

Original Article



Optimal Waist Circumference Cut-off values for Identifying Metabolic Risk Factors in Middle-aged and Elderly Subjects in Shandong Province of China*

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Abstract

Objective To study the optimal waist circumference (WC) cut-off values for identifying metabolic risk factors in middle-aged and elderly subjects in Shandong Province of China.

Methods A total of 2 873 men and 5 559 women were included in this cross-sectional study. Metabolic syndrome (MetS) was diagnosed according to the definition of Chinese Diabetes Society in 2004. The relation between WC and MetS was analyzed by multivariate logistic regression analysis. The optimal WC cut-off values were identified using the area under the ROC curve and the different diagnostic criteria for central obesity were compared.

Results The WC was the risk factor for MetS independent of BMI, blood glucose, blood lipid, and blood pressure. The optimal WC cut-off value was 83.8 cm and 91.1 cm for identifying MetS in women and men, respectively. Compared with 80 cm and 85 cm for women and men, 85 cm and 90 cm had a higher Youden index for identifying all metabolic risk factors and MetS in women and men.

Conclusion The appropriate WC cut-off value is 85 cm and 90 cm for identifying central obesity and MetS in women and men in Shandong Province of China.

Key words: Waist circumference; Metabolic syndrome; Central obesity

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INTRODUCTION

Metabolic syndrome (MetS) is a clustering of metabolic abnormalities characterized by central obesity, hypertension, dyslipidemia and glucose intolerance that collectively increase the risk of diabetes mellitus (DM), cardiovascular disease (CVD), stroke, and overall mortality^[1-2]. Although it is unclear whether MetS is attributed to a single cause, central obesity and insulin resistance are considered as its most important risk factors^[3].

Obesity, one of the most severe health problems worldwide^[4], often leads to chronic diseases such as DM, CVD, and dyslipidemia^[5-6]. Abdominal fat rather than whole-somatic obesity is considered as a more accurate predictor of CVD, metabolic disorders and death than other anthropometric measures such as body mass index (BMI)^[7]. As an indirect measure of visceral fat, measurement of waist circumference (WC) is easy, inexpensive, and non-invasive and corresponds to BMI. It is thus considered as a good diagnostic indicator of abdominal adiposity, both in clinical practice and in epidemiological study^[8-9].

However, because of ethnic differences, the diagnostic criteria for central obesity are different in different regions. Asian-specific diagnostic criteria for central obesity were adopted in the International Diabetes Federation definition and modified definition of the Third Report of the National Cholesterol Education Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (ATPIII)^[10]: the cut-off value was 80 cm and 90 cm for WC in women and men. In the guide for prevention and control of overweight and obesity in Chinese adults, the cut-off value is 80 cm and 85 cm for WC in women and men^[11]. Moreover, a recent study showed that the appropriate WC cut-off value is 85 cm and 90 cm for MetS in women and men based on the visceral fat area measured by MRI^[12]. Thus, no consensus has been reached regarding the diagnostic criteria for central obesity in Chinese population.

The present study aimed to define the optimal WC cut-off values for abdominal obesity and metabolic risk factors in order to establish the unique diagnostic criteria for central obesity in Chinese people.

METHODS

Subjects

A population-based cross-sectional^[13] survey was

carried out in Shandong Province of China from January to April 2012, during which 10 028 subjects with their age ≥ 40 years were recruited from 4 urban communities in Jinan and Jining Cities. Those who lacked of WC values and information for diagnosis of MetS (937), with their diastolic blood pressure higher than systolic blood pressure (40), their fasting plasma glucose (FPG) or 2-h plasma glucose (2hPG) ≤ 3.9 mmol/L (360), and had a history of tumors (259) were excluded from the study. However, some factors that may affect the accurate measurement of WC were not considered and included, such as thyroid function, ascites, and glucocorticoid-taking history, etc. Finally, 8 432 subjects (2 873 men) were included for analysis. This study was approved by the Ethics Committees of Shandong University Qilu Hospital and Shanghai Jiaotong University. All subjects provided their informed consent.

