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Comparative study on prevalence of metabolic syndrome based on three criteria among adults in Zhejiang province, China: an observational study

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ABSTRACT

Objectives In this study, we aimed to estimate the prevalence of metabolic syndrome (MetS) among Chinese adults, describe the disease components and compare utility of the existing international criteria and Chinese diagnostic criteria.

Design, setting and participants A retrospective database analysis was conducted for one hospital in Zhejiang province, China. We analysed data (collected in 2017) from a total of 64 902 participants (37 500 males and 27 402 females), aged between 18 and 97 years, and who met the eligibility criteria.

Main outcome measures We employed three criteria for MetS proposed by the International Diabetes Federation (IDF) in 2005, the 2009 Joint Scientific Statement (harmonising criteria) and the China Diabetes Society (CDS) in 2013 to detect prevalence of MetS. Specifically, we analysed waist circumference, blood pressure, fasting plasma glucose, plasma triglycerides and plasma high-density lipoprotein cholesterol.

Results We found an estimated age-adjusted MetS prevalence of 20.4% using IDF 2005, 30.0% based on harmonising criteria 2009 and 16.3% under the CDS 2013. This prevalence was higher in males, older adults and increased body mass index. Analysis of agreements among the criteria were 87.2% (IDF and CDS), 87.1% (IDF and harmonising criteria) and 81.6% (CDS and harmonising criteria), while their kappa coefficients were 0.641, 0.708 and 0.572 for IDF versus CDS, IDF versus harmonising criteria and CDS versus harmonising criteria, respectively. The most prevalent MetS component was abdominal obesity (50.1%), followed by dyslipidaemia (49.5%) and hypertension (46.8%) using harmonising criteria.

Conclusion These findings revealed moderate agreement among the three criteria with utility in Chinese clinical settings. The harmonising criteria 2009 performed better in early identification of MetS in the Chinese population.

Strengths and limitations of this study

- ► The present study provides updated estimates of the prevalence of metabolic syndrome and its components among adults in China using international criteria, as well as ethnic-specific criteria.
- ► The utility and applicability of three criteria for detection of metabolic syndrome were tested and compared.
- ► A suitable criterion for early detection of metabolic syndrome in Chinese populations was identified.
- ► Health-check data from a large cohort of relatively young Chinese adults were extracted to describe the components of metabolic syndrome.
- ► We sampled one medical centre, from one province in China at a specific time period, the generalisability beyond this study population requires further study.

INTRODUCTION

Metabolic syndrome (MetS) is a multi-component risk factor for cardiovascular diseases (CVD) and type 2 diabetes mellitus (T2DM).[1 2] Although its pathogenesis is unclear, MetS reflects a clustering of cardiometabolic risk factors related to abdominal obesity and insulin resistance. The Global Burden of Disease, Injuries and Risk Factors Study (GBD 2016) reported that metabolic risks are the leading causes of GBD since 1990, contributing to deaths and disabilities.[3] MetS prevalence and its disease-related burden remain high across the world.[4 5] Furthermore, MetS increases the risk of all-cause and CVD mortality, and further impacts sleep disorders as well as incident stroke.[2 6–10] Studies have also reported an association between MetS and certain types of cancers.[11 12] Accurate identification of MetS across populations provides a foundation for effective prevention and management of CVD, obesity, hypertension, T2DM and cancers.

