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Waist circumference, body mass index and waist to hip ratio for prediction of the metabolic syndrome in Chinese

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KEYWORDS
Waist circumference;
Body mass index;
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Metabolic syndrome;
Receiver operating characteristic

Abstract *Background and aims:* To explore the ability of waist circumference (WC), body mass index (BMI) and waist to hip ratio (WHR) to predict two or more non-adipose components of the metabolic syndrome (MetS) among individuals aged 18–85 in North China.
Methods and results: This study is a cluster sample survey of 101,510 individuals, complete data are 75,788 subjects, 59,874 males and 15,914 females. Their ages were 51.9 ± 12.7 years (males) and 48.7 ± 11.5 years (females). Receiver operating characteristic (ROC) analysis was used to examine discrimination and find optimal cut off values of WC, BMI and WHR to predict two or more non-adipose components of MetS. The area under the ROC curve (AURC) for WC (0.694) and BMI (0.692) in females showed no difference. In males BMI (0.657) had a better discrimination than WC (0.634). WHR was weaker in both sexes. The optimal cut off value of WC in males (86.5 cm) was higher than in females (82.1 cm); and that of BMI was about 24 kg/m^2 in both genders. The optimal cut off values of WC, BMI, and WHR, increased with age in both sexes.
Conclusions: BMI and WC are more useful than WHR for predicting two or more non-adipose components of MetS. Cut off values for WC in males, and those of BMI and WHR in both sexes are lower than that in present MetS criteria; WC in females is slightly higher. Cut off values of WC, BMI and WHR were increased with age in the Chinese.

Abbreviations: WC, waist circumference; BMI, body mass index; WHR, waist to hip ratio; MetS, metabolic syndrome; ROC, receiver operating characteristic; AURC, the area under the ROC curve; IDF, International Diabetes Federation; WHO, the World Health Organization; WSR, waist to stature ratio.

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Introduction

The metabolic syndrome (MetS) is the name given to a clustering of metabolic and cardiovascular risk factors that have been widely discussed for at least 20 years. Since the first official definition of the metabolic syndrome put forward by a working group of the World Health Organization (WHO) in 1999 [1], a number of different definitions have been proposed. The most widely accepted of these definitions is the original WHO definition and alternatives proposed by the European Group for the Study of Insulin Resistance (EGIR) [2], and the US National Cholesterol Education Program Adult Treatment Panel III (NCEA-ATPIII) [3]. In 1999, the WHO definition included a measure of obesity and defined obesity in terms of either BMI or WHR. The EGIR (1999) and ATPIII (2001) definitions also introduced waist circumference as a measurement of adiposity. The Chinese Diabetes Society (CDS) also introduced a MetS definition in 2004 [4] and it defined BMI as a measurement of obesity. The latest definition is the one of the International Diabetes Federation (IDF), which takes into account evidence that abdominal obesity is the important component of the metabolic syndrome [5] and proposed waist circumference as an indication of abdominal obesity [6,7].

Various alternative methods of the measurement of obesity, such as WC, BMI and WHR, have been proposed, but their role in defining MetS has not been evaluated. The aim of our study was to perform a comparative validation of WC, BMI and WHR for defining the metabolic syndrome in a Chinese population aged 18—85 in the central north of China. We used the IDF definition of MetS, excluding the measure of obesity, to evaluate which of the WC, BMI and WHR obesity measures, and an appropriate cut off, is most closely predictive of the non-adipose components of the IDF MetS definition. Since it is well known that MetS increases with age, we also investigated whether predictive ability and appropriate cut offs change with age.

Methods

Study designs and population

This study is a workforce survey. The data were obtained from a health examination of the employees of the Kailuan Company in Tangshan city in the central north of China from June 2006 to September 2007. A total of 101,510 employees (81,110 males, 20,400 females) who attended the company sponsored health examinations were recruited to the study, from both rural and urban areas. The city of Tangshan is situated 150 km southeast of Beijing and represents the Chinese population from a socioeconomic perspective. It has approximately 7,190,000 inhabitants.

Questionnaires were administered face-to-face by research doctors; Information obtained included demographic, socioeconomic, dietary, lifestyle, medical history, family medical history, alcohol use and smoking habits, physical activity, sleeping time and quality, educational levels and the income of each respondent.

In total, 101,510 people were identified to take part in the survey. We excluded individuals with too much missing or poorly recorded information. The very elderly, aged over 86 years old, were also excluded. Almost complete data were obtained from 75,788 participants aged 18—85 years of whom 59,874 were males and 15,914 females.