Data Collection

Demographic characteristics and lifestyle of subjects were recorded by face-to-face interview using a standard questionnaire. BMI was calculated as weight (kg) divided by height squared (m^2). WC was measured from the midpoint between the lower rib cage border and the anterior superior iliac spine. Blood pressure was measured 3 consecutive times at 1-min interval with an automated electronic device (OMRON Model HEM-752 FUZZY, Omron Company, Dalian, China) after the subjects had sat for at least 5 min. The mean value of the 3 measurements was used for the analysis. After at least 10 h of overnight fasting, venous blood samples were taken for measuring the serum TG, HDL-C, and FPG levels. The 2-h plasma glucose (2hPG) level was measured after the subjects completed their oral glucose tolerance test (OGTT).

Definition of MetS

Following the 2004 Chinese Diabetes Society (CDS) definition, MetS is defined as the presence of at least 3 of the following components: 1) overweight and/or obesity: $BMI \geq 25.0$ kg/m^2 ; 2) hyperglycemia: $FPG \geq 6.1$ mmol/L and/or $2hPG \geq 7.8$ mmol/L, or previously diagnosed as type 2 DM and received treatment; 3) hypertension: systolic blood pressure/diastolic blood pressure $\geq 140/90$ mmHg, or previously diagnosed as hypertension and received treatment; and 4) dyslipidemia: triglycerides level ≥ 1.7 mmol/L, and/or HDL-C level < 0.9 mmol/L (men) or < 1.0 mmol/L (women)^[13].

Statistical Analysis

Continuous variables with normal distribution are expressed as mean±SD and variables with non-normal distribution are presented as median (interquartile range). The subjects were divided into 2 groups by gender, and the differences were detected by Student's *t* test (continuous variables in normal distribution), Mann-Whitney *U*-test (skewed continuous variables), or chi-square test (categorical variables). The relation between WC and MetS was analyzed by multivariate logistic regression analysis. The appropriate WC cut-off values for identifying subjects with a single metabolic risk factor or MetS were assayed according to the area under the ROC curve. Different WC cut-off values for different diagnostic criteria were compared. Area under the ROC curve was provided with 95% confidence interval (95% CI). The optimal cut-off values were calculated by Youden index [maximum (sensitivity + specificity – 1)]. *P*<0.05 was considered statistically significant. Data were analyzed using the SPSS 16.0 (SPSS Inc., Chicago. IL).

RESULTS**Baseline Characteristics of Subjects**

The baseline characteristics of the subjects (2 873 men with a mean age of 60.34±9.87 years and 5 559 women with a mean age of 57.94±9.62 years) are listed in Table 1. The age, BMI, WC, systolic and diastolic blood pressure, the serum FPG, 2hPG, and TG levels were significantly higher while the serum HDL-C level was significantly lower in males than in females. The prevalence of MetS was significantly higher in males than in females (37.84% vs 32.20%). Except for dyslipidemia, the prevalence of MetS was higher in males than in females (Table 1).

Multivariate Logistic Regression Analysis of Odds Ratio for MetS

Multivariate logistic regression analysis showed that the WC was a risk factor (*P*<0.001) for MetS (Model 1, Table 2). When further adjusted for age and sex in Model 2, the WC also significantly increased the

Table 1. Baseline Characteristics of the Subjects

Characteristics	Total n=8 432	Female n=5 559	Male n=2 873	P-value
Age (year)	58.76±9.77	57.94±9.62	60.34±9.87	<0.001
BMI (kg/m ²)	26.28±3.49	26.17±3.58	26.50±3.31	<0.001
Waist circumference (cm)	87.02±10.07	85.17±9.92	90.60±9.35	<0.001
SBP (mmHg)	140.03±21.08	138.77±21.47	142.48±20.09	<0.001
DBP (mmHg)	80.11±11.60	78.58±11.15	83.09±11.88	<0.001
FPG (mmol/L)	6.20±1.92	6.07±1.79	6.47±2.13	<0.001
2hPG (mmol/L)	7.65±4.01	7.49±3.87	7.97±4.27	<0.001
TG (mmol/L)	1.66±1.38	1.63±1.26	1.71±1.59	0.025
HDL-C (mmol/L)	1.50±0.36	1.55±0.35	1.42±0.37	<0.001
Metabolic risk factors (%)				
Overweight/obesity	5267 (62.46)	3359 (60.42)	1908 (66.41)	<0.001
Hyperglycemia	3480 (41.27)	2166 (38.96)	1314 (45.74)	<0.001
Hypertension	4920(58.35)	3059 (55.03)	1861 (64.78)	<0.001
Dyslipidemia	2881 (34.17)	1883 (33.87)	998 (34.74)	0.428
MetS	2877 (34.12)	1790 (32.20)	1087 (37.84)	<0.001

Note. Data are expressed as mean±SD. BMI=body mass index, SBP=systolic blood pressure, DBP=diastolic blood pressure, FPG=fasting plasma glucose, TG=triglyceride, HDL-C=high-density lipoprotein cholesterol, MetS=metabolic syndrome. *P*<0.05 vs females.

