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Sex-based differences in and risk factors for metabolic syndrome in adults aged 40 years and above in Northeast China: Results from the cross-sectional China national stroke screening survey

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ABSTRACT

Objectives Low levels of income and education are risk factors for metabolic syndrome in the population of Northeast China, which has a high incidence of metabolic syndrome and cardiovascular diseases. This study aimed to determine sex-based differences associated with the prevalence of and risk factors for metabolic syndrome among people older than 40 years in Northeast China; this has not been previously investigated.

Design This study analysed a portion of the large sample data of the national cross-sectional screening of China from 2016. Metabolic syndrome was defined as the presence of any three of the following five risk factors: abnormal waist circumference; high levels of triglycerides, high-density lipoprotein cholesterol or fasting plasma glucose; and elevated blood pressure. Multiple regression analysis was used to investigate sex-based differences in the prevalence of, and risk factors for metabolic syndrome.

Setting The study was conducted in Dehui City, Jilin Province, China.

Participants A total of 4052 participants with complete questionnaire information and laboratory examination results were included.

Results The prevalence of metabolic syndrome was 50.1% overall (38.4% in men and 57.9% in women; p<0.001). High body mass index and hip circumference were associated with metabolic syndrome in both sexes. In addition, physical inactivity (OR and 95% CI 1.44 (1.06 to 1.97); p=0.022) in men and advanced age (OR and 95% CI 1.54 (1.15 to 2.04); p=0.003) in women were factors associated with metabolic syndrome. Women with junior high school education or above and living in rural areas were less likely to have metabolic syndrome. For men, education and rural or urban living had no association with metabolic syndrome.

Conclusions The risk factors for metabolic syndrome have similarities and differences in different sexes; thus, the prevention and treatment of metabolic syndrome should be based on these sex differences.

INTRODUCTION

Metabolic syndrome (MS) is associated with a cluster of cardio-metabolic risk factors and

Strengths and limitations of this study

► This cross-sectional study included a large, representative sample of the Chinese population.

► We used a uniform, precoded questionnaire designed by the national stroke screening survey of China.

► Some results were partially based on self-reported data collected by investigators, which inevitably increased the risk of recall bias.

► Our survey excluded participants who were sick or too weak to complete the interview.

► As a major limitation of all epidemiological investigations, conclusions based on cross-sectional studies cannot be used for causal inferences.

has become one of the major public health threats in China. Higher prevalence of MS greatly increases the burden of morbidity and mortality due to cardiovascular diseases worldwide.[1–3] This burden has increased every year, although it is difficult to differentiate it from unhealthy habits of daily living.[4] There is a significant difference in the prevalence of, and risk factors for MS between men and women.[5] To control and reduce the risk of MS and cardiovascular diseases more effectively, it is necessary to identify high-risk populations and understand the sex-specific, modifiable lifestyle determinants of MS. Northeast China, with its low-income level, has a high incidence of MS and cardiovascular diseases. Specifically, it has the highest incidence and mortality rate of stroke (365 and 159/100 000 person years) in China.[6] Thus, this study aimed to analyse the sex-specific differences in the prevalence of MS and its related risk factors in a population from Northeast China.

POPULATION AND METHODS

Data source and study participants

This population-based cross-sectional study was a part of the Stroke Screening and Prevention Program of the National Health and Family Planning Commission of China (CNSSS). It assessed a population of residents aged 40 years or older, from January to March 2016. The CNSSS is a national epidemiological survey of cerebrovascular diseases conducted to obtain timely and reliable information on the morbidity, prevalence and mortality of stroke in Chinese people over the age of 40.[7] The sampling method employed in this study has been described in detail in other articles.[8] The sample size (N) required for this survey was calculated on a 2.37% stroke prevalence (p) among adults 40 years and older in China,[8] using the formula:

N= $(Z_\alpha^2 pq)/d^2$ (where Z_α = 1.96, α = 0.05, q = 1−p, and d = 0.2p)

