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ORIGINAL CONTRIBUTION

Evaluation of anthropometric indices for metabolic syndrome in Chinese adults aged 40 years and over

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Abstract
Background The prevalence of metabolic syndrome (MetS) is increasing worldwide with a marked impact in cardiovascular disease (CVD) and diabetes risk.
Aim of the study To evaluate the anthropometric indices for metabolic syndrome (MetS) and determine the optimal cut-off values of waist circumference (WC), body mass index (BMI), and waist height ratio (WHtR) for MetS in Chinese adults aged 40 years and over.
Methods A sample of Chinese adults aged 40 years and over including 430 men and 638 women was investigated. Blood pressure, weight, height, and WC were measured; HDL-cholesterol (HDL-C), Triglyceride (TG), and plasma glucose were examined. Receiver operating characteristics (ROC) curve analyses were used to evaluate the optimal cut-off point of WC, BMI, and WHtR for MetS.
Results According to the ROC curve analysis, the optimal cut-off point for WC was found to be 84.0 cm in men and 80.0 cm in women; for BMI, it was 26.0 in men and 25.0 in women; and for WHtR, it was 0.5 in both men and women. WHtR has the highest predictive value for fast plasma glucose in women, while BMI has the better prediction of dyslipidemia in men.
Conclusions Anthropometric indices (WC, BMI, and WHtR) are useful screening tools for obesity, MetS, and CVD risk factors. BMI may be a better indicator than the others for screening obesity, dyslipidemia, and other risk components in Chinese men aged 40 years and over, while WHtR may be better for Chinese women, especially among those aged 70 years and over.

Keywords Waist circumference · Body mass index · Waist height ratio · Receiver operating characteristics

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Introduction

The prevalence of metabolic syndrome (MetS) has increased dramatically with the rapid development of the economy and society; the changed lifestyle and dietary pattern has also shown to be a major risk factor for cardiovascular disease (CVD), diabetes, and other chronic diseases [1, 2].

In the 1999 WHO criteria for MetS, BMI was considered to be one of the optional criteria. As the development of the MetS definitions, waist circumference (WC) has been an optional component of MetS, according to the

Adult Treatment Panel III (ATPIII) guideline [3]. In the International Diabetes Federation (IDF) criteria (2005), central obesity is the major driver of MetS developments [3, 4]. However, in some studies, authors also suggested the use of waist-to-height ratio (WHtR) as an indicator of abdominal obesity to evaluate the variations in body frame size [5–7]. "Keep your waist circumference to less than half your height" (i.e., WHtR 0.5) [8] is a seductively simple target. According to the recent joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the study of obesity, the presence of any 3 of 5 risk factors (elevated WC, elevated triglycerides, reduced high-density lipoprotein cholesterol, elevated blood pressure, and elevated fasting glucose) constitutes a diagnosis of MetS [9].

WC, BMI, and WHtR, all of the three anthropometric measures are useful screening tools to identify obesity. Each index has different associations with obesity-related physiological and pathological processes [10]. Of many ways in measuring body fat and its distributions, anthropometric measurements still play an important role in clinical practice.

The aim of this study was to evaluate WC, BMI, and WHtR in screening MetS and its risk components by using the receiver operating characteristic (ROC) curve analysis, and to determine the optimal cut-off values of these anthropometric indices for MetS in Chinese adults aged 40 years and over.

Methods

Subjects

The subjects were from an epidemiological study on type 2 diabetes conducted in 2004 in Youyi Community, Baoshan District, Shanghai, China [11]. In that study, there were 5,071 people aged 40 years and over, accounting for 50.5% of all eligible inhabitants with permanent residence in the 10 sectors of Youyi community. All participants were face-to-face interviewed by medical staff. Informed consent was obtained from each participant before taking part in the survey. The study was approved by Ethics Committee of Ruijin Hospital, Shanghai Jiaotong University.

