459 (14.5)
55~64 years	567 (39.8)	739 (42.2)	1306 (41.1)
≥65 years	695 (48.8)	715 (40.8)	1410 (44.4)
Education level, n (%):			
Illiterate	75 (5.3)	484 (27.6)	559 (17.6)
<high school	1185 (83.3)	1148 (65.5)	2333 (73.5)
≥High school	163 (11.5)	120 (6.8)	283 (8.9)
Incomes, n (%)			
<2000 yuan	936 (65.8)	1141 (65.1)	2077 (65.4)
2000–6000 yuan	445 (31.3)	558 (31.8)	1003 (31.6)
>6000 yuan	42 (3.0)	53 (3.0)	95 (3.0)
Smoking status, n (%):			
Never smoking	381 (26.8)	1676 (95.7)	2057 (64.8)
Now or ever smoking	1042 (73.2)	76 (4.3)	1118 (35.2)
Alcohol consumption, n (%):			
Never drinking	665 (46.7)	1717 (98.0)	2382 (75.0)
Now or ever drinking	758 (53.3)	35 (2.0)	739 (25.0)
Physical activity, n (%)	867 (60.9)	1083 (61.8)	1950 (61.4)
Self-reported snoring, n (%)	754 (53.0)	882 (50.3)	1636 (51.5)
CVD, n (%)	256 (18.0)	256 (14.6)	512 (16.1)
BMI, means (SD), kg/m^2	25.46 (3.44)	26.28 (3.82)	25.91 (3.68)
BMI, n (%):			
Normal or under weight	494 (34.7)	478 (27.4)	972 (30.6)
Overweight	617 (43.4)	764 (43.7)	1381 (43.5)
Obesity	311 (21.9)	505 (28.9)	816 (25.7)
WC, means (SD), cm	88.24 (9.68)	86.40 (9.56)	87.22 (9.66)
WHR, means (SD)	0.92 (0.06)	0.90 (0.07)	0.91 (0.00)
SBP, means (SD), mmHg	151.87 (20.20)	149.99 (19.66)	150.83 (19.92)
DBP, means (SD), mmHg	87.60 (11.02)	83.25 (10.35)	85.20 (10.87)
SUA, means (SD), μmol/L	329.90 (86.48)	274.66 (77.99)	298.07 (85.92)
Hyperuricemia, n (%)	204 (14.3)	252 (14.4)	456 (14.4)
FBG, means (SD), mmol/L	5.91 (1.54)	6.01 (1.64)	5.98 (1.60)
TC, means (SD), mmol/L	4.92 (0.87)	5.29 (0.93)	5.13 (0.92)
TG, means (SD), mmol/L	1.48 (1.28)	1.73 (1.28)	1.62 (1.29)
HDL-C, means (SD), mmol/L	1.38 (0.47)	1.40 (0.43)	1.39 (0.45)
LDL-C, means (SD), mmol/L	2.95 (0.82)	3.22 (0.92)	3.09 (0.89)

Abbreviations: SD, standard deviation; SBP, systolic blood pressure; DBP, diastolic blood pressure; BP, blood pressure; BMI, body mass index; WC, Waist circumference; FBG, fasting blood glucose; TC, total cholesterol; TG, triglycerides; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; WHR, waist-to-hip-ratio; SUA, serum uric acid.

The significant factors of MetS in the multivariate analysis are presented in Table 4. After multivariable adjustment for confounding factors including sex, age, education level, income level, smoking status, alcohol consumption, BMI, WHR, self-reported snoring, SUA level, and LDL-C level at baseline, compared with the reference group, the risk factors for MetS included female sex, current or ever smoking, BMI, WHR, self-reported snoring, and SUA level. Female sex (OR = 4.791, 95% CI: 3.597, 6.271), smoking (OR = 1.363; 95% CI: 1.035, 1.794), high BMI (OR = 2.565; 95% CI: 2.285, 2.879), high WHR (OR = 1.929; 95% CI: 1.740, 2.138), self-reported snoring (OR =1.221; 95% CI: 1.027, 1.451),

https://doi.org/10.2147/DMSO.S377490

Table 2 Characteristics of Metabolic Syndrome and Its Components

Category	Men	Women	*P* value	Total
MetS, n (%)	582 (40.9)	1093 (62.4)	<0.001	1675 (52.8)
Num. of MetS components, n (%)			<0.001	
1	352 (25.8)	218 (12.7)		570 (18.0)
2	428 (31.4)	408 (23.7)		836 (26.3)
3	317 (23.3)	463 (26.9)		780 (24.6)
4	179 (13.1)	377 (21.9)		556 (17.5)
5	86 (6.3)	253 (14.7)		3339 (10.7)
MetS components, n (%)				
Abdominal obesity	651 (45.7)	1316 (75.1)	<0.001	1967 (62.0)
Raised BP	1286 (90.4)	1549 (88.4)	0.076	2835 (89.3)
Raised FPG	675 (47.4)	840 (47.9)	0.775	1515 (47.7)
Reduced HDL-C	291 (20.4)	778 (44.4)	<0.001	1069 (33.7)
Elevated TG	402 (28.3)	713 (40.9)	<0.001	1115 (35.1)

