Original Article

Effectiveness of Different Waist Circumference Cut-off Values in Predicting Metabolic Syndrome Prevalence and Risk Factors in Adults in China*

ZHOU Hai Cheng[1,$], LAI Ya Xin[1,$], SHAN Zhong Yan[1,#], JIA Wei Ping[2], YANG Wen Ying[3], LU Ju Ming[4], WENG Jian Ping[5], JI Li Nong[6], LIU Jie[7], TIAN Hao Ming[8], JI Qiu He[9], ZHU Da Long[10], CHEN Li[11], GUO Xiao Hui[12], ZHAO Zhi Gang[13], Li Qiang[14], ZHOU Zhi Guang[15], GE Jia Pu[16], and SHAN Guang Liang[17]

1. Department of Endocrinology and Metabolism, Institute of Endocrinology, Liaoning Provincial Key Laboratory of Endocrine Diseases, The First Affiliated Hospital of China Medical University, Shenyang 110001, Liaoning, China; 2. Department of Endocrinology and Metabolism, The Sixth Affiliated People's Hospital of Shanghai Jiaotong University, Shanghai 200233, China; 3. Department of Endocrinology and Metabolism, China-Japan Friendship Hospital, Beijing 100029, China; 4. Department of Endocrinology and Metabolism, Chinese People's Liberation Army General Hospital, Beijing 100853, China; 5. Department of Endocrinology and Metabolism, Sun Yat-sen University Third Hospital, Guangzhou 510630, Guangdong, China; 6. Department of Endocrinology and Metabolism, Peking University People's Hospital, Beijing 100044, China; 7. Department of Endocrinology and Metabolism, Shanxi Provincial People's Hospital, Taiyuan 030012, Shanxi, China; 8. Department of Endocrinology and Metabolism, Sichuan University West China Hospital, Chengdu 610041, Sichuan, China; 9. Department of Endocrinology and Metabolism, Fourth Military Medical University Xijing Hospital, Xi'an 710032, Shaanxi, China; 10. Department of Endocrinology and Metabolism, Affiliated Drum Tower Hospital of Nanjing University Medical School, Nanjing 210008, Jiangsu, China; 11. Department of Endocrinology and Metabolism, Qilu Hospital of Shandong University, Jinan 250012, Shandong, China; 12. Department of Endocrinology and Metabolism, Peking University First Hospital, Beijing 100034, China; 13. Department of Endocrinology and Metabolism, Henan Provincial People's Hospital, Zhengzhou 450003, Henan, China; 14. Department of Endocrinology and Metabolism, Second Affiliated Hospital of Harbin Medical University, Harbin 150001, Heilongjiang, China; 15. Department of Endocrinology and Metabolism, Xiangya Second Hospital of Central South University, Changsha 410008, Hunan, China; 16. Department of Endocrinology and Metabolism, Xinjiang Uygur Autonomous Region Hospital, Urumqi 830001, Xinjiang, China; 17. Department of Epidemiology and Statistics, Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, School of Basic Medicine, Peking Union Medical College, Beijing 100730, China

Abstract

Objective To study the effectiveness of waist circumference cut-off values in predicting the prevalence of metabolic syndrome (MetS) and risk factors in adults in China.

Methods A cross-sectional survey was condcuted in 14 provinces (autonomous region, municipality) in China. A total of 47 325 adults aged ≥20 years were selected by multistage stratified sampling, and questionnaire survey and physical and clinical examination were conducted among them. MetS was defined according to the International Diabetes Federation (IDF) criteria and modified IDF criteria.

*This work was supported by grants from the Chinese Medical Association Foundation and Chinese Diabetes Society.

#Correspondence should be addressed to SHAN Zhong Yan, Tel: 86-24-83283298, Fax: 86-24-83283073, E-mail: shanzhongyan@medmail.com.cn

$ZHOU Hai Cheng and LAI Ya Xin contributed equally to this paper.

Biographical notes of the first authors: ZHOU Hai Cheng, male, born in 1981, doctorial student and working at Department of Endocrinology, First Affiliated Hospital of Dalian Medical University, majoring in metabolic syndrome and insulin resistance; LAI Ya Xin, male, born in 1981, PhD, majoring in thyrotropin and metabolic syndrome.

Received: December 4, 2013; Accepted: February 14, 2014

Results The age-standardized prevalence of MetS was 24.2% (22.1% in men and 25.8% in women) and 19.5% (22.1% in men and 18.0% in women) according to the IDF criteria and modified IDF criteria respectively. The age-standardized prevalence of pre-MetS was 8.1% (8.6% in men and 7.8% in women) according to the modified IDF criteria. The prevalence of MetS was higher in urban residents than rural residents and in northern China residents than in southern China residents. The prevalence of central obesity was about 30% in both men and women according to the ethnicity-specific cut-off values of waist circumference for central obesity (90 cm for men and 85 cm for women). Multivariate regression analysis revealed no significant difference in risk factors between the two MetS definitions.

Conclusion Using both the modified IDF criteria and ethnicity-specific cut-off values of waist circumference can provide more useful information about the prevalence of MetS in China.