Standard protocols were used in all the measurements, which were performed by specially trained doctors and nurses. The study was performed according to the guidelines of the Helsinki Declaration, and was approved by the Ethics Committee of the hospital. Written informed consent was obtained from all the participants.

Anthropometric measurements

Anthropometric indices included height, weight, WC, and hip circumference. All the individuals were measured wearing light clothing without shoes and hats. Height was measured to the nearest 0.1 cm using a portable stadiometer and weight was measured to the nearest 0.1 kg using calibrated platform scales. Waist circumference (WC) was measured to the nearest 0.1 cm at the midpoint between the subcostal margin and the margin of the supracristal plane according to the diagnostic criteria of the IDF. Hip circumference (HC) was measured to the nearest 0.1 cm around the thighs, at the height of the greater trochanter, in the standing position.

Blood pressure was measured to the nearest 1 mmHg with mercury sphygmomanometers using standard recommended procedures. Three readings each of systolic and diastolic blood pressures were recorded, and taken at 5-min intervals. The average of three readings was used in the data analysis. If two of the three measurements differed by more than 5 mmHg, an additional reading was taken.

Laboratory tests

Blood samples were obtained from the antecubital vein and transfused into vacuum tubes containing EDTA in the morning after an overnight fasting period. Plasma glucose, total cholesterol, triglycerides, HDL-cholesterol, and LDL-cholesterol were measured using an autoanalyzer (Hitachi 747; Hitachi, Tokyo, Japan).

Criteria for the metabolic syndrome

According to the new IDF definition for the Chinese population, for a person to be defined as having the metabolic syndrome he/she must be diagnosed as having central obesity (defined as waist circumference $\geq$ 90 cm in males or $\geq$80 cm in females or a BMI $>$ 30 kg/m) plus any two of the following four factors: (1) triglycerides $\geq$ 1.7 mmol/L (150 mg/dL) or specific treatment for this lipid abnormality; (2) HDL-cholesterol $<$ 1.03 mmol/L (40 mg/dL) in males or $<$1.29 mmol/L (50 mg/dL) in females or specific treatment for this lipid abnormality; (3) SBP $\geq$ 130 mm Hg, or DBP $\geq$ 85 mmHg or treatment for previously diagnosed hypertension; (4) Fasting plasma glucose $\geq$ 5.6 mmol/L (100 mg/dL) or previously diagnosed type 2 diabetes [7].

For the ROC analyses the obesity requirement in this definition was omitted, so that MetS is defined in these analyses just by any two of the above factors (1)—(4), since the objective is to establish which obesity measure should be included.

Statistical analysis

Continuous data were expressed as mean ± standard deviation, and differences in means were tested using two-sided *t* tests. The differences of categorical data in different groups were compared using Pearson's Chi-square tests.

To obtain the optimal cut off point for WC, BMI and WHR in predicting the presence of two or more risk factors for the metabolic syndrome (excluding waist circumference to avoid self-correlation), we chose the point on the Receiver Operating Characteristic (ROC) curve which represented the largest sum of sensitivity and specificity [8], or equivalently, of the Youden index: sensitivity + sensitivity − 1. The area under the ROC curve (AURC), was used as a general measure of discrimination of a predictor. To assess whether the difference in the areas under two ROC curves is of statistical significance we used the procedure described in Basic principles of ROC analysis [9].

All analyses were done separately for men and women. The level for statistical significance was set at 0.05 (two-sided). The Statistical Program for Social Sciences, Version 15.0 (SPSS Inc., Chicago, IL) was used for all statistical analyses.

Results

Clinical characteristics of study individuals

The prevalence of MetS according to the IDF criterion was 19.8% in males and 25.1% in females in our study participants. Table 1 shows the general characteristics of the population studied. Because the sample size was very large all gender differences are highly statistically significant ($P < 0.001$), though some of the differences are small.

In both sexes high blood pressure was common (56.3% in males and 40.1% in females), so too hypertriglyceridemia (31.7% in males versus 26.8% in females) and T2DM, IGT, or FPG ≥ 5.6 mmol/L (29.7% in males and 20.9% in females). Low HDL-cholesterol levels were present in 20.1% of the females and 6.9% of the males, respectively.

Table 1 Characteristics of study subjects stratified by gender.