Table 2. Multivariate Logistic Regression Analysis of Odds Ratio for MetS

Independent Variable	Odds Ratio (95% CI)	P-value
Model 1		
WC, per cm	1.09 (1.09-1.10)	<0.001
Model 2		
WC, per cm	1.09 (1.08-1.09)	<0.001
Model 3		
WC, per cm	1.02 (1.01-1.03)	<0.001
BMI, per unit	1.29 (1.26-1.32)	<0.001
FPG, per mmol/L	1.55 (1.50-1.61)	<0.001
TG, per mmol/L	2.17 (2.02-2.33)	<0.001
SBP, per mmHg	1.04 (1.04-1.05)	<0.001

Note. Model 1: unadjusted. Model 2 and Model 3: adjusted for sex and age.

risk of MetS, indicating that the WC is a risk factor for MetS independent of age, sex, BMI, serum FPG, TG, and SBP levels.

Optimal Cut-off Values, AUC, Sensitivity, Specificity, PPV, NPV, and Youden Index of WC Associated with Metabolic Risk Factors

The optimal cut-off values, AUC, sensitivity, specificity, PPV, NPV, and Youden index of WC associated with metabolic risk factors in females and males are listed in Table 3. The ROC of WC for identifying MetS are shown in Figure 1. The optimal WC cut-off value was 83.8 cm and 91.1 cm for identifying MetS in females and males. However, the optimal WC cut-off value was 84.1 cm, 84.2 cm,

Table 3. Optimal Cut-off Values, AUC, Sensitivity, Specificity, PPV, NPV, and Youden Index of WC Associated with Metabolic Risk Factors

Risk Factors	WC Cut-off	AUC (95% CI)	Sensitivity	Specificity	PPV (%)	NPV (%)	Youden Index
Females							
Overweight/obesity	84.1	0.836 (0.825-0.847)	0.715	0.800	84.5	64.8	0.516
	85		0.709	0.801	84.5	64.3	0.510
	80 [#]		0.834	0.665	76.0	80.0	0.499
Hyperglycemia	84.2	0.613 (0.598-0.628)	0.608	0.551	46.4	68.8	0.159
	85		0.604	0.555	46.4	68.7	0.159
	80 [#]		0.807	0.332	43.6	73.0	0.139
Hypertension	84.2	0.642 (0.627-0.656)	0.605	0.603	65.1	55.5	0.208
	85		0.600	0.607	65.1	55.4	0.207
	80 [#]		0.807	0.382	61.5	61.8	0.189
Dyslipidemia	83.3	0.624 (0.609-0.639)	0.666	0.516	41.4	75.1	0.182
	85		0.626	0.554	41.8	74.3	0.180
	80 [#]		0.831	0.333	39.0	79.4	0.164
MetS	83.8	0.736 (0.723-0.749)	0.785	0.573	46.6	84.9	0.358
	85		0.746	0.606	47.4	83.4	0.352
	80 [#]		0.863	0.471	41.3	91.6	0.334
Males							
Overweight/obesity	87.2	0.828 (0.812-0.844)	0.815	0.696	84.1	65.6	0.511
	90 [†]		0.731	0.751	85.3	58.6	0.482
	85 [†]		0.908	0.554	80.1	75.4	0.462
Hyperglycemia	91.2	0.565 (0.544-0.586)	0.512	0.585	51.0	58.7	0.097
	90 [†]		0.533	0.563	49.7	59.5	0.096
	85 [†]		0.750	0.324	47.9	60.7	0.074
Hypertension	90.2	0.622 (0.601-0.643)	0.542	0.635	73.2	43.0	0.177
	90 [†]		0.543	0.634	71.9	44.6	0.177
	85 [†]		0.802	0.337	69.0	48.0	0.139
Dyslipidemia	86.3	0.620 (0.599-0.641)	0.789	0.385	40.6	77.4	0.174
	90 [†]		0.677	0.489	41.3	74.0	0.166
	85 [†]		0.861	0.305	39.7	80.4	0.166
MetS	91.1	0.705 (0.686-0.724)	0.644	0.653	53.0	75.1	0.297
	90 [†]		0.662	0.630	49.9	78.1	0.292
	85 [†]		0.903	0.339	45.4	85.2	0.242

