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Waist to Height Ratio as a Predictor of Abdominal Fat Distribution in Men

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Abstract

The accumulation of fat in visceral (VA) and subcutaneous abdominal adipose tissue (SA) is highly correlated with the metabolic abnormalities that contribute to increased risk of diabetes mellitus and cardiovascular disease. The purpose of the study was to determine which of the four indices—waist circumference (WC), waist-to-hip ratio (WHR), waist to height ratio (WHtR) and body mass index (BMI)—was the best predictor of VA and SA in men. We studied 111 men with a wide range of BMI, WC, WHtR, WHR and BMI determined by standard methods. SA and VA were quantified using computed tomography. In univariate and multiple regression analyses, WHtR had the highest correlation with VA and SA. To assess the relative strength of these associations, we used non-nested regression models. WHtR was a stronger predictor of SA than BMI (P = 0.02), but the relative strength of WC and BMI in predicting SA did not differ significantly (P > 0.05). WHtR was a stronger predictor of VA than WC (P = 0.012), BMI (P < 0.001) or WHR (P < 0.001). In men, WHtR is a good anthropometric index which has a stronger correlation with the distribution of visceral and subcutaneous abdominal adipose tissue than BMI or WHR. Its association is closer to or stronger than WC.

Key Words: central obesity, waist to height ratio, visceral abdominal adipose tissue, subcutaneous abdominal adipose tissue

Introduction

Obesity is a rapidly growing health problem in China. Difference in the regional accumulation of abdominal fat can account specifically for variations in the risk of diabetes and cardiovascular diseases among those who are overweight or obese (4). Accurate quantification of body fat compartments requires imaging techniques such as magnetic resonance imaging (MRI) and computed tomography (CT). However, these techniques are relatively expensive and complex, and are impractical for routine clinical settings or large-scale studies. Simple clinical anthropometric measurements, such as waist circumference (WC), waist/hip ratio (WHR) and body mass index (BMI), may be conveniently used to assess regional adiposity, and some of these surrogate markers correlate reasonably well with laboratory-based measures of adiposity using MRI or CT (3, 5, 10). Recently several studies have demonstrated that waist to height ratio (WHtR) is a better predictor of metabolic risk in oriental people (7, 8, 20). Although the mechanisms that explain the health risk predicted by WHtR are not firmly established, it is often suggested that the risk is explained by its association with elevations in abdominal obesity (2). Given the independent con-

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Table 1. Age distribution of all participants

Age (y)	40~44	45~49	50~54	55~60
Number	19	31	36	25

tribution of visceral fat (VA) (13) and subcutaneous abdominal (SA) (11, 14) in the development of metabolic risk, it is important to understand the influence of anthropometric measurements on abdominal adipose tissue (AT) distribution. Therefore, the main purpose of this study was to investigate the relationship between anthropometric measures of obesity (WC, WHR, WHtR and BMI) and the content of abdominal fat measured by computed tomography in Chinese men and to ascertain which clinical marker was the best predictor of VA and SA. To do so, we measured regional fat distribution by computed tomography in 111 Chinese men with a wide range of BMI.

Materials and Methods

Subjects

Chinese men who underwent health examinations were recruited consecutively from Union Hospital, which was approved by the Ethics Committee at Huazhong Technology University (Wuhan, China). Participants of this study were apparently healthy volunteers aged 40-60 yr. They varied widely in adiposity (BMI: 17.4-33.8 kg/m^2). The criteria for exclusion were pregnancy, spinal deformities, pleural or peritoneal effusion, and a recent weight loss of > 5% of the usual body weight. After giving their written informed consent, the subjects provided a fasting blood sample and completed a self-administered questionnaire on demographic characteristics and general health.

Measurement of Total and Regional Fat and Anthropometric Measurements

Computed Tomography (Somatom Sensation 16, Siemens. Medical Systems, Germany) was used for the determination of VA and SA areas, as previously described (18). Briefly, a cross-sectional scan of 10 mm thickness centered at the L4-L5 vertebral disc space was obtained using 200 mA with a 512 × 512 matrix. The boundary between visceral and subcutaneous AT was defined by the use of the abdominal wall musculature in continuity with the deep fascia of the paraspinal muscles, as has been previously described (6).

Body mass was measured to the nearest 0.1 kg while the subjects were dressed in light clothing. They stood barefoot while height was measured to the nearest 0.1 cm. Waist circumference was measured at the umbilicus level using a plastic tape measure.