Key words: Metabolic syndrome; Waist circumference; Central obesity

Biomed Environ Sci, 2014; 27(5): 325-334 *doi: 10.3967/bes2014.057* *ISSN: 0895-3988*

www.besjournal.com (full text) *CN: 11-2816/Q*

INTRODUCTION

The prevalence of overweight has increased greatly in China due to the changed lifestyle in Chinese people. By the end of 2008, overweight or obese people in China had accounted for nearly 20% of the 1.5 billion overweight or obese people in the world[1-2]. Overweight and obesity are the major forms of metabolic syndrome (MetS) which is an important risk factor for cardiovascular disease (CVD) and diabetes[3-4]. In China, the prevalence of MetS was 9.8% in men and 17.8% in women according to the criteria of the US National Cholesterol Education Program Adult Treatment Panel (ATP III) in a cross-sectional survey conducted in 2000-2001[5]. However, ATP III criteria did not include central obesity for the diagnosis of MetS[6]. The International Diabetes Federation (IDF) definition requires abdominal obesity to be a prerequisite for the diagnosis of MetS and emphasize waist measurement as a simple screening tool[7]. The IDF criteria recognize and emphasize the ethnic differences in waist circumference. For the people of European origin, the IDF specified cut-off value of waist circumference for central obesity is ≥94 cm in men and ≥80 cm in women[7]. For Asian populations, the cut-off value of waist circumference for central obesity is ≥90 cm in men and ≥80 cm in women; but the cut-off value is ≥85 cm for Japanese men and ≥90 cm for Japanese women[8].

One study conducted in a community in Shanghai indicated that the maximal difference in waist circumference between men and women was about 5 cm[9]. Some studies suggested that the appropriate cut-off value of waist circumference for abdominal obesity in Chinese is ≥90 cm for men and ≥85 cm for women[10-12]. The largest Youden index which indicates the best trade-off between sensitivity and specificity can be assessed according to the receiver operating characteristic (ROC) curves[11]. In 2007, the Chinese Joint Committee for Developing Chinese Guidelines (JCDCG) on Prevention and Treatment of Dyslipidemia in Adults recommended a new definition of MetS[10,13] which focuses on the characteristics of metabolic disturbance in China[12]. The waist circumference cut-off value in JCDCG definition is ≥90 cm for men and ≥85 cm for women. If the prevalence of MetS in Chinese adults is analyzed according to the IDF definition, there might be significant bias because the cut-off value for central obesity in women is not suitable for Chinese women. A new modified IDF definition of MetS was proposed in this study, which uses the cut-off value of waist circumference specified in the JCDCG definition.

In this study the IDF definition and modified IDF definition were used to compare the prevalence of MetS in Chinese adults and analyze the related risk factors for MetS.

METHODS

Study Subjects

In this cross-sectional study conducted from June 2007 to May 2008, 47 325 people (18 976 men and 28 349 women) aged ≥20 years were selected by multistage stratified sampling from 152 urban communities and 112 rural villages in 14 provinces (autonomous region, municipality) i.e. Liaoning, Shanxi, Shandong, Shaanxi, Henan, Heilongjiang, Hunan, Guangzhou, Sichuan, Jiangsu, Fujian, Xinjiang, Beijing, and Shanghai. The sampling method, surveyed areas, and population were consistent with a national study[14]. After the exclusion of 2 168 persons whose data about waist circumference, triglycerides (TG), or high-density lipoprotein cholesterol (HDL-C) levels missed, 45 157 adults (17 959 men and 27 198 women), who had complete demographic information, physical examination results and laboratory data, completed the study.

The study protocol and informed consent document were approved by the institutional review board or ethics committee in each of the 14 participating centers. The subjects provided their written informed consent before data collection as in previous study[14].

Data Collection

Questionnaire survey was conducted by well-trained staff among the subjects to collect the information about their demographic characteristics, personal and family medical history and lifestyle risk factors such as cigarette smoking and alcohol consumption[15]. The interview was about the diagnosis and treatment of hypertension, diabetes, dyslipidemia and other chronic diseases. The definitions of cigarette smoking, alcohol consumption and regular leisure time physical activity has been described in previous report[14]. Socioeconomic status of the subjects, including occupation, educational level and income, was recorded. The economic development levels of the provinces (autonomous region, municipality) surveyed were determined according to their gross domestic product (GDP) per capita in 2006, i.e. developed, GDP 23 663-65 473 yuan RMB; intermediately developed, GDP 13 123-9 363 yuan RMB; and underdeveloped, GDP 6 742-12 843 yuan RMB.

Physical examinations were carried out by clinical staff, the body height, body weight, waist circumference and blood pressure of the subjects were measured by using the same standard protocol previously described[15]. Body mass index (BMI) was calculated as body weight divided by square of body height (kg/m^2).

After overnight fasting for at least 10 h, venous blood samples were collected from the subjects for the measurement of fasting plasma glucose (FPG), TG, total cholesterol, HDL-C, and low-density lipoprotein cholesterol (LDL-C). Oral glucose-tolerance tests were performed as in previous study[14]. A subject without history of diabetes was given a cup of standard 75 g glucose drink and a subject self-reporting history of diabetes was given a steamed bun containing about 80 g of complex carbohydrates. Blood samples were taken at 0, 30, and 120 min after the glucose load to measure blood glucose concentration.

The blood samples were centrifuged, plasma glucose level was measured using the hexokinase enzymatic method, serum cholesterol and TG levels were measured using commercial reagents at the clinical biochemical laboratories in provinces (autonomous region, municipality) surveyed.

Definition of MetS

The IDF criteria for MetS were used in this study[7]. MetS was defined as central obesity (waist circumference ≥90 cm in men and ≥80 cm in women) with following two or more conditions: 1. serum TG level ≥1.7 mmol/L, or receiving treatment for this lipid abnormality; 2. HDL-C level <1.03 mmol/L in men and <1.29 mmol/L in women, or receiving treatment for this lipid abnormality; 3. systolic blood pressure (SBP) ≥130 mmHg and/or diastolic blood pressure (DBP) ≥85 mmHg, or receiving treatment of previously diagnosed hypertension; and 4. FPG ≥100 mg/dL (5.6 mmol/L), or previously diagnosed type 2 diabetes. In the modified IDF criteria, the definition of central obesity is waist circumference ≥90 cm in men and ≥85 cm in women and two or more of the above conditions[7].

