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Prevalence and determinants of metabolic syndrome based on three definitions in rural northeast China

Zhi Du[1], Liying Xing[2], Shuang Liu[3], Li Jing[2], Yuanmeng Tian[2], Boqiang Zhang[2], Han Yan[2], Min Lin[4], Shiwen Yu[5] and Yingxian Sun[1,*]

[1]Department of Cardiovascular Medicine, The First Hospital of China Medical University, Shenyang, Liaoning 110001, People's Republic of China: [2]Disease Control and Prevention of Liaoning Province, Shenyang, Liaoning 110001, People's Republic of China: [3]Department of Cardiovascular Ultrasound, The First Hospital of China Medical University, Shenyang, Liaoning 110001, People's Republic of China: [4]Department of Cardiovascular Medicine, Benxi Central Hospital, Benxi, Liaoning 117000, People's Republic of China: [5]Department of Periodontics, School of Stomatology, China Medical University, Shenyang, Liaoning 110001, People's Republic of China

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Abstract

Objective: To gain more comprehensive understanding of metabolic syndrome (Mets) among in general Chinese population.

Design: Cross-sectional study. Mets was defined by three widely accepted definitions including modified Adults Treatment Panel (ATP) III criteria, International Diabetes Federation (IDF) criteria and harmonized definition. Risk factors were evaluated by using multivariate logistic regression.

Setting: Nineteen rural villages in northeast China.

Participants: The survey was conducted in September 2017 and May 2018 on 10 926 individuals.

Results: According to modified ATP III criteria, IDF criteria and harmonised definition, the overall prevalence of Mets was 41·3 % (95 % CI 40·3, 42·2), 34·2 % (95 % CI 33·2, 35·1) and 44·1 % (95 % CI 43·1, 45·1), respectively. Females had a higher prevalence, and elevated blood pressure was the most frequent. Age, female sex, non-peasant worker, higher BMI and lower-annual income were independent risk factors of Mets in all three definitions (all $ps < 0·05$). Based on modified ATP III criteria and harmonised definition, heavy drinking was positively correlated with Mets. In contrast, former drinking was inversely associated with Mets.

Conclusions: Mets is highly prevalent in rural areas of northeast China. Its independent risk factors include higher age, female sex, non-peasantry worker, higher BMI and lower-annual income. Modified ATP III criteria and harmonised definition may be superior definitions of Mets.

Keywords
Metabolic syndrome
Prevalence
Risk factor
Epidemiology

Metabolic syndrome (Mets), despite ambiguity on the precise definition, is a combination of interrelated risk factors including central obesity, elevated blood pressure, dyslipidaemia and hyperglycaemia[1]. It is generally accepted a high (20–30 % in most countries) and increasing prevalence of Mets, regardless of the Mets prevalence estimates may differ depending on the definition used[2,3]. Several studies have emphasised Mets can trigger a series of poor prognosis, such as CVD, diabetes, cardiovascular and all-cause mortality, and has become one of the main threats to human health[4–8]. The occurrence of Mets is related to various factors especially aging, geography, ethnicity and lifestyle[1,2,9–11]. The northeast China, specifically rural area, has its own geography, climate and lifestyles that differ from other regions of China. For example, a high-salt and high-carb diet leads to high prevalence of hypertension and obesity, and a decline in exercise levels caused by prolonged snow, those may trigger a higher prevalence of Mets. Therefore, it is critical to understand the prevalence of Mets in the general population in northeast China.

In the case of rapid progression of lifestyle westernisation and population aging in rural China, understanding updated prevalence trends may be paramount given the potential effect of the Mets and its associated health complications on them. Although previous researches stated the prevalence of Mets in rural northeast China, all the

