Short Communication

Obesity criteria for identifying metabolic risks

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Criteria of obesity in the Chinese population with multiple metabolic risk factors remains unclear. The objective was to determine the best anthropometrical measurements with regard to the metabolic syndrome (MetS) and to propose optimal cut-off values. Between April and August, 2007, 3,704 men and 6,392 women aged 18-85 years were recruited from four community centers. Medical examinations included measurement of weight, height, waist circumference (WC), hip circumference, fasting blood triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), glucose concentrations, and blood pressure (BP). Body mass index (BMI), waist to hip ratio (WHR), WC and waist to stature ratio (WSR) were calculated. Four metabolic risk factors were examined: 1) high BP; 2) high levels of TG; 3) low levels of HDL-C; 4) impaired glucose tolerance. The relationships between studied indices and risk factors were analyzed using partial correlation analyses, analysis of variance (ANOVA), linear regression, and Receiver Operator Characteristic (ROC) curve analysis. The optimal cut-off values of each obesity index were calculated using ROC analysis respectively. All obesity indices were positively associated with metabolic risk factors. Area under curve (AUC) of WC was the largest for ≥ 2 risk factors after adjustment for age in both genders. Optimal cut-off points for WC were 89 cm in men, and 80.5cm, 82.5cm, and 89.5cm in < 40-yr, 40-60-yr, and > 60-yr women respectively. Waist circumference is best associated with metabolic risk factors among the studied indices in Chinese adults. Indices of abdominal obesity for older age groups tend to be higher than younger age groups in women.

Key Words: obesity, waist circumference, metabolic risk factors, ROC curve analysis, Chinese

INTRODUCTION

Obesity is a major risk factor for cardiovascular disease.[1-3] The proportion of individuals with obesity is increasing dramatically around the world during the 21st century.[4] Several studies have indicated that obesity is associated with metabolic risk factors and insulin resistance.[5,6] A series of anthropometric indices have been frequently used in studies for assessing obesity due to their low-cost and simplicity, including body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR) and waist to stature ratio (WSR). A previous study had found that anthropometric indices were associated with metabolic risk factors.[7]

Clustering of clinical and metabolic risk factors, known as "the metabolic syndrome" (MetS), is defined as a combination of four main disorders: abnormal fat distribution, dyslipidemia, hypertension, and hyperglycemia. The World Health Organization (WHO), the National Cholesterol Education Program's Third Adult Treatment Panel Report (ATP), and the International Diabetes Federation (IDF) all published their own definition of MetS, all of which included obesity as an indispensable component.[8-10] Among these definitions, obesity is measured on the basis of WC or BMI. Body mass index correlates well with overall obesity but relatively poorly with abdominal obesity, which is better associated with other indices like WC and WHR. Several studies have investigated and compared different anthropometric indices with respect to metabolic risk factors and outcomes. Waist circumference and WHR are both indicated more closely associated with metabolic risk factors and the cut-offs for WC identifying subjects with obesity are suggested to be 94 cm for men and 80 cm for women respectively.[11,12] However, these results are mainly based on data from Western populations and studies have suggested that there may exist difference between Chinese and Western people on obesity and obesity-related issues.[13,14] A study on Chinese, European and South Asian adults found that the proxy measures of abdominal obesity were uniformly associated with features of the metabolic syndrome in different ethnic groups.[15] Another study indicated ethnic descent modified the relationship between WC and metabolic risk factors, current WC targets derived from relationships in European populations were not applicable to Chinese men and women.[16] Data from the Obesity in Asia Collaboration indicated that the absolute risk of diabetes or hyperten-

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sion tended to be higher among Asians compared with-Caucasians for any given level of BMI, WC or WHR and suggested using of lower anthropometric cut-points to indicate overweight among Asians.[17,18]

A number of studies have already investigated optimal anthropometric targets in Chinese men and women.[19,20] However, the obesity criteria for the Chinese population with multiple metabolic risk factors remain in dispute.

Consequently, we designed the present study on a community-based Chinese population, in order to explore and compare the relationships between anthropometric indices and metabolic risk factors, and to propose optimal cut-off points of the best index of metabolic risk factors for different sexes by age groups in Chinese population.

MATERIALS AND METHODS

Subjects

Subjects of this study were adults (18 to 85 years old) belonging to Chinese Han ethnic group who participated in the Capital Community Cholesterol Education and Intervention Program between June and August 2007. All subjects were residents from urban and rural areas in Beijing. Four primary community centers were included, that represent the average economic characteristics of the residents of Beijing (17 street districts in urban areas and 21 townships in rural areas). From which, 10,108 individuals (3,710 men and 6,398 women) were randomly selected. After a full explanation of this study, individuals who signed written informed consent were enrolled. Of these, 10,096 adults (3,704 men, 6,392 women) completed the survey questionnaires and physical, as well as biochemical examinations. Eleven people (6 men, 5 women) refused the examination. The overall response rate was 99.8%. The Beijing Municipal Science and Technology Commission approved the protocol of this study.

