Racial differences in amounts of visceral adipose tissue in young adults: the CARDIA (Coronary Artery Risk Development in Young Adults) Study[1–3]

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ABSTRACT

Background: In several white populations, visceral adipose tissue (VAT) is a risk factor for development of type 2 diabetes and dyslipidemia. VAT can be accurately assessed by computed topography or magnetic resonance imaging, but is also estimated from anthropometric variables, such as waist-to-hip ratio, waist circumference, or sagittal diameter. To date, anthropometric variables have been used largely in whites and inadequate data are available to evaluate the validity of these variables in other groups.

Objectives: The objectives of this study were to *1*) determine whether amount of VAT in relation to total body fatness differs in different race and sex groups and *2*) determine which anthropometric variables predict amount of VAT in different race and sex groups.

Design: We determined the amount and location of body fat, including assessment of VAT by computed tomography, in young adult white and black men and women participating in the 10-y follow-up of the CARDIA (Coronary Artery Risk Development in Young Adults) Study.

Results: Black men had less visceral fat (73.1 ± 35.9 cm^2) than white men (99.3 ± 40 cm^2), even when VAT was corrected for total body fatness. Black women were more obese than white women and thus had more visceral fat (75.1 ± 37.5 compared with 58.6 ± 35.9 cm^2, respectively). This difference disappeared when corrected for total body fatness.

Conclusions: Both waist circumference and sagittal diameter were good predictors of VAT in all groups. However, the nature of this relation differed such that race- and sex-specific equations will likely be required to estimate VAT from waist circumference or sagittal diameter. *Am J Clin Nutr* 1999; 69:381–7.

KEY WORDS

Visceral adipose tissue, body fat distribution, racial differences, obesity, computed tomography, waist circumference, sagittal diameter, whites, blacks, CARDIA Study, young adults

INTRODUCTION

Obesity greatly increases the risk of developing type 2 diabetes and coronary artery disease (1, 2). It is thought that both the total amount of body fat and the location of excess body fat may contribute to disease risk (3). Risk of type 2 diabetes, coronary artery disease, and all-cause mortality has repeatedly been shown to increase in proportion to increases in body mass index (BMI), an estimation of total adiposity (4–7). Central, or upper body, obesity is strongly linked to insulin resistance in white populations and prospective studies have shown that central obesity is also linked to increased risk of development of type 2 diabetes, myocardial infarction, angina pectoris, stroke, and all-cause mortality in white populations (8–10). In most population studies, central adiposity is defined as a high waist-to-hip ratio (WHR).

Substantial data now suggest that the amount of visceral fat may be strongly associated with risk factors for type 2 diabetes (11–13). Visceral fat can be accurately assessed by computed tomography (CT) scanning or magnetic resonance imaging (14, 15), but is often approximated by waist circumference or sagittal diameter (16). Because the amount of visceral fat for a given WHR can be substantially altered by individual differences in the amount of total body fat, WHR may not provide a good estimation of visceral fat and in particular may not provide good estimates of changes in visceral fat with weight loss (17).

Although blacks (and black women in particular) tend to be more obese than whites (18), the higher risk of type 2 diabetes in blacks than in whites does not appear to be explained by differences in obesity (19). Some reports have suggested that obese black women have a different body fat distribution for a given degree of obesity than do obese white women; in particular, several investigators reported that obese black women have less visceral fat than obese white women at similar BMIs and WHRs (20–22). In these studies, WHR was strongly correlated with total visceral fat in whites but not in blacks. Conway et al (20) reported a much greater correlation between waist circumference and visceral fat in blacks than in whites. Thus, the risk factors for type 2 diabetes appear to be stronger in blacks than in whites, despite blacks having less visceral fat (21, 22). It appears that in addition to racial differences in body fat distribution, there must also be racial differences in the relation between visceral fat and risk of type 2 diabetes.

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The intent of this study was to obtain cross-sectional data to determine whether the amount of visceral adipose tissue (VAT) in relation to total body fat differed among young white and black men and women participating in the 10-y follow-up of the CARDIA (Coronary Artery Risk Development in Young Adults) Study. An additional aim was to determine whether similar anthropometric variables predicted amount of VAT across race and sex groups.

SUBJECTS AND METHODS

Subjects

We recruited subjects who were participating in the 10-y follow-up of the CARDIA Study, a population-based longitudinal study of the development of cardiovascular disease risk factors in young adults (23). Subjects were excluded from the present study for the following reasons: diabetes, use of thyroid replacement medication, weight >136 kg, and pregnancy or lactation (within the past 6 mo). We recruited 400 subjects (≈100 from each race and sex group) from 2 of the CARDIA sites: Birmingham, AL, and Oakland, CA. BMI was distributed similarly (both above and below the median race- and sex-specific BMI values from the year 7 exam) in each group. Three subjects were excluded from the analysis because of abnormal values for thyroid stimulating hormone and 6 were excluded because of incomplete data collection. The final sample size was 100 black men, 96 white men, 90 black women, and 105 white women. Of the 391 subjects, 238 were studied in Oakland and 153 in Birmingham.