A multistage stratified, random cluster sampling method was applied to obtain the sample population. In the first stage, 30 villages and 10 towns were randomly selected from a total of 308 villages (rural) and 14 towns (urban) in Dehui City, using the probability proportional to size (PPS) sampling method. In the second stage, five groups of villages or communities were randomly sampled from both the rural and urban strata using PPS sampling. In the third stage, one participant aged ≥40 years was randomly selected from each household of the selected groups of villages or communities. Respondents who were unwilling to participate in the survey or who were judged to be very frail were excluded. We selected permanent residents aged ≥40 years for inclusion in the study (a calculated total of 4445 participants with an additional 10% loss rate); ultimately, 4100 participants completed the face-to-face survey, with a good response rate of 92.2%. In this substudy of the CNSSS, we used data from participants who completed the study. After excluding 48 participants with incomplete questionnaire information or laboratory examinations, a total of 4052 participants were included in this analysis. The flowchart of the study selection process is shown in figure 1.

Patient and public involvement

Patients and the public were not involved in the development of the research questionnaire, its outcome measures, study design, recruitment methods or the conduct of this study. There is no plan to disseminate the research findings to the participants.

Data collection and measurement

All participants completed a questionnaire that included an assessment of general sociodemographic and health-related information. Physical examinations included assessments of height, weight, neck, waist, and hip circumferences, and blood pressure. Height and weight were measured according to the standard methods; the subjects removed their shoes and hats and wore light clothes. The measurement accuracy was within 0.1 cm and 0.1 kg for the height and weight, respectively. Blood pressure was measured by physicians using an OMRON automatic sphygmomanometer (OMRON HEM-7200, Kyoto, Japan), on the right arm, after placing it parallel to the heart. The subjects were made to rest for 20 min before the blood pressure was measured twice, and mean value was recorded. Blood samples were collected on an empty stomach following overnight fasting (at least 8 hours) to assess fasting plasma glucose (FPG), triglyceride (TG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C) concentrations. The samples were sent to the clinical laboratory of Changchun Kingmed Centre (Chang Chun, Jilin, China) for testing.

Screening protocol and assessment criteria

The definition of MS used in this study was published by the International Diabetes Federation and the American Heart Association/National Heart, Lung, and Blood Institute.[9] The presence of any three of the following five risk factors constituted a diagnosis of MS: (1) waist circumference: ≥90 cm for men, and ≥80 cm for women; (2) TG concentration: ≥1.70 mmol/L (drug treatment for elevated TG levels was an alternative indicator); (3) HDL-C concentration: <1.0 mmol/L for men, and <1.3 mmol/L for women (drug treatment for reduced HDL-C levels was an alternative indicator); (4) blood pressure: systolic blood pressure ≥130 mm Hg and/or diastolic blood pressure ≥85 mm Hg (antihypertensive drug treatment in a patient with a history of hypertension was an alternative indicator); and (5) FPG concentration: ≥5.6 mmol/L (drug treatment for elevated glucose levels was an alternative indicator).

In addition to stratification by sex, participants were also stratified by age into a middle-aged group (40–64 years old) and an elderly group (≥65 years old). The evaluation criteria for other factors, including body mass index (BMI), level of physical inactivity, smoking status, and alcohol consumption are shown in online supplemental table S1.

