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Original Article

Title Page

Sex differences and risk factors of Metabolic syndrome in adults aged more than 40 in Northeast China: Results from the National Stroke Screening Survey

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Search terms: metabolic syndrome, prevalence, sex difference, cross-sectional, risk factor.

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ABSTRACT

Objectives To determine the gender differences and risk factors of Metabolic syndrome (MS) among the populations in northeast China.

Study design This study analyzed a part of the cross-sectional survey data of the National Stroke Screening and Prevention Program of China from 2016. The MS is defined as the presence of any three of the five risk factors: abnormal waist circumference, triglyceride, high-density lipoprotein cholesterol, blood pressure, fasting plasma glucose. Multiple regression analysis was used to investigate the sex-specific prevalence and risk factors of MS.

Setting The study was conducted in the Dehui city, Jilin province, China.

Participants A total of 4052 participants with complete questionnaire information and laboratory examinations were included in this analysis.

Results The prevalence of MS in northeast China (≥ 40 years old) was 50.1%. In the male group, increase in age (≥ 65 years old, OR=1.460, 95%CI: 1.065-2.002), high Body Mass Index (BMI) (overweight: OR=3.324, 95%CI: 2.403-4.598), abnormal neck circumference (OR=2.078, 95%CI: 1.569-2.751), and physical inactivity (OR=1.437, 95%CI: 1.064-1.941) significantly increased the risk of MS. In the female group, increase in age (OR=1.938, 95%CI: 1.466-2.561), high BMI (overweight: OR=3.273, 95%CI: 2.602-4.116), and abnormal neck circumference (OR=1.853, 95%CI: 1.521-2.258) were the underlying cause of MS. People with a junior middle school diploma (OR=0.633, 95%CI: 0.495-0.809) and being underweight (less BMI) (OR=0.238, 95%CI: 0.107-0.529) were less likely to develop MS.

Conclusions The prevalence of MS in women is significantly higher than that in men in northeast China. While increase in age, abnormal neck circumference and BMI significantly increase the risk of MS in women and men, physical inactivity increases the risk of MS only in men. Additionally, higher education reduces the risk of MS in women. Active lifestyle, preventive interventions and improvement in the level of education could reduce the prevalence of MS.

Key words: metabolic syndrome, prevalence, sex difference, cross-sectional, risk factor.

Strengths and limitations of this study

1. This cross-sectional study involves a large representative sample of Chinese people.

2. We used a uniform pre-coded questionnaire designed by the Stroke Screening and Prevention Program of the National Health and Family Planning Commission of China (CNSSS).

3. Partial results are based on self-reported data from the investigators, which inevitably has the drawback of recall bias.

4. Our survey excluded people who were sick or too weak to complete the interview.

INTRODUCTION

Metabolic syndrome (MS) is a metabolic disorder, mainly related to insulin resistance and abdominal obesity.[1] It is a non-communicable disease. In developed countries, the prevalence of MS is higher and shows a trend of increase in every year,[2] which is inseparable from people's daily living habits.[2] MS is not an independent disease, but it is a risk factor for multiple cardiovascular diseases.[3 4] Moreover, there is a significant difference in the prevalence of MS between men and women. And the risk factors that affect MS vary by gender.[5] This paper aims to analyze the differences in the prevalence of MS between men and women in the population in northeast China.

POTULATION 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), among the resident population aged 40 years or above from January 2016 to March 2016. CNSSS is a national epidemiological survey of cerebrovascular diseases to obtain timely and reliable information on the morbidity, prevalence, and mortality of stroke in Chinese people over the age of 40.[6] The sampling method in this experiment has been described in detail in other articles.[7] The sample size (N) for this survey was acquired by calculation on a 2.37% stroke prevalence (p) among adults aged above 40 years in China,[7] using the formula $N=(Z_\alpha{}^2pq)/d^2$ (where $Z_\alpha=1.96$, $\alpha=0.05$, $q=1-p$, and $d=0.2p$).

A multistage stage 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 308 villages (rural) and 14 towns (urban) in the Dehui City using the probability proportional to size (PPS) sampling method. In the second stage, 5 villagers' groups or communities were randomly sampled from both rural and urban strata using PPS. In the third stage, 1 participant aged ≥40 years was randomly selected from each household of the selected villagers' groups or communities. Respondents who were unwilling to participate in the survey or judged to be very frail were excluded. We had selected permanent residents aged ≥40 years to attend the study (a calculated total of 4445 participants with added 10% loss rate), and then, 4100 participants of them completed the face-to-face survey, with a good response rate of 92.2%. In this sub-study of the CNSSS, we used data from participants who finally 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 sample selection framework is presented in Figure 1. The study protocol was approved by the Human Ethics and Research Ethics committees of the First Hospital of Jilin University. Written informed consent was obtained from all study participants before recruitment and data collection.

Patient and public involvement

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

Data collection and measurement

All patients completed a questionnaire that included general information (sociodemographic and health-related information). Physical examination included height, weight, neck circumference, waist circumference, hip circumference, and blood pressure. Height and weight were measured according to the standard. Subjects removed their shoes and hats and wore light clothes. The measurement accuracy was 0.1cm and 0.1kg. Blood pressure was measured by doctors using the OMRON automatic sphygmomanometer (OMRON HEM-7200, KYOTO, Japan). Blood pressure was measured on the right arm, parallel to the heart. The subjects rested for 20 minutes, and then blood pressure was measured twice, and the mean value was taken. Blood samples were measured overnight (at least 8 hours) on an empty stomach for fasting plasma glucose (FPG), triglyceride (TG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C). The samples were sent to the clinical laboratory of Changchun Kingmed center for testing.

Screening protocol and assessment criteria

The definition of MS we adopted in this study was published by International Diabetes Federation (IDF) and the American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI).[8] The presence of any 3 of the 5 risk factors constitutes a diagnosis of MS: 1. Waist circumference: ≥90cm for men, ≥80cm for women; 2. TG: ≥1.70mmol/L （drug treatment for elevated TG is an alternate indicator）; 3. HDL-C: <1.0mmol/L for men, <1.3mmol/ L for women, (drug treatment for reduced HDL-C is an alternate indicator); 4. Blood pressure: systolic blood pressure (SBP) ≥130 and/or diastolic blood pressure (DBP) ≥85mmHg (antihypertensive drug treatment in a patient with a history of hypertension is an alternate indicator); and 5. FPG: ≥5.6mmol/l (drug treatment of elevated glucose is an alternate indicator).

In addition to gender grouping, the participants were divided into the middle-aged group (40-64 years old) and the elderly group (≥65 years old). Evaluation criteria for other factors are shown in supplementary table S1. Those factors include overweight, physical inactivity, smoking, abnormal neck circumference, and alcohol consumption.

Statistical analysis

Continuous variables were presented as median (IQR). Categorical data were presented as number and proportions. Sex differences were compared using Mann-Whitney U test and $\chi 2$-test. Multivariable binary logistic regressions were used to explore independent prevalence factors of MS among adults, and the OR and 95% confidence intervals (CIs) were calculated. All statistical analyses were performed using IBM SPSS 23.0 (SPSS, Inc., New York, NY, USA). *P* < 0.05 was considered statistically significant.

RESULTS

1. General data

There were 4052 participants in the survey. Among them, there were 1619 males and 2433 females with a median age of 53 (47, 62) years. Compared with the females, age, BMI, waist circumference, hip circumference, neck circumference and blood pressure were higher in males, whereas HDL-C and TC were lower (P <0.001). In addition, the proportion of smoking, exercising, living in the rural areas, and drinking alcohol were higher in men, whereas education level (Junior middle school and above) was higher in men, and the difference was statistically significant (except education level and living region P＜0.05, else P＜0.001), as shown in Table 1.

Table 1 General characteristics of participants

	Men (N=1619)	Women (N=2433)	Total (N=4052)	z/χ^2	*P* value
Age(years)	55(48,63)	53(47,61)	53(47,62)	-4.796	＜0.001
BMI(kg/m2)	24.69(22.48,27.06)	23.97(21.94,26.32)	24.23(22.19,26.64)	-5.883	＜0.001
WC(cm)	89(82,94)	84(77,90)	85(80,92)	14.949	＜0.001
HC(cm)	100(94,104)	95(90,100)	96(90,102)	16.774	＜0.001

NC(cm)	36(35,38)	32(31,34)	34(32,36)	39.004	<0.001
Blood pressure					
SBP (mmHg)	139.5(128.5,155)	136(124,153.5)	137.5(125.5,154.4)	-4.935	<0.001
DBP (mmHg)	91.5(83.5,100)	85.5(79.5,94)	87.5(81,96.5)	-13.862	<0.001
Lipid (mmol/l)					
HDL-C	1.24(1.11,1.35)	1.25(1.13,1.39)	1.25(1.12,1.36)	-5.549	<0.001
TC	5.26(4.59,5.96)	5.37(4.7,6.12)	5.34(4.66,6.05)	-3.582	<0.001
LDL-C	1.89(1.5,2.65)	1.9(1.54,2.63)	1.89(1.52,2.65)	-0.833	0.405
TG	1.57(1.1,2.37)	1.62(1.17,2.38)	1.6(1.14,2.38)	-1.520	0.129
FBG	4.9(4.44,5.6)	5(4.5,5.6)	4.9(4.5,5.6)	-1.583	0.114
Physical inactivity n (%)				15.099	<0.001
No	1309(80.9)	1841(75.7)	3150(77.7)		
Yes	310(19.1)	592(24.3)	902(22.3)		
Alcohol consumption n (%)				1340.38	<0.001
Never	693(42.8)	2285(93.9)	2978(73.5)		
Heavy	421(26)	12(0.5)	433(10.7)		
Light/moderate	505(31.2)	136(5.6)	641(15.8)		
Region, n (%)				5.907	0.016
Urban	788(48.7)	1279(52.6)	2067(51)		
Rural	831(51.3)	1154(47.4)	1985(49)		
Education, n(%)				12.123	0.006
≤Primary school	526(32.5)	920(37.8)	1446(35.7)		

Junior middle school	715(44.2)	981(40.3)	1696(41.9)		
Senior middle school	222(13.7)	315(12.9)	537(13.3)		
College and above	156(9.6)	217(8.9)	373(9.2)		
Fruit consumption n(%)				0.728	0.696
≥ 5days/week	1423(87.9)	2157(88.7)	3580(88.4)		
3-4 days/week	151(9.3)	208(8.5)	359(8.9)		
≤ 2 days/week	45(2.8)	68(2.8)	113(2.8)		
Smoke, n(%)				249.210	<0.001
No	563(34.8)	1462(60.1)	2025(50.0)		
Yes	1056(65.2)	971(39.9)	2027(50.0)		

Abbreviations: BMI, body mass index; WC, Waist circumference; HC, Hip circumference; NC, Neck circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; TG, triglyceride; FBG, fasting blood glucose.

Values are expressed as median (IQR) or n (percentage).

2. MS prevalence

Among the 4052 subjects, 2030 met MS diagnosis, with a prevalence of 50.1% (38.4% in males and 57.9% in females). The gender difference was statistically significant (*P* <0.001). Among female population, the prevalence of MS in different age groups was 55.3% and 71.7%, respectively. There were statistical differences between the groups (*P* <0.001), as shown in Table 2a.

Table 2a Prevalence of Metabolic Syndrome

Characteristics	**40-64 (N=3370)**	**65- (N=682)**	**Total (N=4052)**	χ^2	***P* value**

Men （N=1619）	501(38.00)	121(40.20)	622(38.40)	0.495	0.481
Women (N=2433)	1135(55.30)	273(71.70)	1408(57.90)	35.197	＜0.001
Total	1636(48.50)	394(57.80)	2030(50.10)	19.309	＜0.001
χ2	96.155	68.194	147.135		
P	＜0.001	＜0.001	＜0.001		

Values are expressed as n (percentage).

3. Distribution of MS in different genders and different populations

Among middle-aged people (age 40-64), the proportions of waist circumference abnormality in males and females were 84.6% and 91.1%, respectively. The proportions of HDL-C abnormality in males and females were 28.7% and 77.2%, respectively, and the proportions of TG abnormality in males and females were 81.8% and 59.6%, respectively. The proportions of FBG abnormality in males and females were 45.7% and 40.30%, respectively. The proportion of blood pressure abnormality in males and females were 96.6% and 87.2%, respectively. The intergroup statistics were statistically significant (except FBG $P < 0.05$, residual $P < 0.001$). In the elderly group, the proportions of HDL-C abnormality were 26.4% and 74.4%, respectively, and inter-group statistics of which were statistically significant ($P < 0.001$), as shown in Table 2b.