Based on studies conducted in China in 2002[16-17], the following central pre-obesity criteria were recommended: I.e. waist circumference 85-90 cm for men; waist circumference 80-85 cm for for women. The proposed criteria for pre-metabolic syndrome (pre-MetS) used this standard of waist circumference, together with any two or more of the other abnormal conditions included in the IDF definition[7].

Statistical Analysis

Descriptive analysis included estimation of mean values and standard deviations for continuous variables. Prevalence and frequency were expressed as percentage. Student *t*-test was conducted to compare differences of continuous variables and χ^2 test was conducted to determine significant differences in proportions among categorical variables. Age- and sex-standardized prevalence were calculated by using data on population distribution in China in 2006[18]. Multivariate logistic regression analysis was performed to determine the risk factors according to the IDF definition and modified IDF definition. Odds ratios (OR) and 95% confidence intervals (CI) were presented. All the statistical data were analyzed with SPSS 20.0 software. All the reported *P* values were two-tailed and *P* values <0.05 was considered statistically significant.

RESULTS

Demographic Characteristics

The demographic data of the subjects with and without MetS are shown in Table 1. Of the 45 157 adults recruited in the study, 11 237 and 9 022 were diagnosed with MetS according to the IDF criteria and modified IDF criteria, respectively, while 3 786 were diagnosed with pre-MetS according to the modified IDF criteria.

Prevalence of MetS

The prevalence of MetS is shown in Figure 1. The gender-standardized prevalence of MetS was 24.2% (22.1% in men and 25.8% in women) according to the IDF criteria and 19.5% (22.1% in men and 18.0% in women) according to the modified IDF criteria (Figure 1A).

According to the two definitions, the prevalence of MetS increased with age more significantly in women than in men. Due to the different waist circumference cut-off values in the modified IDF criteria, the age specific prevalence of MetS in women according to the modified IDF criteria decreased significantly compared with that according to the IDF criteria (Figure 1B). The overall gender standardized prevalence of pre-MetS was 8.1% (8.6% in men and 7.8% in women) (Figure 1A). The prevalence of pre-MetS was highest in age group 60-69 years (10.8% in men and 13.7% in women) (Figure 1C).

Table 2 and Figure 2 show the prevalence of MetS in areas with different economic development levels. The overall prevalence of MetS was lower in rural residents than in urban residents in these areas according to the IDF criteria and modified-IDF criteria (*P*<0.001). The overall prevalence of MetS was 22.1% in rural residents and 26.5% in urban residents according to the IDF criteria, while the overall prevalence of MetS was 17.7% in rural residents and 21.3% in urban residents according to the modified-IDF criteria (*P*<0.001, Figure 2A).

As shown in Figure 2B, the overall prevalence of MetS was higher in northern China than in southern China (IDF: 28.0% *vs* 19.7%; modified IDF: 23.1% *vs* 14.7%; all *P*<0.001). The prevalence of MetS in women according to the modified-IDF criteria was lower than that according to the IDF criteria.

Prevalence of Central Obesity and Different Forms of MetS

The prevalence of central obesity was 35.1% in men and 47.5% (IDF criteria) or 29.7% (modified IDF criteria) in women. Figure 3A shows the gender specific prevalence of each form of MetS in obese subjects according to the IDF criteria and modified-IDF criteria. The prevalence of elevated blood pressure or hypertension was highest among four MetS

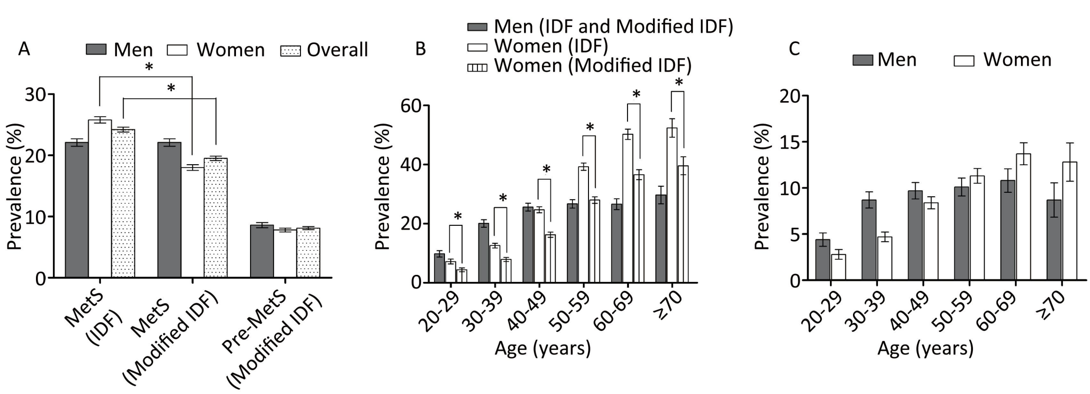

Figure 1. Prevalence of MetS and pre-MetS in adults aged ≥20 years according to IDF criteria and modified IDF criteria. (A) Gender-standardized prevalence of MetS and pre-MetS; (B) Age and gender specific prevalence of MetS; (C) Age and gender specific prevalence of pre-MetS. **P*<0.001, I bars indicate 95%.