Note. The 2004 Chinese Diabetes Society's (CDS) definition of MetS was adopted. [#]WC value of IDF and modified ATP III criteria to define MetS, with the value of the guide for prevention and control of overweight and obesity in Chinese adults to define central obesity. ^{*}WC value of IDF and modified ATP III criteria to define MetS. [†]WC value of the guide for prevention and control of overweight and obesity in Chinese adults to define central obesity. WC: waist circumference, AUC: area under ROC curve, 95% CI: 95% confidence interval, PPV: positive predict value, NPV: negative predict value.

84.2 cm, and 83.3 cm respectively and 87.2 cm, 91.2 cm, 90.2 cm, and 86.3 cm respectively for overweight/obesity, hyperglycemia, hypertension, and dyslipidemia in females and males.

In addition, the 3 different WC cut-off values were compared in order to show which could be used as the diagnostic criteria for central obesity in Chinese population. The Youden index of 85 cm WC was higher than 80 cm WC for identifying all metabolic risk factors and MetS in females (85 cm vs 80 cm), while the Youden index of 90 cm WC was higher than 85 cm WC for identifying all metabolic risk factors and MetS in males (90 cm vs 85 cm), indicating that 85 cm WC is a better cut-off value than 80 cm WC for identifying central obesity and MetS in females and 90 cm WC is a better cut-off value than 85 cm WC for identifying central obesity and MetS in males. Besides, we also analysed the optimal cut-off value of WC of identifying overweight/obesity and MetS using $BMI \geq 24 \text{ kg/m}^2$, compared with the criteria of $BMI \geq 25 \text{ kg/m}^2$, no apparent difference was observed (Supplement Table).

DISCUSSION

Obesity, especially central obesity, plays an important role in the development of MetS and CVD^[14-16]. It was reported that WC is a better identifier of MetS than other obesity indexes, such as BMI, waist hip ratio (WHR), and waist height ratio (WHtR)^[17-18]. As a good indicator of visceral fat, WC is widely used to predict the outcome of MetS. In addition, WC cut-off values are age, gender and ethnicity specific for MetS. It was reported that the WC is 76 cm and 83 cm for detecting multiple risk

factors for MetS in Korean women and men^[19]. Oka et al.^[20] found that the best WC cut-off value is 82.3 cm and 89.8 cm for identifying MetS in Japanese women and men according to the criteria of the Japanese Society of Internal Medicine. The appropriate WC cut-off value is 80-90 cm and 87-90 cm for identifying MetS in Japanese American women and men^[21].

No consensus has been reached on the diagnostic criteria for central obesity in Chinese population. It was reported that the WC cut-off value is 82-84 cm and 86.2-88 cm for identifying cardiovascular risk factors, including diabetes, hypertension, dyslipidemia and MetS, in Chinese women and men in Taiwan Province, China^[22]. A cross-sectional study performed in Shanghai found that the optimal WC cut-off value is 85 cm and 90 cm for identifying abdominal obesity in women and men^[12]. The relation between WC cut-off value and diabetes was evaluated in another study in Shanghai^[23], showing that the optimal WC value is 82 cm and 88 cm for abdominal obesity in women and men. Moreover, a study performed in Beijing showed that the optimal WC cut-off value is 80 cm and 87 cm for identifying MetS in women and men^[24].

