

# Visceral Fat, Waist Circumference, and BMI: Impact of Race/ethnicity

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**Objective:** BMI and waist circumference are used to define risk from excess body fat. Limited data in women suggest that there may be racial/ethnic differences in visceral adipose tissue (VAT) at a given BMI or waist circumference. This study tested the hypothesis that racial/ethnic differences exist in both men and women in the relationship of anthropometric measures of body composition and computed tomography (CT)-determined VAT or subcutaneous adipose tissue (SAT).

**Methods and Procedures:** Subjects included 66 African American, 72 Hispanic, and 47 white men and women, aged  $\geq 45$ . Waist circumference and BMI were measured using standard methods. Total abdominal and L4L5 VAT and SAT were measured using CT.

**Results:** Among both men and women, groups did not differ in waist circumference or BMI. White men had greater L4L5 VAT than African-American men, and both white and Hispanic men had greater total VAT than African-American men. Among women, Hispanics and whites had greater L4L5 VAT than African Americans, and Hispanics had greater total VAT than African Americans. The slope of the linear relationship between BMI or waist circumference and VAT was lower in African Americans than in Hispanics and/or whites.

**Discussion:** Middle-aged and older African-American men and women had lower VAT despite similar BMI and waist circumference measurements. Altered relationships between anthropometric measures and VAT may have implications for defining metabolic risk in different populations. Different waist circumference or BMI cutoff points may be necessary to adequately reflect risk in different racial/ethnic groups.

*Obesity* (2008) **16**, 600–607. doi:10.1038/oby.2007.92

## INTRODUCTION

Minority groups in the United States have higher rates of overweight and obesity compared to whites (1–3). Non-Hispanic blacks and Mexican Americans have rates of combined overweight/obesity of 70 and 73%, respectively, compared to a 62% rate in non-Hispanic whites (4). Particular disparities exist in women, where rates of obesity are 50 and 40% in non-Hispanic black and Mexican Americans compared with 30% in white women (4). Other studies have confirmed this observation of greater adiposity among minority women (1–3).

Anthropometric measurements such as BMI, waist circumference, and waist-to-hip ratio (WHR) are used in large epidemiologic studies to define overweight and obesity, estimate body fat distribution, and/or estimate health risks related to metabolic syndrome. Increments in anthropometric measurements are presumed to correspond with increasing body fat. Of particular interest is an increase in visceral adipose tissue (VAT), since it is

more metabolically active than other adipose tissue sites (5) and appears to contribute to many metabolic abnormalities associated with body weight gain (6–14). Increasing truncal subcutaneous adipose tissue (SAT) may also be a health risk, since it has been associated with insulin resistance in minority groups (15,16).

Some studies have shown that there are racial/ethnic differences in relationships between anthropometric measures of central adiposity and computed tomography (CT)-determined VAT. These studies indicated that African-American women have lower amounts of VAT for a given waist circumference, BMI, or WHR compared to white women (9,15,17–19). Thus, a given anthropometric measurement may represent different amounts of VAT and/or SAT in different racial/ethnic groups. By extension, if VAT is the underlying culprit contributing to metabolic risk, current BMI and waist circumference cutoff points to define risk may overestimate or underestimate risk in different racial/ethnic groups.

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Received 7 May 2007; accepted 15 July 2007; published online 17 January 2008. doi:10.1038/oby.2007.92.

Despite emerging information regarding ethnic differences in body composition, there is still a lack of representation of minorities in clinical cohorts (20–24). Most studies comparing anthropometric measurements to VAT are small and do not include either men or Hispanics (9,15,17–19). Thus, there is paucity of information regarding the impact of race/ethnicity on relationships between anthropometric measures of body composition and VAT. This information is important, in order to refine our understanding of the effect of body fat on metabolic risk. Therefore, 200 Hispanic, African American, and white men and women were recruited to test the hypothesis that racial/ethnic differences existed in both men and women in the relationship of anthropometric measures of body composition and CT-determined truncal VAT or SAT.

## METHODS AND PROCEDURES

### Subjects

Subjects were recruited from North Texas Primary Care Practice-Based Research Network physician practices and from advertisements in the Fort Worth, Texas, area. Subjects were over the age of 45 and had no current or previous history of cardiovascular disease. Race/ethnicity was obtained by self-report. No selection was made on body type or degree of overweight. The cohort of 200 included 76 African American, 74 Hispanic, and 50 white men and women. Of the 200 subjects recruited, usable CT images were obtained from 66 African Americans (45 women, 21 men), 72 Hispanics (52 women, 20 men), and 47 whites (32 women, 15 men).

### Anthropometric measures of body composition

Height was measured to the nearest 0.25 inch, and weight was measured to the nearest 0.25 lb using a standard balance scale. Waist and hip circumferences were measured to the nearest 1/16 inch using a non-stretchable tape. Waist circumference was measured midway between the bottom of the ribcage and the top of the iliac crest. Hip circumference was measured at the level of maximum size of the buttocks (25). Percent body fat was determined using bioimpedance (Tanita, Model TBF-300, Arlington Heights, IL).