Table 1. Demographic Characteristics of Subjects with and without MetS

Variables	Total (*n*=45 157)	IDF			Modified IDF			
		MetS (*n*=11 237)	Non-MetS (*n*=33 920)	*P*	MetS (*n*=9 022)	Pre-MetS (*n*=3 786)	Non-MetS (*n*=33 249)	*P*
Age (years)	45.0±13.7	51.1±12.4	42.9±13.5	<0.001	51.2±12.5	49.5±12.5	42.7±13.5	<0.01
Gender (n, men/women)	17 959/27 198	3 999/7 238	13 960/19 960		3 999/5 023	1 571/2 215	12 389/19 960	
Cigarette smoking-% (95%CI)	24.9 (24.5-25.3)	24.2 (23.4-25.0)	25.1 (24.6-25.6)	0.041	29.2 (28.3-30.1)	26.2 (24.8-27.6)	22.9 (22.4-23.4)	<0.001
Alcohol drinking-% (95%CI)	20.1 (19.7-20.5)	19.7 (19.0-20.4)	20.2 (19.8-20.6)	0.202	23.5 (22.6-24.4)	20.4 (19.1-21.7)	18.6 (18.2-19.0)	<0.001
Physical activity-% (95%CI)	28.1 (27.7-28.5)	32.0 (31.1-32.9)	26.8 (26.3-27.3)	<0.001	31.5 (30.5-32.5)	31.7 (30.2-33.2)	26.0 (25.5-26.5)	<0.001
College or higher level of education-% (95%CI)	22.3 (21.9-22.7)	14.7 (14.0-15.4)	24.8 (24.3-25.3)	<0.001	15.4 (14.7-16.1)	17.7 (16.5-18.9)	24.1 (23.6-24.6)	<0.001
Family history of diabetes-% (95%CI)	13.2 (12.9-13.5)	16.8 (16.1-17.5)	12.0 (11.7-12.3)	<0.001	16.6 (15.8-17.4)	16.9 (15.7-18.1)	11.5 (11.2-11.8)	<0.001
Family history of hypertension-% (95%CI)	35.4 (34.9-35.8)	42.0 (41.1-42.9)	33.2 (32.7-33.7)	<0.001	42.4 (41.4-43.4)	39.8 (38.2-41.4)	32.0 (31.5-32.5)	<0.001
Family history of dyslipidemia-% (95%CI)	10.6 (10.3-10.9)	11.3 (10.7-11.9)	10.3 (10.0-10.6)	0.005	11.4 (10.7-12.1)	10.9 (9.9-11.9)	10.0 (9.7-10.3)	<0.001
Family history of obesity-% (95%CI)	16.1 (15.8-16.4)	20.5 (19.8-21.2)	14.6 (14.2-15.0)	<0.001	21.8 (20.9-22.7)	15.7 (14.5-16.9)	14.2 (13.8-14.6)	<0.001
BMI (kg/m^2)	24.1±3.7	27.2±3.3	23.1±3.2	<0.001	27.7±3.2	24.9±2.3	23.0±3.2	<0.001
Waist circumference (cm)	81.8±10.8	91.9±8.0	78.4±9.4	<0.001	94.3±6.9	84.1±3.0	78.0±9.4	<0.001
SBP (mmHg)	122.4±19.3	134.7±19.5	118.3±17.3	<0.001	135.6±19.6	131.5±18.6	117.6±17.0	<0.01
DBP (mmHg)	78.3±11.3	84.4±11.5	76.3±10.5	<0.001	85.1±11.6	82.9±10.8	75.9±10.3	<0.01
Triglycerides (mmol/L)	1.55±1.13	2.29±1.41	1.31±0.89	<0.001	2.34±1.42	2.24±1.44	1.26±0.81	<0.01
Total cholesterol (mmol/L)	4.72±0.98	5.06±1.00	4.60±0.95	<0.001	5.07±1.00	4.96±1.00	4.59±0.95	<0.01
HDL cholesterol (mmol/L)	1.34±0.34	1.21±0.31	1.38±0.34	<0.001	1.21±0.31	1.19±0.31	1.39±0.34	0.05
LDL cholesterol (mmol/L)	2.76±0.84	3.03±0.88	2.67±0.81	<0.001	3.04±0.89	2.96±0.87	2.66±0.81	<0.001
FPG (mmol/L)	5.37±1.41	6.08±1.84	5.13±1.14	<0.001	6.11±1.83	5.94±1.84	5.09±1.09	<0.01
2h plasma glucose (mmol/L)	6.91±3.32	8.63±4.26	6.34±2.71	<0.001	8.69±4.27	8.17±4.20	6.26±2.59	<0.01

Note. Data are expressed as mean±SD or percentage.

forms in both men and women (65.4%, in men, 53.0% and 58.9% in women), followed by the prevalence of hypertriglyceridemia in men (53.6%) and the prevalence of HDL-C in women (49.1% and 50.2%). Except the prevalence of HDL-C in women, the prevalence of other forms of MetS according to the IDF criteria were lower than those according to the modified IDF criteria (P<0.001).

Figure 3B shows the gender-specific prevalence of central obesity in men according to the IDF criteria (waist circumference ≥90 cm) and in women according to IDF criteria (waist circumference ≥80 cm) and according to modified IDF criteria (waist circumference ≥85 cm). Only 9.6% of men with central obesity recruited in the study had no MetS, while 14.2% and 10.8% of women with central obesity had no MetS. More than 25% of adults (men and women) had at least one form of MetS while more than 40% of obese men and more than 30% of obese women had two forms of MetS. The prevalence of two or more forms of MetS in women with central obesity according to the modified IDF criteria was higher than that according to the IDF criteria.