MetS detection varies depending on the criteria used, different definitions, as well as population composition, including age, sex, ethnicity, nationalities and regions.[2] In the past decades, a number of diagnostic criteria for MetS have been released. Among Chinese populations, the criteria by International Diabetes Federation (IDF 2005) found a pooled MetS prevalence of 24.5% (19.25% in males, 27.0% in females) in mainland China,[13] although an increase from 13.7% (2000–2001) to 21.3% (2009) was reported in other national surveys based on the criteria of the National Cholesterol Education Program (2001).[14 15] More efforts are required in order to generate a consensus on common criteria for MetS and enhance clinical practice.[1] In fact, the Joint Scientific Statement presented a new harmonising definition in 2009.[1] Using this criteria, the estimated prevalence of MetS among US adults was 34.2%, indicating that more than a third of all US adults found with MetS by 2012.[5] However, the evidence on using harmonising criteria 2009 for prevalence estimates is limited in Chinese populations. In 2013, the Chinese Diabetes Society (CDS) released a MetS criteria for Chinese population. It is hypothesised that harmonising criteria 2009 and CDS criteria for MetS are likely to produce different prevalence estimates in Chinese populations than those based on previous criteria. Despite a wealth of studies of prevalence of MetS in the past decade, large cohort studies in Chinese adults are limited and no comparisons of criteria documents were found among IDF 2005, harmonising criteria 2009 and CDS 2013.

Different MetS criteria agree on the essential components but vary in cut-off values with regard to certain components, and there is little evidence to point out that one is more superior to others. Abdominal obesity represents the most prevalent component among MetS risk factors as it precedes the others.[16 17] Measurement of abdominal obesity is by waist circumference (WC), which represents an essential component of the MetS criteria although it varies across all criteria. The threshold for WC (≥90 cm for males and ≥85 cm for females) in CDS 2013 is different from any other MetS criteria.[18] Since WC contributing to MetS remains unsettled, CDS 2013 with modifications of WC and other indexes tends to be more suitable for Chinese population,[19] but this has not been adequately explored. This, therefore, necessitates updating of such evidence using Chinese diagnostic criteria and comparisons with other international criteria to generate a better understanding of prevalence and risk factors of MetS in Chinese populations.

Thus, the main aim of this study was to estimate the prevalence and characteristics of MetS based on population-based health administrative data using two commonly used international criteria and Chinese-specific diagnostic criteria; and to evaluate the utility of these criteria for identification of MetS in Chinese populations.

METHODS

Study design and population

A secondary analysis was conducted to estimate the prevalence of MetS based on health data obtained from the Healthcare Information and Management Systems Society database of a medical centre accredited by the Joint Commission International in Zhejiang province. These data were sourced from permanent residents living and working in Zhejiang, and were collected between January 2017 and December 2017. Demographic characteristics were collected by trained nurses, while information on medical history information and laboratory test results were obtained by certified physicians and chemists using standard protocols and techniques.

Sample screening and assessment of potential MetS risk was based on the following variables: WC, fasting plasma glucose (FPG), blood pressure (BP), plasma triglycerides (TG), plasma high-density lipoprotein cholesterol (HDL-C), as well as histories of hypertension, T2DM, and hyperlipidaemia. Participants who were taking hypolipidaemic, hypoglycaemic or hypotensive medications met the criteria for increased TG and HDL-C, increased FPG or increased BP. A total of 82 123 participants, aged between 18 and 98 years, attended a health examination in 2017 in this medical centre. Data analysis was performed on 64 902 participants and was restricted to individuals who completed patient self-report information and had laboratory results that included essential variables.

Identification of metabolic syndrome

The IDF 2005,[20] the 2009 Joint Scientific Statement (harmonising criteria 2009)[1] and the CDS 2013[19] were selected as standard criteria for estimation of MetS prevalence. Detailed indices and their thresholds for the Chinese population are listed in table 1. By definition, MetS was diagnosed when any three of five risk factors were present. Specifically, it is a requirement of WC for diagnosis in the IDF criteria, but not for the other two criteria.