In addition, a random sample of 1,068 subjects was selected from the 5,071 people for extensive examinations [11]. No statistically significant differences were found between the sample (1,068 people) and the remaining (4,003 people) regarding distributions of age and gender, as well as the mean values of systolic blood pressure (SBP), diastolic blood pressure (DBP), and fasting plasma glucose. Our analyses were based on the data from these 1,068 subjects.

Investigation and measurements

Data were collected by specially trained physicians using standardized methods with stringent levels of quality control. Data on demographic characteristics (age, sex, educational level, and occupation), medical history (hypertension, diabetes, heart disease, and stroke), and lifestyle (smoking and alcohol drinking) were obtained by using a standard questionnaire administered by trained staff. Blood pressure measurements were taken after subjects had been seated for 10 min by using a mercury manometer. Triplicate measurements on the same arm were taken, with at least 30 s between readings. Each patient's SBP and DBP were calculated as the mean of three measurements. Body weight and height were measured in light indoor clothing without shoes, using a standard protocol. Height was measured with the participant standing on a firm, level surface at a right angle to the vertical board of the measurement device. A height board mounted at a 90° angle to a calibrated vertical height bar was used. WC was measured with subjects standing relaxed and in underclothes only, and at the horizontal point between the costal margin and iliac crests that yielded the minimum measurement. Each of these measurements was completed by at least two health-care workers; one took the measurements, and the other recorded the readings. A fasting (8–12 h) capillary blood sample was taken from the participants for the measurement of plasma glucose.

Definition of metabolic syndrome

The International Diabetes Federation (IDF) diagnostic criteria for metabolic syndrome [12] are listed as following:

WC $\geq$80 cm in women or $\geq$90 cm in men plus 2 or more of the following:

(a) Low HDL-C = HDL-C <1.3 mmol/L in women or <1.0 mmol/L in men;
(b) Hypertriglyceridemia = TG $\geq$1.7 mmol/L;
(c) Hypertension = known hypertensive or BP $\geq$130/85 mmHg;
(d) Dysglycemia = fasting PG $\geq$5.6 mmol/L or known to have diabetes mellitus; and

Statistical analysis

All data were expressed as mean value ± standard deviation (SD) unless other indications. Descriptive analyses were performed for all variables, and analyses of variance were used to assess differences among groups for the continuous variables. Partial correlation coefficients were conducted to estimate the relationships between obesity indicators and metabolic risk factors. All statistical analyses were performed using the Statistical Package for Social Science (SPSS for Windows). All P values were based on two-sided tests with a significance level of 0.05.

The method of receiver operating characteristic (ROC) curves was used, by plotting true-positive (sensitivity) against false-positive (1-specificity) rates, to determine the cut-off values for indices. The optimal cut-off points, determined for men and women separately, were defined as the point at which sensitivity plus specificity was maximal. The closest point to the upper left corner of the ROC curve is the one that is often selected as the best combination of true-positive rate and false-positive rate, because this is the closest point to the perfect test. The significance of the difference between two areas of ROC curves was assessed by the method described by Hanley and McNeil [13].

Results

Characteristics of subjects

Of the 1,068 subjects, there were 430 (40.3%) men and 638 (59.7%) women. The mean age (±SD) was 61.32 ± 9.85 years (range 40–88 years, median 61.0 years) (men: range 41–88 years, median 62.0 years; women: range 40–86 years, median 60.0 years). The prevalence of MetS according to the IDF criteria was 24.8%. The prevalence of MetS was significantly higher ($p < 0.001$) in women (29.0%) than in men (18.5%).

Characteristics of study subjects and the level of metabolic risk components are shown in Table 1. There were 47.4% of the subjects having two or more nonadipose components of MetS according to the criteria of IDF. Both men and women with two or more components of MetS had higher values of anthropometric variables, higher levels of blood pressure, and serum lipid ($p < 0.05$), compared with the other subjects. There was no significant difference of age ($p > 0.05$) between the subjects with and those without two or more nonadipose components of MetS, either in men or in women.

