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Prediction of Abdominal Visceral Obesity From Body Mass Index, Waist Circumference and Waist-hip Ratio in Chinese Adults: Receiver Operating Characteristic Curves Analysis

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WEI-PING JIA, JUN-XI LU, KUN-SAN XIANG*, YU-QIAN BAO, HUI-JUAN LU, AND LEI CHEN

Shanghai Diabetic Institute, Shanghai Jiaotong University Affiliated No. 6 People Hospital, Shanghai 200233, China

Objective To evaluate the sensitivity and specificity of body mass index (BMI), waist circumference (WC) and waist-to-hip ratio (WHR) measurements in diagnosing abdominal visceral obesity. **Methods** BMI, WC, and WHR were assessed in 690 Chinese adults (305 men and 385 women) and compared with magnetic resonance imaging (MRI) measurements of abdominal visceral adipose tissue (VA). Receiver operating characteristic (ROC) curves were generated and used to determine the threshold point for each anthropometric parameter. **Results** 1) MRI showed that 61.7% of overweight/obese individuals (BMI≥25 kg/m^2) and 14.2% of normal weight (BMI<25 kg/m^2) individuals had abdominal visceral obesity (VA≥100 cm^2). 2) VA was positively correlated with each anthropometric variable, of which WC showed the highest correlation (r=0.73-0.77, *P*<0.001). 3) The best cut-off points for assessing abdominal visceral obesity were as followed: BMI of 26 kg/m^2, WC of 90 cm, and WHR of 0.93, with WC being the most sensitive and specific factor. 4) Among subjects with BMI≥28 kg/m^2 or WC≥95 cm, 95% of men and 90% of women appeared to have abdominal visceral obesity. **Conclusion** Measurements of BMI, WC, and WHR can be used in the prediction of abdominal visceral obesity, of which WC was the one with better accuracy.

Key words: Body mass index (BMI); Abdominal visceral fat; Anthropometric parameters; Receiver operating characteristic (ROC) curves

INTRODUCTION

Overweight and obesity are of the main risk factors for many chronic adult diseases such as diabetes, hypertension, dyslipidemia and atherosclerosis. In addition to their association with the increment of total body fat, these diseases have recently been demonstrated to be closely related to the accumulation of abdominal visceral (intra-abdominal) fat. Abdominal visceral fat can be determined precisely using magnetic resonance imaging (MRI) and computed tomography (CT) scanning; or it can be estimated by simple anthropometric measurements. Although MRI and CT scanning provide accurate and reliable measurements, they are unsuitable for assaying large groups of individuals. In contrast, anthropometric measurements

*Correspondence should be addressed to Prof. Kun-San XIANG, Shanghai Diabetes Institute, Shanghai Jiaotong University affiliated No.6 People Hospital, 600 Yishan Road, Shanghai 200233, China. E-mail: sphxiang @public.bta.net.cn

Biographical note of the first author: Wei-Ping JIA, female, born in 1956, M.D., Professor, Physician in chief, majoring in obesity and diabetes. E-mail: wpjia@yahoo.com

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are easier to perform, but their precision and reliability remain to be determined.

Therefore, the aims of this study are to investigate the relationship between the content of abdominal visceral fat scanned by MRI and anthropometric indices, and to evaluate the sensitivity, specificity and accuracy of body mass index (BMI), waist circumference (WC) and waist-to-hip ratio (WHR) in the diagnosis of abdominal visceral obesity, which might provide consolidate evidence for rational application of simple anthropometric indices and screening high risk population.

SUBJECTS AND METHODS

Subjects

The subject population consisted of 690 Chinese adults, aged 24-85 years (305 men and 385 women), from local communities, factories, and the outpatient department of our hospital.

Measurements of Body Fat

Abdominal adipose tissue was measured using a whole-body imaging system (SMT-100, Shimadzu Co. Japan) with TR-500 and TE-200 of SE. MRIs were performed in the prone position, at the abdominal level between the L4 and L5 vertebrae. For each subject, abdominal visceral adipose tissue (VA) was calculated using the software provided by the manufacturer[1,2].