### CT-determined VAT, SAT, and total adipose tissue

Abdominal adipose tissue was measured using a 16-slice CT scanner (Toshiba Aquilion 16, Model #TSX-101A, Toshiba America Medical Systems, Tustin, CA). Eight axial CT images of the abdomen were obtained from each subject, with slice number 6 centered on the L4L5 interspace. An additional five slices were obtained every 5 cm above the L4L5 interspace, and two additional slices were obtained 5 and 10 cm below the L4L5 interspace. Collimation of 8 mm was used for each axial slice. The cross-sectional areas of total adipose tissue (TAT) and VAT were quantified on each slice using software-derived algorithms (Analyze, version 6.0, Biomedical Imaging Resource, Rochester, MN). SAT was calculated from each slice as TAT–VAT. From the combined measurements of the eight slices, total abdominal TAT, VAT, and SAT masses were calculated according to previously published methods (26).

### Statistical analyses

Group characteristics were averaged by race and gender and presented as mean  $\pm$  s.e. One-way ANOVA with Tukey's post hoc test was used to determine differences among racial/ethnic groups. Analysis of covariance was used to determine whether relationships between anthropometric variables and L4L5 and total VAT were modified by race/ethnicity. ANOVA and analysis of covariance analyses were done separately for men and women. Because some subjects' body habitus exceeded the field of view of the CT scanner, the total SAT area was not

always visible on the L4L5 scan. As a result, only a subset of subjects was used in L4L5 SAT and TAT analyses (57 African Americans, 68 Hispanics, and 38 whites). Likewise, only subjects whose total SAT area was visible on all scans were included in analyses of total SAT and total TAT (49 African Americans, 63 Hispanics, and 28 whites). Significance was accepted at the 0.05 level.

## RESULTS

### Anthropometric characteristics and VAT

Racial/ethnic group characteristics for men and women are shown in **Table 1**. Among both men and women, the three groups were similar in age. However, among men, white men were significantly heavier than Hispanic men, and both white and African-American men were taller than Hispanic men (both  $P \leq 0.05$ ). White men tended to have higher BMI and waist circumference measures (both  $P < 0.10$ ), but the WHR and body fat percentage did not differ among groups. However, African-American men had significantly less L4L5 VAT compared to white men (**Figure 1a**) and less total VAT (**Figure 1b**) compared to both white and Hispanic men (both  $P \leq 0.05$ ).

Among women, African-American women were heavier than Hispanic women, and both African-American and white women were taller than Hispanic women ( $P \leq 0.05$ , **Table 1**). Waist circumference and BMI did not differ among groups (**Table 1**). Yet the WHR was higher in Hispanic women compared to white women ( $P \leq 0.05$ ), and the overall body fat percentage was higher in African-American women compared to both Hispanic and white women (**Table 1**). Despite similar waist circumferences, African-American women had significantly lower L4L5 VAT compared to both Hispanic and white women (**Figure 1a**) and lower total VAT (**Figure 1b**) compared to Hispanic women (both  $P \leq 0.05$ ).

### Truncal SAT and TAT

L4L5 SAT and total SAT are shown in **Figure 2**. There were no significant differences among racial/ethnic groups L4L5 SAT in either men or women (**Figure 2a**). However, total SAT was greater in African-American women compared to white women (**Figure 2b**,  $P \leq 0.05$ ). L4L5 TAT and overall TAT are shown in **Figure 3**. There were no significant racial/ethnic differences in L4L5 TAT in either men or women (**Figure 3a**). However, overall TAT was greater in African-American and Hispanic women compared to white women (**Figure 3b**,  $P \leq 0.05$ ).

The ratios of VAT/SAT at the L4L5 level (**Figure 4a**) and for the entire abdominal cavity (**Figure 4b**) were calculated to further examine racial/ethnic differences in truncal SAT and VAT distribution. There were no significant differences in VAT/SAT ratios among men. However, both the overall and the L4L5 VAT/SAT ratios were significantly higher in Hispanic women than in African-American and white women ( $P \leq 0.05$ ).

### Relationship between anthropometric measures of body composition and VAT

Within each gender, there were no significant racial/ethnic differences in waist circumference or BMI, but there were significant differences in L4L5 VAT and total VAT. This suggested that the relationship between anthropometric measurements

