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Efficiency of anthropometric indicators of obesity for identifying cardiovascular risk factors in a Chinese population

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ABSTRACT

Objective To evaluate the predictive value of the body mass index (BMI), waist circumference (WC), and waist-to-height ratio (WHtR) for the presence of several cardiovascular risk conditions—hypertension, dyslipidaemia, metabolic syndrome (MS), and type 2 diabetes—in a Chinese population in Jinan, China.

Methods Data for a representative, cross-sectional sample of 3006 adults (mean age; range 20–74 years) in Jinan from 2007 to 2008 were studied. The association of BMI, WC, and WHtR with cardiovascular risk conditions was assessed by use of receiver operating characteristic curve (ROC) analysis and by calculating the area under the ROC (AUC) and age adjusted odds ratios (ORs) for metabolic syndrome, dyslipidaemia, type 2 diabetes, and hypertension.

Results AUC cut-off values showed that the association of WHtR and WC was higher than that for BMI for all risk conditions for both sexes, except for hypertension in men. The AUC values for WC showed a higher association with hypertension and metabolic syndrome for women than men ($p<0.01$ for hypertension, $p<0.05$ for metabolic syndrome). The ORs were highest for WHtR for metabolic syndrome, diabetes, and hypertension in women. The ORs were highest for BMI for hypertension in men.

Conclusions Compared with BMI, measures of central obesity, particularly WHtR, show a better association with obesity related cardiovascular risk conditions for both sexes, except for hypertension in men, in Jinan, China.

INTRODUCTION

Obesity is a major risk factor for cardiovascular diseases and diabetes.[1] Prospective epidemiological studies have shown increased body mass index (BMI) and waist circumference (WC) to be independent risk factors for type 2 diabetes mellitus, coronary artery disease, and hypertension.[2 3] However, the definition of obesity lacks consensus, as does the specific aspects of obesity that contribute to cardiovascular disease.[4] The major disagreement centres on whether it is the total amount or the distribution of adipose tissue that confers a greater risk of cardiovascular disease. Epidemiologic studies have shown that body mass index (BMI), a general measure of obesity, is a powerful predictor of cardiovascular disease.[5 6] However, a growing body of evidence indicates that waist circumference (WC)—a measure of central obesity—also provides information on the risk of cardiovascular disease,[7 8] and other visceral adiposity measures such as waist-to-height ratio (WHtR) appear to be better predictors of cardiometabolic risk factors than BMI.[9–12] Many studies of the association of the total amount or distribution of adipose tissue and cardiovascular risk factors are performed in the USA and Europe; few data are from mainland China, so knowledge of risk factors are lacking in China.

In this study, we aimed to define and compare the cut-off values of BMI, WC, and WHtR for several cardiovascular risk conditions—hypertension, dyslipidaemia, metabolic syndrome, and type 2 diabetes—in a Chinese population in Jinan, China.

METHODS

Study participants

The China National Diabetes and Metabolic Disorders Study, conducted from June 2007 through May 2008, was a cross-sectional study designed to provide current, reliable data on the prevalence of diabetes and associated metabolic risk factors in the adult population in China[13]; we completed the survey in Jinan, Shandong. We used a stratified sampling method to select a representative sample of the general population in six districts of Jinan, Shandong. People with sensory or intellectual deficits, or terminal illness, were excluded. The participants were mainly of Han ethnicity. A total of 3550 people aged 20–74 years were selected and invited to participate in the study; 3025 individuals took part in the survey. A telephone appointment was made a week before the survey, and all participants received an agenda the day before the survey. After excluding data for 19 people, whose 2 h plasma glucose values were lacking, we included data for 3006 people in the final analysis. The Ethics Committee of Qilu Hospital Shandong University approved the protocol. Informed consent was obtained from all subjects.

After fasting overnight, subjects were required to arrive at the community clinic in every district before 07:00 and were asked to complete a questionnaire to document the presence of hypertension, cardiovascular disease, diabetes, and the treatment of these diseases.