Data Collection and Measurements

Data collection was performed in community clinics in the participants' residential areas. The trained staff administered a questionnaire specially designed for this survey. Information about age, sex, alcohol use, family history, and smoking history was collected. Medical history of diabetes, hypertension, stroke, and coronary disease were self-reported. Anthropometric measures were taken according to a standard protocol. Body weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively while the subject was in light clothing without shoes. Waist circumference was measured on bare skin at the level of the umbilicus. Hip circumference was measured over a light undergarment at the level of the widest diameter around the buttocks. Both WC and hip circumference were measured to the nearest 0.1cm. Body mass index was calculated as weight (kg) divided by the square of height (m^2). WSR was calculated as WC (cm) divided by height (cm) and WHR was calculated as WC (cm) divided by hip circumference (cm). Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured using a standard mercury sphygmomanometer in the right arm supporting at the level of heart. The participants rested for at least 5 minutes in seated position before BP measurements. The first and the fifth Korotkoff sound were regarded as the SBP and DBP, respectively. Identical standard of measurement was adopted by trained medical staff at each center.

Blood Examination

Blood samples were collected from all of the subjects after an overnight fast. Biochemical measurements were conducted in a routine manner in the laboratory of People's Hospital of Peking University. Concentrations of total cholesterol (TC) (Enzymatic method), high-density lipoprotein cholesterol (HDL-C) (Direct method), triglycerides (TG) (Enzymatic method), and plasma glucose (PG) (Hexokinase method) were measured. Low-density lipoprotein cholesterol (LDL-C) concentrations were calculated using the Friedewald equation for those individuals with TG <400 mg/dl: LDL-C = TC – HDL-C – TG/5.[21]

Metabolic Risk Factors

We defined 4 metabolic risk factors according to the IDF criteria: (1) high BP was defined as SBP ≥ 130mmHg and/or DBP ≥ 85 mmHg and/or on antihypertensive therapy; (2) impaired glucose tolerance was defined as plasma glucose concentration ≥5.6% or on pharmacological treatment for diabetes; (3) hypertriglyceridemia was defined as non-fasting serum concentration ≥ 1.7mmol/L; (4) low HDL-C level was defined as serum concentration < 1.0 mmol/L for men and < 1.3 mmol/L for women. The sum of risk was defined as the sum of these 4 metabolic risk factors for each participant (0–4).

Statistical Analysis

Most statistical analysis was performed with SPSS 13.0 for Windows statistical package. Both descriptive obesity indices and sum of risk were calculated in males and females. Differences for continuous variables including age, height, weight, SBP, DBP, TG, LDL-C, HDL-C, glucose, hip circumference, WC, BMI, WSR, and WHR between genders were tested with Student's t-test. Correlation coefficients between WC, BMI, WSR, and WHR were calculated by Pearson correlation analyses. Sex-specific quartiles of Obesity indexes were used for analysis. Differences for means of HDL-C, TG, Glucose, SBP, DBP, and sum of risk between quadrinomial variable for each anthropometric indices were tested by one-way ANOVA. Linear regression model was performed to assess linear trends across quartiles of obesity indexes in associating with continuous metabolic risk factors. Quartiles of obesity indexes (value of 1 to 4) were treated as continuous covariates after adjustment for age in linear regression models. Obesity indexes were tested separately in linear regression because they are highly correlated with each other. Partial correlation coefficients were calculated for BMI, WC, WSH or WHR and the 4 metabolic risk factors, as well as the sum of risk after adjustment for age.

Receiver Operating Characteristic curve (ROC curve) analyses were performed using Medcalc 9.6.2.0 (MedCalc Software). The method had been used by Dr. Zhou et al. in 2008 to select the best index in relation to hypertension.[22] The subjects were divided into three subgroups according to age as follows: <40-yr, 40-60-yr, and >60-yr age groups for both men and women. Receiver Operating Characteristic curve analysis were used to determine the

Table 1. The anthropometric indices and demographic characteristics in men and women

	Men (n=3,704)	Women (n=6,392)	*p*-values
Age (years)	52.6±13.8	52.5±13.2	0.659
SBP (mmHg)	129.1±18.5	126.0±19.7	<0.001
DBP (mmHg)	81.9±10.7	78.9±10.3	<0.001
Hip circumference (cm)	97.67±6.89	98.10±7.66	0.004
Height (cm)	167.63±6.25	156.01±5.99	<0.001
Weight (kg)	70.36±11.80	62.08±10.68	<0.001
WC (cm)	89.13±10.38	85.49±10.79	<0.001
BMI (kg/m2)	24.99±3.66	25.49±4.08	<0.001
WSR	0.532±0.061	0.549±0.073	<0.001
WHR	0.911±0.065	0.870±0.073	<0.001
TG (mmol/L)	1.63±1.73	1.49±1.24	<0.001
HDL-C (mmol/L)	1.26±0.38	1.36±0.29	<0.001
Glucose (mmol/L)	5.08±1.68	5.11±1.69	0.356

Mean ± SD

appropriate cut-off values of WC, BMI, WHR, and WSR in relation to multiple metabolic risk factors for each group. We defined the best cut-off value as the value with the highest accuracy that maximizes the Youden's index (sensitivity + specificity - 1).[23] The area under the curve (AUC) reflects the accuracy of 4 indices to identify presence or absence of multiple metabolic risk factors. Values for each AUC can be between 0 and 1. An AUC of 0 indicates that the measure cannot identify the outcome well, while a value of 1 implies perfect performance. Pairwise comparisons between AUCs were performed using z test.