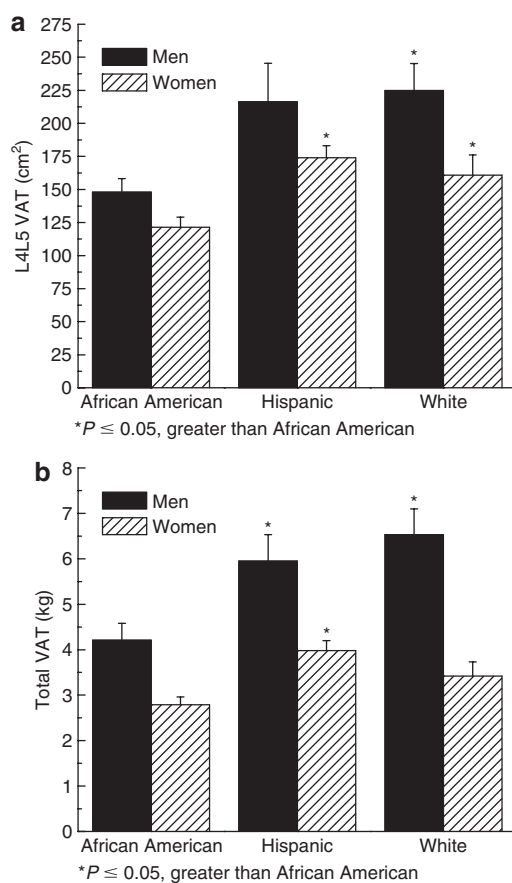
**Table 1 Anthropometric characteristics by race/ethnicity and gender**

	White		African American		Hispanic	
	Men	Women	Men	Women	Men	Women
Age (years)	57.7 ± 1.8	55.7 ± 1.5	56.6 ± 1.8	57.3 ± 1.2	53.3 ± 1.4	54.6 ± 1.2
Height (cm)	175.3 ± 1.3*	160.8 ± 1.1*	173.7 ± 1.1*	160.2 ± 1.2*	164.9 ± 2.3	154.4 ± 0.9
Weight (kg)	106.7 ± 7.0*	84.2 ± 4.2	93.1 ± 3.4	85.0 ± 2.3*	88.1 ± 3.1	76.0 ± 2.3
BMI (kg/m <sup>2</sup> )	34.4 ± 2.0	32.0 ± 1.4	29.9 ± 1.0	32.4 ± 0.9	31.9 ± 1.1	31.5 ± 1.0
WC (cm)	112.4 ± 3.8	96.4 ± 3.2	103.1 ± 2.7	96.0 ± 1.8	105.8 ± 2.7	94.7 ± 1.8
WHR	0.97 ± 0.02	0.82 ± 0.01	0.94 ± 0.01	0.83 ± 0.01	0.98 ± 0.01	0.86 ± 0.01**
Body fat (%)	34.5 ± 2.3	39.7 ± 1.5	30.3 ± 1.7	43.9 ± 0.8***	35.0 ± 2.0	40.9 ± 0.8

Data are mean ± s.e.

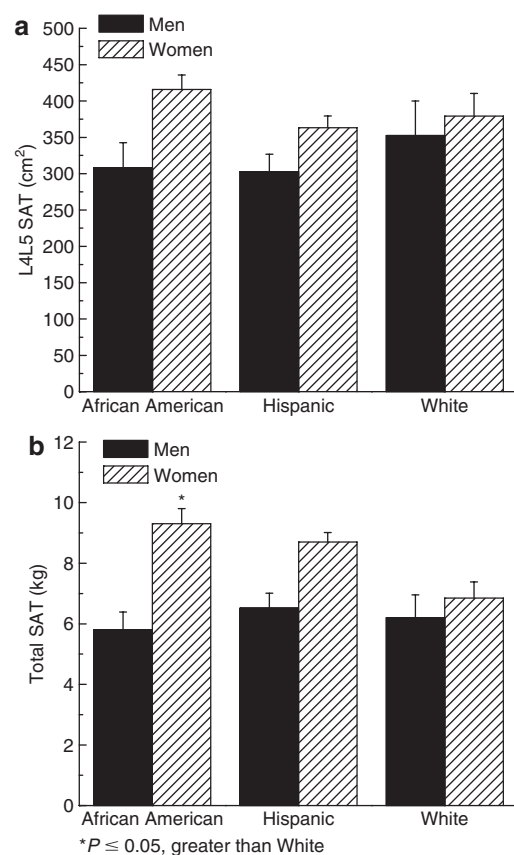
WC, waist circumference; WHR, waist-to-hip ratio.

\* $P \leq 0.05$ , greater than Hispanics of the same gender; \*\* $P \leq 0.05$ , greater than whites of the same gender.



**Figure 1** (a) L4L5 visceral adipose tissue (VAT) among white, African-American and Hispanic men and women ( $n = 163$ ). (b) Total VAT among white, African-American and Hispanic men and women. \* $P \leq 0.05$ , greater than African Americans of the same gender.