Blood pressure and anthropometric measurements

Blood pressure, body weight, height, and WC were measured by standard methods.[14] Body mass index was calculated as weight (kg) divided by height squared (m^2). Trained technicians performed the interview in community clinics in the subjects' residential areas.

Table 1 Descriptive characteristics of the subjects in the study population

Item	Male	Male 45+ years	Female	Female 45+ years
Numbers	1522	989	1484	954
Age (year)	46.2 (9.7)		46.5 (10.4)	
BMI (kg/m^2)	25.8 (3.3)	26.1 (3.1)	24.5 (3.2)*	25.4 (3.2)
WC (cm)	90.9 (8.7)	91.8 (8.4)	81.0 (8.8)**	83.6 (8.9)
WHtR	0.52 (0.05)	0.53 (0.06)	0.51 (0.06)**	0.52 (0.06)
SBP (mm Hg)	124 (14)	127 (15)	120 (15)**	124 (15)
DBP (mm Hg)	82 (9.2)	84 (9)	77 (8)**	78 (8)
FPG (mmol/l)	5.1 (0.9)	5.2 (0.9)	5.1 (0.9)*	5.3 (0.8)
2hPG (mmol/l)	7.1 (1.6)	8.0 (1.9)	7.0 (1.4)	7.8 (1.8)
HDL-C (mmol/l)	1.3 (0.3)	1.3 (0.3)	1.4 (0.3)**	1.4 (0.3)
LDL-C (mmol/l)	3.0 (0.8)	3.4 (0.8)	2.9 (0.8)**	3.0 (0.8)
TG (mmol/l)	1.7 (1.0)	1.8 (1.1)	1.3 (0.8)**	1.4 (0.8)
TC (mmol/l)	5.2 (0.9)	5.6 (0.7)	5.10 (0.9)*	5.5 (0.9)
Metabolic syndrome	32.1%	50.1%	17.1%*	37.0%
Dyslipidaemia	61.3%	61.7%	58.0%	60.0%
Diabetes	12.6%	14.2%	12.1%	15.0%
Hypertension	31.4%	33.7%	19.6%*	24.9%

Statistically different compared between male and female (*$p<0.05$; **$p<0.01$).
BMI, body mass index; DBP, diastolic blood pressure; FPG, fasting plasma glucose; 2hPG, 2 h plasma glucose; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides; WC, waist circumference; WHtR, waist to height ratio.

Laboratory tests

A blood sample was drawn from the antecubital vein for measuring fasting plasma glucose (FPG), total cholesterol (TC), low density lipoprotein cholesterol (LDL-C), triglycerides (TGs), and high density lipoprotein cholesterol (HDL-C). Thereafter, subjects received 75 g glucose orally, and 5 ml blood was collected at 2 h for measurement of plasma glucose. Plasma glucose was measured by the glucose dehydrogenase method, TC by the cholesterol oxidase method, TGs by the enzymatic method, and HDL-C by the direct method; LDL-C concentrations were calculated by the Friedewald equation.

Hypertension was defined as systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg or current treatment with antihypertensive medication.

Metabolic syndrome was defined as the presence of at least two of the following: serum triglycerides ≥1.70 mmol/l, HDL-C <1.04 mmol/l, measured blood pressure ≥130/85 mm Hg, and fasting blood glucose ≥5.6 mmol/l or 2 h plasma glucose of the oral glucose tolerance test (OGTT) ≥7.8 mmol/l.

Dyslipidaemia was defined as TC 5.18 mmol/l, LDL-C 3.37 mmol/l, or HDL-C <1.04 mmol/l.[15]

Diabetes was defined as fasting plasma glucose 7.0 mmol/l or 2 h plasma glucose of OGTT 11.1 mmol/l,[16] use of insulin or oral hypoglycaemic agents, or self reported history of diabetes.