Statistical analysis

The normality of the data was tested using the Kolmogorov-Smirnov test. Non-normally distributed continuous variables are presented as medians (IQRs). Categorical data are presented as numbers and proportions. Significant variables (those with p<0.05) identified in the single variable analysis were selected for the multivariable analyses. Multiple logistic regression analysis was used to explore the independent risk factors of MS in the two sexes, and the ORs and 95% CIs were calculated. All statistical analyses were performed using IBM Statistical Package for the Social Sciences (SPSS) V.23.0 (SPSS, Inc., New York, NY, USA). P<0.05 was considered statistically significant.
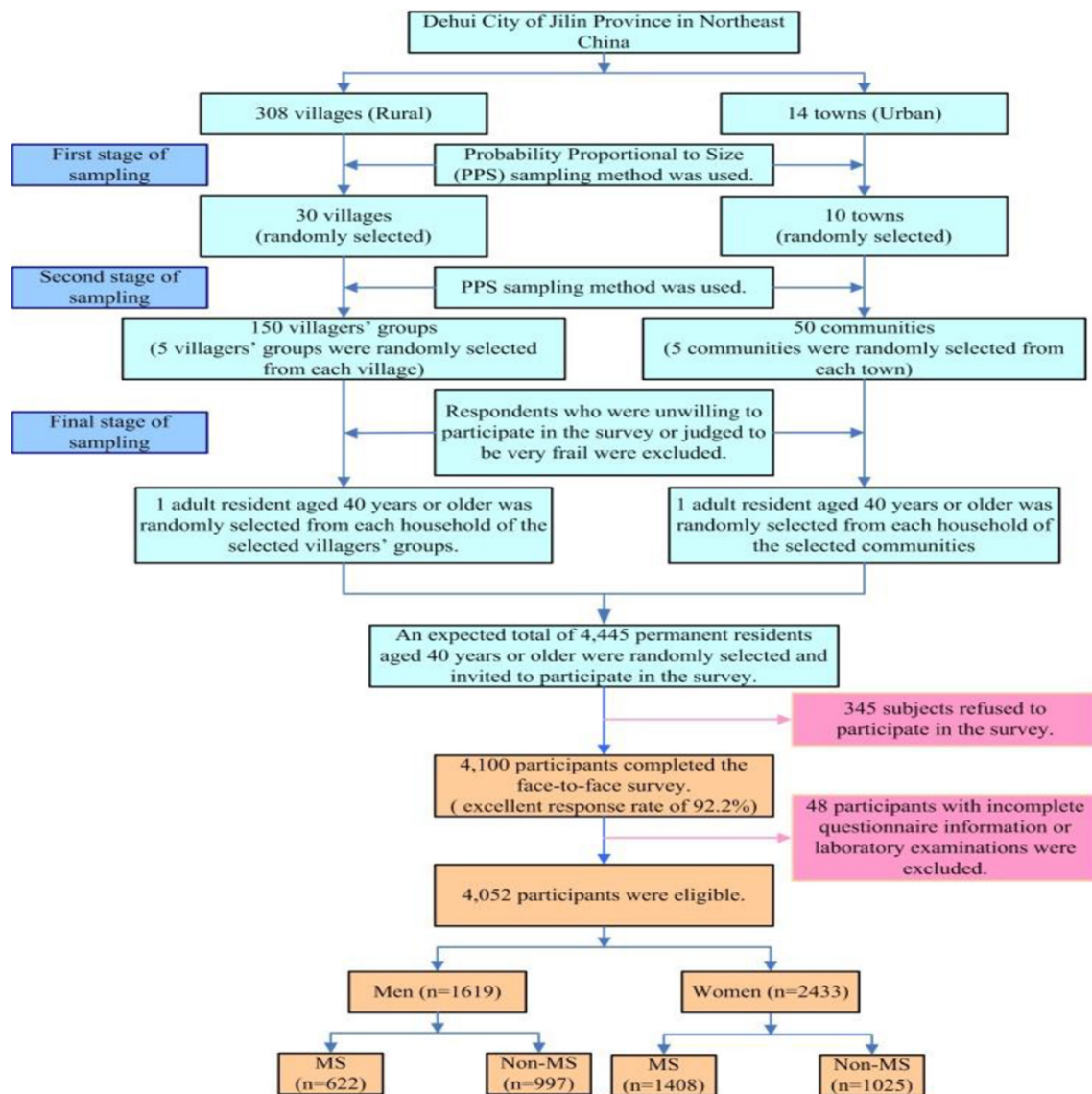
Figure 1 Sampling process in the study. MS, metabolic syndrome.

RESULTS

Among the 4100 participants who completed the face-to-face survey, 4052 were included in the analysis. A total of 2030 individuals met the criteria for MS, and the prevalence was 50.1% overall (38.4% in men and 57.9% in women; $p < 0.001$). Of all the 4052 participants, 1619 were men (40.0%) and 2433 were women (60.0%), with a median age of 53 years (IQR: 47–62). Overall, 76.7% of the participants were educated up to either primary and below or junior middle-school level.

Demographic characteristics of all participants with MS

Table 1 shows that compared with that in men (38.4%), the prevalence of MS in women (57.9%) was significantly higher. Among the 2030 individuals with MS, the median age was 56 years (IQR: 49–63), and for both men and women, more than 80% of the participants with MS were in the group of 40–64 years. The rate of abnormal waist circumference in women (91.6%) was higher than that in men (85.4%). The median neck and hip circumferences

in men were higher than those in women. Compared with men, women had a higher proportion of the following associated risk factors: a lower level of educational attainment, living in a rural area, an abnormal HDL-C concentration, and higher concentrations of TC and LDL-C. However, a higher proportion of men than women had hypertension, abnormal levels of TGs and fasting blood glucose, abnormal BMI, resided in urban areas, had a smoke habit, and cousumed alcohol.