Statistical analysis

Data were managed in Excel 2010 and analysed using SPSS V.22.0 for windows. We calculated body mass index (BMI) as weight divided by the square of the height in metres, and categorised as underweight (BMI <18.5), normal weight (18.5≤BMI<24.0), overweight (24.0≤BMI<28.0) and obesity (28.0≤BMI).[21] Continuous variables were presented as means±SD (normal distributions) with 95% CI, while proportions were calculated for discrete variables. The crude prevalence of MetS and abnormalities were estimated for the overall population, as well as sex and BMI groups, using IDF 2005, harmonising criteria 2009 and CDS 2013. According to the classification proposed by the sixth China Population Census and Population Data,[22] age was categorised into five groups as follows: 18–29, 30–39, 40–49, 50–59 and ≥60 years. Additionally, the standardised prevalence of MetS was weighted and adjusted by age and sex. A Pearson χ^2 test was used to perform comparisons between groups for categorical variables, while one-way analysis of variance was performed to compare differences among groups for continuous variables. To analyse the measures of agreement, we calculated Cohen's kappa coefficient at 95% CI. All analysis results were interpreted at a significance level p value <0.05 and two-tailed test.

Patient and public involvement

Patients and the public were not involved in this study.

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Table 1 Criteria for clinical diagnosis of metabolic syndrome

Variables	Recommended thresholds IDF 2005	Harmonising criteria 2009	CDS 2013
Abdominal obesity (waist circumference)	≥90 cm (male); ≥80 cm (female)	≥85 cm (male); ≥80 cm (female)	≥90 cm (male); ≥85 cm (female)
Triglycerides	≥1.7 mmol/L or treatment	≥1.7 mmol/L or treatment	≥1.7 mmol/L
Plasma high-density lipoprotein cholesterol	<1.03 mmol/L (male); <1.29 mmol/L (female) or treatment	<1.0 mmol/L (male); <1.3 mmol/L (female) or treatment	<1.04 mmol/L
Blood pressure	Systolic ≥130 or diastolic ≥85 mm Hg or treatment	Systolic ≥130 and/or diastolic ≥85 mm Hg or treatment	BP ≥130/85 mm Hg or treatment
Fasting plasma glucose	≥5.6 mmol/L or previously diagnosed T2DM	≥5.6 mmol/L or treatment	≥6.1 mmol/L, and(or) 2hPG≥7.8 mmol/L or treatment

CDS, China Diabetes Society; IDF, International Diabetes Federation; T2DM, type 2 diabetes mellitus.

RESULTS

Overall participants' characteristics

A total of 64 902 participants (37 500 males and 27 402 females), aged 18 and 97 years, were eligible for the study. Of these, 70% were aged between 35 and 65 years, with a mean age of 44.53±12.20 and a range 18–97 years. Participants' characteristics are presented by sex in terms of MetS components (table 2). Briefly, about 24.32%, 7.30% and 49.45% of the participants had a history of hypertension, diabetes and hyperlipidaemia, respectively.

Estimated prevalence of metabolic abnormalities

The prevalence of MetS components according to the three criteria are summarised in table 3. Of the 64 902 participants, the crude prevalence of MetS was 25.8% (95% CI 25.5 to 26.2), 38.0% (95% CI 37.6 to 38.3) and 20.6% (95% CI 20.3 to 20.9) by IDF 2005, harmonising criteria 2009 and CDS 2013, respectively (χ^2=5105.437, p<0.001). The harmonising criteria identified more MetS patients compared with the criteria of IDF and CDS. Prevalence of different metabolic components ranged from 20.0% to 49.5% using IDF 2005, 20.0% to 50.1% based on harmonising criteria 2009 and 11.1% to 34.0% under the CDS 2013. Additionally, we recorded higher MetS frequencies and proportions of abnormal WC, TG, BP and FPG in males than females under all three criteria, and the differences were statistically significant (p<0.001). However, the frequency of reduced HDL-C screened using IDF and harmonising criteria showed contrasting results that was higher in females. Total prevalence of the increased TG (49.5%), based on IDF 2005, was higher than that of the other components. Moreover, the highest prevalence of abnormal components by harmonising criteria 2009 was increased WC (50.1%) and by CDS 2013 was increased BP (34.0%). Table 4 shows the prevalence of MetS based on these three criteria according to BMI categories. These findings indicated that occurrence of MetS increased substantially in the overweight and obesity categories compared with underweight and normal weight categories.