Statistical analysis

Data for subjects were analysed separately by sex. Additionally, we analysed high risk age groups as defined by the American Diabetes Association[16] with ages ≥45 year in men and women. Continuous variables are expressed as mean±SD, and discrete variables as numbers and percentages. Comparisons between groups involved Student t test for continuous variables and χ^2 test for categorical data. Sensitivity and specificity were examined by ROC analysis, and the areas under the ROC curve (AUC) cut-off values were calculated for each anthropometrical parameter and risk condition. An AUC of 1 indicates perfect separation between affected and non-affected subjects, and an AUC of 0.5 indicates no discriminative value of the test. Individual cut-offs were defined as the point on the curve where the sum of sensitivity and specificity was highest. Additionally, we calculated age adjusted odds ratios (ORs) by applying logistic regression models of the different conditions in case of an increase of one SD of the respective anthropometric parameter. Statistical inference is based on 95% confidence intervals (CIs) and 5% p values, respectively. All data analyses involved use of SPSS v11.5 (SPSS Inc). Differences between two AUCs were tested with Z values: with Z >1.96, p is <0.05, and with Z >2.58, p is <0.01. For the comparison of corresponding AUCs for males and females, $Z=(A_A-A_B)/\sqrt{(S_{EA}{}^2+S_{EB}{}^2)}$, where S_E is standard error; for comparing AUCs for anthropometric indicators in predicting the same binary condition,[17] $Z=(A_A-A_B)/\sqrt{(S_{EA}{}^2+S_{EB}{}^2-2\ \gamma S_{EA}\ S_{EB})}$, where γ is the correlation coefficient of A_A and A_B.

RESULTS

Basic characteristics of the study subjects

The characteristics of the study sample are shown in table 1. Mean BMI, WC, WHtR, systolic and diastolic blood pressures, FPG, HDL-C, LDL-C, TG, and TC were higher among men than women. The age and 2 h plasma glucose of OGTT were similar between women and men. The prevalence of metabolic syndrome and hypertension was higher in men than women, that of diabetes and dyslipidaemia was similar between men and women (table 1), and the prevalence increased in the high risk age groups.

Anthropometric variables and cardiovascular risk conditions

The AUC cut-off values for men and women are presented in table 2. For men, the optimal cut-offs for BMI associated with

Table 2 Cut-off values, sensitivity, and specificity for the association of anthropometric parameters with hypertension, metabolic syndrome, dyslipidaemia, and type 2 diabetes (n=3006)

	Body mass index			Waist circumference			Waist to height ratio		
	Cut-offs (kg/m^2)	Sensitivity (%)	Specificity (%)	Cut-offs (cm)	Sensitivity (%)	Specificity (%)	Cut-offs	Sensitivity (%)	Specificity (%)
Women									
Hypertension	24.5	77.9	67.3	83.5	67.4	69.7	0.52	65.3	70.0
Diabetes	24.5	77.2	55.0	82.5	66.7	60.0	0.53	70.2	63.7
Dyslipidaemia	25.0	54.1	62	83.5	43.9	69.7	0.52	62.5	60.8
Metabolic syndrome	24.5	72.7	61.2	83.5	63.6	74.5	0.52	73.2	63.9
Men									
Hypertension	25.0	77.0	50.0	88.5	67.1	57.9	0.53	60.2	58.3
Diabetes	25.0	76.4	42.1	89.5	71.0	52.8	0.52	61.3	65.4
Dyslipidaemia	24.5	72.8	41.0	88.5	66.9	51.0	0.52	65.2	51.4
Metabolic syndrome	25.0	72.2	50.1	87.5	76.1	47.0	0.52	62.0	61.6

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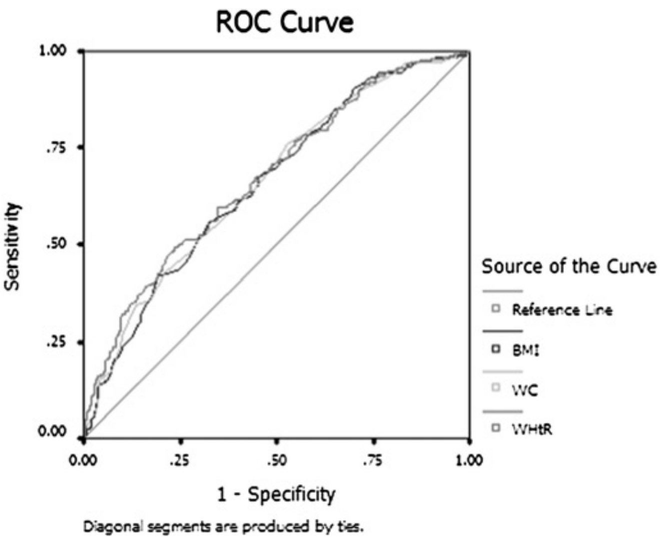

Figure 1 Male metabolic syndrome.