Table 2b The distribution of Metabolic Syndrome in different genders in the populations of age 40-64 and age ≥65

	Age 40-64				**Age ≥65**			
Characteristics (Abnormality)	**Men** (N=501)	**Women** (N=1135)	χ^2	*P* value	**Men** （N=121）	**Women** (N=273)	χ^2	*P* value
WC, n(%)	424(84.60)	1034(91.10)	15.008	＜0.001	107(88.40)	256(93.80)	3.302	0.069

HDL, n(%)	144(28.70)	876(77.20)	347.384	<0.001	32(26.40)	203(74.40)	79.961	<0.001
TG, n(%)	410(81.80)	676(59.60)	77.292	<0.001	79(65.30)	190(69.60)	0.718	0.397
FBG, n(%)	229(45.70)	457(40.30)	4.231	0.04	59(48.80)	127(46.50)	0.169	0.681
BP, n(%)	484(96.60)	990(87.20)	34.293	<0.001	117(96.70)	262(96.00)	0.12	0.729

Abbreviations: WC, Waist circumference; HDL, high-density lipoprotein; TC, total cholesterol; FBG, fasting blood glucose.

Values are expressed as n (percentage).

4. Univariate analysis of MS in different genders

In the male group, compared with the non-MS group, BMI, hip circumference and neck circumference of the population with MS were significantly higher. The population with MS was mostly distributed in urban regions, with a higher proportion of abnormal neck circumference, heavier alcohol consumption, less physical exercise, and lower education level. The difference between groups was statistically significant (except in alcohol consumption and education level *P* <0.05, residual *P* <0.001). In the female group, compared with the non-MS group, the age, BMI, hip circumference, and neck circumference were significantly higher (*P* <0.001). The population with MS were mostly distributed in the rural region and had a higher proportion of abnormal neck circumference, lower education level, and no alcohol consumption (except alcohol consumption *P* <0.05, residual *P* <0.001), as shown in Table 3.

Table 3 Univariate analysis of Metabolic Syndrome in different genders

	Male			Female		
Characteristics	**MS (N=622)**	**Non-MS (N=997)**	***P* value**	**MS (N=1408)**	**Non-MS (N=1025)**	***P* value**
Age (year)	55(48,63)	55(48,62)	0.828	56(49,63)	50(45,57)	<0.001

BMI (Kg/m2)	26.85 (25.15,28.51)	23.51 (21.47,25.26)	＜0.001	25.15 (23.34,27.29)	22.41 (20.70,24.16)	＜0.001
HC (cm)	103(100,107)	96(91,100)	＜0.001	97(93,102)	90(84,95)	＜0.001
NC (cm)	38(36,40)	35(34,37)	＜0.001	33(32,35)	32(30,33)	＜0.001
Smoke, n(%)			0.472			＜0.001
No	223(35.9)	340(34.1)		798(56.7)	664(64.8)	
Yes	399(64.1)	657(65.9)		610(43.3)	361(35.4)	
Physical inactivity n(%)			＜0.001			0.235
No	153(24.6)	157(15.7)		355(25.2)	237(23.0)	
Yes	469(75.4)	840(84.3)		1053(74.8)	788(77.0)	
Alcohol consumption, n(%)			0.006			0.010
Never	251(40.4)	442(44.3)		1340(95.2)	945(92.2)	
Light/moderate	182(29.3)	323(32.4)		63(4.5)	73(7.1)	
Heavier	189(30.4)	232(23.3)		5(0.4)	7(0.7)	
Region, n(%)			＜0.001			＜0.001
Urban	357(57.4)	431(43.2)		666(47.3)	613(59.8)	
Rural	265(42.6)	566(56.8)		742(52.7)	412(40.2)	
Fruit consumption, n(%)			0.690			0.254
≥5days per week	546(87.8)	877(88.0)		1236(87.8)	921(89.9)	
3-4 days per week	61(9.8)	90(9.0)		128(9.1)	80(7.8)	
≤2 days per week	15(2.4)	30(3.0)		44(3.1)	24(2.3)	
BMI, n(%)			＜0.001			＜0.001
Normal	88(14.1)	568(57.0)		465(33.0)	707(69.0)	

Underweight	3(0.5)	13(1.3)		8(0.6)	40(3.9)	
Overweight	144(23.2)	238(23.9)		377(26.8)	162(15.8)	
Apparently overweight	183(29.4)	106(10.6)		281(20.0)	81(7.9)	
Obesity	204(32.8)	72(7.2)		277(19.7)	35(3.4)	
NC, n(%)			<0.001			<0.001
Normal	160(25.7)	662(66.4)		550(39.1)	694(67.7)	
Abnormal	462(74.3)	335(33.6)		858(60.9)	331(32.3)	
Age,n(%)			0.481			<0.001
40-64 years	501(80.5)	817(81.9)		1135(80.6)	917(89.5)	
≥65 years	121(19.5)	180(18.1)		273(19.4)	108(10.5)	
Education, n(%)			0.006			<0.001
≤Primary school	176(28.3)	350(35.1)		630(44.7)	290(28.3)	
Junior middle school	280(45.0)	435(43.6)		549(39.0)	432(42.1)	
Senior middle school	104(16.7)	118(11.8)		149(10.6)	166(16.2)	
College and above	62(10.0)	94(9.4)		80(5.7)	137(13.4)	

Abbreviations: MS, Metabolic syndrome; *BMI, body mass index; HC, Hip circumference; NC, Neck circumference.*
Values are expressed as median (IQR) or n (percentage).

5. Multifactor logistics analysis results

Non-exercising males were more likely to develop MS than those with regular exercise (OR=1.437, 95%CI: 1.064-1.941). Elderly men were more likely to develop MS than middle-aged men (OR=1.460, 95%CI: 1.065-2.002). The risk of developing MS in the male group with neck circumference enlargement was higher than the one with normal neck circumference (OR=2.078, 95%CI: 1.569-2.751). People with higher BMI (overweight) were more likely to develop MS than those with normal BMI (OR=3.324, 95%CI: 2.403-4.598) and the risk of MS was higher for people with higher BMI.

In the female group, elderly women were more likely to develop MS than middle-aged women (OR=1.938, 95%CI: 1.466-2.561). People with higher BMI (overweight) were more likely to develop MS than those with normal BMI (OR=3.273, 95%CI: 2.602-4.116) and the risk of MS was higher for people with higher BMI. People with a lower BMI (underweight) were less likely to develop MS than those with normal BMI (OR=0.238, 95%CI: 0.107-0.529). People with abnormal neck circumference were more likely to develop MS than those with normal neck circumference (OR=1.853, 95%CI: 1.521-2.258). People with a higher education level (at least a junior middle school diploma) were less likely to develop MS than those with a lower education level (primary school diploma and below) (OR=0.633, 95% CI: 0.495-0.809). The risk of MS decreased with higher education level, as shown in Table 4.

Table 4 Multivariate Logistic Regression Analyses on Risk Factors for the Prevalence of Metabolic Syndrome in male and female group

		Men		Women	
Category	**Subcategory**	OR (95%CI)	*P* value	OR (95%CI)	*P* value
Age	**40-64**	1(reference)		1(reference)	
	≥65	1.460(1.065-2.002)	0.019	1.938(1.466-2.561)	<0.001
Education	**≤Primary school**	1(reference)		1(reference)	
	Junior middle school	0.903(0.654-1.247)	0.536	0.633(0.495-0.809)	<0.001

	Senior middle school	1.062(0.673-1.675)	0.796	0.524(0.368-0.745)	<0.001
	College and above	0.672(0.401-1.125)	0.130	0.371(0.247-0.557)	<0.001
Region	**Urban**	1(reference)		1(reference)	
	Rural	0.878(0.636-1.213)	0.430	1.020(0.787-1.321)	0.883
BMI	**Normal**	1(reference)		1(reference)	
	Underweight	1.539(0.419-5.653)	0.516	0.238(0.107-0.529)	<0.001
	Overweight	3.324(2.403-4.598)	<0.001	3.273(2.602-4.116)	<0.001
	Apparently overweight	8.470(5.872-12.22)	<0.001	4.291(3.21-5.737)	<0.001
	Obesity	11.872(7.929-17.776)	<0.001	8.025(5.416-11.89)	<0.001
NC	**Normal**	1(reference)		1(reference)	
	Abnormal	2.078(1.569-2.751)	<0.001	1.853(1.521-2.258)	<0.001
Smoke	**No**	1(reference)		1(reference)	
	Yes	1.248(0.952-1.636)	0.109	1.227(0.982-1.533)	0.071
Sport frequently	**Yes**	1(reference)		1(reference)	
	No	1.437(1.064-1.941)	0.018	1.203(0.964-1.502)	0.103
Alcohol consumption	**Never**	1(reference)		1(reference)	
	Higher drinking	1.300(0.957-1.765)	0.093	0.418(0.115-1.518)	0.185
	Light/moderate	0.869(0.651-1.159)	0.338	0.698(0.471-1.034)	0.073

Abbreviations: BMI, body mass index; NC, Neck circumference; OR, odds ratio.

DISCUSSION

MS has become one of the major public health threat in China. In the current study, the prevalence of MS in northeast China is significantly higher than that in entire

China (33.9%).[9] However in our study, the prevalence of MS was 50.1%. It is higher than previous study. In our study, it is also found that the prevalence of MS in women (57.9%) was higher than that in men (38.4%). In terms of age groups, the prevalence of MS in women was higher than that in men, no matter in the middle-aged group or the elderly group. In addition to gender differences, the prevalence of MS among female groups showed a trend of increase with the increase in age. The prevalence of MS in the elderly group (57.8%) was significantly higher than that in the middle-aged group (48.5%). In most studies, the prevalence of MS in females was higher than that in males,[9,10] but Firmann M's study found that the prevalence of MS in Caucasian males is higher than that in females,[11] which may be related to the difference in the selected race, the investigated population, and the selection criteria. The prevalence of MS is significantly different between regions and races. The gender difference in MS prevalence is mainly related to the increase in insulin resistance and the abnormal lipid metabolism resulting from the decrease in estrogen level after menopause following the increase in age. This change is related to hormone level, but not with aging.[12] In addition, relevant studies have shown that the prevalence of MS in women is significantly higher than that in men, and such a gender-related correlation was strengthened with the increase in age, which is consistent with our findings.

In this study, we also found that the proportion of abnormal waist circumference and HDL in women was significantly higher than that in men, which was the main reason for the higher prevalence of MS in women than in men. This difference was significant in middle-aged group. This is consistent with the study of Dallongeville, a J.[13] The increase in waist circumference is significantly correlated with the occurrence of cardiovascular diseases.[14] In our study, the prevalence of abnormal TG in middle-aged men was significantly higher than that in middle-aged women, but there was no such difference in the elderly population. This is same as reported in the previous studies.[15,16] Therefore, we should mainly observe the occurrence of abdominal obesity in middle-aged and elderly women.

Multivariate regression analysis showed that the prevalence of MS in men was mainly influenced by BMI, and the risk of MS increases with the increase in BMI. The abnormality of neck circumference, increase in age, and physical inactivity are also the main factors influencing the prevalence risk of MS, which was the same as reported in the research results of Zhou JY.[17] Infrequent physical activity increases the risk of MS in men, but not in women. This finding is similar to that of Díaz-Martínez X.[18] In the female group, both the growth in age and the abnormality of neck circumference increase the risk of MS. There is a significant relationship between MS prevalence in females and age, BMI, and neck circumference. Higher education level of females can reduce the prevalence of MS; however, this correlation is not found in the male population. The prevalence of MS in females shows a correlation with education, whereas a negative correlation trend is observed in males, which is similar to the results of Kim OY.[19]

Education level is the most important measure of the social economic status of people, which is not only closely related to the prevalence of cerebrovascular disease,[20] but also affects the prevalence of MS. The specific mechanism by which education affects the prevalence of MS is not clear. It has been considered that education affects people's health mainly by influencing lifestyle, positive attitudes toward health, and accessing the chance of preventive health services.[21] In addition, according to Kim OY's research, the prevalence of MS in South Korea is negatively correlated with education level, which is largely related to the food consumption pattern of Korean people (especially women).[19]

Strengths and limitations

There are several limitations in the study. First, some parts of the results are based on the investigators' self-reported data, with the drawback of inevitable recall bias. Second, people who were sick or too weak to complete the interview were excluded in our survey. Despite these limitations, the main advantage of this study is the use of a large population cohort. After rigorous training prior to the survey, we used a uniform pre-coded questionnaire designed by CNSSS. A reliable method was applied to the study.

CONCLUSION

In our study, the prevalence of MS in women is significantly higher than that in men in northeast China. Higher age, larger neck circumference, and higher BMI significantly increase the risk of MS in women and men, whereas physical inactivity increases the risk of MS only in men, higher education level reduces the prevalence of MS in women. It is important to control abnormal BMI and neck circumference in both men and women, particularly, in women with a low level of education and men with physical inactivity. Such a control can be achieved by influencing lifestyle, positive attitudes toward health, and accessing preventive interventions. Collectively, these efforts will help in lowering the prevalence of MS.

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CONTRIBUTORS

Conception and design: Y Y, and Z-N G. Acquisition of the data: F-L Z and H-Y L.

Data analysis: F-E L, D L, F-L Z. Drafting and revising the manuscript: F-E L. Critical revision: Z-N G, and Y Y. All of the authors approved the final version for publication.