Relationship between anthropometric indices and metabolic risk factors

The partial correlation coefficients were estimated between anthropometric indices and nonadipose components of MetS according to the criteria of IDF (Table 2). All the correlations were controlled for age, education level, smoking, drinking, and occupation. All the three anthropometric indices had significant associations with the five nonadipose components of MetS in both genders. Although such relationships were statistically significant, they were just a little or fairly in extent. For the whole sample, the HDL-C was higher in a relationship with these indices, and the glucose was higher in the relationship with WHtR in women.

ROC analysis

The areas under the ROC curves (AUCs) of various anthropometric indices and metabolic risk components are summarized in Table 3. Differences of all AUC values between WC and the other two indices were rather small and not statistically significant ($p > 0.05$) in detecting metabolic risk factors, either in men or in women.

Table 1 Anthropometric indices, blood pressure, and serum lipid levels in study subjects

	Men				Women			
	Total	Two or more nonadipose components of the IDF criteria other than waist circumference			Total	Two or more nonadipose components of the IDF criteria other than waist circumference		
		Absent	Present	*p*		Absent	Present	*p*
Number of subjects	430	227	203	–	638	335	303	–
Age (years)	62.38 (9.82)	62.93 (10.58)	61.77 (8.87)	>0.05	60.62 (9.80)	60.08 (9.90)	61.22 (9.67)	>0.05
BMI (kg/m^2)	25.11 (3.26)	24.13 (3.08)	26.21 (3.11)	<0.001	25.11 (3.76)	24.16 (3.55)	26.15 (3.71)	<0.001
WHtR	0.50 (0.05)	0.48 (0.04)	0.52 (0.05)	<0.001	0.51 (0.06)	0.50 (0.06)	0.53 (0.06)	<0.001
WC (cm)	84.06 (8.95)	81.42 (8.30)	87.01 (8.75)	<0.001	79.53 (9.11)	77.04 (8.40)	82.29 (9.10)	<0.001
FPG	6.35 (1.88)	5.66 (1.23)	7.12 (2.16)	<0.001	6.05 (1.34)	5.56 (1.06)	6.60 (1.40)	<0.001
SBP (mmHg)	142.00 (21.01)	135.00 (18.44)	149.83 (21.00)	<0.001	141.06 (21.42)	135.41 (19.22)	147.30 (22.02)	<0.001
DBP (mmHg)	83.11 (11.11)	77.87 (8.61)	89.00 (10.67)	<0.001	80.62 (9.80)	77.15 (8.12)	84.45 (10.08)	<0.001
HDL-C (mmol/L)	1.36 (0.38)	1.46 (0.33)	1.26 (0.40)	<0.001	1.51 (0.41)	1.70 (0.39)	1.28 (0.31)	<0.001
TG (mmol/L)	1.60 (1.21)	1.13 (0.50)	2.11 (1.52)	<0.001	1.74 (1.55)	1.13 (0.48)	2.41 (1.98)	<0.001

Values are presented in mean (SD)

FPG fast plasma glucose

Table 2 Correlation coefficients between anthropometric indices and other components for metabolic syndrome

	BMI (kg/m^2)	WC (cm)	WHtR
All subjects[a]			
Systolic BP	0.20*	0.14*	0.16*
Diastolic BP	0.23*	0.23*	0.21*
Triglyceride	0.17*	0.20*	0.21*
HDL-cholesterol	−0.28*	−0.26*	−0.25*
FPG	0.19*	0.23*	0.24*
Men[b]			
Systolic BP	0.16*	0.11*	0.14*
Diastolic BP	0.20*	0.23*	0.22*
Triglyceride	0.20*	0.18*	0.21*
HDL-cholesterol	−0.33*	−0.26*	−0.26*
FPG	0.18*	0.21*	0.22*
Women[b]			
Systolic BP	0.22*	0.15*	0.15*
Diastolic BP	0.24*	0.22*	0.19*
Triglyceride	0.16*	0.21*	0.20*
HDL-cholesterol	−0.25*	−0.26*	−0.24*
FPG	0.21*	0.25*	0.27*

* Significant correlation $p < 0.05$

[a] Correlation analyses controlled for gender, age, educational level, occupation, smoking, and alcohol drinking

[b] Correlation analyses controlled for age, educational level, occupation, smoking, and alcohol drinking

The ROC curves for two or more nonadipose components of the IDF criteria other than WC are illustrated in Fig. 1.