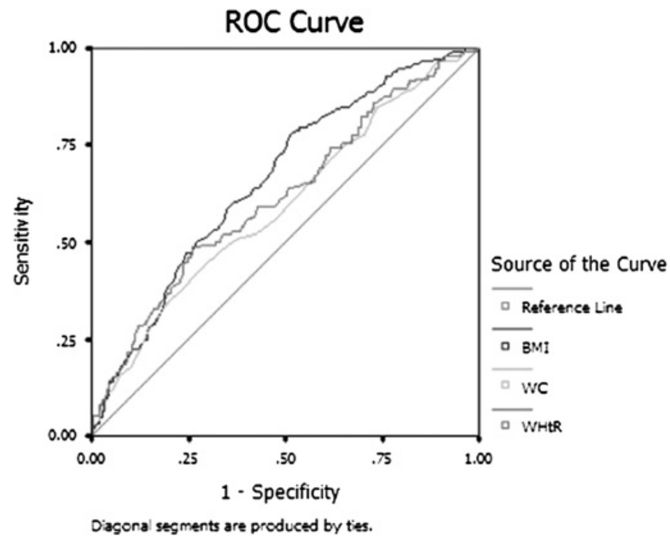

Figure 3 Male hypertension.

hypertension, diabetes, dyslipidaemia, and metabolic syndrome ranged from 24.5–25 kg/m^2, for WC from 87.5–89.5 cm, and for WHtR from 0.52–0.53. For women, the optimal cut-offs for BMI varied from 24.5–25 kg/m^2, for WC from 82.5–83.5 cm, and for WHtR from 0.52–0.53.

The ROC curves for discriminating hypertension, diabetes, dyslipidaemia, and metabolism syndrome by BMI, WC, and WHtR for males and females are shown in (figures 1–8) and their associations are shown in table 3.

For women, regarding diabetes and dyslipidaemia, the AUC values for WHtR were significantly higher than for WC and BMI; regarding hypertension and metabolism syndrome, the AUC values for WHtR and WC were similar, and both were higher than for BMI.

For men, regarding diabetes and metabolic syndrome, the AUC values for WHtR were significantly higher than for WC and BMI; regarding dyslipidaemia, the AUC values for WHtR and WC were similar, and both were higher than for BMI. However, regarding hypertension, the AUC value for BMI was significantly higher than for WHtR. In the high risk age groups, there were significant differences for dyslipidaemia in females, and for diabetes and metabolic syndrome in males.

The AUC values for BMI, WC, and WHtR were all higher for women than for men for all risk factors except dyslipidaemia; however, the AUC values for WC and WHtR were significantly higher for women than men only for hypertension and metabolic syndrome.

ORs for the different risk conditions

Table 4 shows the ORs for the different risk conditions for a one SD increase of the respective anthropometric parameters after adjustment for age. The ORs were highest for WHtR, followed by WC and BMI for metabolic syndrome, diabetes, and hypertension in women. The ORs were highest for BMI, followed by WHtR and WC for hypertension in men.