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CONFLICTS OF INTEREST

None declared.

ETHICS APPROVAL

This subject was approved by the human ethics and research ethics committee of the First Hospital of Jilin University (approval No: 2015-R-250), and written informed consent was obtained from all of the participants.

PROVENANCE AND PEER REVIEW

Not commissioned; externally peer reviewed.

DATA SHARING STATEMENT

The dataset supporting the conclusions of this article can be made available upon request.

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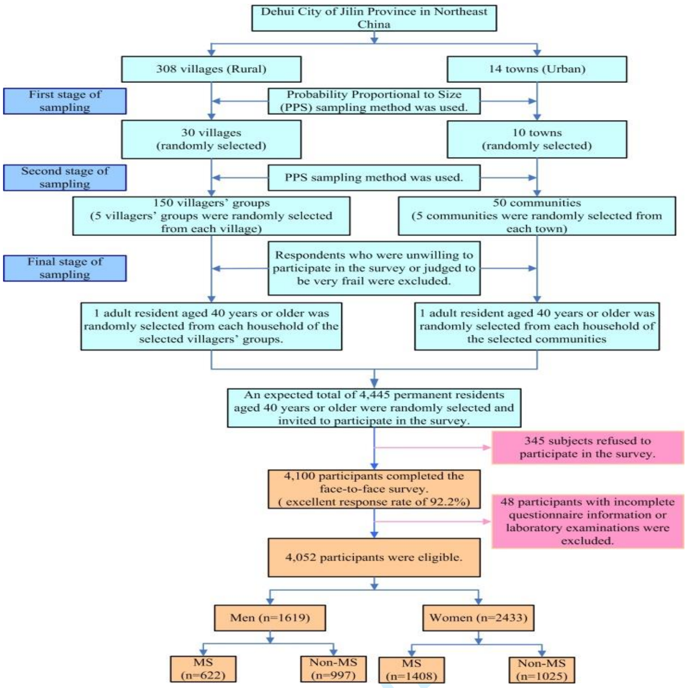
Fig. 1 Sampling process in the study


Dehui City of Jilin Province in Northeast China
308 villages (Rural)
14 towns (Urban)
First stage of sampling
Probability Proportional to Size (PPS) sampling method was used.
30 villages (randomly selected)
10 towns (randomly selected)
Second stage of sampling
PPS sampling method was used.
150 villagers' groups (5 villagers' groups were randomly selected from each village)
50 communities (5 communities were randomly selected from each town)
Final stage of sampling
Respondents who were unwilling to participate in the survey or judged to be very frail were excluded.
1 adult resident aged 40 years or older was randomly selected from each household of the selected villagers' groups.
1 adult resident aged 40 years or older was randomly selected from each household of the selected communities
An expected total of 4,445 permanent residents aged 40 years or older were randomly selected and invited to participate in the survey.
345 subjects refused to participate in the survey.
4,100 participants completed the face-to-face survey. (excellent response rate of 92.2%)
48 participants with incomplete questionnaire information or laboratory examinations were excluded.
4,052 participants were eligible.
Men (n=1619)
Women (n=2433)
MS (n=622)
Non-MS (n=997)
MS (n=1408)
Non-MS (n=1025)

Supplementary Table S1 Definitions of metabolic syndrome-related risk factors in the survey.

Variables	Criteria	References
BMI	BMI was grouped into five categories for our study: underweight (BMI< 18.5 kg/m^2), normal (18.5≤ BMI< 24 kg/m^2), overweight (24≤ BMI< 26 kg/m^2), apparently overweight (26≤ BMI < 28 kg/m^2), obesity (BMI≥ 28 kg/m^2).	Guidelines for diabetes prevention and treatment in China[1]
Abnormal neck circumference	≥37cm for male and ≥33cm for female	Neck circumference as an independent predictive contributor of cardio-metabolic syndrome[2]
Physical inactivity	Physical inactivity is defined as insufficient physical activity; Physical activity is defined as the performance of heavy physical labor or regular physical exercise for more than one year, more than 3 times per week, and for at least 30 minutes per session.	CHNS guidelines[3]
Smoking	A smoker was defined as one who reported smoking one or more cigarettes or was passively exposed to tobacco smoke every day in general for more than 6 consecutive months. A non-smoker was defined as the one who had never smoked, nor passively exposed to tobacco smoke; or, had history of smoking but quit smoking for at least 6 consecutive months previous to the study.	Technical specification of stroke screening and prevention in China[4]
Drinking	The NIAAA sets the standard drink size at about 14g of absolute ethanol, advising limits of no more than three drinks per day or seven drinks per week for men and women. Drinking status was divided into three categories according to the participants' self-report in the previous 6 months: non-drinkers: had never drunk alcoholic beverage; light/moderate drinkers: less than or upto NIAAA limits; heavier drinkers: in excess of NIAAA limits.	NIAAA guidelines[5]
Fruit consumption	Fruit consumption was grouped into three categories for our study: less than or equal to two days per week (≤ 2 d/w), three to four days per week (3–4 d/w), and greater than or equal to five days per week (≥ 5 d/w). And the weight of consumed fruits should reach or exceed two servings per day, and the definition of a serving of a fruit was calculated as 80g.	Fruit and vegetable consumption and stroke: meta-analysis of cohort studies[6]

Abbreviation: BMI, body mass index; CHNS, China Health and Nutrition Survey; NIAAA, National Institute on Alcohol Abuse and Alcoholism.

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3,4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-8
Bias	9	Describe any efforts to address potential sources of bias	*6-7*
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6, 7
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9-11
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	(7)
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-11
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	11,12
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	13-17
		(*b*) Report category boundaries when continuous variables were categorized	12
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18,19
Generalisability	21	Discuss the generalisability (external validity) of the study results	20
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Sex differences and risk factors for Metabolic syndrome in adults aged more than 40 years in Northeast China: Results from the National Stroke Screening Survey

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Original Article

Title Page

Sex differences and risk factors for metabolic syndrome in adults aged more than 40 years in Northeast China: Results from the National Stroke Screening Survey

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Authors contributions: Conception and design: Y Y, and Z-N G. Acquisition of the data: F-L Z and H-Y L. Statistical methods and data analysis: F-e L, P Z, D L, F-L Z.

Drafting and revising the manuscript: F-e L. Critical revision: Z-N G, and Y Y. All of the authors approved the final version for publication.

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Search terms: metabolic syndrome, prevalence, sex difference, cross-sectional, risk factor.

Word count: abstract 300 words; text 3429 words; 48 references; 5 tables and figures.

ABSTRACT

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

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

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

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

Results The prevalence of MS was 50.1% overall (38.4% in males and 57.9% in females; $p<0.001$). High body mass index (BMI) and neck circumference significantly increased the risk of MS for both sexes. In addition, physical inactivity and alcohol consumption in males (odds ratios [ORs] 95%CIs: 1.506[1.117-2.031]; p=0.007 and 1.341[1.001-1.796]; p=0.049) and advanced age in females (ORs 95%CIs: 1.999[1.516-2.634]; $p<0.001$) were factors associated with MS. Women who had a level of education above junior middle school and those who were underweight (BMI <18.5 kg/m^2) were less likely to develop MS, whereas for men, college education was a protective factor against MS.

Conclusions It is necessary to understand sex-specific differences and accurately

identify high-risk groups, which could help formulate better public health policies and educational initiatives to fundamentally reduce the incidence of MS and cardiovascular diseases.

Key words: metabolic syndrome, prevalence, sex difference, cross-sectional, risk factor.

Strengths and limitations of this study

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

2. We used a uniform, pre-coded questionnaire designed by the Stroke Screening and Prevention Program of the National Health and Family Planning Commission of China (CNSSS).

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

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

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

INTRODUCTION

Metabolic syndrome (MS) is associated with a cluster of cardiometabolic risk factors and has become one of the major public health threats in China. The higher prevalence of MS greatly increases the burden of morbidity and mortality of 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, especially the highest incidence and mortality of stroke (365 and 159/100 000 person-years) in China.[6] Thus, this study aimed to analyze 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), which 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 $Z_{\alpha} = 1.96$, $\alpha = 0.05$, $q = 1\text{-}p$, 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 the 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 sub-study 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. The study protocol was approved by the Human Ethics and Research Ethics Committee of the First Hospital of Jilin University, Chang Chun, Jilin, China. Written informed consent was obtained from all study participants before recruitment and data collection.

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 circumference, waist circumference, hip circumference, 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 minutes before the blood pressure was measured twice, and mean value was recorded. Blood samples were collected following overnight fasting (at least eight hours) on an empty stomach 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 Center (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 (IDF) and the American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI).[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 is 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 is an alternative indicator); 4) blood pressure: systolic blood pressure (SBP) ≥130 mmHg and/or diastolic blood pressure (DBP) ≥ 85 mmHg (antihypertensive drug treatment in a patient with a history of hypertension is an alternative indicator); and 5) FPG concentration: ≥ 5.6 mmol/L (drug treatment for elevated glucose levels is an alternative indicator).

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

Statistical analysis

The normalities of the data distributions were tested using the Kolmogorov-Smirnov test. Non-normally distributed continuous variables are presented as medians (IQRs).

The Mann-Whitney U test was used to assess differences between two groups of data with non-normal distributions. Categorical data are presented as numbers and proportions. The differences between groups were assessed using the $\chi 2$-test. Significant variables (those with $P < 0.05$) identified in the univariate analysis were selected for the multivariate analyses. Multiple logistic regression analysis was used to explore the independent risk factors of MS in the two sexes, and the odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. All statistical analyses were performed using IBM Statistical Package for the Social Sciences (SPSS) version 23.0 (SPSS, Inc., New York, NY, USA). $P < 0.05$ was considered statistically significant.

RESULTS

Among the 4,100 participants who completed the face-to-face survey, 4,052 were included in the analysis. A total of 2,030 individuals met the criteria for MS, and the prevalence was 50.1% overall (38.4% in males and 57.9% in females; $p<0.001$). Of all the 4,052 participants, 1,619 were men (40.0%) and 2,433 were women (60.0%), with a median age of 53 (IQR: 47- 62) years. The population were likely to have a lower educational level. In total, 76.7% of the participants had a level of education not higher than that of junior middle school.

1. Demographic characteristics of all participants with MS

Table 1 shows that compared to males, the female participants with MS had the following associated risk factors: a primary school and lower level of educational attainment (44.7% vs. 28.3%; p<0.001), living in a rural area, a normal or underweight BMI, an abnormal HDL-C concentration, and a higher concentration of total cholesterol and LDL-C. Women were also less likely to have an abnormal neck or hip circumference, hypertension, abnormal levels of triglycerides and fasting blood glucose, live in urban areas, and smoke and drink alcohol.

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

	Total	Male	Female	P value
Participants, n (%)	4052(100)	1619 (40.0)	2433 (60.0)	
Cases, n (%)	2030 (50.1)	622 (38.4)	1408 (57.9)	<0.001
Age, years, median (IQR)	56(49,63)	55.72(48,63)	56.19(49,63)	0.216
Age group, n (%)				0.973
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)	<0.001
Neck circumference, median (IQR)	34(32,37)	38.23(36,40)	33.27(32,35)	<0.001
Hip circumference, n (%)	100(95,104)	103.63(100,107)	97.76(93,102)	<0.001
TCHO, mmol/L, median (IQR)	5.52(4.83,6.25)	5.50(4.73,6.12)	5.63(4.87,6.29)	0.004
LDLC, mmol/L, median (IQR)	1.93(1.56,2.64)	2.08(1.5,2.57)	2.19(1.57,2.65)	0.001
HDLC, n (%)	1255(61.8)	176(28.3)	1079(76.6)	<0.001
TG, n (%)	1503(74.0)	508(81.7)	995(70.7)	<0.001
FBG, n (%)	881(43.4)	291(46.8)	590(41.9)	<0.001
Hypertension, n (%)	1853(91.3)	601(96.6)	1252(88.9)	<0.001
Education, n (%)				<0.001
≤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 (%)				<0.001
Urban	1023(50.4)	357(57.4)	666(47.3)	
Rural	1007(49.6)	265(42.6)	742(52.7)	
Smoke, n (%)				<0.001
No	1021(50.3)	223(35.9)	798(56.7)	
Yes	1009(49.7)	399(64.1)	610(43.3)	
Physical inactivity, n (%)				0.768

No	1522(75.0)	469(75.4)	1053(74.8)	
Yes	508(25.0)	153(24.6)	355(25.2)	
Alcohol consumption, n (%)				<0.001
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 (%)				0.609
≥5days 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 (%)				<0.001
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)	

Abbreviations: TCHO, total serum cholesterol; LDLC, Low Density Lipoprotein Cholesterol; HDLC, high-density lipoprotein; TG, triglyceride; FBG, fasting blood glucose; BMI, body mass index.

Values are expressed as n (percentage).