All *p* values in this text were 2-tailed and $p<0.05$ was considered to be statistically significant.

Table 2. Pearson correlation coefficients between anthropometric obesity indices

		WC	BMI	WSR	WHR
Women	WC	—	0.846	0.956	0.788
	BMI	0.846	—	0.828	0.491
	WSR	0.956	0.828	—	0.808
	WHR	0.788	0.491	0.808	—
Men	WC	—	0.878	0.948	0.823
	BMI	0.878	—	0.867	0.442
	WSR	0.948	0.867	—	0.838
	WHR	0.823	0.442	0.838	—

p<0.001 for each coefficient

RESULTS

Of the 10,096 participants, there were 3,694 men (36.7%) and 6,392 women (63.3%). Table1 summarizes the anthropometric indices for obesity and demographic charac-

Table 3. The mean metabolic risk values among subgroups categorized by four anthropometric indices in quartile

	Men					Women				
BMI	<22	22-24	24-27	>27	β P value	<22	22-25	25-28	>28	β *p* value
n	925	919	936	926		1,243	1,841	1,702	1,609	
HDL-C	1.41±0.32	1.30±0.31	1.22±0.52	1.13±0.26	-0.254*	1.48±0.31	1.38±0.29	1.34±0.29	1.27±0.25	-0.156*
TG	1.05±1.01	1.42±1.51	1.84±1.74	2.19±2.20	0.220*	1.02±0.61	1.38±1.05	1.56±1.36	1.79±1.53	0.246*
SBP	124.9±18.9	126.9±17.3	130.8±17.5	133.5±18.9	0.248*	117.9±19.3	123.2±18.7	128.2±18.6	133.3±19.3	0.464*
DBP	77.9±10.4	80.5±9.8	83.2±10.4	85.6±10.7	0.252*	74.1±9.3	77.4±9.7	80.2±9.6	83.2±10.2	0.251*
Glucose	4.8±1.56	5.08±1.68	5.14±1.68	5.27±1.79	0.120*	4.77±1.37	5.06±1.73	5.21±1.80	5.33±1.70	0.192*
sum of risk	0.70±0.74	1.02±0.89	1.30±0.92	1.62±0.96	0.383*	0.61±0.79	1.01±0.99	1.30±1.03	1.60±1.07	0.452*
WC	<82	82-89	89-96	>96		<82	82-89	89-96	>96	
n	865	874	986	983		1,525	1,518	1,723	1,616	
HDL-C	1.43±0.32	1.29±0.29	1.22±0.52	1.13±0.26	-0.270*	1.47±0.29	1.37±0.27	1.34±0.30	1.27±0.27	-0.181*
TG	0.95±0.68	1.47±0.87	1.84±1.74	2.15±1.99	0.225*	0.99±0.65	1.33±0.94	1.63±1.41	1.83±1.54	0.258*
SBP	123.5±18.2	127.8±17.6	129.9±17.6	134.3±18.8	0.247*	116.2±17.3	123.6±18.3	128.4±18.2	135.2±19.9	0.461*
DBP	77.3±10.1	80.7±10.0	82.6±10.3	85.7±10.8	0.248*	74.5±9.36	77.9±9.6	80.4±9.8	82.7±10.4	0.253*
Glucose	4.74±1.37	5.04±1.66	5.14±1.68	5.36±1.89	0.133*	4.66±1.24	4.98±1.53	5.23±1.79	5.54±1.96	0.232*
sum of risk	0.62±0.68	0.97±0.85	1.33±0.93	1.63±0.96	0.398*	0.53±0.72	0.98±0.95	1.35±1.03	1.70±1.07	0.469*
WHR	<0.87	0.87-0.91	0.91-0.95	>0.95		<0.82	0.82-0.87	0.87-0.92	>0.92	
n	902	914	942	933		1,359	1,566	1,945	1,523	
HDL-C	1.39±0.32	1.28±0.45	1.21±0.41	1.17±0.28	-0.208*	1.47±0.28	1.38±0.28	1.33±0.29	1.29±0.29	-0.154*
TG	0.99±0.75	1.58±1.94	1.86±1.70	2.05±2.02	0.226*	0.97±0.63	1.32±1.08	1.59±1.28	1.85±1.54	0.256*
SBP	122.4±17.5	128.8±17.2	129.9±17.5	135.1±19.4	0.239*	115.7±15.9	122.6±17.7	128.4±18.9	135.7±20.5	0.449*
DBP	78.3±9.8	81.7±10.2	82.9±10.5	84.5±11.4	0.208*	75.4±9.4	78.1±9.9	80.2±10.0	81.5±10.6	0.198*
Glucose	4.73±1.38	4.95±1.50	5.14±0.64	5.51±2.04	0.164*	4.61±1.01	4.83±1.26	5.19±1.77	5.74±2.18	0.262*
sum of risk	0.60±0.72	1.07±0.85	1.32±0.94	1.62±0.96	0.386*	0.51±0.70	0.93±0.93	1.31±1.01	1.75±1.08	0.460*
WSR	<0.49	0.49-0.53	0.53-0.57	>0.57		<0.49	0.49-0.54	0.54-0.59	>0.59	
n	986	917	946	932		1,158	1,273	1,981	1,744	
HDL-C	1.41±0.32	1.29±0.54	1.19±0.27	1.15±0.27	-0.248*	1.48±0.29	1.38±0.29	1.35±0.29	1.29±0.28	-0.165*
TG	0.99±0.87	1.62±1.97	1.76±1.53	2.12±2.07	0.221*	0.95±0.62	1.31±0.92	1.56±1.34	1.83±1.53	0.255*
SBP	122.1±17.2	127.7±17.3	130.6±17.5	135.6±19.2	0.263*	114.3±15.9	122.9±18.2	127.7±18.0	135.8±19.9	0.469*
DBP	77.8±9.7	81.1±10.1	82.9±10.5	85.5±11.1	0.252*	74.2±9.1	77.6±9.9	80.2±9.7	82.3±10.5	0.237*
Glucose	4.74±1.39	5.06±1.72	5.18±1.78	5.34±1.77	0.130*	4.59±1.07	4.94±1.55	5.21±1.77	5.53±1.97	0.228*
sum of risk	0.59±0.70	1.07±0.87	1.33±0.91	1.62±0.97	0.390*	0.45±0.64	0.94±0.94	1.28±1.00	1.71±1.08	0.467*