Table 3 The Univariate Analysis of Influence Factors for Metabolic Syndrome

Categories	Non-MetS	MetS	*P* value
Sex:			<0.001
Men	841 (59.1)	582 (40.9)	
Women	659 (37.6)	1093 (62.4)	
Age, means (SD), years	64.4 (8.23)	63.89 (7.61)	0.029
Age group:			0.149
45~54 years	224 (48.8)	235 (51.2)	
55~64 years	590 (45.2)	716 (54.8)	
≥65 years	686 (58.7)	724 (51.3)	
Education level, n (%):			0.001
Illiterate	226 (40.4)	333 (59.6)	
<high school	1142 (48.9)	1191 (51.1)	
≥High school	132 (46.6)	151 (53.4)	
Incomes, n (%)			0.033
<2000 yuan	1016 (48.9)	1061 (51.1)	
2000–6000 yuan	441 (44.0)	562 (56.0)	
>6000 yuan	43 (45.3)	52 (54.7)	
Now or ever smoking	636 (56.9)	482 (43.1)	<0.001
Now or ever drinking	471 (59.4)	322 (40.6)	<0.001
Physical activity, n (%)	911 (46.7)	1039 (53.3)	0.454
Self-reported snoring, n (%)	673 (41.1)	963 (58.9)	<0.001
BMI, means (SD), kg/m^2	24.14 (3.18)	27.50 (3.35)	<0.001
BMI, n (%):			<0.001
Normal or under weight	751 (77.3)	221 (22.7)	
Overweight	595 (43.1)	786 (56.9)	
Obesity	149 (18.3)	667 (81.7)	
WHR, means (SD)	0.89 (0.06)	0.93 (0.06)	0.014
SUA, means (SD), μmol/L	287.37 (81.01)	307.66 (89.02)	0.002
Hyperuricemia, n (%)	144 (31.6)	312 (68.4)	<0.001
LDL-C, means (SD), mmol/L	3.03 (0.80)	3.16 (0.95)	<0.001

Table 4 Risk Factors of Metabolic Syndrome in Multivariate Analysis

Risk Factors	Reference	Crude OR (95% CI)	*P*	Adjusted OR (95% CI)*	*P*
Sex:	Men	1.00		1.00	
Women		2.543 (2.204, 2.933)	<0.001	4.791 (3.597, 6.271)	<0.001
Age	–	0.987 (0.971, 1.004)	0.129	1.084 (0.989, 1.189)	0.084
Education level:	Illiterate	1.00		1.00	
<high school		1.547 (1.262, 1.897)	<0.001	1.004 (0.788, 1.280)	0.972
≥High school		1.118 (0.960, 1.302)	0.151	1.189 (0.823, 1.717)	0.356
Incomes:	<2000 yuan	1.00		1.00	
2000–6000 yuan		1.050 (0.665, 1.659)	0.833	0.981 (0.596, 1.615)	0.940
>6000 yuan		0.862 (0.551, 1.347)	0.514	0.876 (0.536, 1.434)	0.599
Smoking status:	Never smoking	1.00		1.00	
Now or ever smoking		2.047 (1.744, 2.403)	<0.001	1.363 (1.035, 1.794)	0.028
Alcohol consumption:	Never drinking	1.00		1.00	
Now or ever drinking		1.699 (1.409, 2.049)	<0.001	0.863 (0.667, 1.118)	0.250
BMI	–	1.349 (1.313, 1.386)	<0.001	2.565 (2.285, 2.879)	<0.001
WHR	–	1.140 (1.127, 1.152)	<0.001	1.929 (1.740, 2.138)	<0.001
Self-reported snoring	-	1.112 (0.855, 1.446)	0.427	1.221 (1.027, 1.451)	0.024
SUA	-	1.003 (1.002, 1.004)	<0.001	1.291 (1.178. 1.415)	<0.001
LDL-C	-	1.364 (1.257, 1.480)	<0.001	0.985 (0.903, 1.074)	0.731

Notes: *Adjustment for age, sex, education, income, smoking status, alcohol consumption, BMI, WHR, SUA, LDL-C and snore in multivariate analysis.

and elevated SUA level (OR = 1.291; 95% CI: 1.178, 1.415) were significantly associated with a higher likelihood of developing MetS (all $P < 0.05$).