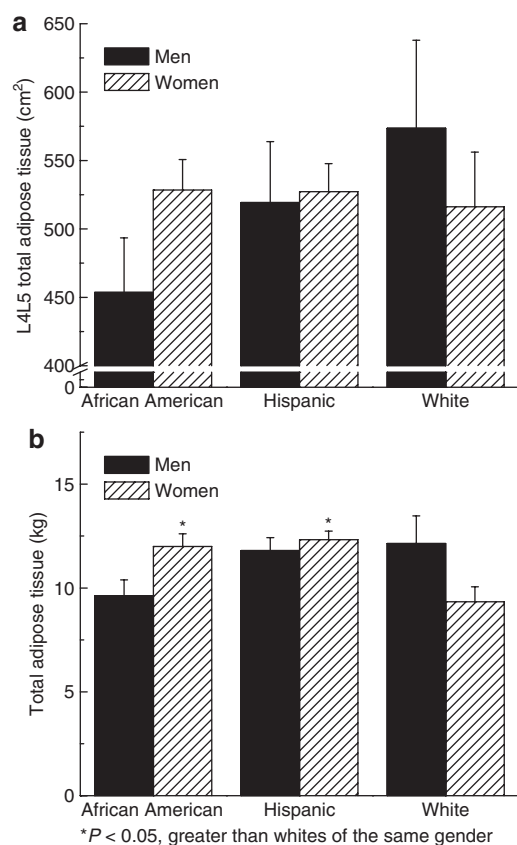
and VAT differed by race/ethnicity. Effects of race/ethnicity on the slopes of the relationships between anthropometric measurements and VAT were tested using analysis of covariance. Significance levels of the interaction terms, which indicate effects of race/ethnicity on the slope, are shown in Table 2. Among men, there were significant differences among groups in the relationships between the independent variables of body weight, BMI, and waist circumference and both dependent



**Figure 2** (a) L4L5 subcutaneous adipose tissue (SAT) in white, African-American and Hispanic men and women ( $n = 163$ ). (b) Total SAT in white, African-American and Hispanic men and women ( $n = 140$ ).

variables (L4L5 VAT and total VAT). Among women, there were group differences in the slopes of the relationships between the independent variables of BMI and waist circumference with both dependent variables. There was also a group difference in the slope of the relationship between body weight and total VAT.

$\beta$ -Coefficients describing the slopes of the significant relationships are shown in Table 3. Among men, increments in body weight, BMI and waist circumference resulted in greater increases in both L4L5 VAT and total VAT in Hispanics.



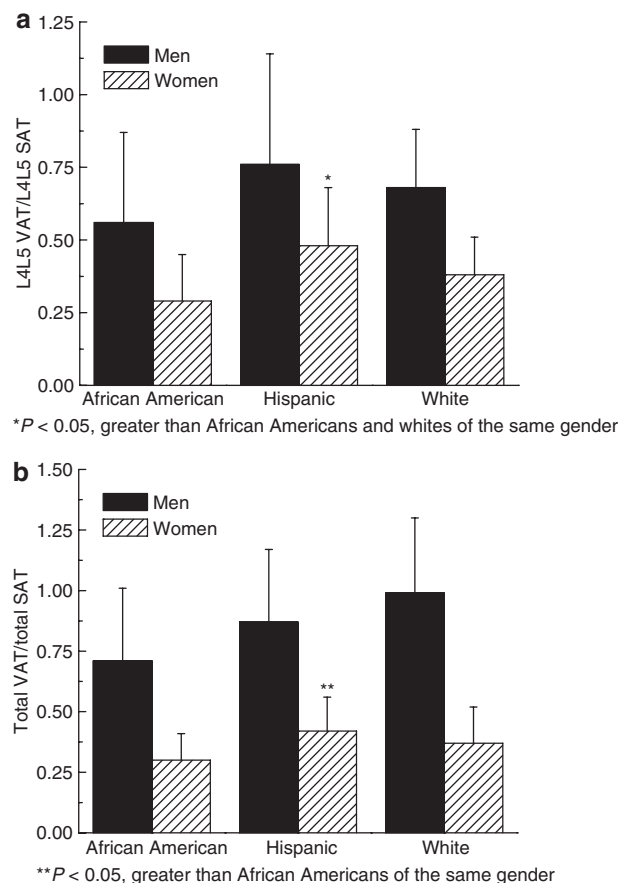
**Figure 3** (a) L4L5 total adipose tissue in white, African-American and Hispanic men and women ( $n = 163$ ). (b) Total adipose tissue mass in white, African-American and Hispanic men and women ( $n = 140$ ). Total adipose tissue is the sum of subcutaneous and visceral adipose tissue at the L4L5 level (a) or for the entire abdominal cavity (b).

Among women,  $\beta$ -Coefficients were similar between Hispanic and white women, but lower in African-American women. Thus, for each increment of body weight, BMI, and waist circumference, increases in VAT were lower in African-American women.

#### Relationship of waist circumference and BMI to VAT

Waist circumference is used by the National Cholesterol Education Program to define one component of the metabolic syndrome (27). Accordingly, the linear relationship between waist circumference and VAT is illustrated in **Figure 5** for women. Notably evident among women were the lower, but still significant, correlations between waist circumference and VAT in African-American women and the lower slope of the waist circumference/VAT relationship. The graphs for men are shown in **Figure 6**. Higher correlations and slopes are evident in the Hispanic men.