	Males	Females
Sample size	59,874	15,914
Age (years)	51.9 ± 12.7	48.7 ± 11.5
Waist circumference (WC) (cm)	87.6 ± 9.1	83.0 ± 10.3
Body mass index (BMI) (kg/m^2)	25.0 ± 3.4	24.7 ± 3.7
Waist to hip ratio (WHR)	0.90 ± 0.06	0.86 ± 0.08
Systolic blood pressure (mmHg)	130.7 ± 19.6	124.2 ± 20.7
Diastolic blood pressure (mmHg)	83.2 ± 10.8	79.0 ± 10.6
Total cholesterol (mmol/L)	4.87(4.22–5.53)	4.91 (4.27–5.58)
Triglyceride (mmol/L)	1.28(.90–1.93)	1.18(.81–1.76)
HDL-cholesterol (mmol/L)	1.5(1.27–1.76)	1.57(1.34–1.83)
LDL-cholesterol (mmol/L)	2.32(1.82–2.80)	2.12(1.63–2.67)
Fasting glucose (mmol/L)	5.12 (4.66–5.71)	4.98(4.55–5.46)
High blood pressure (%)[a]	56.3	40.1
Hypertriglyceridemia (%)[b]	31.7	26.8
Low HDL-cholesterol (%)[b]	6.9	20.1
T2DM, IGT, or FPG ≥ 5.6 mmol/L (%)	29.7	20.9
Regular alcohol drinking (%)	17.8	16.6
Current smokers (%)	38.4	1.4
Regular physical exercise (%)	15.9	13.8
Metabolic syndrome (by IDF) (%)	19.8	25.1

Data are expressed as mean ± S.D., median (interquartile range 25–75%), or percentage. HDL-c, high density lipoprotein cholesterol; T2DM, type 2 diabetes; IGT, impaired glucose tolerance; FPG, fasting plasma glucose; IDF, International Diabetes Federation.

[a] High blood pressure was diagnosed if systolic blood pressure was ≥130 mmHg, or diastolic blood pressure was ≥85 mmHg, or the subject was receiving antihypertensive medications.

[b] Hypertriglyceridemia and Low HDL-cholesterol were diagnosed according to IDF criteria or taking lipid-lowering medication.

ROC curve analyses

Fig. 1 shows ROC curves of WC, BMI and WHR to predict the presence of two or more non-adipose components of MetS as defined by the IDF criteria in females and males. In females, there is essentially no difference in the WC and BMI curves ($P > 0.05$). However, in males, BMI is evidently superior to WC ($P < 0.05$). WHR has the least predictive ability in both females and males.

Table 2 shows AURC values, optimal cut off values and associated measures for each cut off. The optimal cut off value of WC in males (86.5 cm) is higher than that in females (82.1 cm); the best cut off value for BMI is around 24 kg/m^2 both in males (24.5 kg/m^2) and females (24.2 kg/m^2); and the cut off value of WHR is 0.89 in males and 0.83 in females.

Table 3 is an analysis by age. As age increase from 18 to 85, the AURC of WC, BMI and WHR in both males and females decrease. Also, differences between different age groups were observed in the optimal cut off for WC increasing with age. However, for BMI, and WHR there was no obvious pattern with age.

Discussion

The presence of MetS can increase the risk of both type 2 diabetes mellitus (T2DM) and cardiovascular disease (CVD)