Table 2. Subject characteristics

Variables	Men (n = 111)
Age (y)	50.7 ± 8.7 (40, 60)
Height (cm)	167.8 ± 6.6 (145.5, 183.0)
Weight (kg)	70.7 ± 10.9 (47, 96)
BMI (kg/m^2)	25.1 ± 3.6 (17.4, 33.8)
WC (cm)	88.2 ± 9.6 (66.1, 104.5)
WHR	0.95 ± 0.06 (0.82, 1.17)
WHtR	0.53 ± 0.05 (0.37, 0.62)
SA (cm^2)	116.9 ± 49.6 (14.02, 220.1)
VA (cm^2)	125.3 ± 64.1 (10.9, 255.4)

Table 3. Pearson univariate correlation coefficients between regional abdominal fat area and anthropometric measures

	Men (n = 111)				
	BMI	WC	WHR	Height	WHtR
SA	0.703	0.769	0.604	-0.127[a]	0.792
VA	0.722	0.823	0.654	-0.156[b]	0.868

$P < 0.001$, except for [a]$P = 0.184$; [b]$P = 0.103$.

Statistical Analysis

The relations of anthropometric variables (predictor variables) to the measurements of fat mass (dependent variable) were initially examined through separate and combined regression models. Because colinearity diagnostics indicated that WC and WHtR can not be used in the same multiple regression model, we put them in different multiple regression models. The *t*-statistics were used to compare the strength of the relationships. Data were analyzed using SPSS 13.0. To further avoid the problem of multicolinearity with highly correlated variables in multivariable models, the set of non-nested models were then compared using the *t*-distribution, as described by Andel (1), to determine the relative strength of the correlations. The two-tailed 0.05 level of significance was used for all data analyses.

Results

The age distribution is shown in Table 1. Table 2 shows the anthropometric characteristics of the 111 men. The subjects on average were obese (according to the WHO Asia-Pacific guideline for Asian adults), with a wide range of BMI. Five of the subjects had impaired fasting glucose (plasma glucose

Table 4. Age-adjusted relationship between each anthropometric variable and abdominal adipose tissue

Variable	SA			VA		
	Standardized Coefficients*	*t*-statistic	*P*	Standardized Coefficients*	*t*-statistic	*P*
BMI	0.70	10.2	< 0.001	0.71	11.1	< 0.001
WC	0.77	12.3	< 0.001	0.80	14.7	< 0.001
WHR	0.59	7.8	< 0.001	0.64	9.0	< 0.001
WHtR	0.81	13.4	< 0.001	0.86	17.4	< 0.001
BMI†	0.30	3.5	0.001	0.28	3.6	< 0.001
WC	0.54	6.2	< 0.001	0.60	7.8	< 0.001
BMI†	0.21	2.2	0.031	0.13	1.7	0.088
WHtR	0.64	6.6	< 0.001	0.75	9.4	< 0.001

*Standardized Coefficients were age-adjusted by multiple linear regression analysis. †Two anthropometric indices are included in the same model.

Table 5. Comparison of the relative strengths of WC, BMI and WHtR in predicting abdominal adipose tissue areas in non-nested models

	BMI *vs.* WC		BMI *vs.* WHtR		WC *vs.* WHtR		BMI *vs.* WHR		WC *vs.* WHR		WHtR *vs.* WHR	
	t	*P*	*t*	*P*	*t*	*P*	*t*	*P*	*t*	*P*	*t*	*P*
SA	1.57	0.119	2.36	0.020	1.07	0.287	4.34	< 0.001	5.08	< 0.001	4.29	< 0.001
VA	2.67	0.009	4.66	< 0.001	2.56	0.012	5.72	< 0.001	6.47	< 0.001	5.42	< 0.001

t refers to comparison of non-nested model for correlations between anthropometric and CV variables.

concentration 6.1-6.9 mM) and two had diabetes mellitus (fasting glucose concentration ≥ 7.0 mM), seven were hypertensive. Table 3 shows the univariate correlation coefficients between the anthropometric measures of obesity and the two adipose tissue compartments. All of these parameters significantly and positively correlated ($P < 0.001$) with VA and SA. Height had a weak correlation with VA and SA.

Multiple linear regression analyses revealed that after adjusting for age, the association between the anthropometric measures of obesity and CT variables remained significant (Table 4). The *t*-statistics showed that, of the four variables, WHtR had the strongest association with both SA and VA, while the WHR had the weakest association. Combining BMI and WC in the same model, both of them showed a significant relationship with SA and VA, but the *t*-statistic for WC was higher than BMI. After adjusting BMI and WHtR for each other, only WHtR showed a significant relationship with VA. Although both of them showed a significant relationship with SA, the *t*-statistic for WHtR was higher than BMI.