In the present study, the optimal WC cut-off value was 83.8 cm and 91.1 cm for identifying MetS in women and men with their AUC of 0.736 and 0.705 respectively, which corresponds to the BMI of 25 kg/m^2 with the AUC of 0.836 in females and 0.828 in males. The most accurate diagnostic criteria for central obesity in Chinese people were established by comparing the 3 different WC cut-off values. Compared with 80 cm and 85 cm for women and men, 85 cm and 90 cm had a higher Youden index for

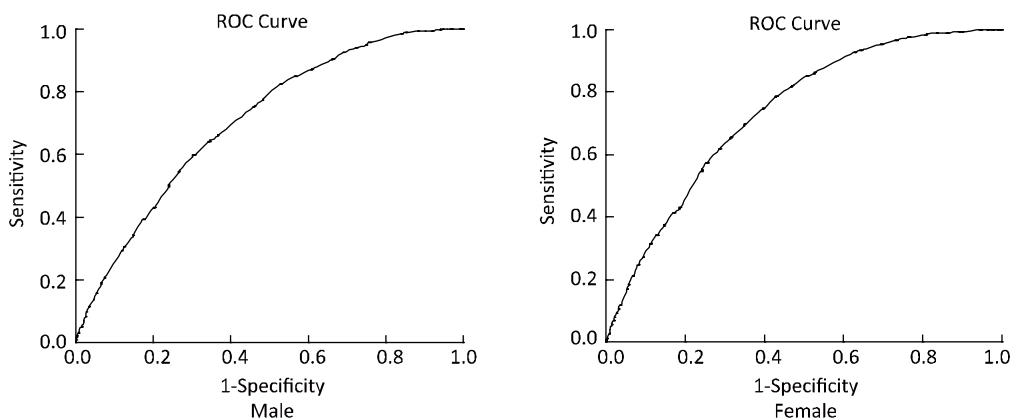


Figure 1. ROC curve of WC for identifying MetS. Sensitivity represents the true-positive results and 1-specificity represents the false-positive results.

identifying all metabolic risk factors and MetS in women and men.

There are some limitations in our study. First, variations in WC of Chinese population existed in different regions. Research based on a large sample of Chinese people showed that people living in the northern region had a larger WC than those living in eastern, western and southern regions, where people have a similar WC^[25], and Shandong Province lies in the east of China. Second, our subjects were middle-aged and elderly urban people, their age differences could not be assessed. Third, the life styles and living standards are different in different regions. Our results may not be applicable to the Chinese population as a whole. Further research is needed to determine the WC cut-off values for identifying MetS and cardiac cerebrovascular events among Chinese people.

In summary, the appropriate WC cut-off value is 85 cm and 90 cm for identifying central obesity and MetS in Chinese women and men. The current WC cut-off value for identifying central obesity and MetS in Chinese people needs to be revised and a consensus should be reached on their best diagnostic criteria.

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Supplement Table. Optimal Cut-off value, AUC, Sensitivity, Specificity, PPV, NPV, and Youden Index of WC for identifying overweight/obesity (BMI ≥ 24 kg/m²) and MetS

Risk Factors	WC Cut-off	AUC (95% CI)	Sensitivity	Specificity	PPV (%)	NPV (%)	Youden Index
Females							
Overweight/obesity	81.9	0.831 (0.81-0.843)	0.760	0.743	88.2	54.9	0.503
	85		0.644	0.841	91.1	48.2	0.485
	80 [#]		0.859	0.624	85.3	63.4	0.483
MetS	83.6	0.711 (0.697-0.724)	0.748	0.568	48.5	80.6	0.316
	85		0.707	0.602	49.1	79.1	0.309
	80 [#]		0.901	0.375	43.9	87.4	0.276
Males							
Overweight/obesity	86.3	0.827 (0.809-0.845)	0.784	0.716	90.9	47.8	0.500
	90 [†]		0.672	0.801	92.4	40.3	0.473
	85 [†]		0.815	0.668	89.3	55.1	0.483
MetS	87.9	0.686 (0.667-0.705)	0.796	0.471	51.6	76.5	0.267
	90 [†]		0.722	0.540	52.7	73.3	0.262
	85 [†]		0.852	0.390	48.8	80.8	0.242

Note. The 2004 Chinese Diabetes Society's (CDS) definition of MetS is adopted. [#]WC value of the IDF and modified ATP III criteria to define MetS, with the value of The Guide for Prevention and Control for Overweight and Obesity in Chinese Adults to define central obesity. ^{*}WC value of IDF and modified ATP III criteria to define MetS. [†]WC value of The Guide for Prevention and Control for Overweight and Obesity in Chinese Adults to define central obesity. WC: waist circumference, AUC: area under ROC curve, 95% CI: 95% confidence interval, PPV: positive predict value, NPV: negative predict value.