Prevalence of metabolic syndrome

Based on the Chinese sixth-population census data, the age-standardised prevalence of MetS was 20.4% (95% CI 20.0 to 20.8), 30.0% (95% CI 29.7 to 30.4) and 16.3% (95% CI 16.0 to 16.6) according to IDF 2005, harmonising criteria 2009 and CDS 2013, respectively (table 5). Considering categorises of sex and age, the estimated prevalence of MetS was higher in males than in females. Additionally, MetS prevalence identified by the IDF 2005

Table 2 Characteristics of participants by sex (n=64 902)

Category	Male (n=37 500) Mean (95% CI)	Female (n=27 402) Mean (95% CI)
Body mass index (kg/m^2)	24.76 (24.73 to 24.79)	22.43 (22.39 to 22.46)
Waist circumference	87.44 (87.35 to 87.53)	75.92 (75.82 to 76.02)
Triglycerides (mmol/L)	1.87 (1.85 to 1.88)	1.20 (1.19 to 1.20)
HDL-cholesterol (mmol/L)	1.13 (1.13 to 1.13)	1.38 (1.37 to 1.38)
Glucose (mmol/L)	5.38 (5.36 to 5.39)	5.07 (5.06 to 5.08)
Systolic blood pressure (mm Hg)	126.96 (126.79 to 127.13)	118.15 (117.93 to 118.36)
Diastolic blood pressure (mm Hg)	76.99 (76.88 to 77.11)	69.78 (69.65 to 69.90)

HDL-cholesterol, high-density lipoprotein cholesterol.

Table 3 Estimated prevalence of metabolic abnormalities screened by the three criteria (N, %)

	IDF 2005				Harmonising criteria 2009				CDS 2013			
Criteria	**Total**	**Male 37 500**	**Female 27 402**	**P value**	**Total**	**Male 37 500**	**Female 27 402**	**P value**	**Total**	**Male 37 500**	**Female 27 402**	**P value**
Increased WC	23 387 (36.0)	14 834 (39.6)	8553 (31.2)	<0.001	32 494 (50.1)	23 941 (63.8)	8553 (31.2)	<0.001	19 175 (29.5)	14 834 (39.6)	4341 (15.8)	<0.001
Increased TG	32 140 (49.5)	21 559 (57.5)	10 581 (38.6)	<0.001	32 140 (49.5)	21 559 (57.5)	10 581 (38.6)	<0.001	19 796 (30.5)	15 267 (40.7)	4529 (16.5)	<0.001
Reduced HDL-C	27 012 (41.6)	15 249 (40.7)	11 763 (42.9)	<0.001	25 514 (39.3)	13 410 (35.8)	12 104 (44.2)	<0.001	19 726 (30.4)	15 905 (42.4)	3821 (13.9)	<0.001
Increased BP	30 386 (46.8)	20 845 (55.6)	9541 (34.8)	<0.001	30 386 (46.8)	20 845 (55.6)	9541 (34.8)	<0.001	22 043 (34.0)	15 589 (41.6)	6454 (23.6)	<0.001
Increased FPG	12 986 (20.0)	9246 (24.7)	3740 (13.6)	<0.001	12 986 (20.0)	9246 (24.7)	3740 (13.6)	<0.001	7233 (11.1)	5338 (14.2)	1895 (6.9)	<0.001
MetS	16 765 (25.8)	11 308 (30.2)	5457 (19.9)	<0.001	24 643 (38.0)	17 828 (47.5)	6815 (24.9)	<0.001	13 360 (20.6)	11 294 (30.1)	2066 (7.5)	<0.001

BP, blood pressure; CDS, China Diabetes Society; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; IDF, International Diabetes Federation; MetS, metabolic syndrome; TG, triglycerides; WC, waist circumference.

and CDS 2013 was similar in males (15.3% vs 15.2%), although it differed for females (9.8% vs 3.7%). Statistical significance in MetS prevalence between males and females across the three criteria was found. Overall, the standardised prevalence of MetS showed upward trends with age with prevalence gradually increasing before age 40, was stabilised from 40 to 59 years, then increased after 60 years.