Univariable analysis of factors associated with MS stratified by sex

Table 2 shows the results of univariable logistic regression for factors associated with MS in men and women. The prevalence of MS was higher in the elderly (figure 2: men:40.2%; women: 71.7%), especially in older women (Table 2: OR (95% CI)=2.04 (1.61 to 2.59); p<0.001). For women, age, BMI, hip and neck circumference, smoking, higher alcohol consumption, geographical region, and level of educational attainment were associated with

Table 1 Sex differences in demographic characteristics and risk factors among participants with metabolic syndrome.

	Total	Male	Female
Participants, n (%)	4052 (100.0)	1619 (40.0)	2433 (60.0)
Cases, n (%)	2030 (50.1)	622 (38.4)	1408 (57.9)
Age, years, median (IQR)	56.00 (49, 63)	55.72 (48, 63)	56.19 (49, 63)
Age group, n (%)			
40–64 years	1636 (80.6)	501 (80.5)	1135 (80.6)
≥65 years	394 (19.4)	121 (19.5)	273 (19.4)
Waist circumference, n (%)	1821 (89.7)	531 (85.4)	1290 (91.6)
Neck circumference, median (IQR)	34.00 (32, 37)	38.23 (36, 40)	33.27 (32, 35)
Hip circumference, n (%)	100.00 (95, 104)	103.63 (100, 107)	97.76 (93, 102)
TCHO, mmol/L, median (IQR)	5.52 (4.83, 6.25)	5.50 (4.73, 6.12)	5.63 (4.87, 6.29)
LDL-C, mmol/L, median (IQR)	1.93 (1.56, 2.64)	2.08 (1.5, 2.57)	2.19 (1.57, 2.65)
HDL-C, n (%)	1255 (61.8)	176 (28.3)	1079 (76.6)
TG, n (%)	1503 (74.0)	508 (81.7)	995 (70.7)
FBG, n (%)	881 (43.4)	291 (46.8)	590 (41.9)
Hypertension, n (%)	1853 (91.3)	601 (96.6)	1252 (88.9)
Education, n (%)			
≤Primary school	806 (39.7)	176 (28.3)	630 (44.7)
Junior middle school	829 (40.8)	280(45)	549(39)
Senior middle school	253 (12.5)	104 (16.7)	149 (10.6)
College and above	142 (7.0)	62 (10.0)	80 (5.7)
Region, n (%)			
Urban	1023 (50.4)	357 (57.4)	666 (47.3)
Rural	1007 (49.6)	265 (42.6)	742 (52.7)
Smoke, n (%)			
No	1021 (50.3)	223 (35.9)	798 (56.7)
Yes	1009 (49.7)	399 (64.1)	610 (43.3)
Physical inactivity, n (%)			
No	1522 (75.0)	469 (75.4)	1053 (74.8)
Yes	508 (25.0)	153 (24.6)	355 (25.2)
Alcohol consumption, n (%)			
Never	1591 (78.4)	251 (40.4)	1340 (95.2)
Light/moderate	245 (12.1)	182 (29.3)	63 (4.5)
Heavier	194 (9.6)	189 (30.4)	5 (0.4)
Fruit consumption, n (%)			
≥5 days per week	1782 (87.8)	546 (87.8)	1236 (87.8)
3–4 days per week	189 (9.3)	61 (9.8)	128 (9.1)
≤2 days per week	59 (2.9)	15 (2.4)	44 (3.1)
BMI, n (%)			
Normal	553 (27.2)	88 (14.1)	465 (33.0)
Underweight	11 (0.5)	3 (0.5)	8 (0.6)
Overweight	521 (25.7)	144 (23.2)	377 (26.8)
Apparently overweight	464 (22.9)	183 (29.4)	281 (20.0)
Obesity	481 (23.7)	204 (32.8)	277 (19.7)

Continued

Table 1	Continued

Values are expressed as n (percentage).
BMI, body mass index; FBG, fasting blood glucose; HDL-C, high-density lipoprotein; LDL-C, low-density lipoprotein cholesterol; TCHO, total serum cholesterol; TG, triglyceride.