Table 2. Prevalence of MetS in Areas with Different Economic Development Levels (%, 95% CI)

Items	IDF (MetS)			Modified IDF					
				MetS			Pre-MetS		
	Overall	Men	Women	Overall	Men	Women	Overall	Men	Women
Developed Rural	24.3 (23.4-25.2)	20.7 (19.3-22.1)	26.7 (25.4-28.0)	19.6 (18.7-20.5)	20.7 (19.3-22.1)	18.9 (17.8-20.0)	8.1 (7.5-8.7)	8.4 (7.4-9.4)	7.8 (7.0-8.6)
Developed Urban	27.8 (27.1-28.5)	25.7 (24.6-26.8)	29.1 (28.2-30.0)	22.4 (21.8-23.0)	25.7 (24.6-26.8)	20.4 (19.6-21.2)	9.1 (8.7-9.5)	9.7 (9.0-10.4)	8.7 (8.1-9.3)
P	<0.001	<0.001	0.003	<0.001	<0.001	0.031	0.011	0.051	0.089
Intermediately developed Rural	20.6 (19.0-22.2)	15.9 (13.8-18.0)	24.8 (22.5-27.1)	16.4 (15.0-17.8)	15.9 (13.8-18.0)	16.9 (14.9-18.9)	7.9 (6.9-8.9)	7.8 (6.3-9.3)	8.0 (6.5-9.4)
Intermediately developed Urban	25.5 (24.5-26.5)	26.5 (24.8-28.2)	24.9 (23.6-26.2)	20.3 (19.4-21.2)	26.5 (24.8-28.2)	16.7 (15.6-17.8)	8.5 (7.8-9.2)	9.0 (7.9-10.1)	8.3 (7.5-9.1)
P	<0.001	<0.001	0.974	<0.001	<0.001	0.909	0.355	0.265	0.791
Underdeveloped Rural	20.0 (18.9-21.1)	17.5 (15.9-19.1)	20.8 (19.4-22.2)	15.6 (14.6-16.6)	17.5 (15.9-19.1)	13.6 (12.4-14.8)	7.5 (6.8-8.2)	7.0 (6.0-8.0)	7.8 (6.9-8.7)
Underdeveloped Urban	23.8 (22.7-24.9)	18.7 (17.1-20.3)	28.3 (26.8-29.8)	19.3 (18.3-20.3)	18.7 (17.1-20.3)	20.5 (19.2-21.8)	7.8 (7.1-8.5)	8.7 (7.6-9.8)	7.3 (6.5-8.1)
P	<0.001	0.31	<0.001	<0.001	0.31	<0.001	0.499	0.042	0.44

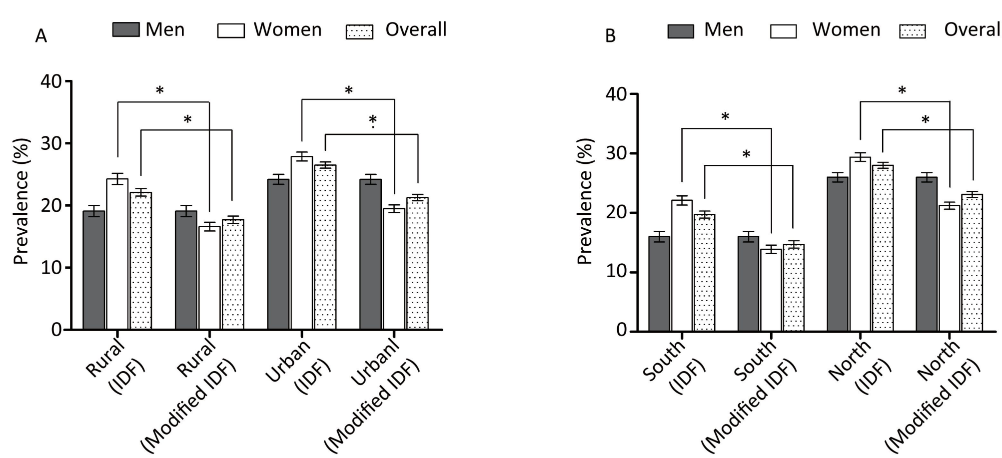

Figure 2. The area-specific prevalence of MetS in men and women according to IDF criteria and modified IDF criteria. (A) Prevalence of MetS in rural residents and urban residents; (B) Prevalence of MetS in southern China and northern China. $^{*}P$<0.001, I bars indicate 95% CI.

Multivariate Risk Assessment

Multivariate logistic regression analysis revealed that age, living in an urban area, higher economic level, current smoking, alcohol consumption, family history of diabetes, hypertension, or obesity were positively correlated with the prevalence of MetS. Education level was negatively correlated with the prevalence of MetS (Table 3). However, only age, family history of diabetes and hypertension were positively correlated with the prevalence of pre-MetS.

DISCUSSION

Central obesity is regarded as a defining factor to predict MetS due to the evidence linking ethnicity-specific waist circumference to cardiovascular disease and other forms of MetS[7]. Recent studies have shown that Asian people have less lean muscle mass and more visceral fat mass at lower BMI and waist circumference than western populations[19]. Although the IDF criteria suggests the waist circumference cut-off values of central obesity to be 90 cm for men and 80 cm for women in South Asian and China[7], it is important to determine the appropriate waist circumference cut-off values for central obesity for Chinese men and women. The prevalence, characteristics and constituent ratio of MetS are different according to the different criteria.