Characteristics of participants with metabolic syndrome

Table 6 outlines the clinical parameters of participants with MetS using the three criteria. There was no statistical significance in the means of all MetS components detected across the three criteria (p>0.05). Overall, the harmonising criteria 2009 identified MetS participants with the lowest BMI, WC, TG, systolic blood pressure (SBP), diastolic blood pressure (DBP) and FPG in males as well as those with the lowest BMI, WC, SBP, DBP and FPG in females.

Relationship among the three criteria

As shown in table 7, the agreement between two criteria was assessed. We found 87.2% agreement between CDS 2013 and IDF 2005, 81.6% between CDS 2013 and harmonising criteria 2009 and 87.1% between IDF 2005 and harmonising criteria 2009. Kappa coefficients for CDS 2013 relative to the other two criteria were 0.641 (95% CI 0.633 to 0.649) and 0.572 (95% CI 0.566 to 0.578), indicating a moderate agreement. This coefficient was also higher in males than in females (0.720 vs 0.414, 0.609 vs 0.395). The kappa coefficient of IDF 2005 and harmonising criteria 2009 was 0.708 (95% CI 0.702 to 0.714). However, it was lower in males compared with females (0.618 vs 0.858).

DISCUSSION

In this study, we provided an estimation of MetS prevalence among Chinese adults in Zhejiang province, east of China, using three standard criteria based on hospital-based cross-sectional data. We screened a large cohort of relatively young Chinese adults with a mean age of 44.53 years, and found age-standardised prevalence of MetS to be 20.4%, 30.0% and 16.3% under the IDF 2005, harmonising criteria 2009, and CDS 2013 criteria, respectively. The current prevalence of MetS, reported herein, was lower than what has previously been reported in older Chinese adults (mean aged at 69 years) using the harmonising criteria 2009 and CDS 2013 (58.2% and 39.2%).[23]

Table 4 Estimated prevalence of MetS relating to abdominal obesity by three criteria (N, %)

	BMI				
Criteria	**Underweight (n=2633)**	**Normal weight (n=32 829)**	**Overweight (n=22 935)**	**Obesity (n=6505)**	**P value**
IDF 2005	2 (0.1)	2028 (6.2)	9519 (41.5)	5216 (80.2)	<0.001
Harmonising criteria 2009	57 (2.2)	5851 (17.8)	13 477 (58.8)	5258 (80.8)	<0.001
CDS 2013	13 (0.5)	1912 (5.8)	7324 (31.9)	4111 (63.2)	<0.001

BMI, body mass index; CDS, China Diabetes Society; IDF, International Diabetes Federation; MetS, metabolic syndrome.

Table 5 Adjusted prevalence of metabolic syndrome by the three criteria by sex and age

		% (95%CI)		
Category	**Sample**	**IDF 2005**	**Harmonising criteria 2009**	**CDS 2013**
Overall	64902	20.4 (20.0 to 20.8)	30.0 (29.7 to 30.4)	16.3 (16.0 to 16.6)
Sex				
Male	37500	15.3 (14.8 to 15.8)	24.0 (23.6 to 24.4)	15.2 (14.8 to 15.8)
Female	27402	9.8 (9.4 to 10.2)	12.3 (12.0 to 12.7)	3.7 (3.5 to 3.9)
χ^2		866.551	3455.032	4937.018
P value		<0.001	<0.001	<0.001
Age				
18–29	7515	1.9 (1.6 to 2.2)	3.0 (2.6 to 3.4)	1.4 (1.1 to 1.7)
30–39	16319	2.6 (2.3 to 2.9)	4.0 (3.7 to 4.3)	2.1 (1.9 to 2.3)
40–49	18977	4.3 (4.0 to 4.6)	6.5 (6.2 to 6.9)	3.7 (3.4 to 4.0)
50–59	14696	4.4 (4.0 to 4.8)	6.3 (5.9 to 6.7)	3.5 (3.2 to 3.8)
≥60	7395	6.1 (5.5 to 6.7)	8.3 (7.7 to 9.0)	4.2 (3.7 to 4.7)
χ^2		4280.676	6104.856	2722.093
P value		<0.001	<0.001	<0.001

CDS, China Diabetes Society; IDF, International Diabetes Federation.