DISCUSSION

This study, part of a national survey in China, evaluated the defining cut-off values of BMI, WC, and WHtR for several cardiovascular risk conditions—hypertension, dyslipidaemia,

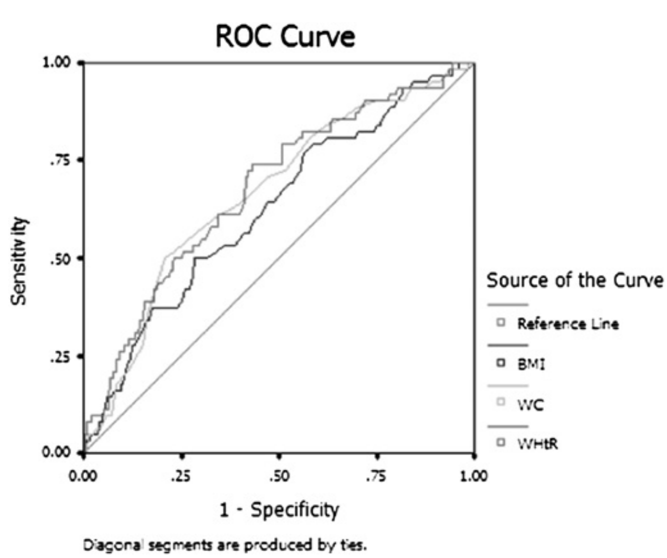

Figure 2 Male type 2 diabetes.

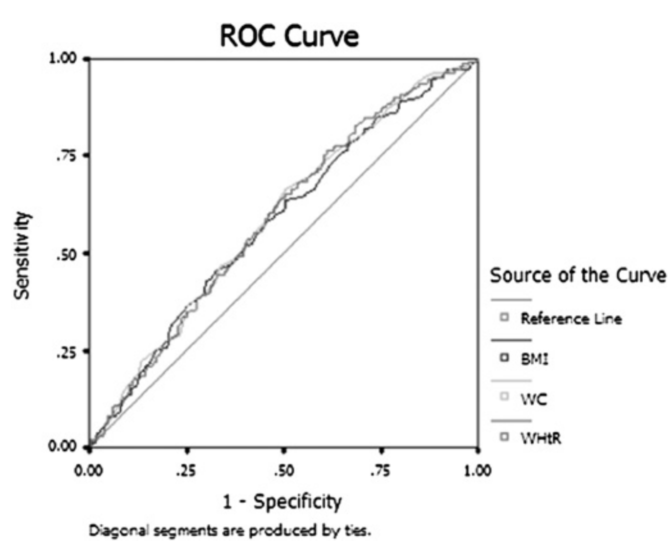

Figure 4 Male dyslipidaemia.

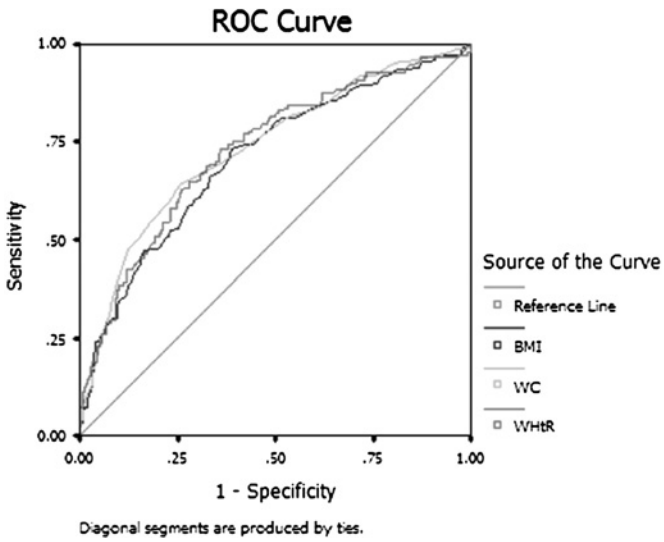

Figure 5 Female metabolic syndrome.

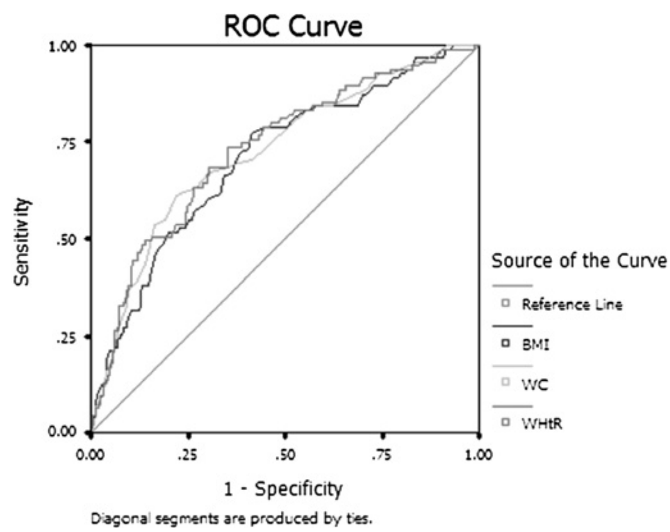

Figure 7 Female hypertension.