The high prevalence of MetS in Chinese adults is associated with the rapid economic development in China. In this study, 19.5% of adults aged ≥20 years both in rural area and in urban area had MetS according to the modified IDF criteria (22.1% of men and 18.0% of women), which was lower than that in some developed countries; e.g. 43.7% in US adults[20]. The prevalence of MetS in Europe reached 32.2% according to the IDF definition[21]. However, in a Korean survey using the same waist circumference cut-off values and modified IDF definition, the age-adjusted prevalence of MetS was significantly lower (13.5% in men and 15.0% in women)[22].

Previous studies have shown that MetS was more common in women than in men[5,20-21], but our study found opposite results in overall prevalence of MetS according to the IDF criteria and modified IDF criteria. The statistical analysis according to the age specific prevalence indicated that men aged <50 years were more likely to develop MetS than women at the same age. Meanwhile, the increase in the prevalence of MetS was more significant in women than in men, especially in women aged ≥50 years, which was consistent with the findings of previous studies[23-24]. This finding might be explained by post-menopausal status which is associated with increased risk of central obesity. Consistent with previous studies[25-26], the MetS prevalence increased significantly with age in both men and women, which might be explained by age-related increases in plasma glucose level and blood pressure[26-27].

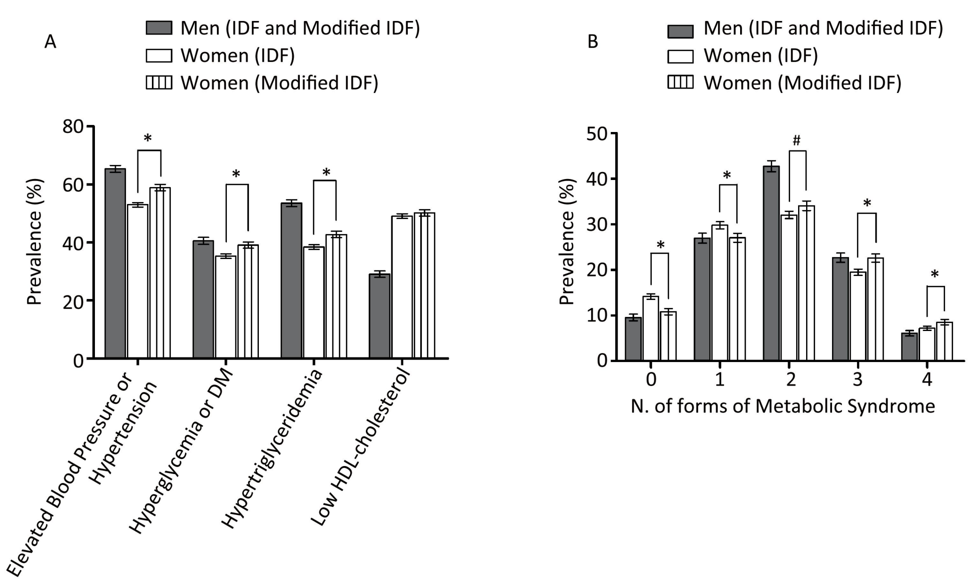

Figure 3. Gender specific prevalence of different forms of MetS in subjects with central obesity (A); Gender specific prevalence of different number of forms of MetS (B). $^{*}P$<0.001, $^{\#}P$<0.05. I bars indicate 95% CI.

Table 3. Multivariate Regression Analysis Results: Association between MetS and Sociodemographic Variables and Lifestyle in Chinese Adults

Variables	IDF (MetS)		Modified IDF (MetS)		Modified IDF (Pre-MetS)	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Sex						
Male	1 (Reference)		1		1	
Female	1.32 (1.24-1.40)	<0.001	0.80 (0.75-0.86)	<0.001	0.87 (0.79-0.95)	0.002
Age group (y)						
20-29	1		1		1	
30-39	1.84 (1.66-2.04)	<0.001	1.87 (1.67-2.09)	<0.001	1.78 (1.53-2.08)	<0.001
40-49	3.28 (2.98-3.62)	<0.001	3.16 (2.84-3.51)	<0.001	2.56 (2.21-2.96)	<0.001
50-59	5.07 (4.60-5.59)	<0.001	4.76 (4.28-5.30)	<0.001	3.16 (2.72-3.65)	<0.001
60-69	6.75 (6.07-7.50)	<0.001	6.14 (5.47-6.89)	<0.001	3.72 (3.18-4.36)	<0.001
≥70	6.88 (6.03-7.85)	<0.001	6.49 (5.64-7.48)	<0.001	3.10 (2.13-3.79)	<0.001
Area						
Rural	1		1		1	
Urban	1.27 (1.21-1.33)	<0.001	1.28 (1.22-1.35)	<0.001	1.07 (0.99-1.15)	0.058
Economic development level						
Underdeveloped	1		1		1	
Intermediately developed	1.09 (1.02-1.17)	0.014	1.08 (1.01-1.17)	0.035	1.07 (0.96-1.18)	0.206
Developed	1.08 (1.02-1.14)	0.013	1.09 (1.03-1.16)	0.005	1.03 (0.95-1.12)	0.461
Education						
< Middle school	1		1		1	
≥ Middle school	0.74 (0.70-0.78)	<0.001	0.74 (0.70-0.79)	<0.001	0.92 (0.85-1.00)	0.051
Smoking						
Never	1		1		1	
Current	1.16 (1.03-1.29)	0.012	1.18 (1.06-1.33)	0.004	1.04 (0.89-1.23)	0.618
Former	0.94 (0.87-1.01)	0.09	0.95 (0.88-1.02)	0.170	0.91 (0.82-1.01)	0.087
Alcohol drinking						
No	1		1		1	
Yes	1.25 (1.17-1.34)	<0.001	1.26 (1.18-1.35)	<0.001	1.01 (0.92-1.12)	0.821
Physical activity						
No	1		1		1	
Yes	0.95 (0.90-0.99)	0.033	0.92 (0.87-0.97)	0.003	1.03 (0.95-1.11)	0.449
Family history of diabetes						
No	1		1		1	
Yes	1.31 (1.22-1.39)	<0.001	1.23 (1.15-1.32)	<0.001	1.32 (1.20-1.45)	<0.001
Family history of hypertension						
No	1		1		1	
Yes	1.31 (1.24-1.37)	<0.001	1.30 (1.23-1.38)	<0.001	1.16 (1.07-1.25)	<0.001
Family history of dyslipidemia						
No	1		1		1	
Yes	0.91 (0.84-0.98)	0.018	0.90 (0.83-0.98)	0.017	0.99 (0.88-1.12)	0.903
Family history of obesity						
No	1		1		1	
Yes	1.48 (1.39-1.57)	<0.001	1.61 (1.51-1.72)	<0.001	0.90 (0.81-0.99)	0.029