*Corresponding author: Email sunyingxian_cmu@126.com

Table 1 Diagnosis criteria of metabolic syndrome used in current study

MetS component	Modified ATP III criteria	IDF criteria	Harmonised definition
Number of risk factors	Three or more of . . .	Obesity and 2 of . . .	Three or more of . . .
Obesity	WC ≥90 cm for Asian-origin male WC ≥80 cm for Asian-origin female	WC ≥90 cm for Chinese male WC ≥80 cm for Chinese female	WC ≥85 cm for Chinese male WC ≥80 cm for Chinese female
Dyslipidaemia			
TAG	≥1·7 mmol/l or drug treatment for elevated TAG	≥1·7 mmol/l or specific treatment for this lipid abnormality	≥1·7 mmol/l or drug treatment for elevated TAG
HDL	<1·03 mmol/l in men or <1·29 mmol/l in women or drug treatment for reduced HDL-cholesterol	<1·03 mmol/l in men or <1·29 mmol/l in women or specific treatment for this lipid abnormality	<1·03 mmol/l in men or <1·29 mmol/l in women or drug treatment for reduced HDL-cholesterol
Blood pressure	SBP ≥130 mmHg or/and DBP ≥85 mmHg or drug treatment for hypertension	SBP ≥130 mmHg or/and DBP ≥85 mmHg or treatment of previously diagnosed hypertension	SBP ≥130 mmHg or/and DBP ≥85 mmHg or drug treatment for hypertension
Hyperglycaemia	FBG ≥5·6 mmol/l or drug treatment for elevated glucose	FBG ≥5·6 mmol/l or previously diagnosed T2DM	≥5·6 mmol/l or drug treatment for elevated glucose

SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose.

results were not accurate. Respecting definition, Mets was diagnosed using currently taking dyslipidaemia medication, rather than specific treatment for raised TAG and/or increased HDL-cholesterol. This disadvantage could lead to overestimation of the prevalence of Mets[10]. Alternatively, only hypertensive residents were recruited decade ago[12] or including partial urban population[13].

To gain a comprehensive and accurate understanding of Mets among rural northeast Chinese population, the current study, involving 9790 participants aged at least 40 years older, used three widely accepted definitions (modified Adults Treatment Panel (ATP) III criteria in 2005[14], International Diabetes Federation (IDF) criteria in 2005[15] a harmonized definition in 2009[1], Table 1) to report and compare the prevalence of Mets and identified its determinants by multivariate stepwise logistic regression models.

Methods

Study population

This cross-sectional study was undertaken from September 2017 to May 2018 in rural areas of Liaoning Province. A multi-stage, stratified and cluster random sampling method was used to ensure that the sample was representative. Four counties (Chaoyang, Lingyuan, Liaoyang and Donggang) were randomly selected from the central, eastern and western regions of Liaoning Province. Thereafter, nineteen rural villages were randomly selected from these four counties. All permanent residents aged ≥40 years in each village (*n* 12 808), except those who were pregnant or had a mental disorder, were eligible to participate; 10 926 (85·3 %) completed the study. We further excluded participants did not provide blood specimens (*n* 26) and with CVD (*n* 1110). Eventually, data from a total of 9790 (89·6 %) subjects (3866 men and 5924 women) were analysed.

Data collection and measurement

Data were collected by a team consisting of specialists trained in the prevention and control of chronic disease, cardiologists and neurologists, using a face-to-face interview and a self-administered questionnaire during a single clinic visit. All the team members underwent rigorous knowledge training before data collection and completed pilot interviews (performed with volunteers). Further instruction and support were provided by study authors during data collection.

Demographic and clinical data, including data on age, sex, socioeconomic status (education, occupation, marital status and annual household income), lifestyle (smoking, drinking and physical activity), comorbidities (such as hypertension, diabetes and dyslipidaemia) and other medical history (such as coronary artery disease, cerebrovascular disease) were collected using a self-administered questionnaire. To ensure that data were recorded truthfully and carefully (with an accuracy of at least 98 %), trained staff scanned the questionnaires, and relevant information was manually extracted, with double entry included as a quality check.

Current smoking was defined as more than one cigarette per day and cumulative smoking more than 6 months. Participants who met the above criteria in the past but did not smoke during the interview were defined as former smokers. Participants who were unable to meet the above conditions were defined as none-smokers[9]. Participants were asked whether they regularly consumed alcohol, their average alcohol consumption per day and the number of days per month that they consumed alcohol. They were divided into four categories: never drank, moderate drinkers, heavy drinkers and former drinkers. One drink was defined as containing 15 g of ethanol[16]. Moderate drinking was defined as up to 1 drink/d for women and up to 2 drinks/d for men; heavy drinking was defined as >1 drink/d for women and >2 drinks/d for men[17]. Regular exercise was defined as moderate intensity exercise (equivalent to walking) for ≥30 min and ≥3 times per week, which moderate and heavy manual workers fulfil due to their work[18].