2. Univariate analysis of factors associated with MS by sex

Table 2 shows the prevalence of MS according to different demographic characteristics and risk factors in men and women. The prevalence of MS in woman was significantly higher than that in men (P <0.001). The prevalence of MS was higher in the elderly (men: 40.2%; women: 71.7%), especially in older women (Figure 2). In the female group, age, BMI, hip and neck circumference, smoking, alcohol drinking, geographical region, and level of educational attainment were associated with MS, whereas physical inactivity and fruit consumption were not. In men, the risk factors associated with MS were similar, except for age and smoking. Unlike in women, physical inactivity was also a risk factor in men.

Table 2 Distribution of metabolic syndrome (MS) in men and women according to different demographic characteristics

Characteristics	Male			Female		
	Total	case, (n%)	*P* value	Total	case, (n%)	*P* value
Cases, n (%)	1619	622(38.4)	-	2433	1408(57.9)	-
Age, year, median (IQR)	55(48,63)	55(48,63)	0.828	53(47,61)	56(49,63)	<0.001
Age group, n (%)			0.481			<0.001
40-64 years	1318	501(38.0)		2052	1135(55.3)	
≥65 years	301	121(40.2)		381	273(71.7)	
BMI, Kg/m2, median (IQR)	24.69 (22.48,27.06)	26.85 (25.15,28.51)	<0.001	23.97 (21.94,26.32)	25.15 (23.34,27.29)	<0.001
BMI, n (%)			<0.001			<0.001
Normal	656	88(13.4)		1172	465(39.7)	
Underweight	16	3(18.8)		48	8(16.7)	
Overweight	382	144(37.7)		539	377(69.9)	
Apparently overweight	289	183(63.3)		362	281(77.6)	
Obesity	276	204(73.9)		312	277(88.8)	
HC, cm, median (IQR)	100(94,104)	103(100,107)	<0.001	95(90,100)	97(93,102)	<0.001
NC, cm, median (IQR)	36(35,38)	38(36,40)	<0.001	32(31,34)	33(32,35)	<0.001
Smoke, n (%)			0.472			<0.001
No	563	223(39.6)		1462	798(54.6)	
Yes	1056	399(37.8)		971	610(62.8)	
Physical inactivity n (%)			<0.001			0.235
Yes	1309	153(49.4)		1841	355(60.0)	
No	310	469(35.8)		592	1053(57.2)	
Alcohol consumption n (%)			0.006			0.010
Never	693	251(36.2)		2285	1340(58.6)	
Light/moderate	505	182(36.0)		136	63(46.3)	
Heavier	421	189(44.9)		12	5(41.7)	
Region, n (%)			< 0.001			< 0.001
Urban	788	357(45.3)		1279	666(53.1)	
Rural	831	265(31.9)		1154	742(64.3)	
Fruit consumption n (%)			0.690			0.254
≥5days per week	1423	546(38.4)		2157	1236(57.3)	
3-4 days per week	151	61(40.4)		208	128(61.5)	
≤2 days per week	45	15(33.3)		68	44(64.7)	
Education, n (%)			0.006			< 0.001
≤Primary school	526	176(33.5)		920	630(68.5)	
Junior middle school	715	280(39.2)		981	549(56.0)	
Senior middle school	222	104(46.8)		315	149(47.3)	
College and above	156	62(39.7)		217	80(36.9)	

Abbreviations: BMI, body mass index; HC, Hip circumference; NC, Neck circumference.

Values are expressed as median (IQR) or n (percentage).

3. Relationship between risk factors and MS in the multivariate logistic regression analysis

The multivariate analysis in Table 3 shows that BMI and neck circumference were significantly associated with MS in both men and women. Higher educational attainment and an underweight BMI were not associated with MS in either sex.

In the male group, the ORs (95% CIs) were 3.202 (2.321–4.419; p <0.001) for the overweight BMI, 7.932 (5.530–11.376; p <0.001) for the apparently overweight BMI, and 11.059 (7.431–16.459; p <0.001) for the obese BMI groups compared to the reference value for a normal BMI; for neck circumference, it was 2.095 (1.584–2.772; p < 0.001). Physical inactivity and higher alcohol consumption were associated with MS in men (OR 1.506, 95% CI [1.117–2.031], *p*=0.007; and OR 1.341, 95% CI [1.001–1.796], *p* = 0.049, respectively). An OR of 0.584 (0.353–0.968; *p*=0.037) was observed for a college level of education and higher compared to the reference value for primary school education.

In the female group, the ORs (95% CIs) were 3.262 (2.594–4.101; *p* <0.001) for the overweight BMI, 4.251 (3.181–5.680; *p* < 0.001) for the apparently overweight BMI, and 8.023 (5.415–11.885; *p* <0.001) for the obese BMI groups compared to the reference value for a normal BMI. For neck circumference, the OR was 1.865 (1.531–2.272; *p* < 0.001). Advanced age (≥65 years) was associated with MS in women (OR 1.999, 95% CI [1.516–2.634]; *p* < 0.001). For the underweight BMI, the OR (95% CI) was 0.238 ([0.107–0.529]; *p* <0.001). In women, for a level of educational attainment of junior middle school, the OR was 0.630 ([0.492–0.805]; *p* <0.001); for senior middle school, it was 0.526 ([0.370–0.748]; *p* < 0.001), and for college and above, it was 0.376 ([0.251–0.564]; *p* < 0.001).

Table 3 Multivariate logistic regression analyses on risk factors for the prevalence of metabolic syndrome (MS) in males and females.

Category	Reference	Male		Female	
		OR (95% CI)	*P*	OR (95% CI)	*P*
Age group	**40-64 years**				
≥65years		-	-	1.999(1.516-2.634)	< 0.001
Education	**≤Primary school**				
Junior middle school		0.859(0.624-1.183)	0.351	0.630(0.492-0.805)	< 0.001
Senior middle school		0.986(0.629-1.548)	0.952	0.526(0.370-0.748)	< 0.001
College and above		0.584(0.353-0.968)	0.037	0.376(0.251-0.564)	< 0.001
Region	**urban**				
Rural		0.889(0.647-1.221)	0.466	0.994(0.769-1.285)	0.963
BMI	**Normal**				
Overweight		3.202(2.321-4.419)	< 0.001	3.262(2.594-4.101)	< 0.001
Apparently overweight		7.932(5.530-11.376)	< 0.001	4.251(3.181-5.680)	< 0.001
Obesity		11.059(7.431-16.459)	< 0.001	8.023(5.415-11.885)	< 0.001
Neck circumference	-	2.095(1.584-2.772)	< 0.001	1.865(1.531-2.272)	< 0.001
Smoke	**No**				
Yes		-	-	1.217(0.975-1.519)	0.083
Physical inactivity	**Physical activity**				
Yes		1.506(1.117-2.031)	0.007	-	-
Alcohol consumption	**Never**				
Light/moderate drinking		0.883(0.667-1.170)	0.386	0.701(0.473-1.040)	0.077
Higher drinking		1.341(1.001-1.796)	0.049	0.435(0.120-1.575)	0.205

Abbreviations: BMI, body mass index; OR, odds ratio.

DISCUSSION

In this study, we evaluated sex differences in the prevalence of MS and its relative determinants in a low-income population from Northeast China. We found that a high BMI and large neck circumstance were risk factors for MS, and a higher BMI was associated with a higher prevalence of MS in both sexes. In addition, higher educational attainment was a protective factor against MS in both sexes, although the effect was greater in women. An underweight BMI was also a protective factor in women. Advanced age (≥ 65 years) was a risk factor only for women, whereas physical inactivity and excessive alcohol consumption were risk factors only in men.

The prevalence of MS has been steadily increasing due to unhealthy lifestyles in low- 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–middle- and high-income populations was shown to be 33.9% in 2010;[1] however, in our study, it was 50.1%. This may be due to the fact that most of the participants in our study population had a lower educational level and income, which may have had an additive effect on the main, increasing trend. In most studies, the prevalence of MS in females was higher than that in males;[1 12] for example, in Mexico, the prevalence in females was 55.6%, whereas in males, it was 38.2%.[13] Similar sex disparities have been found in Middle Eastern countries, although few sex differences have been reported in populations from the European Union that have a lower MS prevalence.[14] Contrarily, there are also studies, which have reported that the prevalence of MS in males is higher than that in females in Caucasian,[15] in American adolescents,[16] and in Far East Asian and Japanese population, and the rate was twice as high as that in women from Macau.[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 19 20] Our results were consistent with those reported in most countries that women had a higher prevalence of MS than men,[21 22 23 24] (57.9% in females and 38.4% in males; $p < 0.001$). 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] consistent with our own findings. Females ≥ 65 years old had a 1.999- fold risk of MS and 95%CI(1.516-2.634) compared to younger ones (40-65 years old). The sex differences may be mainly related to the increase in insulin resistance and abnormal lipid metabolism resulting from the decrease in estrogen levels after menopause as women age. Thus, this change may be related to changes in hormone levels, rather than aging itself.[26]

It is well known that MS prevalence increases as BMI increases,[27] and a previous study found a BMI over 30.0 kg/m^2 was a risk factor;[28] our study also found that higher BMI, the higher the risk of MS. Compared to a normal BMI, the risk was 3.262-, 4.251-, and 8.023-fold higher in overweight, significantly overweight, and obese women, respectively; in men, the risk increased 3.202-, 7.932-, and 11.059-fold, respectively. These findings suggest that weight gain in men (BMI ≥ 24) increases the risk of MS more significantly than it does in women; this has been reported in both sexes in a study of Turkish adults.[29] 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.[30] As reported in a 2018 meta-analysis, neck circumference was not associated with MS;[31] however, a 2018 Chinese community-based study of those over 50 years old showed that neck circumference was associated with MS, although the two studies used different definitions.[32] In our study, the risk of MS increased by 1.865-fold in women and 2.095-fold in men for every 1 cm increase in neck circumference. Neck circumference combined with BMI are effective indicators of being overweight or obese, and such individuals are more prone to developing MS.

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.[33] The specific mechanism by which education affects the prevalence of MS is unclear, although it has been considered that education affects people's health mainly by influencing their lifestyles and positive attitudes toward health, and by increasing their access to preventive health services.[34] In addition, MS prevalence has been negatively correlated with educational level in South Korea, which is largely related to the dietary patterns of Koreans (especially in women).[35] In the female group in our study, compared to a level of education of primary school or less, the ORs indicated a 0.630-fold, 0.526-fold, and 0.376-fold risk of developing MS in those who had completed junior middle-school, senior middle-school, and college and above, respectively. This suggested that a higher educational level can reduce the risk of MS; however, in the male population, this advantage was found only in those who had a college education, with an OR of 0.584 (95% CI: 0.353–0.968). The negative association between MS prevalence and educational level was significant in females, which is similar to the results of a previous study.[35] A study of the third National Health and Nutrition Examination Survey found that low income and educational levels were associated with a higher prevalence of MS in females than in males.[36] Our study population is characterized by having both a low income and a low level of education, both of which contribute to a higher MS prevalence. The high percentage of females and males with a primary school education or below was 37.8% and 32.5%, respectively, which may partially explain the high prevalence of MS in women.[24]

Alcohol consumption and physical inactivity were the main risk factors in the male group, consistent with the findings of a previous study.[37] Infrequent physical activity results in a 1.506-fold increased risk of MS in men, but not in women, in agreement with previous findings;[38] however, physical activity has been suggested to be a low risk factor for MS, as has beer consumption.[39] Conversely, it has also been shown that heavy alcohol consumption with binge drinking increased the risk of MS in Korean men, regardless of their BMI.[40] Similarly, our study also showed that the population with higher consumption of alcohol had a 1.341- fold increased risk of MS incidence and 95%CI(1.001-1.796), compared to the population that never consumed alcohol. Additionally, the population with physical inactivity had a 1.506- fold increased risk of MS and 95%CI(1.117-2.031), compared to the population with physical activity. Chinese studies have found that smoking was associated with increased MS prevalence, regardless of sex or BMI classification.[41] In addition, smoking was independently associated with MS[42] in a dose-dependent manner,[43] and increased cigarette consumption of more than 20 pack-years is associated with a 1.81-fold increased MS prevalence compared to that in non-smokers in women.[39] The association between fruit consumption, geographical region, hip circumference, and MS risk remains unclear; in our study, there was no significant differences in MS risk related to these factors between men and women.

Lifestyle interventions resulted in a 2.61-fold reduced risk of MS compared with the control group in a previous study,[44] and an investigation of dietary patterns showed that the Chinese pattern (high in grains, vegetables, fruit, salted fish and eggs, soyabean, and 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 ways dietary patterns were associated with increased MS prevalence have been reported; 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] Weekly exercise while consuming > 2,000 kcal per day may strongly protect middle-aged men not only from obesity, but also from MS. 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 and regularly consume alcohol, further effort should be made to control body weight, especially by focusing on reducing high BMI and neck circumference. For women, especially the elderly, efforts should be made to control their weight more actively to maintain their BMI and neck circumference at a normal level or below to reduce the risk of MS, and a focus should be directed at changes in hormone levels. 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 identify high-risk groups could help to develop better public health policies and educational initiatives and reduce the incidence of MS and vascular diseases.