Comparisons of the relative strength of these anthropometric measures in predicting adipose tissue masses are shown in Table 5. The *t-values* in Table 5 refer to the comparisons of the non-nested models and a *P* value < 0.05 indicates a significant difference in the strength of the association (correlation coefficient) shown in Table 3. WHtR was a stronger predictor of SA than both BMI ($P = 0.02$) and WHR ($P < 0.001$). The association between WHtR and SA was a little stronger than that between WC and SA, although the relative strength of WHtR and WC in predicting SA did not differ significantly ($P > 0.05$). However, WHtR was a stronger predictor of VA than WC ($P = 0.012$), BMI ($P < 0.001$) or WHR ($P < 0.001$).

Discussion

Central obesity plays an important role in insulin resistance and associated cardiovascular disease. Our previous study (21) has shown that WHtR is a better predictor than WC, BMI or WHR for the evaluation of CHD risk factors. We hypothesize that WHtR may have a stronger correlation with the distribution of visceral and subcutaneous abdominal adipose tissue than WC, WHR or BMI. Consistent with previous observations (3, 10), we also found in men WC was a better anthropometric index than BMI or WHR in predicting the distribution of adipose tissue. However WHtR had the highest correlation with intra-abdominal fat (r = 0.868). This was higher than the correlations of WC (r = 0.823), BMI (r = 0.722) or

WHR (r = 0.654).

Our findings indicated that WHtR predicted SA better than BMI (r = 0.703) and WHR(r = 0.604). Its correlation with subcutaneous fat (r = 0.792) was also a little better than that of WC (r = 0.769), though the difference was not significant.

Several studies have examined the association of conventional anthropometric measures with regional abdominal adipose tissues in obesity. Using computed tomography, Ferland *et al*. (6) reported that WHR was a good predictor of intra-abdominal adipose tissue in obese women. Using MRI Chan *et al*. (3) found that in 59 Caucasian men WC was a better predictor of the distribution of adipose tissue in the abdominal region than WHR or BMI. While Janssen *et al*. (9) found that both BMI and WC predicted the distribution of abdominal subcutaneous and visceral fat in Caucasian men and women. Jia *et al*. (10) reported that in Chinese, measurements of BMI, WC, and WHR could be used in the prediction of abdominal visceral obesity, of which WC was the one with better accuracy. However, none of these studies took WHtR into account. Although Ashwell's study (2) focused on the association of WHtR with intra-abdominal adipose tissue, and similar to our results, it was found that WHtR was the best predictor of VA in both men and women, they did not examine the association of WHtR with subcutaneous adipose tissue. Another Japanese study (15) by Miyatake *et al*. established a formula for predicting visceral adipose tissue based on anthropometric measurements. It is interesting that although WHtR was not included in their initial design, both WC and height entered coincidently the formula for predicting visceral adipose tissue accumulation, and the relationship of WC with visceral fat area was contrary to that of height, which supported our results.

BMI has been conventionally used to define and classify overweight and obesity. However, BMI has considerable limitations in predicting intra-abdominal fat accumulation, even subcutaneous-abdominal fat accumulation. We found that BMI had a weaker association with intra and subcutaneous abdominal fat than WHtR (Table 3). The WHR is also a practical index of regional adipose tissue distribution and has been widely used to investigate the relations between regional adipose tissue distribution and metabolic profile (5). As seen in Table 3, WHR was reasonably well correlated with the mass of all adipose tissue. However, the WHR value did not account for the large variations in the level of abdominal visceral adipose tissues (16).

Since the univariate approach used in the present study to examine the association between the variables produced a set of non-nested models, a simple comparison of values of R^2 was not valid. To avoid the problems of multicolinearity with highly correlated anthropometric variables in multivariate models, we used non-nested models to compare the relative strength of the anthropometric indices in association with regional adipose tissue masses. These non-nested models were compared using *t*-tests that accounted for the residual sums of squares for the model and the correlation between the independent variables.

VA and SA volumes were measured using single-slice computed tomography imaging at the umbilicus level. As previously reported (10, 12, 17, 19, 22), the VA and SA partial volumes derived from single images had been shown to have a high correlation with the respective total volumes for VA and SA by computed tomography or magnetic resonance imaging, so this method was used in the present study.

In summary, this study provides evidence that WHtR is an important surrogate marker of the distribution of adiposity in the abdominal region in men. Accordingly, we propose that WHtR is probably the most convenient and reliable clinical measure of abdominal fat compartments. Our study does not imply any clinical value in measuring the WHR or BMI of this group of subjects. Whether our conclusions also apply to women, younger age groups or other racial groups with different body habitus, merits further investigation.

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