Using the linear-regression equations generated by these data, predicted VAT at the cutoff points to define metabolic syndrome in women (88 cm) and men (102 cm) were calculated. At the waist circumference cutoff points in women, predicted L4L5 VAT was 148.4 cm<sup>2</sup> in Hispanics, 123.8 cm<sup>2</sup> in whites, and 101.9 cm<sup>2</sup> in African Americans. Predicted total VAT at the waist circumference cutoff point in women was

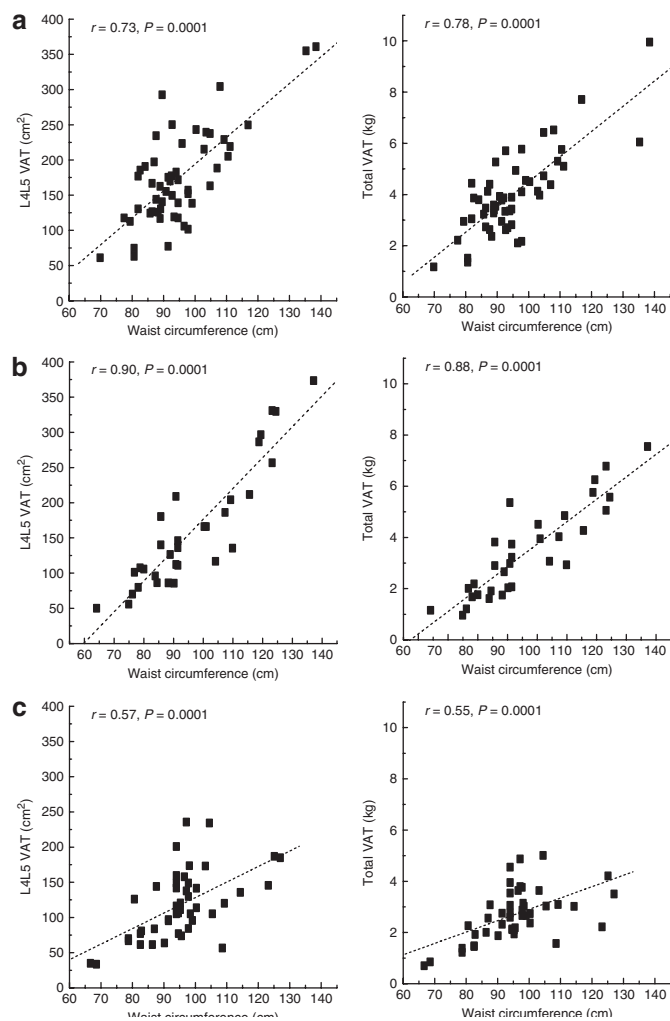


**Figure 4** (a) L4L5 visceral adipose tissue (VAT)/subcutaneous adipose tissue (SAT) ratio among white, African-American and Hispanic men and women. (b) Total VAT/total SAT ratio among white, African-American and Hispanic men and women. \* $P \leq 0.05$ , greater than African Americans and whites of the same gender; \*\* $P \leq 0.05$ , greater than African Americans of the same gender.

3.23 kg in Hispanics, 2.69 kg in whites, and 2.34 in African Americans. At the waist circumference cutoff points in men, predicted L4L5 VAT was 183.5 cm<sup>2</sup> in Hispanics, 202.5 cm<sup>2</sup> in whites, and 145.7 cm<sup>2</sup> in African Americans. Predicted total VAT at the waist circumference cutoff point in men was 5.23 kg in Hispanics, 5.81 kg in whites, and 4.05 in African Americans.

BMI is used by the National Health and Nutrition Examination Surveys to define overweight and obesity (4). Therefore, the linear relationship between BMI and VAT is illustrated in **Figure 7** for women and **Figure 8** for men. At the BMI cutoff point to define overweight (25 kg/m<sup>2</sup>), predicted L4L5 VAT in women was 131.2 cm<sup>2</sup> for Hispanics, 97.9 cm<sup>2</sup> for whites and 93.9 cm<sup>2</sup> in African Americans. Predicted total VAT was 2.91, 2.19, and 2.24 kg, respectively. Predicted L4L5 VAT in men was 78.4 cm<sup>2</sup> for Hispanics, 176.8 cm<sup>2</sup> for whites, and 129.7 cm<sup>2</sup> for African Americans, while predicted total VAT was 3.01, 5.19, and 3.07 kg, respectively.