CONCLUSION

In our study, the prevalence of MS in women was significantly higher than that in men in Northeast China. It is necessary to accurately identify groups at high risk of MS based on sex-specific factors. We observed that those at the highest risk were elderly women with a low level of education and men with physical inactivity, excessive alcohol consumption, and a lower than college level of education. Abnormal BMI and large neck circumference were risk factors in both sexes. Health management and disease prevention organizations need to actively publicize such information to increase public attention and encourage those at risk to actively change their lifestyle and reduce the impact of preventable risk factors. These changes could fundamentally reduce the growing incidence of MS and the cardiovascular disease burden. These changes could fundamentally reduce the growing incidence of MS and the cardiovascular disease burden. There were also several limitations to this study, such as some self-reported data collected, blood samples measured only once, a lack of consideration of certain lifestyle factors or residual confounders, people sick or too weak excluded. Besides, the conclusion from cross-sectional studies cannot be used for causal inferences, and prospective and randomized studies are needed.

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CONFLICTS OF INTEREST

None declared.

ETHICS APPROVAL

This subject was approved by the human ethics and research ethics committee of the First Hospital of Jilin University (approval No: 2015-R-250), and written informed consent was obtained from all of the participants.

PROVENANCE AND PEER REVIEW

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DATA SHARING STATEMENT

The dataset supporting the conclusions of this article can be made available upon request.

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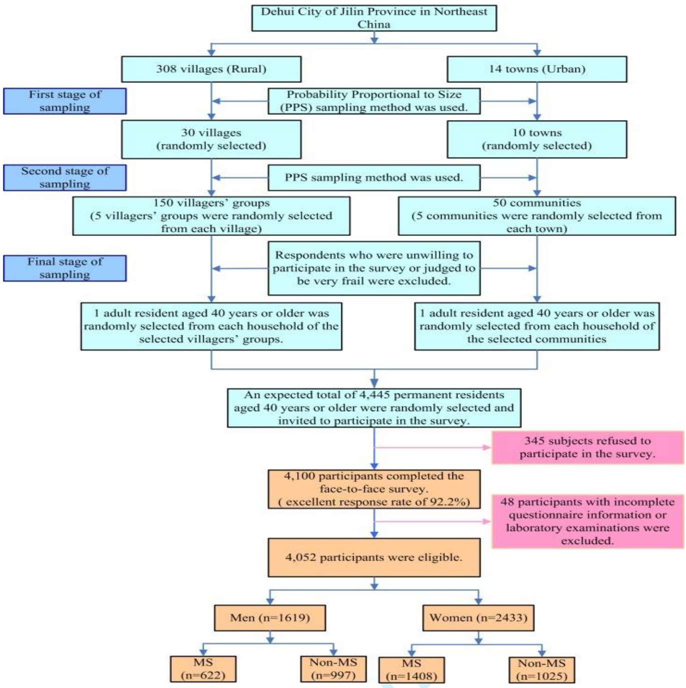
Fig. 1 Sampling process in the study

Fig. 2 Prevalence of metabolic syndrome in different sexes and ages in the study


Dehui City of Jilin Province in Northeast China
308 villages (Rural)
14 towns (Urban)
First stage of sampling
Probability Proportional to Size (PPS) sampling method was used.
30 villages (randomly selected)
10 towns (randomly selected)
Second stage of sampling
PPS sampling method was used.
150 villagers' groups (5 villagers' groups were randomly selected from each village)
50 communities (5 communities were randomly selected from each town)
Final stage of sampling
Respondents who were unwilling to participate in the survey or judged to be very frail were excluded.
1 adult resident aged 40 years or older was randomly selected from each household of the selected villagers' groups.
1 adult resident aged 40 years or older was randomly selected from each household of the selected communities
An expected total of 4,445 permanent residents aged 40 years or older were randomly selected and invited to participate in the survey.
345 subjects refused to participate in the survey.
4,100 participants completed the face-to-face survey. (excellent response rate of 92.2%)
48 participants with incomplete questionnaire information or laboratory examinations were excluded.
4,052 participants were eligible.
Men (n=1619)
Women (n=2433)
MS (n=622)
Non-MS (n=997)
MS (n=1408)
Non-MS (n=1025)

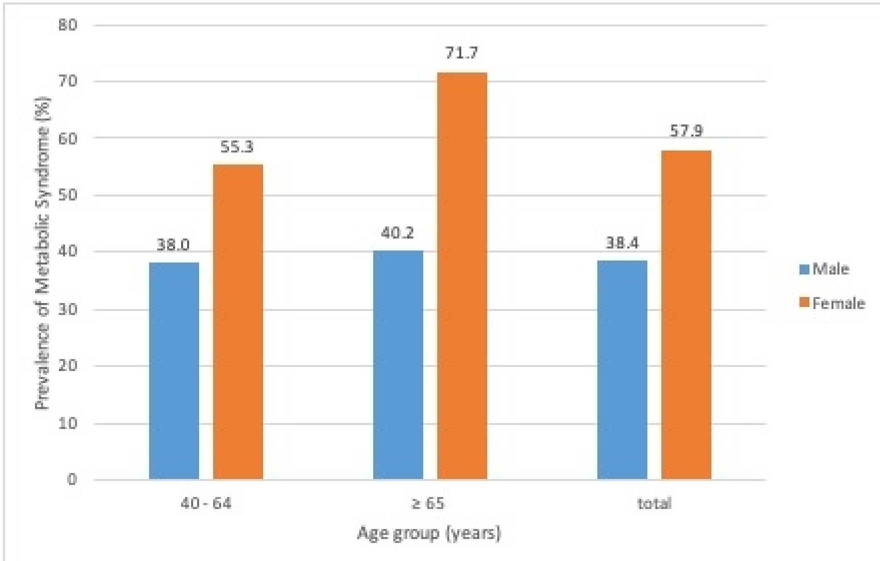


Fig. 2 Prevalence of metabolic syndrome in different sexes and ages in the study

156x99mm (72 x 72 DPI)

Supplementary Table S1 Definitions of metabolic syndrome-related risk factors in the survey.

Variables	Criteria	References
BMI	BMI was grouped into five categories for our study: underweight (BMI< 18.5 kg/m²), normal (18.5≤ BMI< 24 kg/m²), overweight (24≤ BMI< 26 kg/m²), apparently overweight (26≤ BMI < 28 kg/m²), obesity (BMI≥ 28 kg/m²).	Guidelines for diabetes prevention and treatment in China[1]
Abnormal neck circumference	≥37cm for male and ≥33cm for female	Neck circumference as an independent predictive contributor of cardio-metabolic syndrome[2]
Physical inactivity	Physical inactivity is defined as insufficient physical activity; Physical activity is defined as the performance of heavy physical labor or regular physical exercise for more than one year, more than 3 times per week, and for at least 30 minutes per session.	CHNS guidelines[3]
Smoking	A smoker was defined as one who reported smoking one or more cigarettes or was passively exposed to tobacco smoke every day in general for more than 6 consecutive months. A non-smoker was defined as the one who had never smoked, nor passively exposed to tobacco smoke; or, had history of smoking but quit smoking for at least 6 consecutive months previous to the study.	Technical specification of stroke screening and prevention in China[4]
Drinking	The NIAAA sets the standard drink size at about 14g of absolute ethanol, advising limits of no more than three drinks per day or seven drinks per week for men and women. Drinking status was divided into three categories according to the participants' self-report in the previous 6 months: non-drinkers: had never drunk alcoholic beverage; light/moderate drinkers: less than or upto NIAAA limits; heavier drinkers: in excess of NIAAA limits.	NIAAA guidelines[5]
Fruit consumption	Fruit consumption was grouped into three categories for our study: less than or equal to two days per week (≤ 2 d/w), three to four days per week (3–4 d/w), and greater than or equal to five days per week (≥ 5 d/w). And the weight of consumed fruits should reach or exceed two servings per day, and the definition of a serving of a fruit was calculated as 80g.	Fruit and vegetable consumption and stroke: meta-analysis of cohort studies[6]

Abbreviation: BMI, body mass index; CHNS, China Health and Nutrition Survey; NIAAA, National Institute on Alcohol Abuse and Alcoholism.

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3,4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-8
Bias	9	Describe any efforts to address potential sources of bias	*6-7*
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6, 7
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9-11
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	(7)
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-11
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	11,12
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	13-17
		(*b*) Report category boundaries when continuous variables were categorized	12
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18,19
Generalisability	21	Discuss the generalisability (external validity) of the study results	20
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Sex-based differences in and risk factors for metabolic syndrome in adults aged 40 years and above in Northeast China: Results from the National Stroke Screening Survey

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Original Article

TITLE PAGE

Sex-based differences in and risk factors for metabolic syndrome in adults aged 40 years and above in Northeast China: Results from the National Stroke Screening Survey

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Authors contributions: Conception and design: Y Y, and Z-N G. Acquisition of the data: F-L Z and H-Y L. Statistical methods and data analysis: F-e L, P Z, D L, F-L Z.

Drafting and revising the manuscript: F-e L. Critical revision: Z-N G, and Y Y. All of the authors approved the final version for publication.

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Search terms: metabolic syndrome, prevalence, sex difference, cross-sectional, risk factor.

Word count: abstract 282 words; text 3359 words; 52 references; 3 tables and 2 figures.

ABSTRACT

Objectives

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

Study design

This study analyzed a portion of the large sample data of the national cross-sectional screening of China from 2016. MS 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 MS.

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 MS was 50.1% overall (38.4% in males and 57.9% in females; $p<0.001$). High body mass index (BMI) and hip circumference were associated with MS in both sexes. In addition, physical inactivity (odds ratio [OR] and 95% confidence interval [CI]: 1.441 [1.055, 1.969]; $p = 0.022$) in males and advanced age (OR and 95% CI: 1.536 [1.154, 2.043]; $p = 0.003$) in females were factors associated with MS. Women with junior high school education or above and living in rural areas were less likely to have MS, unlike men.

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

Key words: metabolic syndrome, prevalence, sex difference, cross-sectional, risk factor.

Strengths and limitations of this study

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

2. We used a uniform, pre-coded questionnaire designed by the Stroke Screening and Prevention Program of the National Health and Family Planning Commission of China (CNSSS).

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

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

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

INTRODUCTION

Metabolic syndrome (MS) is associated with a cluster of cardiometabolic risk factors and has become one of the major public health threats in China. The higher prevalence of MS greatly increases the burden of morbidity and mortality of 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, especially the highest incidence and mortality of stroke (365 and 159/100 000 person-years) in China.[6] Thus, this study aimed to analyze 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), which 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 $Z_{\alpha} = 1.96$, $\alpha = 0.05$, $q = 1-p$, 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 the 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 sub-study 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. The study protocol was approved by the Human Ethics and Research Ethics Committee of the First Hospital of Jilin University, Chang Chun, Jilin, China. Written informed consent was obtained from all study participants before recruitment and data collection.

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 circumference, waist circumference, hip circumference, 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 minutes 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 Center (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 (AHA/NHLBI).[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 is 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 is an alternative indicator); 4) blood pressure: systolic blood pressure (SBP) ≥130 mmHg and/or diastolic blood pressure (DBP) ≥ 85 mmHg (antihypertensive drug treatment in a patient with a history of hypertension is an alternative indicator); and 5) FPG concentration: ≥ 5.6 mmol/L (drug treatment for elevated glucose levels is an alternative indicator).

In addition to stratifying by sex, participants were stratified by age into a middle-aged group (40–64 years old) and an elderly group (≥ 65 years old). The evaluation criteria for the other factors, including BMI, level of physical inactivity, smoking status, and alcohol consumption are shown in Supplementary 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). The Mann-Whitney U test was used to assess differences between two groups of data with non-normal distributions. Categorical data are presented as numbers and proportions. The differences between groups were assessed using the χ^2-test. Significant variables (those with $P < 0.05$) identified in the univariate analysis were selected for the multivariate analyses. Multiple logistic regression analysis was used to explore the independent risk factors of MS in the two sexes, and the odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. All statistical analyses were performed using IBM Statistical Package for the Social Sciences (SPSS) version 23.0 (SPSS, Inc., New York, NY, USA). $P < 0.05$ was considered statistically significant.

RESULTS

Among the 4,100 participants who completed the face-to-face survey, 4,052 were included in the analysis. A total of 2,030 individuals met the criteria for MS, and the prevalence was 50.1% overall (38.4% in males and 57.9% in females; $p < 0.001$). Of all the 4,052 participants, 1,619 were men (40.0%) and 2,433 were women (60.0%), with a median age of 53 years (IQR: 47–62). Overall, 76.7% of the participants had a level of education not higher than that of junior middle school.