Based on IDF 2005, the prevalence of MetS in this study was similar to that of a national investigation (18.2% from the China Health and Nutrition Survey in 2009 based on the sample of 7488 participants conducted in nine provinces)[15] and a regional investigation (18.0% based on the sample of 17437 participants from Zhejiang province in 2010).[24] A review suggested that onset of MetS is a serious public health problem owing to changes in lifestyles, and shows a trend towards higher prevalence among young adults.[4 5] Hence, our study provides important insights into the need to identify MetS for early prevention.

We found that the harmonising criteria identified more MetS patients compared with the IDF and CDS two criteria. Specifically, the cut-off value for WC in males was lower, while HDL-C for females was a little higher under harmonising criteria 2009 relative to IDF 2005. In addition, abdominal obesity is a mandatory requirement for a diagnosis of MetS and leads to a relatively low detected disease rate on IDF 2005. Due to lack of a separated threshold of HDL-C between males and females, no option of including hyperlipidaemia treatment, lower cut-off values of WC and higher cut-off values of FPG indicated that MetS prevalence was the lowest using CDS 2013. The prognostic impact of MetS criteria on CVD has also been tested in previous studies. For example, Vinluan *et al*[25] found that adjusted HRs for risk of CVD by the IDF was 1.31 (95%CI 1.00 to 1.50). Another study indicated that the HRs of the harmonising criteria 2009 for incident CVD was 1.70 (1.34–2.17), which was higher than that of 1.54 (1.22–19.94) by IDF 2005.[26] In order

Table 6 Comparisons of clinical characteristics of participants with metabolic syndrome by three criteria (mean, SD)

	Male			Female			
	IDF 2005	**Harmonising criteria 2009**	**CDS 2013**	**IDF 2005**	**Harmonising criteria 2009**	**CDS 2013**	**P value**
Age	47.93 (11.44)	47.83 (11.51)	48.29 (11.00)	53.92 (11.41)	53.36 (11.31)	55.50 (11.01)	0.970
BMI	27.51 (2.54)	26.31 (2.75)	26.94 (2.79)	25.78 (2.78)	25.07 (2.98)	26.21 (3.19)	0.636
WC	96.08 (5.43)	92.18 (6.91)	94.10 (6.86)	87.06 (6.21)	84.61 (7.65)	88.14 (8.00)	0.869
TG	2.57 (2.06)	2.49 (1.98)	2.86 (2.17)	1.87 (1.14)	1.88 (1.13)	2.48 (1.35)	0.529
HDL-C	1.01 (0.23)	1.02 (0.24)	0.97 (0.20)	1.19 (0.27)	1.19 (0.27)	1.06 (0.23)	0.681
SBP	133.89 (16.55)	133.07 (16.74)	134.07 (17.35)	134.03 (19.83)	133.49 (19.95)	138.22 (20.84)	0.270
DBP	82.02 (11.50)	81.29 (11.43)	82.42 (11.91)	76.81 (11.56)	76.66 (11.67)	79.34 (12.39)	0.829
FPG	5.85 (1.65)	5.79 (1.61)	5.97 (1.83)	5.61 (1.28)	5.61 (1.69)	6.04 (1.70)	0.212

P value < 0.05.
BMI, body mass index; CDS, China Diabetes Society; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; IDF, International Diabetes Federation; SBP, systolic blood pressure; TG, triglycerides; WC, waist circumference.