The predictive values for the subjects with two or more nonadipose components of MetS according to the IDF criteria are shown in Table 4. Sensitivity, specificity, positive and negative predictive values, and the Youden index for WC, BMI, and WHtR are presented. WHtR had the highest Youden index in men, while BMI had the lowest in women.

According to the ROC curve, the optimal cut-off values in men were found to be 84.0 cm for WC, 26.0 for BMI, and 0.5 for WHtR; while in women, the values were 80.0 for WC, 25.0 for BMI, and 0.5 for WHtR.

Discussion

The present study comprising 1,068 Chinese adults aged 40 years and over aimed to comparatively evaluate WC, BMI, and WHtR as indicators of metabolic risk components and determine the optimal cut-off points of these three anthropometric parameters.

Association of WC and MetS

From the WHO criteria (1999) to IDF (2005), WC is always one component of the diagnostic criteria for MetS [4]. Though in the latest joint interim statement in 2009 [9], elevated WC was no longer regarded as a prerequisite for

Table 3 Areas under ROC curve (AUC) of various anthropometric indices and MetS risk factors

	All subjects AUC (95% CI)	Men AUC (95% CI)	Women AUC (95% CI)
Two or more nonadipose components of the IDF criteria other than waist circumference			
WC	0.67 (0.63–0.70)	0.68 (0.63–0.73)	0.67 (0.63–0.72)
BMI	0.67 (0.64–0.70)	0.69 (0.64–0.74)	0.66 (0.62–0.70)
WHtR	0.67 (0.64–0.71)	0.68 (0.63–0.73)	0.67 (0.63–0.71)
BP			
WC	0.61 (0.58–0.65)	0.60 (0.55–0.66)	0.61 (0.56–0.65)
BMI	0.62 (0.58–0.65)	0.62 (0.56–0.67)	0.62 (0.58–0.67)
WHtR	0.60 (0.56–0.63)	0.61 (0.55–0.66)	0.60 (0.55–0.64)
FPG			
WC	0.66 (0.63–0.70)	0.66 (0.61–0.72)	0.65 (0.61–0.70)
BMI	0.64 (0.60–0.67)	0.65 (0.59–0.70)	0.63 (0.59–0.68)
WHtR	0.65 (0.61–0.68)	0.66 (0.60–0.71)	0.65 (0.60–0.69)
TG			
WC	0.63 (0.59–0.66)	0.64 (0.58–0.69)	0.65 (0.61–0.69)
BMI	0.64 (0.60–0.67)	0.66 (0.60–0.70)	0.63 (0.59–0.68)
WHtR	0.65 (0.62–0.68)	0.64 (0.59–0.70)	0.65 (0.60–0.69)
HDL-C			
WC	0.57 (0.53–0.61)	0.61 (0.54–0.69)	0.62 (0.58–0.67)
BMI	0.60 (0.56–0.64)	0.62 (0.55–0.70)	0.61 (0.56–0.65)
WHtR	0.62 (0.58–0.66)	0.60 (0.52–0.68)	0.62 (0.58–0.67)