For anthropometric parameters of body fat, height (in m) and weight (in kg) were measured with subjects standing without shoes and hat, and in light attire. BMI ,which was regarded as an index for total body fat, was calculated as kg/m^2. WC (in cm), the parameter for the visceral fat, was determined as the circumference of the same position as in MRI scanning. For WHR, the index for regional body fat distribution, was calculated as the ratio of the circumference of waist to hip (H), in which H was the measurement of the largest extension of the buttocks.

Statistical Analyses

For determining increased abdominal visceral fat, a VA value of 100 cm^2 was selected as the cut-off point[3-5]. Student's *t*-test was used for the comparison of the measurement data between groups, and Pearson's correlation coefficients were utilized in analyzing the relationship between the MRI-determined and anthropometric measurements of body fat. Receiver operating characteristic (ROC) curves were used to select the optimal threshold points at which increased abdominal visceral fat was measured. All statistical analyses were performed using SAS software.

RESULTS

Characteristics of Anthropometric Parameters for Abdominal Visceral Obesity

Among the 690 survey subjects, 275 (40%) were found to have abdominal visceral fat areas greater than or equal to 100 cm^2 and were diagnosed as abdominal visceral obesity. Among them 132 of the 305 men (43%) and 143 of the 385 women (37%) surveyed had VA $\geqslant$100 cm^2. Of the subjects with BMI < 25 kg/m^2, 14.2% (17% of men and 12% of women) were diagnosed as having increased abdominal visceral fat, while among the subjects with BMI $\geqslant$25 kg/m^2, 61.7% (67% of men and 57% of women) had increased abdominal visceral fat. Age, BMI, WC and WHR (P<0.001) were significantly higher in subjects with increased abdominal visceral fat than those without (Table 1).

TABLE 1

Clinical Characteristics of Chinese Adults Without (VA<100cm^2) and With (VA≥100cm^2) Increased Abdominal Visceral Fat ($\bar{x}\pm s$)

	Men (n=305)			Women (n=385)		
	VA<100 cm^2 (n=173)	VA≥100 cm^2 (n=132)	t-value	VA<100 cm^2 (n=242)	VA≥100 cm^2 (n=143)	t-value
Age (yr)	54.50±11.50	59.02±10.18	3.57[a]	51.40±10.00	57.90±10.10	6.17[a]
Weight (kg)	66.95±0.81	77.73±0.89	8.91[a]	59.20±0.55	70.32±0.89	10.61[a]
Height (m)	1.68±0.06	1.67±0.05	1.78	1.57±0.06	1.56±0.05	1.12
BMI (kg/m^2)	23.59±2.91	27.83±3.17	12.12[a]	24.06±3.39	28.76±3.83	12.54[a]
WC (cm)	82.39±8.68	95.81±8.33	13.69[a]	82.13±10.46	97.49±10.25	13.11[a]
WHR	0.89±0.06	0.96±0.04	11.12[a]	0.89±0.10	0.96±0.07	7.97[a]
VA (cm^2)	68.86±23.84	137.21±31.28	23.34[a]	61.24±23.83	134.43±31.54	23.99[a]

Note. [a]P<0.001 between VA≥100 cm^2 group and VA<100 cm^2 group: P<0.001

TABLE 2

Correlation Between Abdominal Visceral Fat and Anthropometric Measurements of Body Fat

Variable	r-value	Men (n=305) P-value	r-value	Women (n=385) P-value
AGE	0.23	0.0001	0.35	0.0001
BMI	0.70	0.0001	0.68	0.0001
WC	0.77	0.0001	0.73	0.0001
WHR	0.63	0.0001	0.48	0.0001

Correlation Between Body Fat Measurements by MRI and by Anthropometric Parameters

VA was positively correlated with BMI, WC, and WHR in the entire subject population, in which WC was the highest (r=0.73-0.77, P<0.0001). VA also showed a weak correlation with age (Table 2).