At the BMI cutoff point to define obesity (30 kg/m<sup>2</sup>), predicted L4L5 VAT in women was 164.2 cm<sup>2</sup> for Hispanics, 143.0 cm<sup>2</sup> for whites and 112.6 cm<sup>2</sup> in African Americans, and predicted total VAT was 3.73, 3.08, and 2.59 kg, respectively. The predicted L4L5

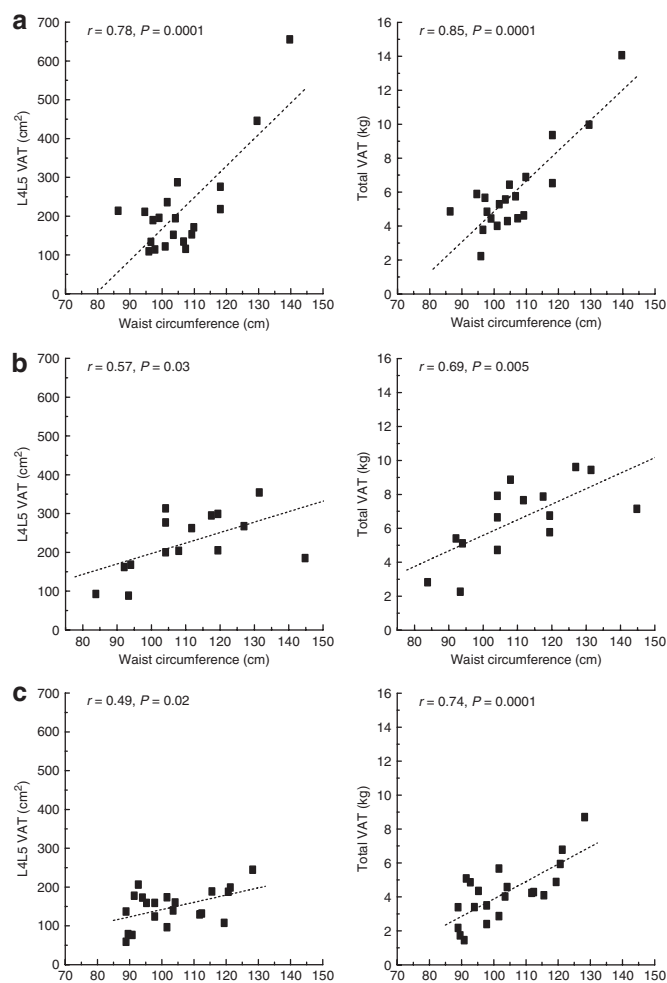


**Figure 5** Relationship between waist circumference and L4L5 visceral adipose tissue (VAT) (left) and total VAT (right) in (a) Hispanic, (b) white, and (c) African-American women.

VAT in men was 177.2 cm<sup>2</sup> for Hispanics, 201.4 cm<sup>2</sup> for whites, and 142.2 cm<sup>2</sup> for African Americans while predicted total VAT was 5.11, 5.97, and 3.93 kg, respectively.

## DISCUSSION

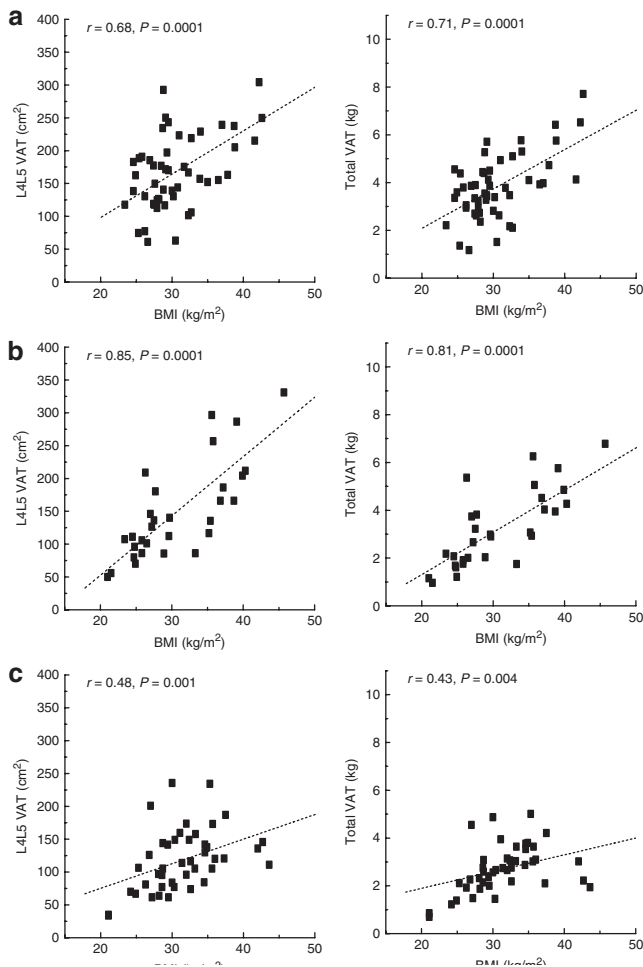
These data revealed important differences in truncal body fat distribution in African American, Hispanic and white middle-aged and older men and women. Importantly, African American men and women consistently had lower VAT compared to Hispanics and/or whites, despite having similar average waist circumference and BMI measurements. As a result, there were racial/ethnic differences in truncal VAT/SAT distribution, particularly among women. Further, there were racial/ethnic differences in the relationships between waist circumference or BMI and VAT, such that increments in these anthropometric variables resulted in smaller increases in VAT in African Americans. There were also apparent racial/ethnic differences in predicted VAT at both the waist circumference cutoff points to define the obesity component of the metabolic syndrome and the BMI cutoff points to define overweight and