MS, whereas physical inactivity and fruit consumption were not. For men, the risk factors associated with MS were similar, except for age, smoking and higher alcohol consumption. Unlike in women, physical inactivity and light/moderate alcohol consumption were also risk factors in men.

Relationship between risk factors and MS in the multivariable logistic regression analysis

Multivariable analysis revealed that BMI and hip circumference were significantly associated with MS in both men and women (table 3). Age, region and educational attainment were associated with MS in women, while physical inactivity was associated with MS in men. Neck circumference, an underweight BMI, smoking, and alcohol consumption were not associated with MS in either sex.

For men, BMI, hip circumference and physical inactivity were associated with MS. The ORs (95% CIs) were 2.07 (1.48 to 2.90; p<0.001) for overweight BMI, 3.77 (2.54 to 5.60; p<0.001) for apparently overweight BMI, and 3.25 (2.02 to 5.24; p<0.001) for obese BMI. For hip circumference, the OR (95% CI) was 1.12 (1.09 to 1.15; p<0.001). Physical inactivity was associated with MS in men (OR 1.44, 95% CI (1.06 to 1.97), p=0.022).

Table 2 Univariable logistic regression analyses on risk factors for the prevalence of metabolic syndrome in men and women

Category	Reference	Male OR (95% CI)	P value	Female OR (95% CI)	P value
Age group	**40–64 years**				
≥65 years		1.10 (0.85 to 1.42)	0.482	2.04 (1.61 to 2.59)	<0.001
HP	–	1.20 (1.18 to 1.22)	<0.001	1.16 (1.14 to 1.17)	<0.001
NC	–	1.44 (1.38 to 1.51)	<0.001	1.37 (1.31 to 1.42)	<0.001
Region	**Urban**				
Rural		0.57 (0.46 to 0.69)	<0.001	1.66 (1.41 to 1.95)	<0.001
Smoke	**No**				
Yes		0.93 (0.75 to 1.14)	0.472	1.41 (1.19 to 1.66)	<0.001
Physical inactivity	**Physical activity**				
Yes		1.75 (1.36 to 2.24)	<0.001	1.12 (0.93 to 1.35)	0.235
Alcohol consumption	**Never**				
Light/moderate drinking		1.44 (1.12 to 1.84)	0.004	0.50 (0.16 to 1.59)	0.243
Higher drinking		0.99 (0.78 to 1.26)	0.949	0.61 (0.43 to 0.86)	0.005
Fruit consumption	**≥5 days/week**				
3–4 days per week		1.09 (0.77 to 1.53)	0.627	1.19 (0.89 to 1.60)	0.238
≤2 days per week		0.80 (0.43 to 1.51)	0.494	1.37 (0.83 to 2.26)	0.226
Education	**≤Primary school**				
Junior middle school		1.28 (1.01 to 1.62)	0.040	0.59 (0.49 to 0.71)	<0.001
Senior middle school		1.75 (1.27 to 2.41)	0.001	0.41 (0.32 to 0.54)	<0.001
College and above		1.31 (0.91 to 1.90)	0.149	0.27 (0.20 to 0.37)	<0.001
BMI	**Normal**				
Underweight		1.49 (0.42 to 5.33)	0.540	0.30 (0.14 to 0.66)	0.002
Overweight		3.91 (2.88 to 5.30)	<0.001	3.54 (2.85 to 4.40)	<0.001
Apparently overweight		11.14 (8.03 to 15.47)	<0.001	5.28 (4.01 to 6.93)	<0.001
Obesity		18.29 (12.89 to 25.96)	<0.001	12.03 (8.31 to 17.43)	<0.001