In the sensitivity analyses, the risk factors for MetS remained similar to those in the main analysis (Table 5).

Table 5 The Sensitivity Analyses of the Association of Metabolic Syndrome with Relative Risk Factors

Risk Factors	Reference	Crude OR (95% CI)	*P*	Adjusted OR (95% CI)	*P*
Sex:	Men	1.00		1.00	
Women		1.712 (1.363, 2.151)	<0.001	4.651 (3.410, 6.345)	<0.001
Age	–	0.988 (0.971, 1.001)	0.152	1.013 (0.999, 1.026)	0.062
Education level:	Illiterate	1.00		1.00	
<High school		0.857 (0.658, 1.115)	0.250	0.909 (0.691, 1.194)	0.492
≥High school		0.958 (0.678, 1.338)	0.780	1.080 (0.803, 1.452)	0.613
Incomes:	<2000 yuan	1.00		1.00	
2000–6000 yuan		1.257 (0.746, 2.117)	0.390	0.971 (0.572, 1.649)	0.914
>6000 yuan		0.890 (0.533, 1.487)	0.890	0.906 (0.535, 1.532)	0.712
Smoking status:	Never smoking	1.00		1.00	
Now or ever smoking		1.450 (0.970, 2.166)	0.070	1.378 (1.013, 1.875)	0.041
Alcohol consumption:	Never drinking			1.00	
Now or ever drinking		1.030 (0.508, 2.087)	0.935	0.808 (0.607, 1.076)	0.144
BMI	–	1.347 (1.289, 1.407)	<0.001	2.493 (2.201, 2.823)	<0.001
WHR	–	1.117 (1.101, 1.134)	<0.001	1.862 (1.665, 2.082)	<0.001
Self-reported snoring	-	1.631 (1.337, 1.991)	<0.001	1.239 (1.027, 1.451)	0.025
SUA	-	1.004 (1.002, 1.005)	<0.001	1.319 (1.192. 1.458)	<0.001
LDL-C	-	1.057 (0.891, 1.254)	0.521	1.004 (0.912, 1.105)	0.942

Notes: Adjustments for age, sex, education, income, smoking status, alcohol consumption, BMI, WHR, SUA, LDL-C and snore in multivariate analysis.

https://doi.org/10.2147/DMSO.S377490

Discussion

This is the first investigation into the prevalence and risk factors for metabolic abnormalities in rural areas of China with a high stroke risk. The total prevalence of MetS was 52.8%, of which high BP and abdominal obesity were the major components in both sexes, accounting for 89.3% and 62.0%, respectively. Female sex, smoking, self-reported snoring, high BMI, WHR, and SUA level were independent risk factors for MetS.

MetS often accompanies obesity and type 2 diabetes and is associated with a high risk of cardiovascular diseases and stroke independent of the diagnostic criteria used.[17–19] The high prevalence of MetS in rural areas based on epidemiological studies has caused great concern in the aging society in China. Two health surveys conducted in southern China reported that the age-standardized prevalence of MetS increased fourfold (from 5.4% in 2002 to 21.3% in 2010) in individuals aged ≥ 20 years.[21] An earlier study conducted in 2010 showed that MetS was prevalent at 10.8% among rural adults in northwest China according International Diabetes Federation criteria.[21] In the current study conducted in 2019, a high total prevalence of MetS was observed, ie, up to 52%, in the low-income, low-education population aged ≥ 45 years, which is a higher prevalence than that reported in previous reports. However, these data are consistent with those reported in a 2004 study based on the same diagnostic criteria for MetS, which demonstrated a prevalence of 56.9% among a rural older population in China.[22] In view of the rising prevalence of MetS, rapid economic development and accelerated changes in dietary patterns and lifestyles may play an important role.[21] For instance, a higher consumption of snacks and fried food was observed among rural residents.[23]

The current results show a sex-specific prevalence of MetS, which was higher in women than in men, similar to previous findings.[21,24] The China Health and Retirement Longitudinal Study (CHARLS) illustrated that women had a 2.94-fold greater risk of MetS (95% CI 2.55–3.39, $P < 0.001$) compared with that of men. In contrast, the findings of the Third National Health and Nutrition Examination Survey revealed that MetS was more prevalent in men than in women (30.53% vs 20.44%).[25] Given that sex-related factors are susceptible to social and cultural behaviors, dietary habits, and psychosocial factors, women are more prone than men to developing MetS in response to work stress and lower socioeconomic status,[26] especially in rural areas. The Fourth Korea National Health and Nutrition Examination Surveys conducted in 2014 also revealed that sex-specific socioeconomic disparities in adulthood have differential effects on the prevalence of MetS.[9] A previous study has shown that in both mice and humans, adipose mitochondrial functions are elevated in females and are strongly associated with adiposity, insulin resistance, and plasma lipids.[27] Since sex differences in the prevalence of MetS may translate to different cardiovascular-associated risks,[25] more attention should be paid to the consequence of sex disparities on metabolic disorders.