Insulin resistance is believed to be the underlying mechanism of MetS, and central obesity may play an important role in the pathogenesis of insulin resistance and MetS[28]. The prevalence of central obesity in women was 47.5% according to the waist circumference cut-off value ≥80 cm, which was lower than the prevalence in men (35.1%). However, the prevalence of central obesity in women declined to 29.7% according to the modified waist circumference cut-off value, which may be a more reliable way to indicate the women's pre-epidemic level of central obesity. The present data show a substantial difference in the distribution of different forms of MetS, and elevated blood pressure or hypertension were the most common forms among the subjects with central obesity, which was consistent with the finding of other studies[21,26]. However, consistent with the adjustment of waist circumference cut-off values for women in our study, the prevalence of all the forms of MetS, except the prevalence of HDL-C, was higher in obese women with waist circumstance ≥85 cm than in those with waist circumstance ≥80 cm. Our data indicated that the prevalence of two or more forms of MetS in women with central obesity according to the modified IDF criteria were higher than that according to the IDF criteria. Which indicating that larger waist circumference is more closely associated with other metabolic risk factors.

Multivariate regression analysis revealed that risk factors were similar in the context of using IDF definition or modified IDF definition, which indicated there are no significant differences in risk factors between the two MetS definitions. However, only age, family history of diabetes and family history of hypertension were the risk factors for pre-MetS. Living in urban area and developed area were positively associated with MetS risk in our study, which was consistent with the findings in previous studies conducted in Asia[29-31] and Africa[32-33]. People living in urban area or developed area have higher dietary fat intake and less regular leisure time physical activity than people living in rural area and underdeveloped area[34]. Better education can benefit people in the prevention of MetS[26]. Moreover, highly educated people can get more social, economic, and psychological support[26].

There are several limitations in this study. 1, This was a cross-sectional study, so we did not perform any long-term follow-up. 2, The subjects in urban area and women were oversampled; we took this condition into account when we calculated statistical weights. 3, CVD outcomes and the incidence of diabetes were not observed. 4, The detailed data about annual income per capita were insufficient by nearly 10%, so we did not include the annual income per capita in the multivariate regression analysis of risk factors. 5, The absence of data about diet pattern made it impossible to analyze the correlation between nutrition and central obesity.

In conclusion, the prevalence of MetS was high in China according to the IDF criteria and modified IDF criteria. Using ethnicity-specific cutoff values of waist circumference, the prevalence of central obesity was about 30% in both men and women. Our findings suggest that using both modified IDF criteria and ethnicity-specific cut-off values of waist circumference can provide more useful information about the prevalence of MetS in China.

CONFLICTS OF INTEREST

There were no potential conflicts of interest relevant to this article.

AUTHOR CONTRIBUTIONS

Zhou HC, Lai YX, and Shan ZY designed the study. Shan ZY, Jia WP, Yang WY, Lu JM, Weng JP, Ji LN, Liu J, Tian HM, Ji QH, Zhu DL, Chen L, Guo XH, Zhao ZG, Li Q, Zhou ZG, Ge JP, and Shan GL performed the experiments and provided the reagents, materials and analysis tools. Zhou HC and Lai YX analyzed the data. Zhou HC, Lai YX, and Shan ZY wrote the paper.

REFERENCES

1. Wu Y. Overweight and obesity in China. BMJ, 2006; 333, 362-3.
2. WHO: World health statistics. Geneva: World Health Organization; 2012.
3. InterAct Consortium, Langenberg C, Sharp SJ, et al. Long-term risk of incident type 2 diabetes and measures of overall and regional obesity: the EPIC-InterAct case-cohort study. PLoS Med, 2012; 9, e1001230.
4. Garber AJ. The metabolic syndrome. Med Clin North Am, 2004; 88, 837-46.
5. Gu D, Reynolds K, Wu X, et al. Prevalence of the metabolic syndrome and overweight among adults in China. Lancet, 2005; 365, 1398-405.
6. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive Summary of The Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III). JAMA, 2001; 285, 2486-97.
7. Alberti KG, Zimmet P, Shaw J, et al. The metabolic syndrome-a new worldwide definition. Lancet, 2005; 366, 1059-62.
8. Grundy SM, Cleeman JI, Daniels SR, et al. Diagnosis and