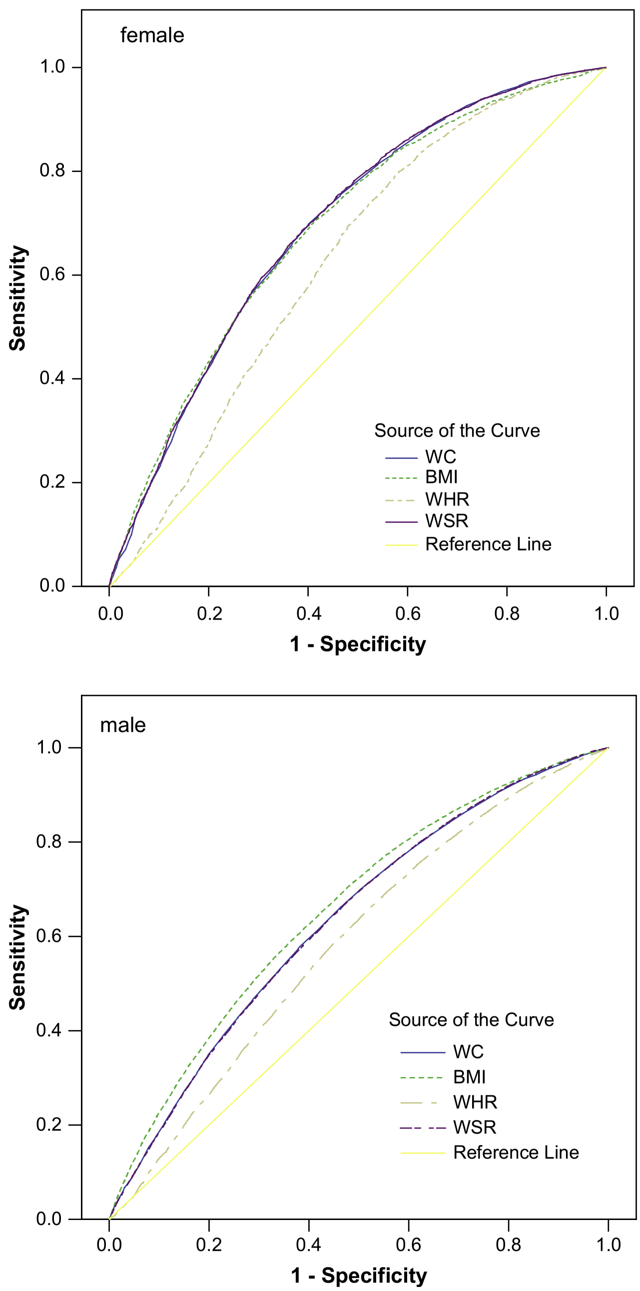

Figure 1 ROC curves of WC, BMI, WHR and WSR for the definition of two or more non-adipose components of MetS as defined by the IDF criteria in females and males.

[10,11]. At the same time its prevalence is increasing in both developed and developing countries [12–16]. We found a prevalence of 25.1% in females and 19.8% in males using the IDF diagnostic criteria, which is close to the prevalence reported from Taiwan: females (22.4%) males (18.1%) using the same IDF criteria [17]. However, the situation is complicated by there being many criteria for the diagnosis of MetS. Most definitions include some measure of obesity, but the measures and the cut off values differ. This study has evaluated and compared the extent to which three body stature measures, WC, BMI and WHR are able to predict two or more non-adipose components

Table 2 Areas under the ROC curve, cut offs, sensitivity and specificity of WC, BMI, WHR and WSR.

	AURC (95%CI)	*P*	Cut off	Sen (95% CI)	Spe (95% CI)	PPV (95% CI)	NPV (95% CI)	Youden index
Female								
WC (cm)	0.694 (0.686–0.703)	–	82.05	0.70 (0.69–0.71)	0.60 (0.59–0.61)	0.34 (0.33–0.35)	0.87 (0.86–0.88)	0.30
BMI (kg/m^2)	0.692 (0.683–0.700)	0.630	24.22	0.70 (0.69–0.71)	0.59 (0.58–0.60)	0.33 (0.32–0.34)	0.87 (0.86–0.88)	0.29
WHR	0.626 (0.617–0.635)*	<0.001	0.83	0.80 (0.79–0.81)	0.42 (0.41–0.43)	0.29 (0.28–0.30)	0.88 (0.87–0.89)	0.22
WSR	0.697 (0.688–0.705)	0.092	0.52	0.69 (0.68–0.70)	0.61 (0.60–0.62)	0.37 (0.36–0.38)	0.85 (0.84–0.86)	0.3
Male								
WC (cm)	0.634 (0.630–0.639)	–	86.45	0.66 (0.65–0.67)	0.54 (0.53–0.54)	0.34 (0.33–0.34)	0.82 (0.81–0.82)	0.20
BMI (kg/m^2)	0.657 (0.653–0.662)*	<0.001	24.54	0.69 (0.68–0.70)	0.54 (0.53–0.54)	0.37 (0.36–0.37)	0.82 (0.81–0.82)	0.23
WHR	0.586 (0.581–0.591)*	<0.001	0.89	0.66 (0.65–0.67)	0.48 (0.47–0.48)	0.31 (0.30–0.31)	0.80 (0.79–0.80)	0.14
WSR	0.634 (0.629–0.638)	0.500	0.51	0.67 (0.66–0.68)	0.53 (0.52–0.53)	0.26 (0.25–0.26)	0.87 (0.86–0.87)	0.2

AURC, areas under the ROC curve; Sen,sensitivity; Spe, specificity; PPV, positive predictive value; NPV, negative predictive value; *significance level ($P < 0.05$).

Table 3 Areas under the ROC curve and cut offs of WC, BMI, WHR and WSR by age groups.