Procedures

CT scans were performed with a 9800 CT scanner (General Electric Medical Systems, Milwaukee) in Oakland (238 scans) and with either a 9800 CT scanner (43 scans) or a General Electric high-speed CT scanner (110 scans) in Birmingham. (All abdominal CT scans in women were obtained during the first 10 d of the menstrual cycle unless the woman had undergone a tubal ligation or hysterectomy or was using oral contraceptives.) After a scout image was obtained, the L4-L5 vertebral space was localized and a single CT image was acquired through the center of the disc (140 kV, 240–340 mA•s, 10-mm slice thickness). Images were transferred to the central reading center at the University of Colorado Health Sciences Center on optical disks or tape storage media for analysis. Abdominal adipose tissue regions were analyzed and VAT and subcutaneous adipose tissue (SAT) were determined by using techniques described previously (14, 17). Analysis programs were developed by the central reading center by using intermediate density lipoprotein (RSI Inc, Boulder, CO). The analysis relies on a bimodal image histogram resulting from the distribution of CT numbers in adipose tissue and muscle. The peaks are readily separable and the area of adipose tissue in the image is determined by the area under the adipose tissue peak of the histogram. Analysis was performed on a SPARC 20 (Sun Microsystems, Inc, Mountain View, CA).

Additionally, to be eligible for this study, subjects must have completed the following components of the 10-y follow-up of the CARDIA Study: anthropometry and measurement of total body fat by dual-energy X-ray absorptiometry. BMI was calculated as weight (in kg) divided by height squared (in m). Waist girth was measured midway between the iliac crest and the lowest lateral portion of the rib cage and anteriorly midway between the xyphoid process of the sternum and the umbilicus (the intent was to measure the smallest circumference at the level of the waist). Hip girth was measured at the level of the symphysis pubis anteriorly and posteriorly at the level of the maximal protrusion of the gluteal muscles. From these measures, WHR was calculated. Skinfold thicknesses were obtained at 3 sites: subscapula, suprailium, and triceps. The sum of these 3 skinfold thicknesses was used as a variable. Sagittal diameter was assessed from the CT scans and was the maximum diameter taken at the midline on the L4-L5 scan.

Total body fat was determined by dual-energy X-ray absorptiometry in the enhanced total-body-array scanning mode with a Hologic 2000 densitometer (Hologic, Inc, Waltham, MA) at each site (Oakland and Birmingham). A traveling phantom was used to ensure comparability between sites.

Data analysis

The SAS statistical package (version 6.08; SAS Institute Inc, Cary, NC) was used for all analyses. Differences in anthropometric and body fat measures between whites and blacks for men and women and between the sexes by race were evaluated with *t* tests. Adjusted means were calculated by the general linear model method for each sex to compare VAT and SAT between races; race × sex interactions were evaluated by two-factor analysis of variance. Adjustments were made for age, CARDIA center, and selected measures. Predictors of VAT were assessed in a univariate manner by examining correlations and in regression models in which age was controlled for.

RESULTS

Anthropometric variables

The mean values of several anthropometric characteristics in each of the subgroups are shown in **Table 1**. Black and white men did not differ significantly in height, weight, BMI, sum of 3 skinfold thicknesses, waist circumference, or sagittal diameter. WHR, however, was significantly higher in white men than in black men. Among women, blacks had a significantly higher mean weight, BMI, sum of 3 skinfold thicknesses, waist circumference, WHR, and sagittal diameter than whites.

White men had a greater waist circumference and higher BMI than white women, but black men had a lower BMI than black women. Black men and women did not differ significantly in waist circumference. The sum of 3 skinfold thicknesses was higher in women than in men in both whites and blacks.

Adipose tissue

Adipose tissue measures in all subgroups are shown in **Table 2**. White men had a significantly higher percentage body fat, greater total body fat content, and more VAT than did black men. SAT was not significantly different between these 2 groups, nor was the ratio of VAT to SAT (VAT:SAT). Black women had a significantly higher percentage body fat, greater total body fat content, more VAT, more SAT, and a lower VAT:SAT than did white women.

Among blacks, women had a significantly higher percentage body fat, more total body fat, more SAT, and a lower VAT:SAT than did men. VAT was not significantly different between black men and women. Among whites, women had a significantly higher percentage body fat, more total body fat, less VAT, more SAT, and a lower VAT:SAT than did men.