95% CI 95% confidence interval

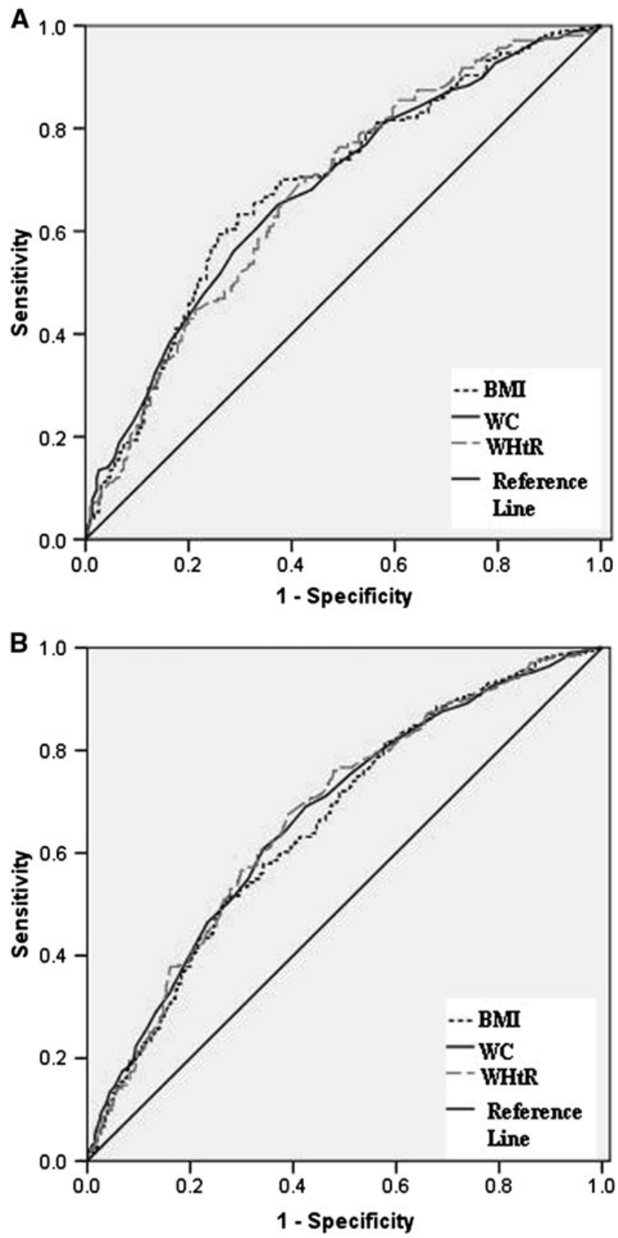

Fig. 1 ROC curves for waist circumference (*WC*), body mass index (*BMI*), and waist-to-height ratio (*WHtR*) to predict the presence of two or more components of MetS, as defined by the criteria by International Diabetes Federation (*IDF*), in men (**a**) and in women (**b**)

diagnosis of MetS, it remained one of 5 criteria. Our data also confirmed that an increasing risk with other nonadipose components for MetS was associated with the increasing WC.

According to the IDF diagnosis criteria in 2007, the prevalence of MetS was significantly higher ($p < 0.001$) in women (29.0%) than in men (18.5%) in our study. If we calculated with the optimal cut-off values of WC (84.0 cm in men and 80.0 cm in women) based on our analysis, the prevalence of MetS would be 29.0% for women and 25.6% for men and the difference between women and men would be not significant ($p > 0.05$). Therefore, our results may indicate a better identification of MetS among Chinese adult men. It was reported from a population-based study with subjects aged 20–79 years in Taiwan that the prevalence of MetS was lower in women than in men before the age group of 50 years, while higher in women than in men beyond the age group of 60 years [14].

Thus, optimal WC cut-off values will likely vary according to the population studied and should be validated according to ethnicity, as well as gender and age-specificity [15]. For a long time, the cut-off values of WC were followed in China according to those recommended by the IDF, i.e., 90 cm for men and 80 cm for women. Despite this standard is much more suitable than any other previous criteria, there are still many controversies. Bao et al. [16] estimated the appropriate cutoffs of WC were 90 cm in men and 85 cm in women, which were associated with a high risk for MetS in Chinese people aged over 50 years. According to the latest joint interim statement in 2009 [9], WC threshold for abdominal obesity in Chinese population was recommended as 85 cm or more for men and 80 cm or more for women, with which our results were quite consistent.

Association of BMI and MetS

Among the three anthropometric indices for MetS, BMI is always used to evaluate the general obesity. Whereas WC is used relatively more common than BMI, a number of investigators prefer adopting BMI. In their minds, the BMI corrected for a measure of body length would greatly enhance the ability and accuracy in measuring the risk for the development of MetS. WC has been found to be more closely associated with obesity-related metabolic abnormalities than BMI [17–19], but there is a continuous increase in the risk for MetS with increasing BMI in our investigation. Both obesity-related morbidity and mortality have been shown to increase with increasing BMI from many other population-based studies [20]. Jassen [18] suggested that their observations reinforced the importance of using both BMI and WC in clinical practice. There was no significant difference in the results from ROC curve analysis between WC and BMI ($p > 0.05$) in our study.