Table 7 Agreement of the three criteria

Criteria	Male (n=37 500) Number	%	Female (n=27 402) Number	%	Total (n=64 902) Number	%
CDS 2013 vs IDF 2005						
(+) (+)	9093	24.2	1800	6.6	10 893	16.8
(+) (–)	2201	5.9	266	1.0	2467	3.8
(–) (+)	2215	5.9	3657	13.3	5872	9.0
(–) (–)	23 991	64.0	21 679	79.1	45 670	70.4
Kappa value, 95% CI	0.720* (0.712 to 0.728)		0.414* (0.400 to 0.428)		0.641* (0.633 to 0.649)	
CDS 2013 vs harmonising criteria 2009						
(+) (+)	10 968	29.2	2066	7.5	13 034	20.1
(+) (–)	326	0.9	0	0	326	0.5
(–) (+)	6860	18.3	4749	17.3	11 609	17.9
(–) (–)	19 346	51.6	20 587	75.1	39 933	61.5
Kappa value, 95% CI	0.609* (0.601 to 0.617)		0.395* (0.383 to 0.407)		0.572* (0.566 to 0.578)	
IDF 2005 vs harmonising criteria 2009						
(+) (+)	11 061	29.5	5457	19.9	16 518	25.5
(+) (–)	247	0.7	0	0	247	0.4
(–) (+)	6767	18.0	1358	5.0	8125	12.5
(–) (–)	19 425	51.8	20 587	75.1	40 012	61.6
Kappa value, 95% CI	0.618* (0.610 to 0.626)		0.858* (0.850 to 0.866)		0.708* (0.702 to 0.714)	

The differences between every two criteria were evaluated by χ^2 test. '+' means that patient was diagnosed as metabolic syndrome by the given criteria; '–' means that patient was no metabolic syndrome by the given criteria.
*P value < 0.001.
CDS, China Diabetes Society; IDF, International Diabetes Federation.

to find a preferred approach for identifying adults with MetS, future studies should compare the predictive ability of different MetS criteria for CVD in a given situation.

One interesting finding from the study was the impact of different thresholds on the sex difference in the estimation of MetS prevalence. Similarly, previous studies have reported that sex differences needed to be considered when discussing lipid and lipoprotein metabolism and susceptibility to develop obesity, diabetes and CVD.[27–29] We found a higher MetS prevalence in males than females across all three criteria, based on the male to female ratio (1.02) among Chinese adults (aged 18 years and older) in 2010. This corroborated results from previous studies which indicated higher MetS prevalence in males before the age of 50 years and higher in females after the age of 50 years,[30 31] MetS prevalence by different age groups are recommended for future studies.[13 32] We observed similar MetS prevalence in males (15.3% vs 15.2%), but this was higher in females (9.8% vs 3.7%) based on IDF 2005 and CDS 2013. Since we did not administer drug treatment for dyslipidaemia, the detected TG disorder by CDS 2013 was less than that detected under the other two criteria. Additionally, we found much lower frequency of HDL-C disorders in females using CDS 2013 compared with IDF 2005 and harmonising criteria 2009, and this is likely due to the same cut-off values regardless of sexes. The other differences can be attributed to the cut-off values of abnormal WC and FPG, which results in higher proportions in females using IDF 2005 relative to CDS 2013. Regardless of the MetS criteria used, the increased MetS prevalence trends were related to advanced age and increased BMI, which is consistent with previous studies.[13 16]