TABLE 1
Anthropomorphic measurements by race and sex[1]

	Black men (n = 100)	White men (n = 96)	Black women (n = 90)	White women (n = 105)
Weight (kg)	85.2 ± 14.4[2]	83.5 ± 11.8[3]	80.2 ± 15.8[3]	67.7 ± 14.4
Height (cm)	177.9 ± 6.7[4]	179.0 ± 6.6[3]	164 ± 6.8	165.6 ± 6.6
BMI (kg/m^2)	26.9 ± 4.2[4]	26.0 ± 3.4[5]	29.6 ± 5.6[3]	24.7 ± 5.2
Sum of 3 skinfold thicknesses	50.9 ± 20.7[4]	51.7 ± 14.1[5]	82.8 ± 25.1[3]	58.7 ± 25.3
Waist circumference (cm)	87.6 ± 10.2	89.2 ± 8.6[3]	86.6 ± 12.1[3]	76.1 ± 10.4
WHR	0.84 ± 0.05[4,6]	0.87 ± 0.05[3]	0.79 ± 0.07[3]	0.74 ± 0.05
Sagittal diameter (mm)	220.8 ± 32.3[4]	216.9 ± 26.1[3]	238.9 ± 35.7[3]	195.8 ± 37.1

[1]$\bar{x}$ ± SD. WHR, waist-to-hip ratio.
[2,4]Significantly different from black women: [2]$P \leq 0.05$, [4]$P \leq 0.001$.
[3,5]Significantly different from white women: [3]$P \leq 0.001$, [5]$P \leq 0.05$.
[6]Significantly different from white men, $P \leq 0.01$.

TABLE 2
Amount and location of body fat mass by race and sex[1]

	Black men (n = 100)	White men (n = 96)	Black women (n = 90)	White women (n = 105)
Total percentage fat (%)	21.3 ± 7.2[2,3]	24.6 ± 5.8[4]	40.7 ± 7.1[4]	35.7 ± 9.6
Total fat (kg)	18.5 ± 8.4[2,5]	20.6 ± 6.8[6]	32.7 ± 10.6[4]	24.8 ± 11.9
VAT (cm^2)	73.1 ± 35.9[3]	99.3 ± 40.0[4]	75.1 ± 37.5[6]	58.6 ± 35.9
SAT (cm^2)	206.3 ± 111.7[2]	212.2 ± 77.3[4]	398.4 ± 145.6[4]	274.1 ± 153.8
VAT:SAT	0.43 ± 0.32[2]	0.49 ± 0.17[4]	0.20 ± 0.09[7]	0.23 ± 0.12

[1]$\bar{x}$ ± SD. VAT, visceral adipose tissue; SAT, subcutaneous adipose tissue.
[2]Significantly different from black women, $P \leq 0.001$.
[3,5]Significantly different from white men: [3]$P \leq 0.001$, [5]$P \leq 0.05$.
[4,6,7]Significantly different from white women: [4]$P \leq 0.001$, [6]$P \leq 0.01$, [7]$P \leq 0.05$.

TABLE 3
Adiposity measures adjusted for age, study center, and selected anthropomorphic measures in men[1]

	VAT		SAT	
Adjustment variable	Blacks (n = 100)	Whites (n = 96)	Blacks (n = 100)	Whites (n = 96)
	cm^2			
Total percentage fat	79.9 ± 2.9[2]	92.2 ± 3.0	226.8 ± 5.1[3]	190.8 ± 5.2
Total body fat (in kg)	77.4 ± 2.8[3]	94.8 ± 2.8	218.4 ± 3.6[3]	199.5 ± 3.7
BMI	71.6 ± 3.1[3]	100.8 ± 3.2	197.6 ± 5.4[2]	221.2 ± 5.5
Waist circumference	75.9 ± 2.7[3]	96.4 ± 2.7	212.4 ± 5.2	205.8 ± 5.3
WHR	78.1 ± 3.0[3]	94.1 ± 3.0	215.6 ± 8.3	202.5 ± 8.4
Sagittal diameter	72.0 ± 2.5[3]	100.4 ± 2.6	200.5 ± 4.6[4]	218.2 ± 4.7

[1]$\bar{x}$ ± SD. VAT, visceral adipose tissue; SAT, subcutaneous adipose tissue; WHR, waist-to-hip ratio.
[2–4]Significantly different from whites: [2]$P \leq 0.005$, [3]$P \leq 0.001$, [4]$P \leq 0.01$.