Our results indicated the optimal cut-off values for BMI as 26.0 for men and 25.0 for women. According to the results, BMI was a suitable indicator for dyslipidemia in men, especially for those with low HDL-C, and BMI may be better than the other two indices for indicating MetS in men aged 40 years and over.

Association of WHtR and MetS

WHtR in some communities [20, 21] have been suggested as a better screening measure for cardiovascular risk

Table 4 Prediction of MetS with WC, BMI, and WHtR

	Cut-off point	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Youden index
Men						
IDF WC cut-off point, cm	90.0	38.6	83.5	67.8	60.1	0.22
Optimal WC cut-off point, cm	84.0	65.5	63.0	61.5	67.0	0.29
Optimal WHtR cut-off point	0.5	65.5	62.1	60.9	66.6	0.28
Optimal BMI cut-off point (kg/m^2)	26.0	59.6	74.0	67.4	67.0	0.34
Women						
IDF WC cut-off point (cm)	80.0	60.6	65.7	61.6	65.1	0.26
Optimal WC cut-off point (cm)	80.0	60.6	65.7	61.6	65.1	0.26
Optimal WHtR cut-off point	0.5	67.2	60.9	60.8	67.3	0.28
Optimal BMI cut-off point (kg/m^2)	25.0	57.8	65.7	60.3	63.3	0.24

PPV positive predictive value; *NPV* negative predictive value

The optimal cut-off point was obtained from Youden index as [maximum (Youden index = sensitivity + specificity −1)]

factors and an indicator of abdominal obesity. It has been argued that WHtR is not only more sensitive than BMI but also a boundary value of 0.5 can be applied in all age groups, men as well as women, and different ethnic groups [6].

In our data, there were no significant differences of AUC values among these three indices, whereas the Youden index of WHtR is superior to the other two indices in women. The optimal point for WHtR was the same as that suggested by Ashwell and Hsieh [22]. Data from other studies suggested that WHtR was a better predictor of CVD risk factors [23]. The boundary value of 0.5 was consistent with the cut-off value as proposed [8, 24]. It was suggested that the WHtR could be more sensitive than BMI and also could be applied in all age groups. Our investigation has showed that, in women, WHtR is a better indicator for the subjects with two or more nonadipose components of MetS than WC and BMI, according to the Youden index, and it seems a better choice for women than for men. This gender difference may be attributed to the fact that endogenous androgen and estradiol metabolism, which are related to the body fat distribution, can significantly affect the adipokine secretion from adiposities [25, 26].

As a public health tool, we have shown that BMI may be a little better than WC and WHtR in measurement of risk components of MetS, especially in male subjects. It may be explained in part with that BMI is a strong predictor of skeletal muscle and highly correlated with muscle mass [27]. The relationship between abdominal obesity and MetS may be much closer than general obesity in women. Agarwal et al. suggested to develop an international standard protocol for the measurement of WC after having examined 11 ways of the measurement differing by anatomical site, posture, respiratory phase, and time since last meal [28]. The limitation of our study is its cross-sectional design. A long-term prospective cohort study may provide a better basis for evaluating the diagnostic importance of anthropometric indices—WC, BMI, and WHtR.

Conclusion

Anthropometric indices (WC, BMI, and WHtR) are useful screening tools for obesity, MetS or its components, and CVD risk factors. Though they are affected by age, gender, ethnic, or even the measurement site that can contribute to the differences, they are still valuable markers as predictors of metabolic disturbances and associated diseases. BMI may be a better indicator than the others for screening obesity, dyslipidemia, and other risk components in Chinese men aged 40 years and over, while WHtR may be better for Chinese women, especially among those aged 70 years and over.

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Conflict of interest The authors declare that they have no conflict of interest.

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