Values are expressed as median (IQR) or n (percentage).
BMI, body mass index; HC, hip circumference; NC, neck circumference.
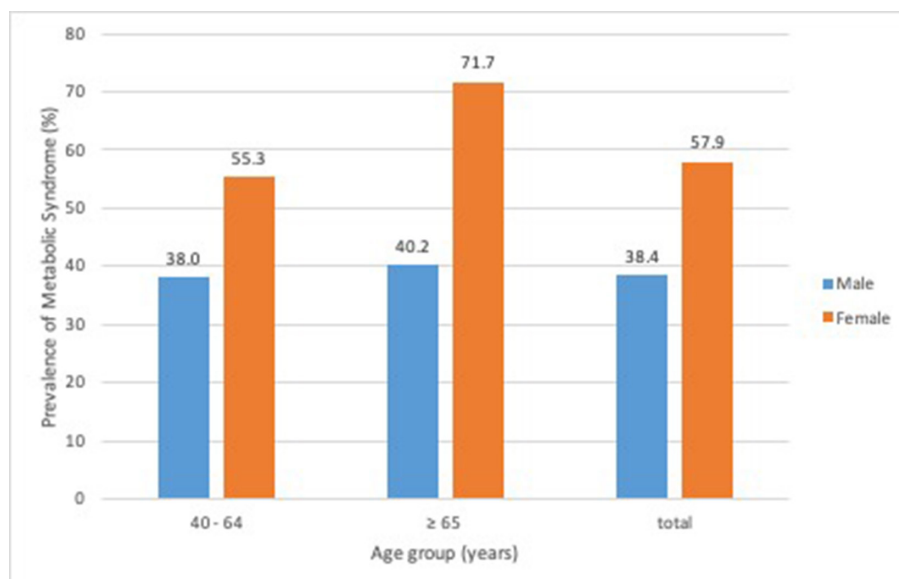
Figure 2 Prevalence of metabolic syndrome in different sexes and ages in the study.

Table 3 Multivariable logistic regression analyses on risk factors for the prevalence of metabolic syndrome in men and women.

		Male		Female	
Category	Reference	OR (95% CI)	P value	OR (95% CI)	P value
Age group	**40–64 years**				
≥65 years		–	–	1.54 (1.15 to 2.04)	0.003
Education	**≤Primary school**				
Junior middle school		0.92 (0.66 to 1.27)	0.606	0.62 (0.48 to 0.79)	<0.001
Senior middle school		1.01 (0.64 to 1.61)	0.953	0.58 (0.40 to 0.83)	0.003
College and above		0.73 (0.43 to 1.23)	0.231	0.43 (0.29 to 0.66)	<0.001
Region	**Urban**				
Rural		0.82 (0.59 to 1.13)	0.223	0.74 (0.56 to 0.97)	0.028
BMI	**Normal**				
Underweight		2.46 (0.58 to 10.50)	0.223	0.57 (0.25 to 1.30)	0.183
Overweight		2.07 (1.48 to 2.90)	<0.001	2.09 (1.63 to 2.68)	<0.001
Apparently overweight		3.77 (2.54 to 5.60)	<0.001	2.01 (1.46 to 2.79)	<0.001
Obesity		3.25 (2.02 to 5.24)	<0.001	2.55 (1.62 to 4.00)	<0.001
Neck circumference	–	1.19 (0.95 to 1.50)	0.128	1.19 (0.95 to 1.50)	0.128
Smoke	**No**				
Yes		–	–	1.19 (0.95 to 1.50)	0.128
Physical inactivity	**Physical activity**				
Yes		1.44 (1.06 to 1.97)	0.022	–	–
Alcohol consumption	**Never**				
Light/moderate drinking		0.88 (0.66 to 1.18)	0.400	0.72 (0.48 to 1.08)	0.112
Higher drinking		1.32 (0.98 to 1.78)	0.07	0.43 (0.11 to 1.63)	0.215
Hip circumference		1.12 (1.09 to 1.15)	<0.001	1.10 (1.08 to 1.12)	<0.001

BMI, body mass index.;

For women, BMI, hip circumference and advanced age were associated with MS. Rural residence and junior middle-school education or above were negatively associated with MS. The higher the education attainment, the lower the risk of MS. The ORs (95% CIs) were 2.09 (1.63 to 2.68; p<0.001) for overweight BMI, 2.01 (1.46 to 2.79; p<0.001) for apparently overweight BMI, and 2.55 (1.62, 4.00; p<0.001) for obese BMI groups. For hip circumference, the OR (95% CI) was 1.10 (1.08 to 1.12; p<0.001). The OR (95% CI) for advanced age (≥65 years) was 1.54 (1.15 to 2.04); p=0.003). The OR (95% CI) for living in a rural region was 0.74 (0.56 to 0.97; p=0.028). For an educational level of junior middle-school, the OR (95% CI) was 0.62 (0.48 to 0.79; p<0.001); for senior middle-school, it was 0.58 (0.40 to 0.83; p=0.003), and for college and above, it was 0.43 (0.29 to 0.66; p<0.001).