1. Demographic characteristics of all participants with MS

Table 1 shows that compared with that in males (38.4%), the prevalence of MS in females (57.9%) was significantly higher. Among the 2,030 individuals with MS, the median age was 56 years (IQR: 49–63) and more than 80% of participants with MS, both males and females, were in the group of 40–64 years. The rate of abnormal waist circumference in females (91.6%) was higher than that in males (85.4%). The median neck circumference and hip circumference in males were higher than those in females. Compared with males, females were more likely to have the following associated risk factors: a lower level of educational attainment, living in a rural area, a normal BMI, an abnormal HDL-C concentration, and higher concentrations of TC and LDL-C. Men were also more likely to have hypertension, abnormal levels of triglycerides and fasting blood glucose, live in urban areas, and smoke and drink alcohol.

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

	Total	Male	Female
Participants, n (%)	4052(100)	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)
LDLC, mmol/L, median (IQR)	1.93(1.56, 2.64)	2.08(1.5, 2.57)	2.19(1.57, 2.65)
HDLC, 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 (%)			
≥5days 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)

Abbreviations: TCHO, total serum cholesterol; LDLC, Low Density Lipoprotein Cholesterol; HDLC, high-density lipoprotein; TG, triglyceride; FBG, fasting blood glucose; BMI, body mass index.

Values are expressed as n (percentage).

2. Univariate analysis of factors associated with MS 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 (men: 40.2%; women: 71.7%), especially in older women (Figure 2; OR [95% CI] = 2.042 [1.608, 2.594]; P < 0.001). For females, age, BMI, hip and neck circumference, smoking, higher alcohol consumption, geographical region, and level of educational attainment were associated with MS, whereas physical inactivity and fruit consumption were not. For males, 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.

Table 2 Univariate logistic regression analyses on risk factors for the prevalence of metabolic syndrome (MS) in males and females

Category	Reference	Male		Female	
		OR (95% CI)	*P*	OR (95% CI)	*P*
Age group	**40-64 years**				
≥65years		1.096(0.849, 1.416)	0.482	2.042(1.608, 2.594)	<0.001
HP	-	1.199(1.175, 1.224)	<0.001	1.157(1.141, 1.173)	<0.001
NC	-	1.442(1.378, 1.509)	<0.001	1.365(1.31, 1.422)	<0.001
Region	**Urban**				
Rural		0.565(0.462, 0.692)	<0.001	1.658(1.408, 1.951)	<0.001
Smoke	**No**				
Yes		0.926(0.751, 1.142)	0.472	1.406(1.191, 1.660)	<0.001
Physical inactivity	**Physical activity**				
Yes		1.745(1.360, 2.240)	<0.001	1.121(0.928, 1.354)	0.235
Alcohol consumption	**Never**				
Light/moderate drinking		1.435(1.121, 1.836)	0.004	0.504(0.159, 1.592)	0.243
Higher drinking		0.992(0.782, 1.260)	0.949	0.609(0.430, 0.861)	0.005
Fruit consumption	**≥5days/week**				
3-4 days per week		1.089(0.773, 1.533)	0.627	1.192(0.890, 1.597)	0.238
≤2 days per week		0.803(0.428, 1.506)	0.494	1.366(0.825, 2.263)	0.226
Education	**≤Primary school**				
Junior middle school		1.280(1.012, 1.620)	0.040	0.585(0.485, 0.706)	<0.001
Senior middle school		1.753(1.273, 2.413)	0.001	0.413(0.318, 0.537)	<0.001
College and above		1.312(0.908, 1.896)	0.149	0.269(0.197, 0.366)	<0.001
BMI	**Normal**				
Underweight		1.490(0.416, 5.332)	0.540	0.304(0.141, 0.655)	0.002
Overweight		3.905(2.878, 5.300)	<0.001	3.538(2.845, 4.401)	<0.001
Apparently overweight		11.143(8.026, 15.470)	<0.001	5.275(4.013, 6.934)	<0.001
Obesity		18.288(12.885, 25.955)	<0.001	12.033(8.307, 17.431)	<0.001

Abbreviations: BMI, body mass index; HC, Hip circumference; NC, Neck circumference.

Values are expressed as median (IQR) or n (percentage).

3. Relationship between risk factors and MS in the multivariate logistic regression analysis

Multivariate analysis reveals 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 females, while physical inactivity was associated with MS in males. Neck circumference, an underweight BMI, smoking, and alcohol consumption were not associated with MS in either sex.

For males, BMI, hip circumference, and physical inactivity were associated with MS. The ORs (95% CIs) were 2.067 (1.475, 2.896; $p < 0.001$) for overweight BMI, 3.771 (2.539, 6.601; $p < 0.001$) for apparently overweight BMI, and 3.253 (2.019, 5.241; $p < 0.001$) for obese BMI. For hip circumference, the OR (95% CI) was 1.115 (1.086, 1.146; $p < 0.001$). Physical inactivity was associated with MS in males (OR 1.441, 95% CI [1.055, 1.969], $p = 0.022$).

For females, 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 2.091 (1.633, 2.677; $p < 0.001$) for overweight BMI, 2.014 (1.455, 2.786; $p < 0.001$) for apparently overweight BMI, and 2.546 (1.623, 3.995; $p < 0.001$) for obese BMI groups. For hip circumference, the OR (95% CI) was 1.098 (1.077, 1.119; $p < 0.001$). The OR (95% CI) for advanced age (≥ 65 years) was 1.536 (1.154, 2.043); $p = 0.003$). The OR (95% CI) for living in a rural region was 0.737 (0.561, 0.967; $p = 0.028$). For an educational level of junior middle school, the OR (95% CI) was 0.616 (0.479, 0.791; $p < 0.001$); for senior middle school, it was 0.580 (0.404, 0.833; $p = 0.003$), and for college and above, it was 0.434 (0.286, 0.660; $p < 0.001$).

Table 3 Multivariate logistic regression analyses on risk factors for the prevalence of metabolic syndrome (MS) in males and females.

		Male		Female	
Category	**Reference**	**OR (95% CI)**	***P***	**OR (95% CI)**	***P***
Age group	**40-64 years**				
≥65years		-	-	1.536(1.154,2.043)	0.003
Education	**≤Primary school**				
Junior middle school		0.918(0.662, 1.272)	0.606	0.616(0.479, 0.791)	<0.001

Senior middle school		1.014(0.639, 1.609)	0.953	0.580(0.404, 0.833)	0.003
College and above		0.727(0.431, 1.225)	0.231	0.434(0.286, 0.660)	<0.001
Region	**Urban**				
Rural		0.815(0.586, 1.133)	0.223	0.737(0.561, 0.967)	0.028
BMI	**Normal**				
Underweight		2.464(0.578, 10.502)	0.223	0.569(0.248, 1.304)	0.183
Overweight		2.067(1.475, 2.896)	<0.001	2.091(1.633, 2.677)	<0.001
Apparently overweight		3.771(2.539, 5.601)	<0.001	2.014(1.455, 2.786)	<0.001
Obesity		3.253(2.019, 5.241)	<0.001	2.546(1.623, 3.995)	<0.001
Neck circumference	-	1.193(0.951, 1.498)	0.128	1.193(0.951, 1.498)	0.128
Smoke	**No**				
Yes		-	-	1.193(0.951, 1.498)	0.128
Physical inactivity	**Physical activity**				
Yes		1.441(1.055, 1.969)	0.022	-	-
Alcohol consumption	**Never**				
Light/moderate drinking		0.883(0.662, 1.179)	0.4	0.720(0.479, 1.080)	0.112
Higher drinking		1.320(0.978, 1.783)	0.07	0.431(0.114, 1.628)	0.215
Hip circumference		1.115(1.086, 1.146)	<0.001	1.098(1.077, 1.119)	<0.001

Abbreviations: BMI, body mass index; OR, odds ratio.

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 females than in males, a high BMI and large hip circumstance were risk factors for MS in both sexes. In addition, advanced age (≥ 65 years) was a risk factor only for females, whereas physical inactivity was a risk factor only for males. 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- 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–middle- and high-income populations was shown to be 33.9% in 2010;[1] however, in our study, it was 50.1%. This may be due to the fact that 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 females was higher than that in males;[1 12] for example, in Mexico, the prevalence in females was 55.6%, whereas in males, 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] Contrarily, the prevalence of MS in males is higher than that in females in Caucasians,[15] American adolescents,[16] and Far East Asian and Japanese populations, and twice that in women from Macau.[17] These differences may be related to race, the period in which the studies were conducted, the geographic region, and the selected criteria used.[18 19 20] Our results were consistent with those reported in most countries that women had a higher prevalence of MS than men[21 22 23 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 females aged ≥ 65 years had a 1.536-fold higher risk of MS than those aged 40–65 years. As estrogen levels decrease in women after menopause, an increase in insulin resistance and abnormal lipid metabolism result. Thus, the sex differences observed may be related to changes in hormone levels, rather than aging itself.[26]

It is well known that MS prevalence increases when BMI (≥ 24 kg/m^2) is higher than normal. Compared with that with a normal BMI, the risk of metabolic syndrome with an overweight and obese BMI was 3.11- and 17.18-fold in Korean females and 4.30- and 10.91-fold in Korean males 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 2.091-, 2.014-, and 2.546-fold higher in overweight, significantly overweight, and obese females, respectively; in males, the risk increased

2.067-, 3.771-, and 3.253-fold, respectively. These findings also suggest that weight gain in males (BMI ≥ 26 kg/m^2) increases the risk of MS more substantially than it does in females; 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 1.098-fold in women and 1.115-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 males in our study, consistent with the findings of a previous study.[33] Infrequent physical activity results in a 1.441-fold increased risk of MS in men, but not in women, in agreement with previous findings;[34] and 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, although it has 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 negative correlation between educational level and MS prevalence is largely related to the dietary patterns of Koreans (especially in women).[40] For females in our study, the ORs indicated a 0.616-fold, 0.580-fold, and 0.434-fold risk of developing MS in those who had completed junior middle-school, senior middle-school, and college and above, respectively. This suggests that a higher educational level can reduce the risk of MS; however, this relationship was not found in males. The negative association between MS prevalence and educational level was significant in females, 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 females than in males.[41] Our study population is characterized by having both a low income and a low level of education, both of which contribute to a higher MS prevalence. The high percentage of included females 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 to have MS than those in rural areas in 2009,[42] but the opposite was true among urban adults in Jiangxi province, China in 2015, and rural females were more likely to have MS than urban ones, unlike males.[43] In our study, MS was negatively associated with living in rural regions (OR: 0.737 [0.561, 0.967], p = 0.028) but not with living in urban regions. The differences may be caused by the degree of economic development, life habits, and dietary patterns; for example, rural women have lower fat intake and more activity than urban women.[44]

Lifestyle interventions resulted in a 2.61-fold reduced risk of MS compared with the control group in a previous study,[45] and an investigation of dietary patterns showed that the Chinese pattern (high in grains, vegetables, fruit, salted fish and eggs, soyabean, and 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.).[46] Sex differences in the ways dietary patterns were associated with increased MS prevalence have been reported; 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,[47] as increased physical activity decreased the risk by 19–24%;[48] in men, every hour of exercise may decrease MS risk by 2%.[49] Whereas the daily sedentary behavior linearly increases the risk of metabolic syndrome by 1.09 times per hour.[50] 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.[51] 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, and a focus should be directed at changes in hormone levels, especially low concentrations of sex hormone-binding globulin and testosterones, which increase the odds of MS.[52] 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 and educational initiatives and reduce the incidence of MS and vascular diseases.

Strengths and limitations

There were also several limitations to this study. Some data was 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 generalizability of the results. Moreover, cross-sectional studies cannot be used to make causal inferences, and subsequent prospective and randomized 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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CONFLICTS OF INTEREST

None declared.

ETHICS APPROVAL

This subject was approved by the human ethics and research ethics committee of the First Hospital of Jilin University (approval No: 2015-R-250), and written informed consent was obtained from all of the participants.

PROVENANCE AND PEER REVIEW

Not commissioned; externally peer reviewed.

DATA SHARING STATEMENT

The dataset supporting the conclusions of this article can be made available upon request.