* *p*<0.001; β= Linear Regression Coefficient for trend across anthropometric indices quartiles

Table 4. Age-adjusted partial correlation coefficients for BMI, WC, WHR or WSR and the 4 metabolic risk factors and the sum of risk factors for Chinese adults

	SBP	DBP	TG	HDL-C	Glu	sum of risk
Men						
WC	0.205	0.283	0.265	-0.283	0.115	0.397
BMI	0.200	0.286	0.257	-0.279	0.094	0.381
WHR	0.195	0.231	0.245	-0.223	0.140	0.355
WSR	0.227	0.279	0.249	-0.267	0.105	0.382
Women						
WC	0.253	0.282	0.213	-0.260	0.149	0.343
BMI	0.262	0.307	0.192	-0.233	0.097	0.316
WHR	0.211	0.195	0.206	-0.234	0.189	0.315
WSR	0.269	0.270	0.198	-0.243	0.144	0.329

p<0.0001 for each coefficient

teristics of the male and female participants. There was no difference in terms of the mean age between male (52.6±13.8; range, 18 to 85 years) and female (52.5±13.2; Range, 18 to 85 years). The mean glucose concentration was similar in both sexes. Men had higher mean BP (systolic and diastolic) and higher level of LDL-C, TG, but lower HDL-C. Among the 4 obesity indexes, the mean WC and WHR were larger in men than in women, whereas the mean BMI and WSR were larger in women. The means of BMI, WC, WSR and WHR were 24.99kg/m2, 89.13cm, 0.532, and 0.911, respectively, for men and 25.49kg/m^2, 85.49 cm, 0.549, and 0.870, respectively, for women.

Sex-specific mean metabolic risk factors and sum of risk by obesity indexes quartiles are shown in Table 2. For both men and women, mean SBP, DBP, LDL-C, TG, glucose values, and mean sum of risk were higher, but mean HDL-C values were lower, with higher BMI, WC, WHR, and WSR. Graded relations with sum of risk were stronger across WC quartiles than across BMI, WSR, and WHR in both men and women.

The correlations between obesity indices were all very strong (ranged from 0.788 to 0.956 in men and from 0.823 to 0.948 in women) (see Table 3), except for BMI with WHR (women r = 0.491; men r = 0.442, $p < 0.001$).