Determination of Optimal Cut-off Points for Anthropometric Parameters of Body Fat in the Evaluation of Abdominal Visceral Obesity

Abdominal visceral fat areas≥100 cm^2 scanned by MRI was used as gold criteria to evaluate the accuracy of the anthropometric parameters (BMI, WC and WHR) in determining abdominal visceral obesity, and ROC curves were generated to select the optimal threshold points. For each parameter, 15 intervals were used. That is, BMIs between 21 and 35 kg/m^2 were evaluated at each integral unit; WCs between 60 and 130 cm were evaluated at 5-cm intervals; and WHRs between 0.79 and 1.07 were evaluated at 0.2-unit intervals.

When the anthropometric parameters were evaluated using our ROC curves, the analytical result showed that: the optimal BMI threshold point was at 26 kg/m^2, the optimal WC threshold point was 90 cm, and the optimal WHR threshold point was 0.93, regardless of sex.

In evaluating the sensitivity and specificity of these optimal threshold points for determining abdominal visceral obesity with anthropometric parameters, we found that the sensitivity and specificity of BMI were 68.9% and 83.8% in men and 76.2% and 74.0% in women respectively. The sensitivity and specificity of WC were 78.0% and 82.7% in men, and 79.0% and 74.4% in women respectively. The sensitivity and specificity of WHR were 78.8% and 71.7% in men and 68.5% and 65.3% in women respectively (Table 3).

TABLE 3

Optimal Cut-off Points for the Anthropometric Determination of Abdominal Visceral Obesity

	Men(VA≥100 cm^2)					Women(VA≥100 cm^2)			
Variable	Cut-off Point	Sensitivity	Specificity	False Positives (%)	False Negatives (%)	Sensitivity	Specificity	False Positives (%)	False Negatives (%)
BMI	23.0	98.5	39.3	60.7	1.5	94.4	37.2	62.8	5.6
(kg/m^2)	24.0	88.6	61.3	38.7	11.4	90.9	49.2	50.8	9.1
	25.0	81.1	69.9	30.1	18.9	86.0	62.4	37.6	14.0
	26.0	68.9	83.8	16.2	31.1	76.2	74.0	26.0	23.8
	27.0	57.6	87.3	12.7	42.4	65.7	81.8	18.2	34.3
	28.0	43.2	95.4	4.6	56.8	55.2	88.8	11.2	44.8
	29.0	34.8	97.7	2.3	65.2	42.6	91.7	8.3	57.4
	30.0	23.5	99.4	0.6	76.5	35.0	95.0	5.0	65.0
WC	70.0	100.0	8.1	91.9	0.0	100.0	9.9	90.1	0.0
(cm)	75.0	100.0	17.9	82.1	0.0	100.0	20.6	79.4	0.0
	80.0	100.0	34.1	65.9	0.0	97.9	33.9	66.1	2.1
	85.0	96.2	58.4	41.6	3.8	95.1	57.4	42.6	4.9
	90.0	78.0	82.7	17.3	22.0	79.0	74.4	25.6	21.0
	95.0	47.0	94.2	5.8	53.0	12.8	87.2	12.8	87.2
	100.0	27.3	98.8	1.2	72.7	7.4	92.6	7.4	92.6
	105.0	15.2	99.4	0.6	84.8	2.9	97.1	2.9	97.1
WHR	0.83	100.0	16.2	83.8	0.0	97.2	20.3	79.7	2.8
	0.85	100.0	21.4	78.6	0.0	94.4	28.5	71.5	5.6
	0.87	98.5	28.9	71.1	1.5	91.6	38.0	62.0	8.4
	0.89	96.2	39.3	60.7	3.8	85.3	46.7	53.3	14.7
	0.91	90.2	59.5	40.5	9.8	77.6	57.0	43.0	22.4
	0. 93	78.8	71.7	28.3	21.2	68.5	65.3	34.7	31.5
	0.95	66.7	80.4	19.6	33.3	56.4	72.7	27.3	43.6
	0.97	45.5	88.4	11.6	54.5	48.3	76.0	24.0	51.7