Each participant was recorded as having medical history of a specific disease (such as diabetes, coronary artery disease) if he/she answered 'Yes' to the question 'Have you been diagnosed with [specific disease] by a certified doctor?'. Cerebrovascular diseases (such as ischemic or haemorrhagic stroke) were diagnosed by a neurologist according to the WHO recommendations and confirmed with computed tomography (CT) and/or MRI[19]. The diagnosis of CHD was based on self-reported history, and angina was recognised for hospitalisation of secondary and above medical institutions. Participants were asked during interview whether they had taken prescription medication for blood pressure, lipid control, glucose control or certain diseases in the past 2 weeks. Those who answered 'yes' were asked to report the name, dose and frequency of each drug if known. Those who did not remember the exact dose were asked the number of pills taken. We cleaned the data and matched all the names given to those of generic drugs in the China Pharmacopoeia 2015, with a 95 % success rate.

Physical measurements, including height, weight and waist circumference (WC), were obtained during the interview. WC was measured at a point midway between the lowest rib and the iliac crest in a horizontal plane using non-elastic tape. These parameters were measured to the nearest 0·1 kg and 0·1 cm, as appropriate, with participants wearing lightweight clothes without shoes. The BMI was calculated as weight (kg) divided by the square of the height (m^2). A central steering committee with a subcommittee for quality control was established to ensure that data were obtained according to standardised protocols. For each participant, blood pressure was measured three times at 2-min intervals after at least 5 min of rest in a seated position using a standardised automatic electronic sphygmomanometer (J30; Omron). Hypertension was defined as a mean systolic blood pressure (SBP) ≥140 mmHg or a mean diastolic blood pressure (DBP) ≥90 mmHg, and/or self-reported use of antihypertensive medication in the past 2 weeks[20].

Fasting blood samples were collected from participants after at least 8 h of overnight fasting. The samples were obtained from an antecubital vein using BD Vacutainer tubes containing ethylenediaminetetraacetic acid (EDTA; Becton, Dickinson and Co.), and serum was subsequently isolated from whole blood. Thereafter, serum samples were frozen at −20 C for storage. Subsequently, the biochemical parameters, comprising fasting blood glucose (FBG), glycosylated Hb (HbA1c), serum lipid profiles including total cholesterol (TC), TAG, serum HDL-cholesterol and LDL-cholesterol were measured using an Abbott Diagnostics C800i auto-analyzer (Abbott Laboratories) with commercial kits. The laboratory tests were carried out at three laboratories. In addition, we randomly selected 10 % of specimens from each laboratory for centralised re-testing by China's Ministry of Health's National Center for Clinical Laboratory to ensure that the testing was accurate. Reproducible indices for lab examination were more than 95 %. Diabetes mellitus was diagnosed as an FBG ≥7·0 mmol/l or HbA1c ≥6·5 %, and/or self-reported diagnosis that was previously determined by a physician[21].

Statistics analysis

Continuous variables are reported as means and SDs, and categorical variables are reported as frequencies and percentages in each subgroup. Student's t test and χ^2 tests were used, as appropriate, to compare differences between male and female. We calculated the prevalence of each component of the Mets. The overall, age- or/and sex-specific prevalence of Mets was analysed. The Sixth China Population Census data were used to standardise the prevalence of Mets. In addition, stepwise multivariate logistic regression analyses were carried out to evaluate the risk factors for Mets. For the regression models, multivariable adjustment was performed for known demographic characteristics (age, sex) and certified clinical variables (BMI, level of education, marital status, smoke status, annual income, drinking status, exercise regularly and occupation) in previous studies. Regarding importance of menopause on metabolic profiles, we evaluated age independent role of menopause status in female subjects in the model. Finally, participants with CVD were included, and the association between Mets with CVD was evaluated by logistic regression. ORs and 95 % CIs are presented for the logistic regression analyses. Statistical analyses were performed using the statistical software package IBM SPSS statistics software version 22.0 (SPSS Inc.); $P < 0·05$ were considered statistically significant.