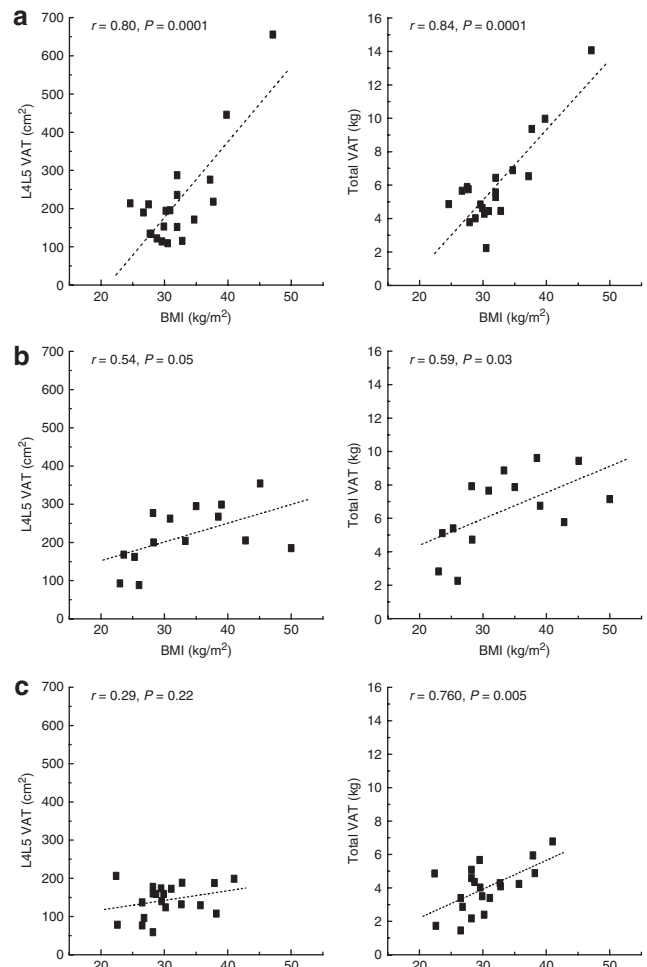
**Figure 6** Relationship between waist circumference and L4L5 visceral adipose tissue (VAT) (left) and total VAT (right) in (a) Hispanic, (b) white, and (c) African-American men.

obesity. Taken together, these data suggest that BMI and waist circumference do not adequately mirror visceral fat accumulations in different racial/ethnic groups.

The present data are in general agreement with earlier studies which demonstrated that African-American women had lower VAT than white women of the same BMI, waist circumference, or WHR (9,15,17–19). These earlier studies had small sample sizes of primarily premenopausal women. This study extends those observations to include Hispanics and men, as well as middle-aged and older women. Yet findings of lower VAT in African Americans are not universal. One study demonstrated that BMI, waist circumference and VAT were all *higher* in African-American women than in white women. However, VAT was lower in African-American women after adjusting for waist circumference but not after adjustment for BMI (28). In the same study, African-American men had similar BMI and waist circumference measures as white men but *less* VAT (28). Similarly, the biracial Bogalusa Heart Study found that African-American women had higher BMI values than white women and that African Americans (men and women) had higher waist circumferences and sagittal diameters compared to whites (23).



**Figure 7** Relationship between BMI and L4L5 visceral adipose tissue (VAT) (left) and total VAT (right) in (a) Hispanic, (b) white, and (c) African-American women.



**Figure 8** Relationship between BMI and L4L5 visceral adipose tissue (VAT) (left) and total VAT (right) in (a) Hispanic, (b) white, and (c) African-American men.

Unfortunately, VAT was not measured so the underlying relationship between anthropometric measurements and VAT was not determined. Still other studies have not shown a racial difference in VAT between African-American and white women (29). Differences in the conclusions reached in these studies may be due to differences in age, menopausal status, socioeconomic status, diet, and/or geographical location.