metabolic syndrome, and type 2 diabetes—in a Chinese population in Jinan, China. A BMI of 24.5 kg/m^2 for both men and women, a WC of 88.5 cm for men and 83.5 cm for women, and a WHtR of 0.52 for both men and women were found optimal cut-offs for defining overweight and central adiposity in this population. Our cut-offs for the Chinese population were slightly higher in Jinan than in Shanghai,[18] possibly because we examined a high risk population with a high prevalence of morbidity and obesity in China. Indeed, the prevalence of metabolic syndrome and obesity was found to be higher in residents from northern than southern China.[19]

In terms of identifying the four cardiovascular risk factors, WHtR performed significantly better than did WC, or as good as WC for males and females; and both WHtR and WC performed significantly better than did BMI, except for identifying hypertension in males. Our study supports the proposition that measures of central obesity, in particular WHtR, provide a superior tool for discriminating obesity related cardiovascular risk compared with BMI for both sexes, except for hypertension in males.

A number of mechanisms support our findings. First, from the biological perspective, most of the metabolic components for cardio-metabolic syndrome are related to visceral adiposity, especially insulin resistance. Second, from a conceptual point of view, BMI seems to represent more accurately total body fat and not regional fat. Moreover, BMI does not differentiate fat and lean body mass. Results from most of the cross-sectional studies have shown a stronger association of cardiovascular disease risk factors with central obesity (WC) than with general obesity (BMI) in China,[11] Singapore,[20] Japan,[21] and Australia,[22] which is in agreement with our results for diabetes, dyslipidaemia, and metabolic syndrome. Although WC is a simple measure of abdominal obesity, it does not take into account differences in body height. WHtR, which takes into account differences in body height, may have contributed to the higher AUC value for WHtR than WC. Several studies have shown WHtR is better for discriminating obesity related cardiovascular risk than WC,[10–12] which is in agreement with our results for diabetes in both sexes.

Regarding the ability to identify hypertension in males, BMI gave significantly better values than did WC and WHtR. Studies from Asia have shown WC is no better than BMI in discriminating hypertension.[23–25] Increased BMI caused an increase in body fluid volume, in peripheral resistance (eg, hyperinsulinaemia, and hyperactivity of the renin–angiotensin

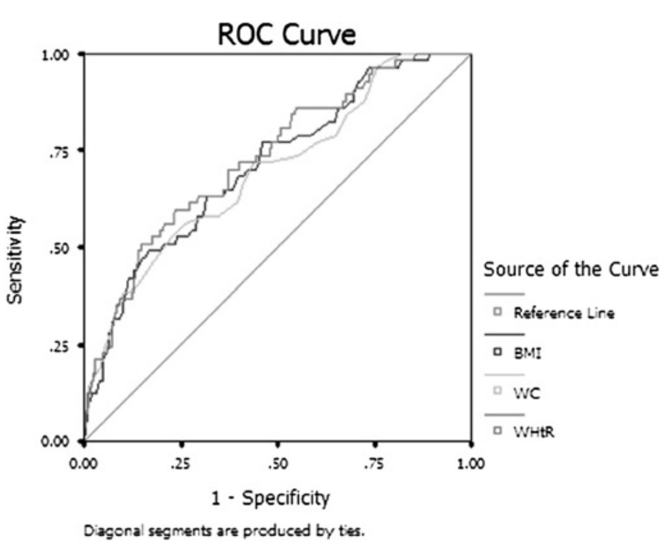

Figure 6 Female type 2 diabetes.