DISCUSSION

In this study, we evaluated sex-based differences in the prevalence of MS and its relative determinants in a low-income population from Northeast China. We found that in addition to being significantly more prevalent in women than in men, a high BMI, and large hip circumference were risk factors for MS in both sexes. In addition, advanced age (≥65 years) was a risk factor only for women, whereas physical inactivity was a risk factor only for men. Furthermore, educational attainment and living in a rural region were negatively associated with MS in women, but not in men.

The prevalence of MS has been steadily increasing due to unhealthy lifestyles in low-income and high-income regions,[10 11] and there are known sex differences.

The prevalence of MS in those living in the Chinese mainland for both the low-income, middle-income and high-income populations was shown to be 33.9% in 2010[1]; however, in our study, it was 50.1%. This may be because most of the participants in our study population had a lower educational level and income, which may have had an additive effect on the primary, increasing trend. In most studies, the prevalence of MS in women was higher than that in men[1 12]; for example, in Mexico, the prevalence in women was 55.6%, whereas in men, it was 38.2%.[13] Similar sex disparities were observed in Middle Eastern countries, but few sex differences have been reported in the European Union, which has a lower MS prevalence overall.[14] In contrast, the prevalence of MS in men is higher than that in women in Caucasians,[15] American adolescents,[16] Far East Asian and Japanese populations, and in Macau, it is twice that in women.[17] These differences may be related to race, the period in which the studies were conducted, the geographic region and the selection criteria used.[18–20] Our results were consistent with those reported in most countries that women had a higher prevalence of MS than men.[21–24] In addition, these sex-related differences were shown to be greater in women of advanced age, but remained relatively stable with respect to age in men in East China.[25] This was consistent with our own findings

that women aged ≥65 years had a 1.536-fold higher risk of MS than those aged 40–65 years. A decrease in oestrogen levels in women after menopause results in an increase in insulin resistance and abnormal lipid metabolism. Thus, the sex differences observed may be related to changes in hormone levels, rather than ageing itself.[26]

It is well known that MS prevalence increases when BMI ($\geq 24 \, \text{kg/m}^2$) is higher than normal. Compared with individuals with a normal BMI, the risk of MS with an overweight and obese BMI was 3.11-fold and 17.18-fold in Korean women, and 4.30-fold and 10.91-fold in Korean men without diabetes mellitus, respectively.[27] Our study also found that compared with a normal BMI, a higher BMI was associated with higher odds of MS. The risk was 2.09-fold, 2.01-fold and 2.55-fold higher in overweight, significantly overweight and obese females, respectively. In men, the risk increased 2.07-fold, 3.77-fold and 3.25-fold, respectively. These findings also suggest that weight gain in men (BMI $\geq 26 \, \text{kg/m}^2$) increases the risk of MS more substantially than it does in women; this positive association has also been reported in a study of Turkish adults.[28] An Israeli cohort study claimed that a normal BMI had a high negative predictive value in both men (98%) and women (96%) with respect to MS.[29] The inverse association was found between hip circumference and metabolic risk factors in Tehranian women.[30] Further, weak predictive ability was found for hip circumference. In our study, the risk of MS increased 1.10-fold in women and 1.12-fold in men for every 1 cm increase in hip circumference but not in neck circumference. Thus, BMI combined with hip circumference is an effective indicator of being overweight or obese, and such individuals are more prone to developing MS. Whether obesity or insulin resistance is a cause or consequence of MS is still under debate.[31] Adipokines produced by abnormal adipocytes cause insulin resistance, and visceral obesity may be a causal factor of metabolic disease.[32]

Physical inactivity was a main risk factor for men in our study, consistent with the findings of a previous study.[33] Infrequent physical activity results in a 1.44-fold increased risk of MS in men, but not in women, this is consistent with previous findings.[34] Moreover, physical activity has been suggested to be associated with a low risk for MS.[35] Studies have also found that binge drinking and smoking were associated with increased MS prevalence, regardless of sex or BMI.[36 37] The association between fruit consumption, neck circumference and MS risk remains unclear; in our study, no significant associations were observed among alcohol consumption, smoking, fruit consumption or neck circumference.