To determine the accuracy of these optimal threshold points, we compared the diagnoses based on each anthropometric parameter with those based on MRI. Compared with MRI diagnoses, the accuracy of the diagnoses based on the BMI threshold point was 77.4% for men and 74.8% for women; the accuracy of diagnoses based on the WC threshold point was 80.6% for men and 76.1% for women; and the accuracy of diagnoses based on the WHR threshold point was 74.8% for men and 66.5% for women. Thus, for each of the three anthropometric measurements, the diagnostic accuracy was higher for men than for women. Of the three measurements, WC provided the highest precision for both sexes. For BMIs ≥28 kg/m^2 and for WC ≥95 cm, 95% of men and about 90% of women had abdominal visceral fat areas ≥100 cm^2, while for WHR ≥0.95, 80% of men and 70% of women had abdominal visceral fat areas ≥100 cm^2 (Fig.1, Table 3).

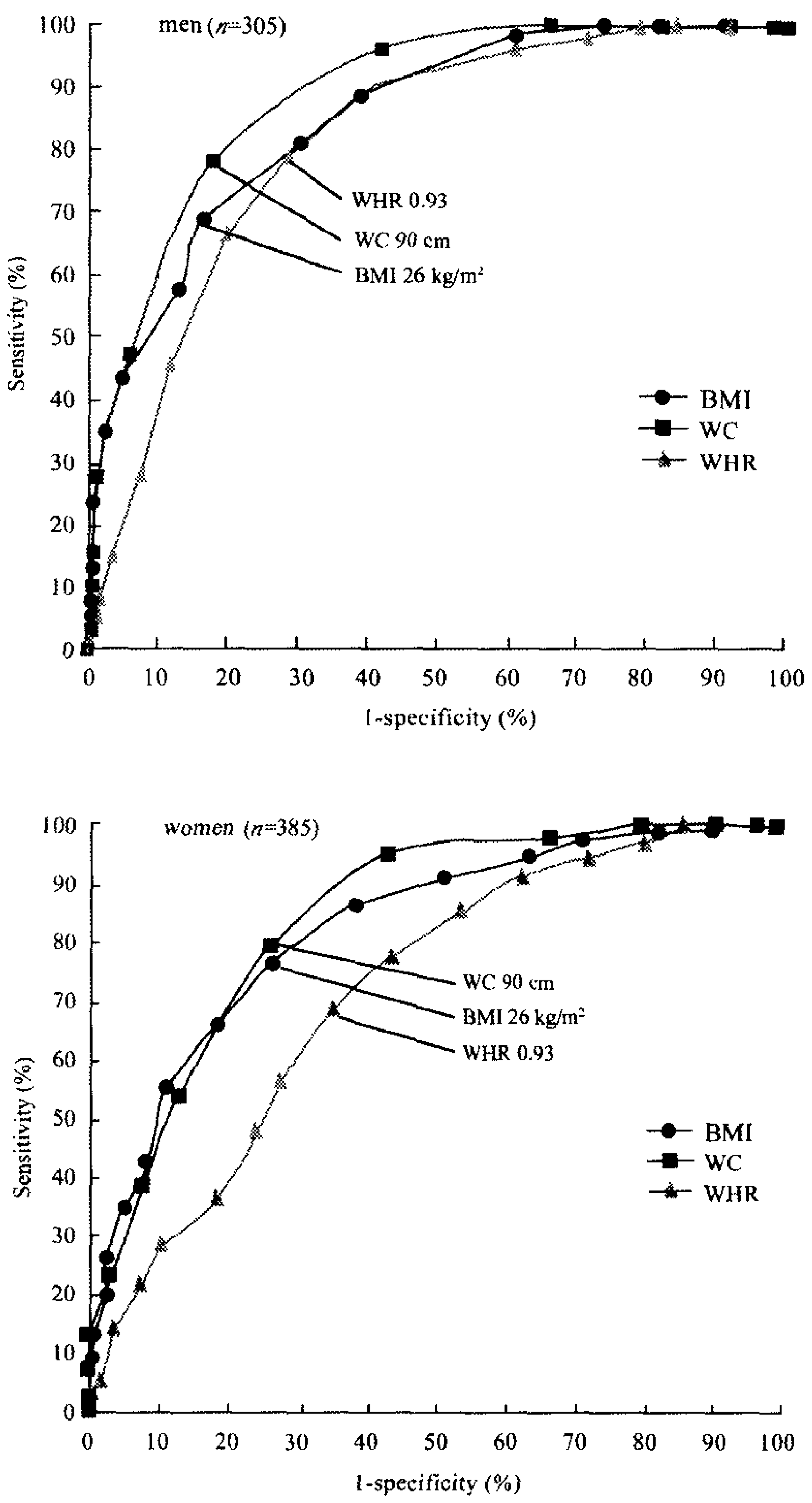

FIG. 1. ROC curves of BMI, WC and WHR for the determination of abdominal visceral obesity (VA ≥ 100 cm^2)

DISCUSSION

When the anthropometric parameters was compared with the more precise MRI in diagnosing abdominal visceral obesity in Chinese adults, the results were as followed: 1) 62% of overweight/obese subjects and 14% of normal weight individuals appeared to have abdominal visceral obesity (VA ≥ 100 cm^2) diagnosed by MRI. 2) When MRI measurements were compared with those based on the anthropometric parameters, significant positive correlations between each of them (BMI, WC and WHR) and VA were found, with WC showing the highest correlation. 3) In assessing abdominal visceral obesity in this population, the optimal cut-off points were: BMI of 26 kg/m^2, WC of 90 cm and WHR of 0.95. 4) 95% of men and about 90% of women appeared to have abdominal visceral obesity at BMI≥28 kg/m^2, and at WC≥95 cm.