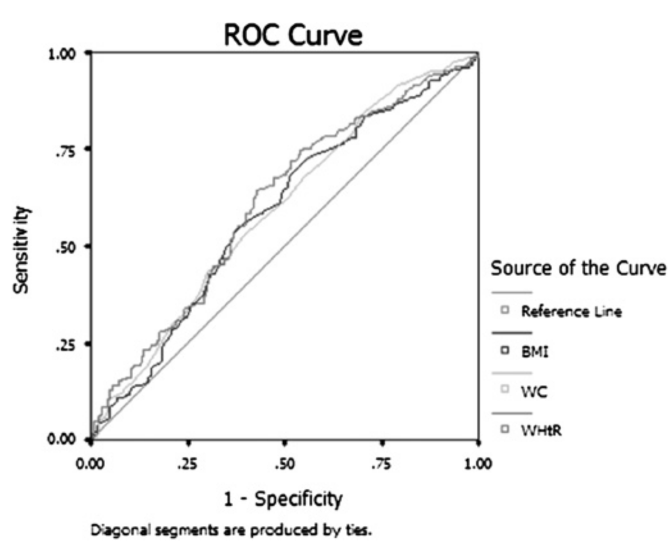

Figure 8 Female dyslipidaemia.

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Table 3 Association of anthropometric variables with hypertension, type 2 diabetes, dyslipidaemia, and metabolic syndrome (n=3006)

	Body mass index		Waist circumference		Waist to height ratio	
	AUC	95% CI	AUC	95% CI	AUC	95% CI
Female						
Hypertension	0.71	0.65 to 0.76	0.73**	0.67 to 0.78	0.73**	0.67 to 0.78
Diabetes	0.70	0.62 to 0.77	0.70	0.64 to 0.76	0.73*	0.66 to 0.79
Dyslipidaemia	0.58	0.53 to 0.63	0.59	0.54 to 0.65	0.61*	0.55 to 0.66
Metabolic syndrome	0.71	0.66 to 0.76	0.73†	0.68 to 0.79	0.73†	0.68 to 0.79
Female +45						
Hypertension	0.68	0.61 to 0.73	0.70	0.64 to 0.75	0.71	0.63 to 0.76
Diabetes	0.66	0.57 to 0.74	0.68	0.59 to 0.75	0.69	0.63 to 0.75
Dyslipidaemia	0.58	0.52 to 0.63	0.58	0.53 to 0.65	0.60*	0.55 to 0.64
Metabolic syndrome	0.70	0.64 to 0.75	0.73	0.66 to 0.77	0.73	0.67 to 0.79
Male						
Hypertension	0.66*	0.61 to 0.74	0.59**	0.54 to 0.65	0.62**	0.56 to 0.68
Diabetes	0.62	0.55 to 0.68	0.66	0.61 to 0.71	0.68*	0.61 to 0.74
Dyslipidaemia	0.58	0.53 to 0.563	0.59	0.54 to 0.63	0.59	0.54 to 0.64
Metabolic syndrome	0.66	0.61 to 0.72	0.66†	0.62 to 0.71	0.68*†	0.63 to 0.74
Male +45						
Hypertension	0.65*	0.60 to 0.70	0.59	0.53 to 0.64	0.61	0.54 to 0.63
Diabetes	0.61	0.56 to 0.66	0.64	0.59 to 0.69	0.66*	0.60 to 0.71
Dyslipidaemia	0.57	0.52 to 0.62	0.58	0.53 to 0.64	0.58	0.53 to 0.62
Metabolic syndrome	0.64	0.58 to 0.69	0.66	0.61 to 0.70	0.67*	0.62 to 0.72

*For the comparison of AUCs for anthropometric indicators in predicting the same binary condition, AUC is significantly larger than the next smaller AUC; significance was calculated only for the difference between parameters with the highest and second highest AUC.
†For the comparison of corresponding AUCs for males and females (**p<0.01; *p<0.05).

system, leads to functional constriction and structural hypertrophy), and in cardiac output. These factors are all associated with hypertension. Increased WC or WHR causes an increase in visceral fat that leads to increased leptin and insulin resistance, all factors associated with hypertension.[26] Also, compared to other races and ethnicities, Asians accumulate more total body fat and visceral fat with increased body weight.[27] In defining hypertension, the AUC values for WC were higher for women than men. One study showed obesity related hypertension with different hypertension subtypes in men and women.[28] Further studies should assess determinants of mean arterial pressure in obesity and the role of sex in the pathogenesis of obesity related hypertension.