Table 4 shows the results of partial correlation coefficients of obesity indices with metabolic risk factors and sum of risk. For both men and women, all 4 measures of obesity were strongly associated with the 4 metabolic risk

Table 5. Areas under the receiver-operating characteristic curves of obesity indices for clustering greater or equal to 2 metabolic risk factors

	WC	WHR	WSR	BMI	Correlation orders
Men (n)					
< 40-yr (687)	0.779(0.744,0.810)	0.754(0.718,0.787)	0.773(0.738,0.805)	0.778(0.744,0.811)	WC,BMI,WSR > WHR ($p < 0.05$)
40-60-yr(1,859)	0.718(0.703,0.732)	0.705(0.690,0.720)	0.707(0.692,0.722)	0.705(0.690,0.719)	WC > WSR,WHR, BMI ($p < 0.05$)
> 60-yr (1,158)	0.698(0.669,0.725)	0.683(0.654,0.711)	0.686(0.657,0.713)	0.684(0.656,0.712)	WC > WSR,WHR,BMI ($p < 0.05$)
Women (n)					
< 40-yr(1,132)	0.786(0.760,0.811)	0.773(0.746,0.798)	0.784(0.757,0.808)	0.755(0.727,0.781)	WC,WSR,WHR > BMI ($p < 0.05$)
40-60-yr(3,423)	0.747(0.737,0.758)	0.739(0.728,0.750)	0.742(0.731,0.753)	0.741(0.730,0.752)	WC > WSR,WHR,BMI ($p < 0.05$)
> 60-yr(1,837)	0.627(0.604,0.650)	0.614(0.590,0.637)	0.618(0.594,0.641)	0.622(0.598,0.645)	WC > WSR,BMI > WHR ($p < 0.05$)

The data for WC, WHR, WSR, BMI are presented as Mean ± SD; 95% confidence interval.
The correlation orders are the differences of the results of the difference test of the area under the receiver-operating characteristic curves for each obesity index in each age group for both males and females. For example: WC,BMI,WSR>WHR means that the AUCs for WC, BMI and WSR are significantly higher than the AUC for WHR, the others are on the analogy of the example.

Table 6. The cut-off point for WC, WHR, WSH and BMI to identify subjects with greater or equal to 2 metabolic risk factors

	WC	WHR	WSR	BMI
	Cut-off (sensitivity, specificity)	Cut-off (sensitivity, specificity)	Cut-off (sensitivity, specificity)	Cut-off (sensitivity, specificity)
Men (n)				
< 40-yr (687)	89.0 (78.8%, 68.7%)	0.91 (66.5%, 73.4%)	0.53 (70.9%, 72.9%)	25.3 (78.8%, 66.3%)
40-60-yr (1,859)	89.0 (72.4%, 61.7%)	0.91 (70.7%, 60.8%)	0.53 (68.9%, 62.1%)	25.4 (64.7%, 65.0%)
> 60-yr (1,158)	89.0 (71.6%, 62.0%)	0.92 (68.5%, 59.3%)	0.53 (71.6%, 56.6%)	25.3 (71.1%, 58.7%)
Women (n)				
< 40-yr (1,132)	80.5 (79.0%, 66.0%)	0.85 (62.1%, 77.9%)	0.49 (87.9%, 58.5%)	26.0 (62.9%, 75.8%)
40-60-yr (3,423)	82.5 (81.0%, 51.5%)	0.86 (73.7%, 59.6%)	0.54 (72.8%, 60.3%)	25.6 (63.8%, 63.3%)
> 60-yr (1,837)	89.5 (58.3%, 62.5%)	0.89 (66.2%, 52.5%)	0.55 (74.3%, 44.8%)	26.0 (55.0%, 63.7%)

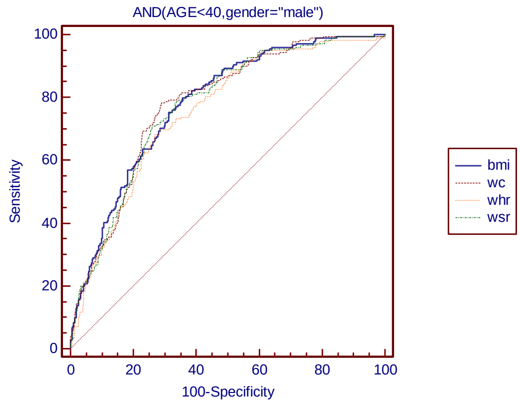

Figure 1. ROC curves for WC, BMI, WSR, and WHR in <40 males.

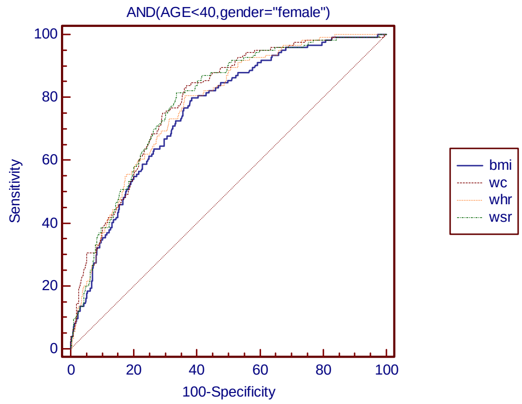

Figure 2. ROC curves for WC, BMI, WSR, and WHR in <40 females.