During the 1970s and 1980s, researchers described the relationship between upper-body obesity (centralized obesity) and chronic adult diseases, including diabetes, hypertension, dyslipidemia and atherosclerosis. WC and WHR were utilized to evaluate regional abdominal fat and body fat distribution abnormalities. Later, more precise measurements (CT and MRI) of body fat further revealed the relationship between locations of body fat accumulation and these chronic adult diseases, demonstrating the pathogenic effects of abdominal visceral fat accumulation.

In our previous studies, we assayed specific body fat distribution in diabetic patients and found increased intra-abdominal fat and decreased femoral subcutaneous adipose tissue depots compared to non-diabetic controls[6]. These alterations were even more pronounced in diabetic patients with blood lipid disorders and/or hypertension[6]. It was found that even non-diabetic individuals with abdominal visceral obesity had metabolic abnormalities, including significantly elevated levels of insulin and free fatty acids, and decreased insulin-mediated glucose utilization[7,8]. Furthermore, studies of body fat distribution and insulin resistance have shown that the effect of abdominal visceral fat on insulin sensitivity accounted up to 62%[7,8]. Thus, individuals with accumulated abdominal visceral fat are at a greater risk for type 2 diabetes, hypertension, dyslipidemia and atherosclerosis. The effective screening of this high-risk population is thus important in the prevention and treatment of these diseases.

Although CT and MRI screenings provide accurate and reliable measurements of abdominal visceral obesity, expensive equipment and a dedicated location are required, making them unsuitable for screening large groups of individuals. The anthropometric parameters we have utilized – BMI, WC and WHR – provide a simple and reliable method for estimating abdominal visceral obesity and are thus more useful for screening large groups of individuals.

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