The AUC values for BMI, WC, and WHtR were all higher for women than for men for most risk factors; these results are similar to those from the study by Schneider *et al*[10] and The Decoda Study Group,[25] although the AUC values between men and women were not compared in their studies.

Our study has some limitations. This was a cross-sectional study. Therefore, our data show only the association with present risk factor conditions but do not directly predict the future risk of cardiovascular events. To elucidate which anthropometric parameter can predict cardiovascular events, prospective studies are necessary. It is of note that AUCs of ROC analyses were not adjusted by age in our study. Therefore, the relationship between each anthropometric measure and different cardiovascular and metabolic risk factors may be confounded by the influence of ageing, underestimating the actual predictive value accounted in ROC analysis (eg, hypertension in men). In fact, our AUCs values were in general lower than studies conducted in other different western communities or eastern ethnic groups[3 10 12 29] and the recent meta-analysis by Lee *et al*.[30] Also, our subjects were from Jinan, so the study's findings cannot necessarily be representative of all the people in China.

In summary, our data suggest that a BMI of 24.5 kg/m^2 for both men and women, a WC of 88.5 cm for men and 83.5 cm for women, and a WHtR of 0.52 for both men and women are optimal cut-offs for defining overweight and central adiposity in the adult population of Jinan, China. Measures of central obesity, particularly WHtR, are better for discriminating obesity

Table 4 OR and 95% CI for risk conditions corresponding to one SD increase in body mass index, waist circumference, and waist to height ratio in women and in men

	Body mass index	Waist circumference	Waist to height ratio
Women			
Hypertension	1.31 (1.14 to −1.49)	1.33 (1.12 to 1.53)	1.43 (1.19 to 1.66)
Diabetes	1.26 (1.11 to 1.42)	1.29 (1.15 to 1.45)	1.42 (1.19 to 1.67)
Dyslipidaemia	1.12 (0.96 to 1.29)	1.13 (1.00 to 1.30)	1.11 (0.94 to 1.26)
Metabolic syndrome	1.29 (1.13 to 1.47)	1.34 (1.16 to 1.51)	1.44 (1.24 to 1.64)
Men			
Hypertension	1.39 (1.13 to 1.67)	1.32 (1.11 to 1.54)	1.34 (1.09 to 1.60)
Diabetes	1.27 (1.11 to 1.44)	1.33 (1.12 to 1.57)	1.37 (1.12 to 1.58)
Dyslipidaemia	1.14 (1.02 to 1.28)	1.17 (1.06 to 1.30)	1.19 (1.02 to 1.35)
Metabolic syndrome	1.28 (1.13 to 1.43)	1.35 (1.13 to 1.55)	1.40 (1.17 to 1.65)

Main messages

- Compared with body mass index, measures of central obesity, particularly waist-to-height ratio, show a better association with cardiovascular risk conditions in adults in Jinan, China.
- A body mass index of 24.5 kg/m^2 for men and women, a waist circumference of 88.5 cm for men and 83.5 cm for women, and a waist to height ratio of 0.52 for men and women are optimal cut-offs for defining overweight and central adiposity.

Current research questions

- Further studies should assess determinants of mean arterial pressure in obesity and the role of sex in the pathogenesis of obesity related hypertension.

related cardiovascular risk than is BMI for both men and women, except for hypertension in men.

Funding A National diabetes mellitus and metabolic syndrome survey was done in China from 2007 to 2008, and we completed the survey in Jinan, Shandong.

Competing interests None.

Patient consent Obtained.

Ethics approval The Ethics Committee of the Qilu Hospital Shandong University approved the protocol.

Provenance and peer review Not commissioned; externally peer reviewed.

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