Results

Our study included 9790 subjects (mean age 59·4 ± 10·1, males 39·5 %). Clinical characteristics by sex are shown in Table 2. Compared with female subjects, male participants were significantly older and had significantly higher DBP (all *ps* < 0·05). However, male had significantly lower BMI, TAG and HDL-cholesterol (all *ps* < 0·05). In addition, male comprised a significantly higher proportion of high education level, with prevalence of smokers, drinkers and individuals who exercised regularly (all *ps* < 0·05).

The prevalence of single component of the Mets was shown in Fig. 1 according to modified ATP III criteria, IDF criteria and harmonised definition. Elevated blood pressure (≥130/85 mmHg or/and drug treatment for hypertension) was the most common component of Mets in both sexes. However, the prevalence of reduced HDL-cholesterol (<1·03 mmol/l in men or <1·29 mmol/l in women or/and specific treatment for this lipid abnormality)

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Table 2 Characteristics of the study sample

	Male (*n* 3866)				Female (*n* 5924)				
Variable	Mean	*n*	%	SD	Mean	*n*	%	SD	*P*-value
Age (years)	60·5			10·2	58·7			9·9	<0·001
BMI (kg/m^2)	24·2			3·6	25·1			3·8	<0·001
WC (cm)	83·4			10·2	83·0			10·1	0·098
SBP (mmHg)	144·3			21·8	144·6			24·2	0·446
DBP (mmHg)	87·6			11·6	85·5			11·8	<0·001
TAG (mmol/l)	1·6			1·5	1·7			1·5	<0·001
HDL-cholesterol (mmol/l)	1·9			0·7	2·0			0·8	<0·001
FBG (mmol/l)	6·1			1·7	6·1			1·9	0·380
Level of education									
Primary school or below		1855	48·0			3836	64·8		<0·001
Middle school		1514	39·2			1695	28·6		
High school or above		497	12·8			393	6·6		
Annual income (CNY/year)									
≤5000		1438	37·2			2612	44·1		<0·001
5001–10 000		874	22·6			1265	21·3		
10 001–20 000		740	19·1			1113	18·8		
>20 000		814	21·1			934	15·8		
Marital status									
Married		3406	88·1			5214	88·0		<0·001
Unmarried		126	3·3			4	0·1		
Divorced, widowed, other		334	8·6			706	11·9		
Smoking status									
Never smoked		1022	26·4			5393	91·0		<0·001
Former smoker		659	17·1			108	1·8		
Current smoker		2185	56·5			423	7·2		
Drinking status									
Never drank		1473	38·1			5296	89·4		<0·001
Moderate drinker		1295	33·5			557	9·4		
Heavy drinker		951	24·6			44	0·7		
Former drinker		147	3·8			27	0·5		
Exercise regularly		3372	87·2			5005	84·5		<0·001
Peasantry		3313	80·5			4944	83·5		<0·001

WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose.
Data are presented as mean (sd) or *n* (%), as appropriate

was the lowest (6·3 % in men *v.* 16·0 % in women) among these individual components.

According to modified ATP III criteria, IDF criteria and harmonised definition, the overall prevalence of Mets was 41·3 % (4040/9790), 34·2 % (3345/9790) and 44·1 % (4316/9790), respectively. The age- and sex-adjusted prevalence of Mets was 38·2, 30·9 and 41·8 %. There was a higher age-adjusted prevalence of Mets in women than in men (modified ATP III criteria: 32·4 *v.* 44·2 %, IDF criteria: 22·7 *v.* 39·9 %, harmonised definition: 39·6 *v.* 44·2 %). Regardless of the adapted definitions, the prevalence of the Mets increased slightly with age until about 70 years of age and then decline. Participants aged 60–69 years had the highest prevalence, while the lowest prevalence appeared in participants aged 40–49 years. Related details are shown in Table 3.

Table 4 shows the potential risk factors for Mets, as identified by the multivariate logistic regression models. Whatever definition of Mets was used, stepwise multivariate logistic regression analysis manifested that the risk of Mets increased by 33–41 % for each 10-year increase in age. The risk of Mets in female subjects was significantly higher than that in male subjects according to modified ATP III criteria (OR 2·05, 95 % CI 1·82, 2·31), IDF criteria (OR 3·14, 95 % CI 2·75, 3·60) and harmonised definition (OR 1·41, 95 % CI 1·39, 1·44). Meanwhile, lower-annual income, higher BMI and non-peasantry worker were equally significant independent risk factors. However, levels of education, marital status, smoke status and exercise status were excluded in regression analysis. Besides, drinking status also showed a consistent correlation in three Mets definitions.