management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation, 2005; 112, 2735-52.
9. Jia WP, Xiang KS, Chen L, et al. Epidemiological study on obesity and its comorbidities in urban Chinese older than 20 years of age in Shanghai, China. Obes Rev, 2002; 3, 157-65.
10. Joint Committee for Developing Chinese Guidelines on Prevention and Treatment of Dyslipidemia in Adults. Chinese guidelines on prevention and treatment of dyslipidemia in adults. Zhonghua Xin Xue Guan Bing Za Zhi, 2007; 35, 390-419. (In Chinese)
11. Bao Y, Lu J, Wang C, et al. Optimal waist circumference cutoffs for abdominal obesity in Chinese. Atherosclerosis, 2008; 201, 378-84.
12. Hou X, Lu J, Weng J, et al. Impact of waist circumference and body mass index on risk of cardiometabolic disorder and cardiovascular disease in Chinese adults: a national diabetes and metabolic disorders survey. PLoS One, 2013; 8, e57319.
13. Wang C, Hou X, Bao Y, et al. The metabolic syndrome increased risk of cardio-vascular events in Chinese-a community based study. Int J Cardiol, 2010; 139, 159-65.
14. Yang W, Lu J, Weng J, et al. Prevalence of diabetes among men and women in China. N Engl J Med, 2010; 362, 1090-101.
15. Luepker RV, Evans A, McKeigue P, et al. Cardiovascular survey methods. 3rd ed. Geneva: World Health Organization, 2004.
16. Zhai Y, Zhao WH, Zhou BF, et al. Verification of the cut-off waist circumference for defining central obesity in Chinese adults. Zhonghua Liu Xing Bing Xue Za Zhi, 2006; 27, 560-5. (In Chinese)
17. Zhai Y, Zhao WH, and Chen CM. Verification on the cut-offs of waist circumference for defining central obesity in Chinese elderly and tall adults. Zhonghua Liu Xing Bing Xue Za Zhi, 2010; 31, 621-5. (In Chinese)
18. National Bureau of Statistics of China. China statistical yearbook-2006.Beijing: China Statistics Press, 2006. (http://www. stats.gov.cn/tjsj/ndsj/2006/indexeh.htm) (In Chinese)
19. Li R, Lu W, Jia J, et al. Relationships between indices of obesity and its cardiovascular comorbidities in a Chinese population. Circ J, 2008; 72, 973-8.
20. Pan JJ, Qu HQ, Rentfro A, et al. Prevalence of metabolic syndrome and risks of abnormal serum alanine aminotransferase in Hispanics: a population-based study. PLoS One, 2011; 6, e21515.
21. Gavrila D, Salmerón D, Egea-Caparrós JM, et al. Prevalence of metabolic syndrome in Murcia Region, a southern European Mediterranean area with low cardiovascular risk and high obesity. BMC Public Health, 2011; 11, 562.
22. Park HS, Lee SY, Kim SM, et al. Prevalence of the metabolic syndrome among Korean adults according to the criteria of the International Diabetes Federation. Diabetes Care, 2006; 29, 933-4.
23. Jouyandeh Z, Nayebzadeh F, Qorbani M, et al. Metabolic syndrome and menopause. J Diabetes Metab Disord, 2013; 12, 1.
24. Chedraui P, San Miguel G, Vintimilla-Sigüenza I, et al. The metabolic syndrome and its components in postmenopausal women. Gynecol Endocrinol, 2013; 29, 563-8.
25. Hildrum B, Mykletun A, Hole T, et al. Age-specific prevalence of the metabolic syndrome defined by the International Diabetes Federation and the National Cholesterol Education Program: the Norwegian HUNT 2 study. BMC Public Health, 2007; 7, 220.
26. Alkerwi A, Donneau AF, Sauvageot N, et al. Dietary, behavioural and socio-economic determinants of the metabolic syndrome among adults in Luxembourg: findings from the ORISCAV-LUX study. Public Health Nutr, 2012; 15, 849-59.
27. Alexander CM, Landsman PB, Grundy SM. The influence of age and body mass index on the metabolic syndrome and its components. Diabetes Obes Metab, 2008; 10, 246-50.
28. Wang GR, Li L, Pan YH, et al. Prevalence of metabolic syndrome among urban community residents in China. BMC Public Health, 2013; 13, 599.
29. Lim H, Nguyen T, Choue R, et al. Sociodemographic disparities in the composition of metabolic syndrome components among adults in South Korea. Diabetes Care, 2012; 35, 2028-35.
30. Mohamud WN, Ismail AA, Sharifuddin A, et al. Prevalence of metabolic syndrome and its risk factors in adult Malaysians: results of a nationwide survey. Diabetes Res Clin Pract, 2011; 91, 239-45.
31. Delavari A, Forouzanfar MH, Alikhani S, et al. First nationwide study of the prevalence of the metabolic syndrome and optimal cutoff points of waist circumference in the Middle East: the national survey of risk factors for noncommunicable diseases of Iran. Diabetes Care, 2009; 32, 1092-7.
32. Ntandou G, Delisle H, Agueh V, et al. Abdominal obesity explains the positive rural-urban gradient in the prevalence of the metabolic syndrome in Benin, West Africa. Nutr Res, 2009; 29, 180-9.
33. Belfki H, Ali SB, Aounallah-Skhiri H, et al. Prevalence and determinants of the metabolic syndrome among Tunisian adults: results of the Transition and Health Impact in North Africa (TAHINA) project. Public Health Nutr, 2013; 16, 582-90.
34. Zuo H, Shi Z, Hu X, et al. Prevalence of metabolic syndrome and factors associated with its components in Chinese adults. Metabolism, 2009; 58, 1102-8.