The only significant finding in the VAT/SAT ratio analyses was the higher ratio among Hispanic women. Use of a calculated ratio has acknowledged limitations and resulted in relatively large error terms. This likely limited the power of the analyses. Qualitatively, however, it is notable that both African-American men and women appeared to have lower L4L5 and total VAT/SAT ratios. Thus, given BMI and waist circumference, measurements appeared to represent relatively greater amounts of SAT in African Americans. While VAT is often considered to present the greatest metabolic risk, SAT has also been correlated with insulin resistance in African-American women (15). Further the combined effect of SAT and VAT was associated with insulin resistance in Hispanics and African Americans such that when both were high, insulin sensitivity was very low. Further, SAT,

**Table 2** Significance level of interaction terms testing for racial/ethnic differences in slope of relationship between anthropometric measurements and visceral adipose tissue (VAT) in men and women

Independent variables	L4L5 VAT		Total VAT	
	Men (n = 56)	Women (n = 129)	Men (n = 56)	Women (n = 129)
Body weight	0.0015	0.0948	0.0043	0.0113
BMI	0.0001	0.0038	0.0052	0.0054
Waist circumference	0.0009	0.0047	0.0304	0.0010
Percent fat	0.2951	0.1586	0.7447	0.0871

Values represent level of significance of the interaction term testing for difference of slopes.

but not VAT, was associated with the acute insulin response to glucose ingestion (16). Thus, the relatively higher SAT in African Americans may still pose a substantial metabolic risk.

At the waist circumference cutoff points used to indicate increased central adiposity in the metabolic syndrome (27),

**Table 3 Slope of relationships between anthropometric measurements and visceral adipose tissue (VAT): effect of race/ethnicity**

	Men			Women		
	Hispanic (n = 20)	White (n = 15)	African American (n = 21)	Hispanic (n = 52)	White (n = 32)	African American (n = 45)
Total VAT						
Body weight	0.146	0.044	0.071	0.074	0.057	0.034
BMI	0.420	0.157	0.172	0.165	0.177	0.070
Waist circumference	0.179	0.092	0.102	0.098	0.088	0.044
L4L5 VAT						
Body weight	6.243	1.158	1.159	–	–	–
BMI	19.764	4.811	2.514	6.606	9.023	3.741
Waist circumference	8.111	2.696	1.868	3.814	4.384	2.205

Values represent  $\beta$ -Coefficients.

predicted VAT was lowest in African Americans. However, at the BMI cutoff points indicating overweight and obesity, the effect of different slopes of the BMI/VAT relationship in African Americans was evident, that is, at a BMI of 25 kg/m<sup>2</sup>, both predicted L4L5 VAT and total VAT were higher in Hispanic women than in African-American and white women. However, at a BMI of 30 kg/m<sup>2</sup>, both predicted L4L5 VAT and lower predicted VAT were considerably lower in African-American women. In men, Hispanics had the lowest predicted L4L5 VAT at a BMI of 25 kg/m<sup>2</sup>, but African Americans had the lowest predicted L4L5 VAT at a BMI of 30 kg/m<sup>2</sup>. Lower predicted total VAT in African-American men was not apparent at a BMI of 25 kg/m<sup>2</sup> but was clearly evident at a BMI of 30 kg/m<sup>2</sup>. Thus, while a BMI of 30 kg/m<sup>2</sup> is used to categorize individuals as obese, it is clear that this may not reflect the same underlying adipose distribution in different racial/ethnic groups.

Few studies have evaluated the relationship between waist circumference or BMI and VAT in racial/ethnic minorities. In one study, correlations between both sagittal diameter and waist circumference and VAT were stated to be similar in African-American and white men and women (30). However, the data were only presented for the overall sample, so it is difficult to compare them with the present results. Another study demonstrated that African Americans and Hispanics had lower waist circumferences at the BMI cutoff points of 25 and 30 kg/m<sup>2</sup> (31). However, both these measures are surrogates for underlying fat, and neither is a “gold standard” for comparison purposes. Thus, this study did not shed any light on underlying visceral fat. A third study demonstrated that waist circumference cutoff points for defining metabolic risk (102 and 88 cm, respectively, for men and women) provided dissimilar positive and negative predictive values among white, black, and Hispanic men and women (32). VAT was not measured in this study, but the dissimilar predictive values may be due to dissimilar underlying adipose distribution. By contrast, this study provided comparisons between surrogates of body fat and CT-determined VAT. This provides a more accurate representation of how well anthropometric measures of central adiposity reflect underlying body fat in different ethnic groups.

These data provide intriguing insights into important racial/ethnic differences between anthropometric measures of body composition and underlying visceral fat. However, results must still be viewed with caution because of the relatively small number of subjects in the race/gender subgroupings. Further research is needed to determine the generalizability of these results to groups that differ in age, health status, or geographic location. Effects of diet or exercise history on fat distribution may also be warranted to further refine these findings.

In conclusion, these data demonstrated that middle-aged and older African-American men and women had lower visceral fat than Hispanic and white men and women, despite similar BMI and waist circumference measurements. These data support the observation (28) that race- and sex-specific equations are required to estimate VAT from waist circumference measurements. The altered relationship between anthropometric measures of body composition and VAT may have implications for defining metabolic risk in different populations. Different waist circumferences or BMI cut off points may be necessary to adequately reflect risk in different racial/ethnic groups.

#### ACKNOWLEDGMENTS

This study was supported by a grant P20 MD001633 from the National Center for Minority Health and Health Disparities (NCMHD), National Institutes of Health. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the NCMHD.

#### DISCLOSURE

The authors declared no conflict of interest.

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