Discussion

In the current study, we found the age- and sex-adjusted prevalence of Mets was 38·2, 30·9 and 41·8 % in rural northeast China, according to modified ATP III criteria, IDF criteria and harmonised definition, respectively. Elevated blood pressure (≥130/85 mmHg or/and drug treatment for hypertension) was still the most common component of Mets. Whatever definition of Mets was used, stepwise multivariate logistic regression analysis demonstrated that higher age, female sex, non-peasantry worker and higher BMI and annual income were independent risk factors of Mets.

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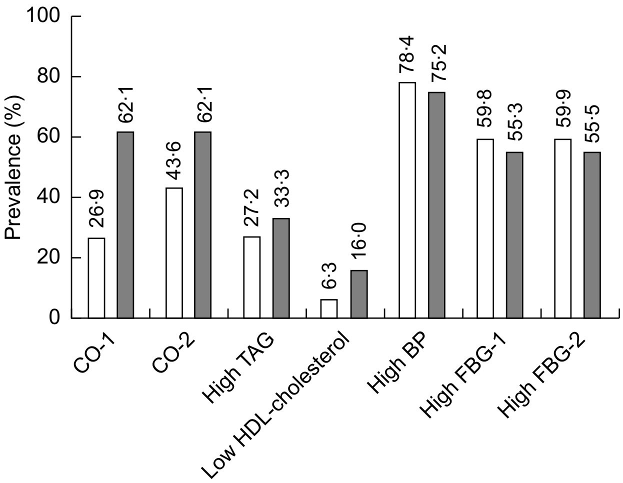

Fig. 1 Prevalence of each component of the metabolic syndrome based on three definitions. □, men; ■, women
CO-1 = WC ≥90 cm for male or waist circumference (WC) ≥80 cm for female; CO-2 = WC ≥85 cm for male or WC ≥80 cm for female; high TAG = TAG ≥1·7 mmol/l or specific treatment for elevated TAG; low HDL-cholesterol <1·03 mmol/l in men or <1·29 mmol/l in women or specific treatment for this lipid abnormality; high-BP = systolic blood pressure ≥130 mmHg or/and diastolic blood pressure ≥85 mmHg or drug treatment for hypertension; high-FBG-1 = fasting blood glucose ≥5·6 mmol/l or drug treatment for elevated glucose; high-FBG-2 = fasting blood glucose ≥5·6 mmol/l or previously diagnosed T2DM; *P* value < 0·001 for the comparison between men and women in each group.

In terms of northeast rural population, the prevalence of Mets in our current study was similar to Yu *et al.*'s study which was based on modified ATP III criteria (32·4 *v.* 31·4 % in male, 44·2 *v.* 45·6 % in female, 38·2 *v.* 39·0 % in total)[10]. According to IDF criteria, our result was slightly lower than Zhang *et al.*'s lecture in hypertension participants (34·7 %)[12], but higher than the outcome another study based on urban and rural residents (22·4 %)[13]. In the first two studies, sample encompassed individuals aged ≥35 year, which is considerably lower, and individuals with hypertension in the latter study. Further, there were a slice of deviations from the diagnostic criteria in the former study. Accordingly, we have reasons to infer that the prevalence of Mets may still be on the rise.

The current prevalence of Mets was similar to the results of Nantong's participants in 2013 based on harmonised definition (39·6 *v.* 39·8 % in male, 44·2 *v.* 45·0 % in female, 41·8 *v.* 42·6 % in total)[22]. However, the prevalence of Mets was higher in our study than the published estimates of the prevalence of Mets. The prevalence among rural northwest adults in China was 15·1 % (modified ATP III criteria) and 10·8 % (IDF criteria), respectively[9]. The age standardised prevalence based on IDF criteria and harmonised definition was 21·33 and 26·50 %, respectively, in Xinjiang rural areas[23]. A meta-analysis from mainland China stated that the prevalence of Mets in rural areas was just 19·2 % (IDF criteria)[24]. Even if some studies were conducted in