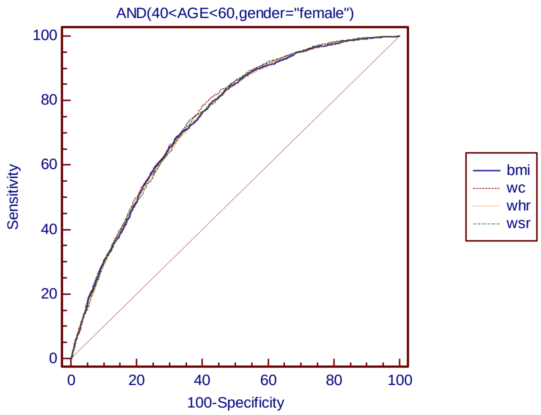

Figure 3. ROC curves for WC, BMI, WSR, and WHR in 40-60 females.

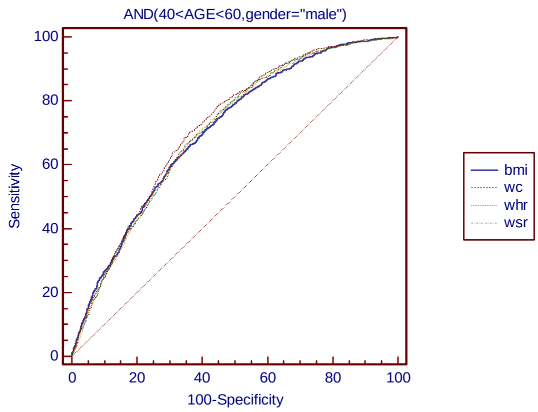

Figure 4. ROC curves for WC, BMI, WSR, and WHR in 40-60 males.

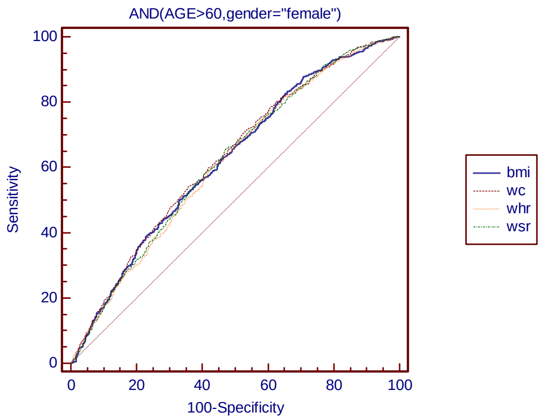

Figure 5. ROC curves for WC, BMI, WSR, and WHR in >60 females.

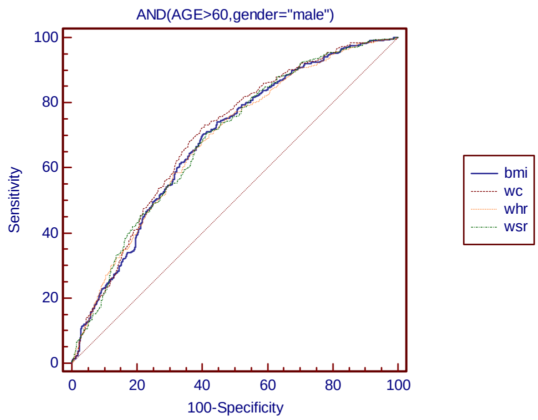

Figure 6. ROC curves for WC, BMI, WSR, and WHR in >60 males.

factors and the sum of risk after adjustment for age. In males, the correlation coefficients between 4 indexes and sum of risk ranged from 0.355 to 0.397, whereas in females, a slightly lower but still significant correlation was detected with the coefficients ranging from 0.315 to 0.343. WC versus other indexes had slightly higher correlation coefficients.

Table 5 displays the AUCs for each obesity index and their 95% CIs in the < 40-yr, 40-60-yr and > 60-yr age group in both men and women, respectively. After adjustment for age, the AUCs for WC were always higher than those for BMI, WSR, and WHR in different age groups. However, pairwise comparison indicated that the differences between the AUCs for WC, BMI and WSR were not statistically significant ($p > 0.05$) in the < 40-yr group in males. In females, the differences between the AUCs for WC, WSR and WHR were not statistically significant ($p > 0.05$) in the < 40-yr group. In the > 60-yr and 40-60-yr groups, the AUCs for WC were significantly higher than those for WSR, WHR and BMI in males and females.

Figures 1-6 illustrates the ROC curves comparing the diagnostic performance for MetS of the 4 indices in each age group in men and women. Of the 4 indexes, WC predicted the metabolic risk factors best in males and females in > 40-yr age groups.

Table 6 shows the optimal cut-offs for WC, BMI, WHR, and WSR in predicting 2 or more metabolic risk factors in three age groups in males and females. The sensitivity and specificity rates corresponding to the optimal cut-off values are also presented in the table. In males, the cut-off values were the same in different age groups for each obesity index. The cut-off values for WC, WSR, WHR and BMI were 89cm, 0.53, 0.9 and 25kg/m^2, respectively, in each age group. In females, the cut-off values for each index increased with age except for BMI. The optimal cut-off values for WC were 80.5cm, 82.5, and 89.5cm in < 40-yr, 40-60-yr, and > 60-yr female groups, respectively. The BMI cut-offs were 26, 25.6 and 26 kg/m^2 in < 40-yr, 40-60-yr and > 60-yr group, respectively. Sensitivity ranged from 64.7% to 78.8% and from 55.0% to 87.9%; specificity ranged from 56.6% to 73.4% and from 44.8% to 77.9% for men and women, respectively.