Educational level is the most important measure of socioeconomic status, which has been shown to not only affect the prevalence of MS, but is also closely related to the prevalence of cerebrovascular disease.[38] The specific mechanism by which education affects the prevalence of MS is unclear. It has, however, been considered that education influences people's lifestyles and positive attitudes toward health, and increases their access to

preventive health services.[39] In addition, it is reported in South Korea, that the negative correlation between educational level and MS prevalence is largely related to the dietary patterns of Koreans (especially in women).[40] For women in our study, the ORs indicated a 0.62-fold, 0.58-fold and 0.43-fold risk of developing MS in those who had completed junior middle school, senior middle school, as well as college and above, respectively. This suggests that a higher educational level can reduce the risk of MS; however, this relationship was not found in men. The negative association between MS prevalence and educational level was significant in women, which is similar to the results of a previous study.[40] A National Survey found that low income and educational levels were associated with a higher prevalence of MS in women than in men.[41] Our study population was characterised by having both a low income and a low level of education, both of which contributed to a higher MS prevalence. The percentage of included women with a primary school education or below was 37.8%, which may partially explain the high prevalence of MS in women.[24] Urban adults (≥18 years old) in China were more likely than rural adults to have MS in 2009,[22] The opposite was true among urban adults in Jiangxi province, China in 2015, as women living in rural areas were more likely than urban females to have MS. These findings were not observed among men.[42] In our study, MS was negatively associated with living in rural regions (OR: 0.74 (0.56 to 0.97), p=0.028) but not with living in urban regions. The differences may be caused by the degree of economic development, lifestyle habits and dietary patterns; for example, rural women have lower fat intake and more activity than urban women.[43]

Lifestyle interventions resulted in a 2.61-fold reduced risk of MS compared with the control group in a previous study.[44] An investigation of dietary patterns showed that the Chinese pattern (high in grains, vegetables, fruit, salted fish and eggs, soyabean, etc) was associated with a lower risk of MS than the animal food pattern (high in meats, fish and shrimp, eggs, seafood, alcoholic beverages, etc.).[45] Sex differences in the dietary patterns were associated with increased MS prevalence; for example, an increased prevalence was observed in men consuming an 'animal and fried food' diet, and women consuming a 'high-salt and energy' diet.[19] Muscle strength and cardiorespiratory fitness may independently and jointly reduce the incidence of MS,[46] as increased physical activity decreased the risk by 19%–24%.[47] In men, every hour of exercise may decrease MS risk by 2%.[48] In contrast, daily sedentary behaviour linearly increases the risk of MS by 1.09 times per hour.[49] To prevent the onset of MS, a better understanding of modifiable lifestyle factors is needed in high-risk populations; for example, in men who are physically inactive, further effort should be made to control body weight, especially by focusing on reducing high BMI and hip circumference. Moreover, exercise can result in high brain insulin sensitivity, which can help to lose more body weight and body fat with a lower regain.[50] For women, especially the elderly outside rural regions,

efforts should be made to control weight to maintain BMI and hip circumference at normal levels to reduce the risk of MS. Focus should also be directed at changes in hormone levels, especially the low concentrations of sex hormone-binding globulin and testosterones, which increase the odds of MS.[51] In the long run, a higher level of educational attainment can reduce the risk of MS. Understanding these factors and the sex differences between them, as well as accurately identifying high-risk groups, could help to develop better public health policies, educational initiatives and reduce the incidence of MS and vascular diseases. There were also several limitations to this study. Some data were self-reported, each parameter in blood was only sampled and measured once, and some lifestyle factors and potential residual confounders were not assessed. Furthermore, people who were sick or too weak to participate were excluded, which may impact the generalisability of the results. Moreover, cross-sectional studies cannot be used to make causal inferences, and subsequent prospective and randomised studies are needed.

CONCLUSION

In our study, we found that risk factors for MS have both sex-based similarities and differences; thus, the prevention and treatment of MS should consider patients' sex.

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