Table 3 Prevalence of metabolic syndrome stratified by age and sex among the study participants

	Modified ATP III criteria						IFD criteria						Harmonised definition					
	Male		Female		Total		Male		Female		Total		Male		Female		Total	
Age (years)	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
40–49 (*n* 1835)	219	34·7	400	33·3	619	33·7	164	25·9	364	30·3	528	28·8	266	42·1	400	33·3	666	36·3
50–59 (*n* 3041)	391	35·2	942	48·8	1333	43·8	258	23·2	836	43·3	1094	36·0	470	42·3	942	48·8	1412	46·4
60–69 (*n* 3334)	414	29·8	1066	54·9	1480	44·4	277	19·9	949	48·8	1226	36·8	512	36·8	1066	54·9	1578	47·3
70–79 (*n* 1314)	133	21·7	374	53·4	507	38·6	88	14·4	330	47·1	418	31·8	181	29·5	374	53·4	555	42·2
80+ (*n* 266)	29	24·2	72	49·3	101	38·0	21	17·5	58	39·7	79	29·7	33	27·5	72	49·3	105	39·5
Overall (*n* 9790)	1186	30·7	2854	48·2	4040	41·3	808	20·9	2537	42·8	3345	34·2	1462	37·8	2854	48·2	4316	44·1
ASSR*	32·4		44·2		38·2		22·7		39·3		30·9		39·6		44·2		41·8	

ASSR = age- and sex-standardised rates.
Percentages represent the number of subjects with metabolic syndrome among the total number of subjects; data are presented as *n* (%).
*ASSRs by China census population 2010.

Table 4 The risk factors of metabolic syndrome by stepwise logistic regression

Variable	Modified ATP III criteria			IFD criteria			Harmonized definition		
	OR	95 % CI	*P*-value	OR	95 % CI	*P*-value	OR	95 % CI	*P*-value
Age (per 10 years)	1·33	1·26, 1·40	<0·001	1·41	1·33, 1·50	<0·001	1·33	1·26, 1·40	<0·001
Female *v.* male	2·05	1·82, 2·31	<0·001	3·14	2·75, 3·60	<0·001	1·41	1·26, 1·58	<0·001
BMI (per kg/m^2)	1·40	1·38, 1·43	<0·001	1·54	1·51, 1·57	<0·001	1·41	1·39, 1·44	<0·001
Annual income (CNY/year)									
≤5000	1			1			1		
5001–10 000	0·72	0·63, 0·82	<0·001	0·73	0·64, 0·84	<0·001	0·73	0·64, 0·82	<0·001
10 001–20 000	0·71	0·62, 0·82	<0·001	0·72	0·62, 0·84	<0·001	0·71	0·62, 0·81	<0·001
>20 000	0·65	0·56, 0·75	<0·001	0·70	0·60, 0·82	<0·001	0·67	0·58, 0·78	<0·001
Drinking status									
Never drank	1			1			1		
Moderate drinker	0·91	0·79, 1·05	0·182	1·01	0·86, 1·17	0·941	0·97	0·85, 1·11	0·649
Heavy drinker	1·41	1·17, 1·69	<0·001	1·17	0·95, 1·45	0·145	1·53	1·28, 1·82	<0·001
Former drinker	0·45	0·29, 0·70	<0·001	0·57	0·34, 0·93	0·026	0·52	0·35, 0·78	0·001
Peasantry (yes/no)	0·67	0·59, 0·76	<0·001	0·59	0·52, 0·68	<0·001	0·71	0·62, 0·80	<0·001

Level of education, marital status, smoke status and exercise regularly were excluded in three diagnosis criteria.