As noted, the criterion for abdominal obesity variously defined across the three criteria and this has an impact on MetS prevalence. Abdominal obesity has been reported to be a predisposing factor of insulin resistance, hypertension and dyslipidaemia in both male and female patients.[29 33 34] Measurement of BMI is routinely performed in metabolic-related studies, though not the priority in predicting cardiometabolic risk.[35] WC was a useful predictor of metabolic morbidities and adopted in recent MetS definitions.[1 17 36] A large cohort study among Chinese showed that WC was valid to predict the abnormal BP.[37] Another study recognised WC as a better index for MetS status for its predictive ability and wide use in clinical settings.[38] The WC threshold in females was higher in CDS 2013 compared with IDF 2005 and harmonising criteria 2009, although the differences of detected values among MetS patients showed no statistical significances (p>0.05). Previous data pointed out that healthy Chinese have more visceral adipose tissue than Europeans with the same WC using imaging technology, suggesting that the cut-off value of WC for Chinese could be lower than other ethnicities.[39] Liu *et al*[40] reported that the optimal cut-off WC to detect multiple cardiometabolic risk factors was 91.3 and 87.1 cm in males and females, respectively. Zeng *et al*[41] determined that WC of 85.0 cm in males and 75.0 cm in females were the optimal thresholds to predict all CVD risk factors in Chinese using receiver operating characteristic analysis. Though CDS 2013 has attempted to bridge differences of population-specific criteria on WC, compared with other international criteria using experimental studies,[18] a more elaborate analysis is needed using this approach to prove the rationality of WC cut-off threshold (90 cm for males and 85 cm for females).

Among all MetS components analysed, dyslipidaemia was the most common dysfunction. Particularly, 49.45% of 64 902 participants were diagnosed with hyperlipidaemia, while the frequency of abnormal TG in overall populations ranged from 30.5% to 49.5% under all three criteria. These results were similar to those reported in an epidemiological survey in east China, in which TG disorder was found to be a significant risk factor.[32] Previous data reported that obesity, dyslipidaemia and increased FPG were prevalent components of MetS among Han Chinese using CDS 2013.[42] A national survey in Indonesia reported decreased HDL-C and hypertension as the two most prevalent risk factors for MetS.[43] In this study, the detectable rates of increased BP were significantly high among Chinese adults, ranging from 34.0% to 46.8%. Based on this, the IDF 2005 and harmonising criteria 2009 were better at identifying more patients with hypertension than CDS 2013.

Notably, we found good agreements among the three criteria. Our findings were similar to results from a study that estimated MetS prevalence among 1832 elderly in China, with agreements ranging from 81.1% to 88.3%, and kappa coefficients of 0.625 (IDF 2005 and CDS 2013), 0.768 (IDF 2005 and harmonising criteria 2009) and 0.634 (CDS 2013 and harmonising criteria 2009).[23] This is in line with the previous study that all three criteria are feasible in Chinese populations for the identification of MetS. The concordance between IDF 2005 and harmonising criteria 2009 based on their greater similarity was further supported by a study from Ethiopia.[44] The difference of their kappa coefficients by sex was due to the WC criterion that it is identical in females but different in males. From our findings, using harmonising criteria 2009 is likely to improve identification of high-risk cardiometabolic factors in Chinese populations for early intervention of MetS.

Limitations

The design and findings of the study presented several limitations. First, due to a cross-sectional study design, the current sampling came from one medical centre at a specific time period and from one province in China, may limit generalisability. It will be important to use a larger sample and up-to-date data in future studies on prevalence of MetS among Chinese population. Early MetS diagnosis, using population-based health data, could increase risk perception and awareness towards a healthier lifestyle. A multicentre investigation would be valuable in future research to examine disease-related outcomes of MetS based on long-term follow-up data in specific populations. Second, this study provides descriptive evidence for the prevalence of MetS rather than analytical findings on the degree of different criteria to predict the incidence of CVD and T2DM. In this regard, it will be important to further explore the utility and applicability of the three criteria using ethnic-specific thresholds for Chinese cultures and populations.

CONCLUSION

The current study estimated prevalence of MetS using IDF 2005, harmonising criteria 2009 and CDS 2013, and found significant differences in sex and BMI. Since MetS components are all reversible, their early identification using data from health examinations could lead to the development of effective prevention approaches for obesity, cardiometabolic diseases and T2DM. Based on our results, we recommended the harmonising criteria 2009 for generation of strict cut-off thresholds of MetS components. This is the most preferred criteria for identifying individuals at risk for MetS. Future research should elucidate the predictive ability of MetS criteria for cardiometabolic-related diseases.

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