DISCUSSION

Clustering of metabolic risk factors including type 2 diabetes, hypertension, and dislipidemia have been shown to increase the risk and mortality of cardiovascular disease in longitudinal studies.[24] Several studies have found that obesity and insulin resistance are associated with series of metabolic risk factors.[6,25]

Due to the difficulty and inconvenience of measuring body fat accurately in clinical practice, simple anthropometric index including WC, BMI, WSR and WHR were used as a surrogate parameter to assess the degree of obesity and to identify those with metabolic risk factors. Several studies have tried to find out which anthropometric index correlates most closely with incidence or prevalence of MetS, when used to define obesity.[26] But the results of recent studies assessing the association of BMI, WHR, WSR or WC with cardiovascular risks are conflicting. The definition of obesity is still controversial in Asia. Some study reported that BMI was as good as or even better than abdominal obesity indexes. Dr He reported in 2007 that BMI, as a measure of overall adiposity, was strongly associated with increased prevalence of CVD independent of MetS in elderly Chinese individuals.[27] Dr Sakurai et al found that the risk ratio of having accumulations of two or more metabolic abnormalities was higher for WC than for BMI in men, whereas it was higher for BMI in women.[28] Some studies supported the central obesity indices. Dr Hsieh reported that the percentages of obesity risk factors in MetS were highest for W/Ht > or =0.5 in both genders and suggested using waist-to-height ratio to assess obesity.[29] Data from the Obesity in Asia Collaboration indicate that measures of central obesity, in particular, WC, are better discriminators of diabetes and hypertension in Asians and Caucasians, compared with BMI.[18]

The importance of WC for the Chinese population had been showed in our study. The cross-sectional study was designed to explore candidate definitions of obesity in Chinese adults who have different anthropometric characteristics in comparison with Westerners. In order to accomplish this, we evaluated WC, BMI, WSR, and WHR separately. Our data showed that all 4 anthropometric indices related fairly well to metabolic risk factors. In addition, the indexes correlated well with each other in both men and women. We also investigated the correlation between each obesity-related anthropometric index and each of metabolic risk factors or the sum of these 4 metabolic risk factors. Waist circumference showed the strongest correlation to sum of risk in both genders. As a result, WC may predict multiple metabolic risk factors best in the 4 obesity measures for men and women in > 40-yr age groups. Adults > 40-yr warrant more attention from researchers than younger adults because of the high prevalence of obesity in this group. Receiver Operator Characteristic curves can be used to compare the the diagnostic performance of two or more laboratory or diagnostic tests.[30] In our study, the obesity indexes compared by ROC curve had been adjusted for age with a multivariate linear stepwise logistic regression model, which made the conclusions more reliable.

Calculated simply from the weight and height data, BMI could be obtained more easily than other 3 indexes. However, compared with BMI, anthropometric indices of abdominal obesity (WC, WSR, WHR) are the preferred measure for abdominal obesity for they are more strongly correlated with visceral adipose tissue (VAT).[31] Visceral adipose tissue promotes insulin resistance, which may be the possible reason for the stronger association between abdominal obesity indexes and the metabolic factors, in comparison with BMI. Results of many clinical studies supported the hypothesis that abdominal obesity was the main risk factor in the clinical development of diabetes.[32,33] A retrospective study showed that WC was a very good predictor of insulin sensitivity and a WC of < 100 cm could exclude insulin resistance in both sexes.[34] Dr Mamtani reported that WC had the higher overall predictive accuracy in predicting the risk of type 2 diabetes than other indexs.[35] Similar to recent study, we have found that Chinese subjects with abdominal obesity are at greater risk in the development of MetS than individuals with general obesity. Furthermore, our study showed that WC is superior to WHR or WSH. Waist to hip ratio had been considered to predict metabolic risks better than WC for including an index of hip circumference. Increased hip circumference is associated with increased incidence of hypertension, diabetes, and dyslipideamia.[36] However, recent clinical trials showed that WHR was not superior to WC as a measure of CVD risk.[37] Furthermore, hip circumference could not be obtained routinely and the measure is more difficult to perform and less reliable than WC. Waist to hip ratio could remain constant when the weight of individual increases or loses and it may not be a suitable index for assessing obesity. Therefore, we support adopting measurements of WC as a valuable tool to evaluate the risk of MetS.