urban areas or including urban areas, the prevalence of Mets was lower than ours. Results of The CHPSNE Study manifested that the overall prevalence of Mets was 27·4 % (men 27·9 % and women 26·8 %) according to modified ATP III criteria[25]. Gu *et al.* asserted prevalence of Mets in nationally representative participants aged 35–74 years was 13·7 % (men 9·8 % and women 17·8 %)[26]. Another nationally representative sampling from the China Health and Nutrition Survey shown 21·3 % (modified ATP III criteria), 18·2 % (IDF criteria) of characters have Mets[27]. Among the Northeast Chinese people, their daily diet contains excessive salt, such as pickles and preserved beancurd. Long-term high salt intake is an important environmental factor involved in the aggravation of hypertension, which may be a possible explanation for the high prevalence of Mets found in our study. However, the prevalence of Mets was higher than ours in CHAP study in Shandong: 58 % using IDF criteria, 61·6 % using harmonised definition and it might be because the participants were older[11]. Meanwhile, the prevalence of Mets was similar to other countries. The Iran national study conducted in 2007 suggested that age-standardised prevalence of Mets was 37·4 % (IDF criteria) and 41·6 % (modified ATP III criteria). The prevalence of Mets was 28·8 % (male 23·1 % and female 33·5 %) according to IDF criteria in Turkey[28]. In the USA, the prevalence based on modified ATP III criteria was 33 % (men 30·3 % and women 35·6 %), and the age-standardised prevalence of the Mets was 35·0 % (men 33·7 % and women 36·0 %) according to harmonised definition[29]. Compared with the results of the above surveys, the present study revealed Mets was still a healthy challenge in northeast rural areas.

In our study, whatever definition was selected, a sex difference in the prevalence of Mets was found, being higher in females than in males. Stepwise logistic regression models also indicated that being female was independent risk factor. This conclusion was consistent with some researches[9–12,23,26], but different from a previous study (27·9 % in men and 26·8 % in women)[25]. Postmenopausal status may have effects on Mets because of insulin resistance and central obesity after menopause[30]. Our results also indicated that the risk of Mets increased by approximately 75 % for post-menopausal female (see online supplementary material, Supplemental Table 1). Besides, the multivariate logistic regression models also showed that prevalence increased with age in three different definitions, which was similar to previous studies[9,10,23,29]. BMI also showed a positive correlation with Mets. This was subject to explaining because BMI, such as WC, was a manifestation of obesity. In subjects with BMI > 30 kg/m^2, central obesity could be assumed and WC did not need to be measured[15]. Of course, the results suggested also exercise regularly, healthy dietary program and other healthy behaviours and lifestyles would be helpful to maintain the optimal standardised weight, thereby lowering the prevalence of MetS[27]. Moreover, annual income was negatively correlated with Mets, while the result was opposite to previous studies[9,10,25]. The result suggests subjects with high income had begun to concern their health in northeast rural areas. Peasantry had a lower prevalence than non-peasantry, which was due to heavy physical labour and light diet habit.

The most frequent component of Mets was elevated blood pressure in the current study, which coincided with previous studies[9,10]. However, it was out of keeping with a recent meta-analysis in mainland China, in which hypertension was the most common component in men, whereas central obesity was the most common feature in women[24]. Similarly, central obesity was the most common component in the USA 2009–2010 (56·07 %), and the prevalence of central obesity was increasing[31]. The demographic characteristics of cold climate and high-salt diet may be the crucial reasons in our study.

Interestingly, according to modified ATP III criteria and harmonised definition, heavy drinking had positive relation to Mets, which further certified these results of studies[32,33]. Besides, participants with CVD (*n* 1110) were included, and we analysed the associations between Mets with CVD by logistic regression. The results suggested that the association between Mets and cerebrovascular disease and coronary artery disease was similar under modified ATP III criteria and harmonized definition, which were significant prior to IDF criteria (see online supplementary material, Supplemental Table 2). Overall, results suggested that modified ATP III criteria and harmonised definition might be better definitions of Mets.

There are some limitations in our study. First, the cross-sectional design of the study only allowed assessment of the associations between Mets and risk factors rather than causal links. Second, although our study included a large number of subjects, these participants were from northeast China and over 40 years old. This may reduce the applicability of our results to other populations. Finally, some confounding factors proved in other studies such as sleep duration, number of child, beans, bean products and tea intake, as well as various pressures are not collection in our study. Large-sample prospective studies are needed to confirm the results.

Conclusion

The current study confirms that the accurate prevalence of Mets is increasingly high among a general population from rural areas of northeast China, especially in the female population. It demonstrates that females need more attention to prevent and control Mets. The final definition of a Mets is needed to identify and intervene patients as early as possible based on relevant risks.

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Supplementary Material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980019004166.

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