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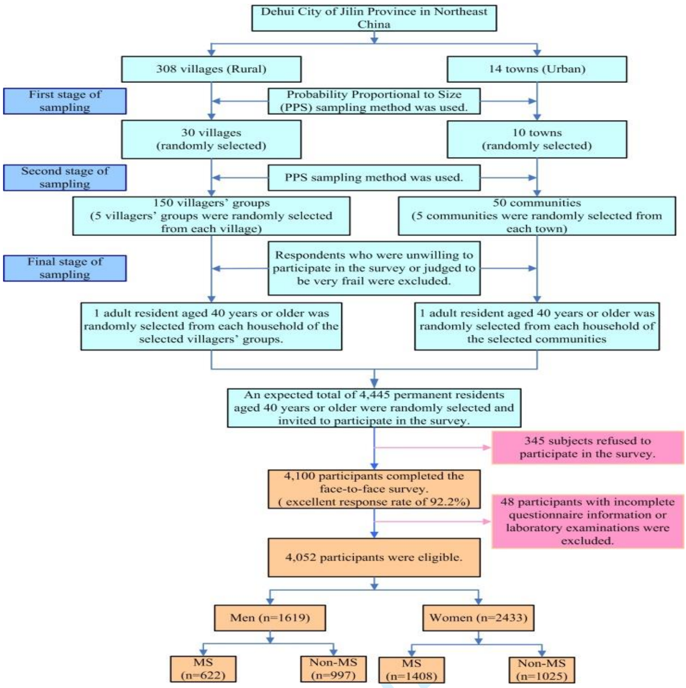
Fig. 1 Sampling process in the study

Fig. 2 Prevalence of metabolic syndrome in different sexes and ages in the study


Dehui City of Jilin Province in Northeast China
308 villages (Rural)
14 towns (Urban)
First stage of sampling
Probability Proportional to Size (PPS) sampling method was used.
30 villages (randomly selected)
10 towns (randomly selected)
Second stage of sampling
PPS sampling method was used.
150 villagers' groups (5 villagers' groups were randomly selected from each village)
50 communities (5 communities were randomly selected from each town)
Final stage of sampling
Respondents who were unwilling to participate in the survey or judged to be very frail were excluded.
1 adult resident aged 40 years or older was randomly selected from each household of the selected villagers' groups.
1 adult resident aged 40 years or older was randomly selected from each household of the selected communities
An expected total of 4,445 permanent residents aged 40 years or older were randomly selected and invited to participate in the survey.
345 subjects refused to participate in the survey.
4,100 participants completed the face-to-face survey. (excellent response rate of 92.2%)
48 participants with incomplete questionnaire information or laboratory examinations were excluded.
4,052 participants were eligible.
Men (n=1619)
Women (n=2433)
MS (n=622)
Non-MS (n=997)
MS (n=1408)
Non-MS (n=1025)

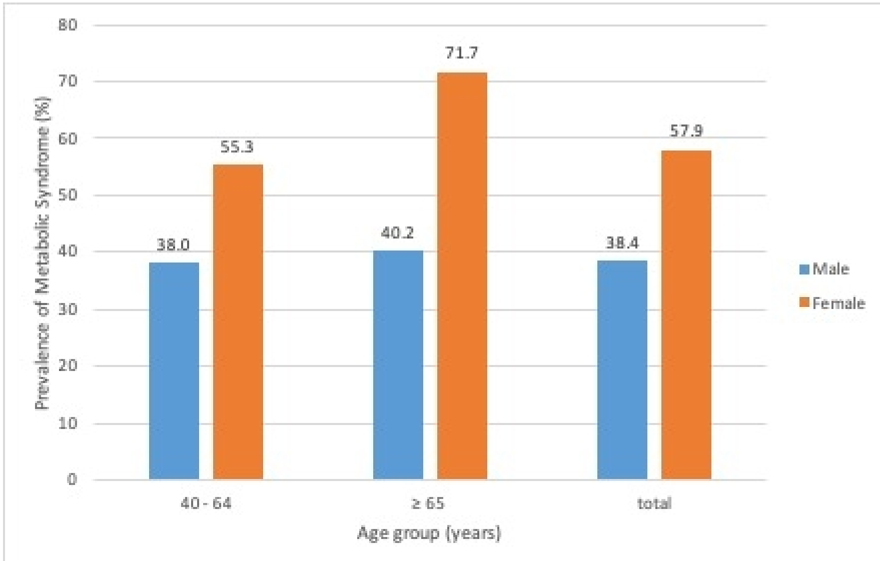


Fig. 2 Prevalence of metabolic syndrome in different sexes and ages in the study

156x99mm (72 x 72 DPI)

Supplementary Table S1 Definitions of metabolic syndrome-related risk factors in the survey.

Variables	Criteria	References
BMI	BMI was grouped into five categories for our study: underweight (BMI< 18.5 kg/m^2), normal (18.5≤ BMI< 24 kg/m^2), overweight (24≤ BMI< 26 kg/m^2), apparently overweight (26≤ BMI < 28 kg/m^2), obesity (BMI≥ 28 kg/m^2).	Guidelines for diabetes prevention and treatment in China[1]
Abnormal neck circumference	≥37cm for male and ≥33cm for female	Neck circumference as an independent predictive contributor of cardio-metabolic syndrome[2]
Physical inactivity	Physical inactivity is defined as insufficient physical activity; Physical activity is defined as the performance of heavy physical labor or regular physical exercise for more than one year, more than 3 times per week, and for at least 30 minutes per session.	CHNS guidelines[3]
Smoking	A smoker was defined as one who reported smoking one or more cigarettes or was passively exposed to tobacco smoke every day in general for more than 6 consecutive months. A non-smoker was defined as the one who had never smoked, nor passively exposed to tobacco smoke; or, had history of smoking but quit smoking for at least 6 consecutive months previous to the study.	Technical specification of stroke screening and prevention in China[4]
Drinking	The NIAAA sets the standard drink size at about 14g of absolute ethanol, advising limits of no more than three drinks per day or seven drinks per week for men and women. Drinking status was divided into three categories according to the participants' self-report in the previous 6 months: non-drinkers: had never drunk alcoholic beverage; light/moderate drinkers: less than or upto NIAAA limits; heavier drinkers: in excess of NIAAA limits.	NIAAA guidelines[5]
Fruit consumption	Fruit consumption was grouped into three categories for our study: less than or equal to two days per week (≤ 2 d/w), three to four days per week (3–4 d/w), and greater than or equal to five days per week (≥ 5 d/w). And the weight of consumed fruits should reach or exceed two servings per day, and the definition of a serving of a fruit was calculated as 80g.	Fruit and vegetable consumption and stroke: meta-analysis of cohort studies[6]

Abbreviation: BMI, body mass index; CHNS, China Health and Nutrition Survey; NIAAA, National Institute on Alcohol Abuse and Alcoholism.

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3,4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-8
Bias	9	Describe any efforts to address potential sources of bias	*6-7*
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6, 7
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9-11
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	(7)
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-11
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	11,12
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	13-17
		(*b*) Report category boundaries when continuous variables were categorized	12
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18,19
Generalisability	21	Discuss the generalisability (external validity) of the study results	20
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

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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Original Article

TITLE PAGE

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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Authors contributions: Conception and design: Y Y, and Z-N G. Acquisition of the data: F-L Z and H-Y L. Statistical methods and data analysis: F-e L, P Z, D L, F-L Z.

Drafting and revising the manuscript: F-e L. Critical revision: Z-N G, and Y Y. All of the authors approved the final version for publication.

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Search terms: metabolic syndrome, prevalence, sex difference, cross-sectional, risk factor.

Word count: abstract 300 words; text 3339 words; 52 references; 3 tables and 2 figures.

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 analyzed 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 males and 57.9% in females; $p<0.001$). High body mass index and hip circumference were associated with metabolic syndrome in both sexes. In addition, physical inactivity (odds ratio [OR] and 95% confidence interval [CI]: 1.441 [1.055, 1.969]; $p = 0.022$) in males and advanced age (OR and 95% CI: 1.536 [1.154, 2.043]; $p = 0.003$) in females 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.

Key words: metabolic syndrome, prevalence, sex difference, cross-sectional, risk factor.

Strengths and limitations of this study

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

2. We used a uniform, pre-coded questionnaire designed by the national stroke screening survey of China.

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

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

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

INTRODUCTION

Metabolic syndrome (MS) is associated with a cluster of cardiometabolic risk factors and 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 analyze 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 $Z_{\alpha} = 1.96$, $\alpha = 0.05$, $q = 1\text{-}p$, 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 sub-study 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. The study protocol was approved by the Human Ethics and Research Ethics Committee of the First Hospital of Jilin University, Chang Chun, Jilin, China (2015-R-250). Written informed consent was obtained from all study participants before recruitment and data collection.

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 minutes 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 Center (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 (AHA/NHLBI).[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 (SBP) ≥130 mmHg and/or diastolic blood pressure (DBP) ≥ 85 mmHg (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 BMI, level of physical inactivity, smoking status, and alcohol consumption are shown in Supplementary 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 odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. All statistical analyses were performed using IBM Statistical Package for the Social Sciences (SPSS) version 23.0 (SPSS, Inc., New York, NY, USA). $P < 0.05$ was considered statistically significant.

RESULTS

Among the 4,100 participants who completed the face-to-face survey, 4,052 were included in the analysis. A total of 2,030 individuals met the criteria for MS, and the prevalence was 50.1% overall (38.4% in males and 57.9% in females; $p < 0.001$). Of all the 4,052 participants, 1,619 were men (40.0%) and 2,433 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.

1. Demographic characteristics of all participants with MS

Table 1 shows that compared with that in males (38.4%), the prevalence of MS in females (57.9%) was significantly higher. Among the 2,030 individuals with MS, the median age was 56 years (IQR: 49–63), and for both males and females, more than 80% of the participants with MS were in the group of 40–64 years. The rate of abnormal waist circumference in females (91.6%) was higher than that in males (85.4%). The median neck and hip circumferences in males were higher than those in females were. Compared with males, females 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 triglycerides and fasting blood glucose, abnormal BMI, resided in urban areas, had a smoke habit, and cousumed alcohol.

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

	Total	Male	Female
Participants, n (%)	4052(100)	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 (%)			
≥5days 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)

Abbreviations: TCHO, total serum cholesterol; LDL-C, low-Density Lipoprotein Cholesterol; HDL-C, high-density lipoprotein; TG, triglyceride; FBG, fasting blood glucose; BMI, body mass index.

Values are expressed as n (percentage).

2. 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 (men: 40.2%; women: 71.7%), especially in older women (Figure 2; OR [95% CI] = 2.042 [1.608, 2.594]; P < 0.001). For females, age, BMI, hip and neck circumference, smoking, higher alcohol consumption, geographical region, and level of educational attainment were associated with MS, whereas physical inactivity and fruit consumption were not. For males, 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.

Table 2 Univariable logistic regression analyses on risk factors for the prevalence of metabolic syndrome (MS) in males and females

Category	Reference	Male		Female	
		OR (95% CI)	*P*	OR (95% CI)	*P*
Age group	**40-64 years**				
≥65years		1.10(0.85, 1.42)	0.482	2.04(1.61, 2.59)	<0.001
HP	-	1.20(1.18, 1.22)	<0.001	1.16(1.14, 1.17)	<0.001
NC	-	1.44(1.38, 1.51)	<0.001	1.37(1.31, 1.42)	<0.001
Region	**Urban**				
Rural		0.57(0.46, 0.69)	<0.001	1.66(1.41, 1.95)	<0.001
Smoke	**No**				
Yes		0.93(0.75, 1.14)	0.472	1.41(1.19, 1.66)	<0.001
Physical inactivity	**Physical activity**				
Yes		1.75(1.36, 2.24)	<0.001	1.12(0.93, 1.35)	0.235
Alcohol consumption	**Never**				
Light/moderate drinking		1.44(1.12, 1.84)	0.004	0.50(0.16, 1.59)	0.243
Higher drinking		0.99(0.78, 1.26)	0.949	0.61(0.43, 0.86)	0.005
Fruit consumption	**≥5days/week**				
3-4 days per week		1.09(0.77, 1.53)	0.627	1.19(0.89, 1.60)	0.238
≤2 days per week		0.80(0.43, 1.51)	0.494	1.37(0.83, 2.26)	0.226
Education	**≤Primary school**				
Junior middle-school		1.28(1.01, 1.62)	0.040	0.59(0.49, 0.71)	<0.001
Senior middle-school		1.75(1.27, 2.41)	0.001	0.41(0.32, 0.54)	<0.001
College and above		1.31(0.91, 1.90)	0.149	0.27(0.20, 0.37)	<0.001
BMI	**Normal**				
Underweight		1.49(0.42, 5.33)	0.540	0.30(0.14, 0.66)	0.002
Overweight		3.91(2.88, 5.30)	<0.001	3.54(2.85, 4.40)	<0.001
Apparently overweight		11.143(8.03, 15.47)	<0.001	5.28(4.01, 6.93)	<0.001
Obesity		18.29(12.89, 25.96)	<0.001	12.03(8.31, 17.43)	<0.001

Abbreviations: BMI, body mass index; HC, Hip circumference; NC, Neck circumference.

Values are expressed as median (IQR) or n (percentage).

3. 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 females, while physical inactivity was associated with MS in males. Neck circumference, an underweight BMI, smoking, and alcohol consumption were not associated with MS in either sex.

For males, BMI, hip circumference, and physical inactivity were associated with MS. The ORs (95% CIs) were 2.067 (1.475, 2.896; p < 0.001) for overweight BMI, 3.771 (2.539, 6.601; p < 0.001) for apparently overweight BMI, and 3.253 (2.019, 5.241; p < 0.001) for obese BMI. For hip circumference, the OR (95% CI) was 1.115 (1.086, 1.146; p < 0.001). Physical inactivity was associated with MS in males (OR 1.441, 95% CI [1.055, 1.969], *p* = 0.022).