Another purpose of this study was to investigate the appropriate cut-offs of obesity indices to identify subjects with multiple metabolic risk factors. Obesity has been defined by WHO as WC ≥90cm in men, ≥80cm in women, and BMI ≥25kg/m^2 for Asian-Pacific populations.[38] The definition of MetS released by IDF adopted the same criterion for central obesity in 2005. Recently, several studies suggested lower cut-off values for BMI and WC in the identification of Chinese patients with high risk of cardiovascular disease. Dr Wildman reported a BMI cut-off of 24 kg/m^2 and a WC cut-off of 80 cm for both men and women would be appropriate for the categorization of overweight and central adiposity among Chinese adults.[39] Dr Zhou advised the level of 85 cm and 80 cm as the cut-off values of WC for middle-aged men and women, respectively in identifying clustering of two or more risk components.[40] However, Bao et al. reported that the optimal cut-off of waist circumference for abdominal obesity is 90 cm for men and 85 cm for women in the Chinese population.[41] The optimal obesity indexes cut-off as a criterion for MetS among the Chinese have been in dispute for their low sensitivity and specificity.

The primary finding of this study was that the obesity cut-offs were the same across different age groups in men, whereas the cut-off values for each index increased with age except for BMI in women. Considering the balance between the sensibility and specificity in identifying clustering of multiple metabolic risk factors, a WC of 89cm appeared appropriate in men with different age. The optimal cut-off value of BMI was 25kg/m^2 in men of different ages. These outcomes are similar with the obesity criterion defined for men by WHO (WC $\geq$ 90cm; BMI $\geq$ 25kg/m^2).[37] However, the cut-off values of WC ranged from 80.5cm to 89.5cm according to different age groups in women in our study. We observed that only the cut-off value in < 40-yr age group was similar to the IDF criterion for women. The cut-offs of WC for > 40-yr women in our study were higher than that of criterion from recent studies in the Chinese. Indices of abdominal obesity (WC, WSR, WHR) for older age groups, especially for the > 60-yr age group, tended to be higher than the younger age groups in women. Another find was that the WC cut-off for identifying multiple metabolic risk factors was more sensitive and specific in men compared with that in women. Moreover, age group analysis of the ROC curves in this study showed that WC cut-off was more sensitive and specific in younger age groups than in older age groups for both genders. Specificity and sensitivity were as high as 68.7% and 78.8% respectively at a WC cut-off of 89 cm for men in the < 40-yr age group. This evidence suggests the possibility of using different index cut-off values for different age groups, especially in women. We have suggested that both a sex-specific and an age-specific obesity criterion be applied for Chinese adults.

The large sample size of the present study makes it possible to perform statistical analyses using more than one method and enables us to stratify our ROC curve analysis by age groups, which makes the results more convincing. Another strength of the present study is its community-based samples. However, there are still limitations in our study. The cross-sectional design makes it difficult to infer that the increase of WC is the cause of metabolic risk factors and evaluate prognostic significance of the obesity measures. Longitudinal studies with a large sample size and a follow-up of the present study are needed to further explore these questions.

CONCLUSION

All anthropometric indices for obesity are positively correlated with metabolic risk factors. After adjustment for age, WC has a greater association with clustering of 2 or more metabolic risk factors than WSR, WHR, and BMI based on the ROC analyses. These results have indicated that WC might predict the metabolic risk factors better than other simple obesity measures. The optimal cut-off values of WC are 89cm for men in all age groups and 80.5 cm, 82.5cm, 89.5cm in < 40-yr, 40-60-yr and > 60-yr for women, respectively. Further investigation with follow-up study is needed to explore whether the criteria can be used to define MetS in Chinese adults.

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AUTHOR DISCLOSURES

We declare that we have no conflict of interest.

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Short Communication

Obesity criteria for identifying metabolic risks

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代谢综合征的肥胖标准

与多个代谢危险因素相关的中国人群的肥胖标准尚存在争议。本研究目的是寻找检出代谢综合征的最佳人体测量指标及适宜切点值。于 2007 年 4 月至 8 月期间，调查了北京市四个社区的年龄在 18-85 岁之间的居民，其中男性 3704 位，女性 6392 位。所有人检测了身高、体重、腰围（WC）、臀围、血压（BP）、血清甘油三酯水平（TG）、高密度脂蛋白胆固醇（HDL-C）水平及空腹血糖水平。分别计算了每个人的体重指数(BMI)、腰围身高比（WSR）和腰臀比（WHR）。四个代谢危险因素包括 1）高血压; 2)高 TG 血症; 3)低 HDL-C 血症; 4)高血糖。分析人体测量指标与代谢风险关系的统计方法包括偏相关分析、方差分析、线性回归和接收器運作特性(ROC)曲线分析，适宜切点值由 ROC 分析得出。所有肥胖指标均与代谢危险因素有正相关。校正年龄后，腰围检出 2 个以上代谢危险因素聚集的敏感性、特异性最佳。男性腰围切点值是 89 cm，而女性在小於 40 岁、40-60 岁和大於 60 岁年龄组的腰围切点值分别为 80.5 cm、82.5 cm 和 89.5 cm。因此，在本研究的人体测量指标中，腰围与中国成人代谢危险因素的相关性最强，老年女性人群的肥胖指标高于較年輕女性。

關鍵字：肥胖、腰围、代谢危险因素、ROC 曲线分析、中国人