	Female		Male	
	AURC (95%CI)	Cut off point	AURC (95%CI)	Cut off point
Age of 18—34 years				
WC (cm)	0.702 (0.660—0.745)	73.75	0.684 (0.668—0.700)	83.55
BMI (kg/m^2)	0.744 (0.703—0.785)	23.39	0.707 (0.691—0.723)	24.42
WHR	0.638 (0.594—0.681)	0.81	0.649 (0.632—0.665)*	0.88
WSR	0.695 (0.651—0.739)	0.48	0.684 (0.668—0.700)	0.49
Age of 35—49 years				
WC (cm)	0.650 (0.635—0.666)	80.05	0.625 (0.617—0.634)	86.65
BMI (kg/m^2)	0.679 (0.663—0.694)	24.28	0.662 (0.654—0.670)*	25.39
WHR	0.592 (0.576—0.608)*	0.83	0.582 (0.574—0.591)*	0.89
WSR	0.646 (0.630—0.661)	0.49	0.625 (0.616—0.633)	0.51
Age of 50—64 years				
WC (cm)	0.638 (0.624—0.652)	84.80	0.622 (0.615—0.628)	86.35
BMI (kg/m^2)	0.646 (0.633—0.660)	25.63	0.652 (0.645—0.658)*	25.11
WHR	0.584 (0.569—0.598)*	0.84	0.571 (0.564—0.578)*	0.90
WSR	0.636 (0.622—0.650)	0.53	0.618 (0.611—0.625)	0.52
Age of 65—85 years				
WC (cm)	0.632 (0.605—0.660)	87.10	0.622 (0.610—0.633)	88.05
BMI (kg/m^2)	0.647 (0.619—0.675)	24.15	0.653 (0.642—0.664)*	23.93
WHR	0.583 (0.554—0.612)	0.86	0.564 (0.553—0.575)*	0.89
WSR	0.615 (0.587—0.644)	0.55	0.618 (0.607—0.629)	0.53

*Significance level ($P < 0.05$).

(without WC) of MetS when defined by the IDF criteria, excluding a measure of obesity.

The study was conducted on a very large Chinese population; we used ROC analysis to address the issue of predictive ability. Our main finding is that WC is best able to discriminate MetS, with an optimal cut off of 82 cm for women and 86.5 cm for men. In men it is clear that WC is a better predictor than BMI, but for women BMI and WC have the same predictive ability. WHR in both sexes is a much weaker predictor.

BMI and WC are two commonly accepted anthropometric indices for predicting MetS. Also some studies report that WHR identifies patients with abdominal obesity. However, WC has been suggested as being a more practical measure of abdominal fat mass and total body fat and is more closely correlated with abdominal adipose tissue than WHR [18,19]. Yang et al. reported that the AURC of WC and BMI for obesity were high in both sexes and subjects aged 20—45 years and those of WHR were a little lower in the central south of China [20]. In our study, the AURC for WHR was lower than those for BMI and WC. Some results among Omani Arabs (ref) aged over 25 suggest that the three indices WC, BMI, WHR predicted prevalent CVD risk factors equally well. Similar results were found in an Australian study [21].

We found a gender difference of about 5 cm in the optimal cut off of WC for men and women. Our results agree very closely with those in an Iranian study (ref). However, another Chinese study suggested using the same WC cut off value (80 cm) for both men and women [22]. Others have suggested the WC cut off points of 80—85 cm for men and 75—80 cm for women, supporting a 5-cm gap between the values for men and women [23—25]. Huang et al. also reported that the cut off values of WC in predicting cardiovascular risk factors, including type 2 diabetes, hypertension, dyslipidemia and MetS, were 86.2—88.0 cm in men and 82.0—84.0 cm in women in Taiwan [26]. According to the IDF criterion for MetS, including the anthropometric WC measurement, the cut off point for men (90 cm) is 10 cm greater than that for women (80 cm) [7].

We found that in individuals older than 65 years, the cut off values of WC, BMI, and WHR are similar between males and females. These results are similar to the study in men and women aged over 60 years in Shanghai [27]. Thus the current WC cut off for Chinese women using the IDF criteria might need to be modified. The same study indicated that the BMI cut off of 24 kg/m^2 for both men and women, and a WC cut off of 85 cm for men and 80 cm for women might be appropriate in identifying adults at high risk of developing cardiovascular disease and serve as public health action thresholds in Shanghai [28]. This is in line with the cut off points of WC and BMI in our results. In our study, the cut off values for BMI were different between age groups and were similar in males and females in the same age group, the best cut off values for BMI are also around 24 kg/m^2 in males and 24.2 kg/m^2 in females, The difference may result from the divergence in dietetic habits between north and south China. Although our study has demonstrated that WHR is a weak predictor, our optimal cut offs (0.89 in men, 0.83 in women) are close to those suggested by the WHO and close to Yang et al. (0.86 in males and 0.79 in females) [20].

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