For females, 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 2.091 (1.633, 2.677; *p* < 0.001) for overweight BMI, 2.014 (1.455, 2.786; *p* < 0.001) for apparently overweight BMI, and 2.546 (1.623, 3.995; *p* < 0.001) for obese BMI groups. For hip circumference, the OR (95% CI) was 1.098 (1.077, 1.119; *p* < 0.001). The OR (95% CI) for advanced age (≥ 65 years) was 1.536 (1.154, 2.043); p = 0.003). The OR (95% CI) for living in a rural region was 0.737 (0.561, 0.967; p = 0.028). For an educational level of junior middle-school, the OR (95% CI) was 0.616 (0.479, 0.791; p < 0.001); for senior middle-school, it was 0.580 (0.404, 0.833; p = 0.003), and for college and above, it was 0.434 (0.286, 0.660; p < 0.001).

Table 3 Multivariable logistic regression analyses on risk factors for the prevalence of metabolic syndrome (MS) in males and females.

		Male		Female	
Category	**Reference**	**OR (95% CI)**	***P***	**OR (95% CI)**	***P***
Age group	**40-64 years**				
≥65years		-	-	1.54(1.15,2.04)	0.003
Education	**≤Primary school**				
Junior middle-school		0.92(0.66, 1.27)	0.606	0.616(0.48, 0.79)	<0.001
Senior middle-school		1.01(0.64, 1.61)	0.953	0.58(0.40, 0.83)	0.003
College and above		0.73(0.43, 1.23)	0.231	0.43(0.29, 0.66)	<0.001
Region	**Urban**				
Rural		0.82(0.59, 1.13)	0.223	0.74(0.56, 0.97)	0.028

BMI	**Normal**				
Underweight		2.46(0.58, 10.50)	0.223	0.57(0.25, 1.30)	0.183
Overweight		2.07(1.48, 2.90)	<0.001	2.09(1.63, 2.68)	<0.001
Apparently overweight		3.77(2.54, 5.60)	<0.001	2.01(1.46, 2.79)	<0.001
Obesity		3.25(2.02, 5.24)	<0.001	2.55(1.62, 4.00)	<0.001
Neck circumference	**-**	1.19(0.95, 1.50)	0.128	1.19(0.95, 1.50)	0.128
Smoke	**No**				
Yes		-	-	1.19(0.95, 1.50)	0.128
Physical inactivity	**Physical activity**				
Yes		1.44(1.06, 1.97)	0.022	-	-
Alcohol consumption	**Never**				
Light/moderate drinking		0.88(0.66, 1.18)	0.400	0.72(0.48, 1.08)	0.112
Higher drinking		1.32(0.98, 1.78)	0.07	0.431(0.11, 1.63)	0.215
Hip circumference		1.12(1.09, 1.15)	<0.001	1.10(1.08, 1.12)	<0.001

Abbreviations: BMI, body mass index; OR, odds ratio.

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 females than in males, 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 females, whereas physical inactivity was a risk factor only for males. 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- 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–, middle-, 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 females was higher than that in males;[1 12] for example, in Mexico, the prevalence in females was 55.6%, whereas in males, 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 males is higher than that in females in Caucasians,[15] American adolescents,[16] Far East Asian and Japanese populations, and in Macau, it is twice that in women from.[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 19 20] Our results were consistent with those reported in most countries that women had a higher prevalence of MS than men[21 22 23 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 females aged ≥ 65 years had a 1.536-fold higher risk of MS than those aged 40–65 years. A decrease in estrogen levels in women after menopause, results in an increase in insulin resistance and abnormal lipid metabolism result. Thus, the sex differences observed may be related to changes in hormone levels, rather than aging itself.[26]

It is well known that MS prevalence increases when BMI (≥ 24 kg/m^2) is higher than normal. Compared with individuals with a normal BMI, the risk of metabolic syndrome with an overweight and obese BMI was 3.11- and 17.18-fold in Korean females, and 4.30- and 10.91-fold in Korean males 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 2.091-, 2.014-, and 2.546-fold higher in overweight, significantly overweight, and obese females, respectively. In males, the risk increased 2.067-, 3.771-, and 3.253-fold, respectively. These findings also suggest that weight gain in males (BMI ≥ 26 kg/m^2) increases the risk of MS more substantially than it does in females; 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 1.098-fold in women and 1.115-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 males in our study, consistent with the findings of a previous study.[33] Infrequent physical activity results in a 1.441-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 females in our study, the ORs indicated a 0.616-fold, 0.580-fold, and 0.434-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 males. The negative association between MS prevalence and educational level was significant in females, 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 females than in males.[41] Our study population was characterized 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 females 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,[42] The opposite was true among urban adults in Jiangxi province, China in 2015, as females living in rural areas were more likely than urban females to have MS. These findings were not observed among males.[43] In our study, MS was negatively associated with living in rural regions (OR: 0.737 [0.561, 0.967], $p = 0.028$) 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.[44]

Lifestyle interventions resulted in a 2.61-fold reduced risk of MS compared with the control group in a previous study.[45] Aninvestigation of dietary patterns showed that the Chinese pattern (high in grains, vegetables, fruit, salted fish and eggs, soyabean, and 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.).[46] 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,[47] as increased physical activity decreased the risk by 19–24%.[48] In men, every hour of exercise may decrease MS risk by 2%.[49] In contrast, daily sedentary behavior linearly increases the risk of metabolic syndrome by 1.09 times per hour.[50] 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.[51] 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.[52] 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 was 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 generalizability of the results. Moreover, cross-sectional studies cannot be used to make causal inferences, and subsequent prospective and randomized 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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CONFLICTS OF INTEREST

None declared.

ETHICS APPROVAL

This subject was approved by the human ethics and research ethics committee of the First Hospital of Jilin University (approval No: 2015-R-250), and written informed consent was obtained from all of the participants.

PROVENANCE AND PEER REVIEW

Not commissioned; externally peer reviewed.

DATA SHARING STATEMENT

The dataset supporting the conclusions of this article can be made available upon request.

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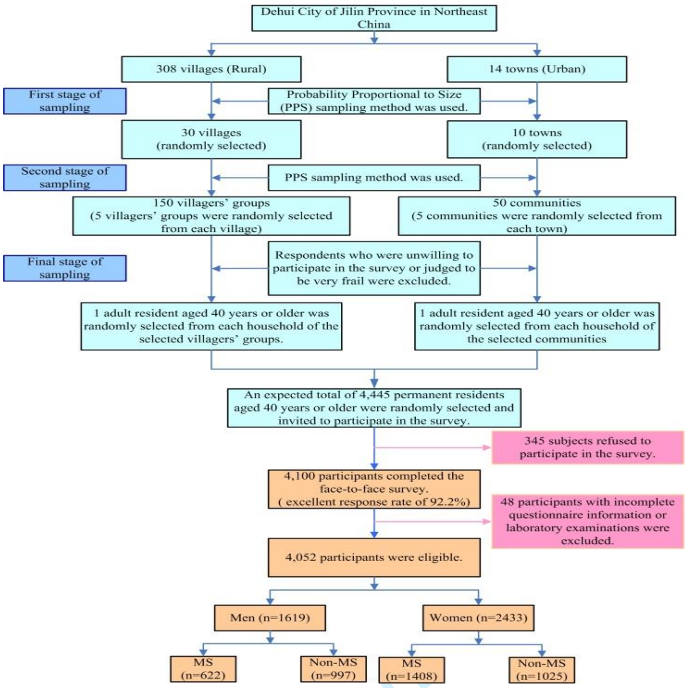
Fig. 1 Sampling process in the study

Fig. 2 Prevalence of metabolic syndrome in different sexes and ages in the study


Dehui City of Jilin Province in Northeast China
308 villages (Rural)
14 towns (Urban)
First stage of sampling
Probability Proportional to Size (PPS) sampling method was used.
30 villages (randomly selected)
10 towns (randomly selected)
Second stage of sampling
PPS sampling method was used.
150 villagers' groups (5 villagers' groups were randomly selected from each village)
50 communities (5 communities were randomly selected from each town)
Final stage of sampling
Respondents who were unwilling to participate in the survey or judged to be very frail were excluded.
1 adult resident aged 40 years or older was randomly selected from each household of the selected villagers' groups.
1 adult resident aged 40 years or older was randomly selected from each household of the selected communities
An expected total of 4,445 permanent residents aged 40 years or older were randomly selected and invited to participate in the survey.
345 subjects refused to participate in the survey.
4,100 participants completed the face-to-face survey. (excellent response rate of 92.2%)
48 participants with incomplete questionnaire information or laboratory examinations were excluded.
4,052 participants were eligible.
Men (n=1619)
Women (n=2433)
MS (n=622)
Non-MS (n=997)
MS (n=1408)
Non-MS (n=1025)

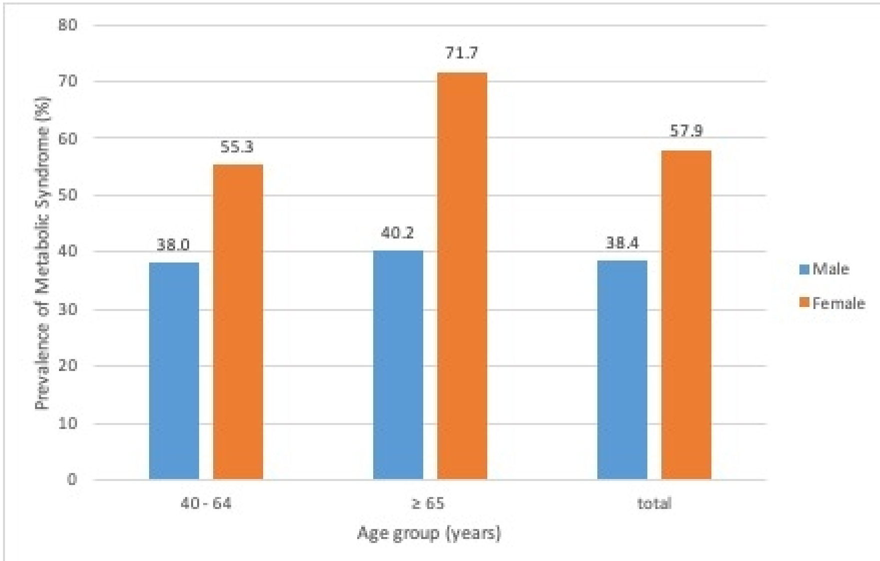


Fig. 2 Prevalence of metabolic syndrome in different sexes and ages in the study

156x99mm (72 x 72 DPI)

Supplementary Table S1 Definitions of metabolic syndrome-related risk factors in the survey.

Variables	Criteria	References
BMI	BMI was grouped into five categories for our study: underweight (BMI< 18.5 kg/m^2), normal (18.5≤ BMI< 24 kg/m^2), overweight (24≤ BMI< 26 kg/m^2), apparently overweight (26≤ BMI < 28 kg/m^2), obesity (BMI≥ 28 kg/m^2).	Guidelines for diabetes prevention and treatment in China[1]
Abnormal neck circumference	≥37cm for male and ≥33cm for female	Neck circumference as an independent predictive contributor of cardio-metabolic syndrome[2]
Physical inactivity	Physical inactivity is defined as insufficient physical activity; Physical activity is defined as the performance of heavy physical labor or regular physical exercise for more than one year, more than 3 times per week, and for at least 30 minutes per session.	CHNS guidelines[3]
Smoking	A smoker was defined as one who reported smoking one or more cigarettes or was passively exposed to tobacco smoke every day in general for more than 6 consecutive months. A non-smoker was defined as the one who had never smoked, nor passively exposed to tobacco smoke; or, had history of smoking but quit smoking for at least 6 consecutive months previous to the study.	Technical specification of stroke screening and prevention in China[4]
Drinking	The NIAAA sets the standard drink size at about 14g of absolute ethanol, advising limits of no more than three drinks per day or seven drinks per week for men and women. Drinking status was divided into three categories according to the participants' self-report in the previous 6 months: non-drinkers: had never drunk alcoholic beverage; light/moderate drinkers: less than or upto NIAAA limits; heavier drinkers: in excess of NIAAA limits.	NIAAA guidelines[5]
Fruit consumption	Fruit consumption was grouped into three categories for our study: less than or equal to two days per week (≤ 2 d/w), three to four days per week (3–4 d/w), and greater than or equal to five days per week (≥ 5 d/w). And the weight of consumed fruits should reach or exceed two servings per day, and the definition of a serving of a fruit was calculated as 80g.	Fruit and vegetable consumption and stroke: meta-analysis of cohort studies[6]

Abbreviation: BMI, body mass index; CHNS, China Health and Nutrition Survey; NIAAA, National Institute on Alcohol Abuse and Alcoholism.

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3,4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-8
Bias	9	Describe any efforts to address potential sources of bias	*6-7*
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6, 7
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9-11
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	(7)
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-11
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	11,12
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	13-17
		(*b*) Report category boundaries when continuous variables were categorized	12
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18,19
Generalisability	21	Discuss the generalisability (external validity) of the study results	20
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.