The prevalence of high blood pressure and abdominal obesity is of great concern in rural areas. These findings are consistent with those of previous reports.[28] Data from the 2017 Beijing Chronic Disease and Risk Factors Surveillance, which examined a representative sample of 12,597 urban residents, found that the proportion of high blood pressure and central obesity were 42.02 and 43.06%, respectively. Strategies aiming to prevent and control the epidemic of high blood pressure and obesity should be prioritized to reduce the occurrence and progression of MetS in rural areas.

Previous epidemiological evidence suggests that chronic smoking is associated with the development of MetS[29,30] and is a risk factor for cardiovascular events.[31] Moreover, a meta-analysis of prospective studies reported that active smoking is associated with the development of MetS;[29] however, the pathophysiological interaction between cigarette smoking and MetS requires further elucidation. Similar to the previous results, current or ever-smoking based on self-reported questionnaire has been associated with a high risk of MetS after adjustment in multivariate analysis and sensitivity analysis in this study.

Obesity, which is associated with metabolic disturbances, is rapidly becoming more prevalent in developing countries, leading to increased morbidity and mortality due to cardiovascular disease and T2DM.[32–34] BMI, as well as indices of abdominal obesity (WC and WHR), have been associated with a higher cardiometabolic risk.[35–37] In the present study, BMI and WHR were found to be linked to MetS. A study on Nigerian population showed that both WC and WHR were good predictors of MetS.[38] Further, data from a cross-sectional study in China showed that BMI and WC were more useful than WHR in predicting two or more non-adipose components of MetS.[39] These findings suggest the need to further explore the role of obesity measurement tools in assessing MetS risk.

Snoring, a common but weak specific marker of obstructive sleep apnea, is associated with potential cardiovascular events.[40] We observed that 51.5% of middle-aged or older individuals reported a habit of snoring. Several epidemiological studies have suggested a significant association between self-reported snoring and MetS and its components.[41,42] A meta-analysis of 40 studies with 966,652 participants showed that snoring was a risk factor of MetS, and a linear trend was detected in the association between snoring and all MetS components except low-HDL.[43] In a Korean multi-rural communities cohort study, snoring was found to be significantly and linearly associated with MetS.[44] Similarly, our data showed that self-reported snoring was a relevant determinant for MetS, with an OR of 1.221. The long-term effects of snoring on metabolic disorders and their underlying mechanisms deserve further investigation.

The prevalence of high SUA in adults was 14.4%. At normal SUA levels, uric acid can scavenge oxygen radicals and protect the erythrocyte membrane from lipid oxidation,[45] while high SUA levels are associated with cardiovascular disease, diabetes mellitus, and MetS.[46–48] Our findings are similar to those of a study conducted among Bangladeshi adults, which showed that elevated SUA was significantly associated with the prevalence of MetS and its components.[49] However, whether elevated SUA levels are a risk factor or only a biomarker in the progression and development of MetS remains controversial. Further longitudinal studies are required to determine if a high SUA level is an additional component of MetS.

The present study has several limitations. First, as is inherent in a cross-sectional study, our findings are subject to the effects of confounding factors, and no conclusions regarding causality can be drawn. More relevant prospective studies are therefore necessary. Second, the present findings are based on a rural population aged ≥45 years. It is important to include populations with different ethnic and socioeconomic backgrounds and of a greater age range for more accurate and generalizable results. Third, other confounders, such as differing noise pollution, drugs, and a more detailed diet analysis may also influence the results and need further investigation.

Conclusions

In summary, MetS is highly prevalent in a low-income and low-education Chinese population with a high incidence of stroke. Appropriate management of high blood pressure and abdominal obesity, major components in both sexes, is necessary; blood pressure should be maintained within the normal range and visceral fat reduced. Early preventive and therapeutic interventions for these significant risk factors for MetS are crucial to curb metabolic abnormalities. Targeted prevention and treatment plans should be formulated based on individual differences.

Data Sharing Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the Tianjin Medical University General Hospital; this study complies with the Declaration of Helsinki. All participants provided written informed consent.

Acknowledgments

We thank all participants of the Tianjin Brain Study, and local medical care professionals for their valuable contributions.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

There is no funding to report.

Disclosure

The authors declare no competing financial interests.

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