TABLE 4
Adiposity measures adjusted for age, study center, and selected anthropomorphic measures in women[1]

	VAT		SAT	
Adjustment variable	Blacks (n = 90)	Whites (n = 105)	Blacks (n = 90)	Whites (n = 105)
	cm^2			
Total percentage fat	69.5 ± 3.1	63.4 ± 2.8	358.0 ± 8.2[2]	308.7 ± 7.6
Total body fat (in kg)	66.9 ± 2.9	65.6 ± 2.6	343.8 ± 5.5[3]	320.9 ± 5.1
BMI	63.6 ± 2.8	68.4 ± 2.6	330.4 ± 7.4	332.4 ± 6.8
Waist circumference	61.7 ± 2.4[4]	70.1 ± 2.2	333.8 ± 9.6	329.5 ± 8.8
WHR	66.7 ± 3.2	65.8 ± 2.9	373.4 ± 15.7[2]	295.5 ± 14.4
Sagittal diameter	58.3 ± 2.6[2]	72.9 ± 2.4	308.1 ± 6.4[2]	351.5 ± 5.8

[1]$\bar{x}$ ± SD. VAT, visceral adipose tissue; SAT, subcutaneous adipose tissue; WHR, waist-to-hip ratio.
[2–4]Significantly different from whites: [2]$P \leq 0.001$, [3]$P \leq 0.005$, [4]$P \leq 0.05$.

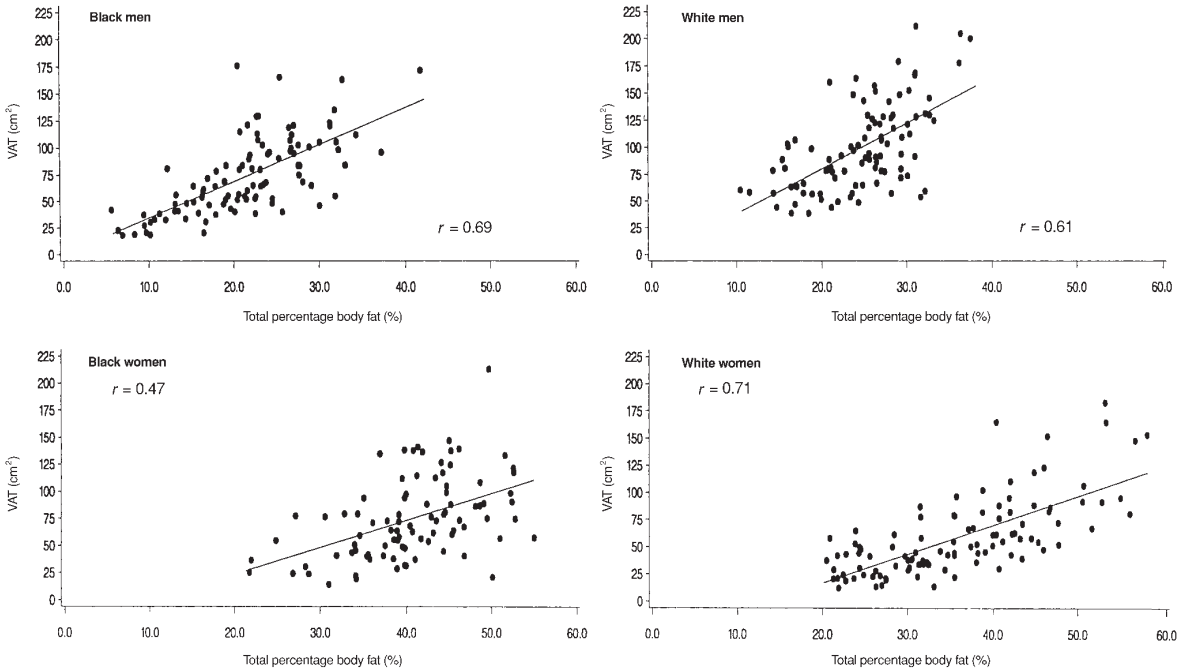

FIGURE 1. Relation between total percentage body fat and visceral adipose tissue (VAT) in black men (n = 100), white men (n = 96), black women (n = 90), and white women (n = 105).

Adjusted measures of VAT and SAT

We found a significant race × sex interaction in VAT ($P < 0.0001$). Because of differences in amount of body fat, measures of VAT and SAT were adjusted for total body adiposity and for waist circumference, WHR, and sagittal diameter. The mean adjusted values for VAT and SAT in men are shown in **Table 3**. VAT was significantly lower in black men than in white men when adjusted for percentage body fat, total body fat, BMI, waist circumference, WHR, or sagittal diameter. The pattern with SAT was less consistent. SAT was significantly higher in black men than in white men when adjusted for total percentage fat and total body fat, but significantly lower when adjusted for BMI or sagittal diameter. SAT was not significantly different between black and white men when adjusted for waist circumference.

The same values for women are shown in **Table 4**. VAT was significantly lower in black women than in white women when adjusted for waist circumference or sagittal diameter, but not

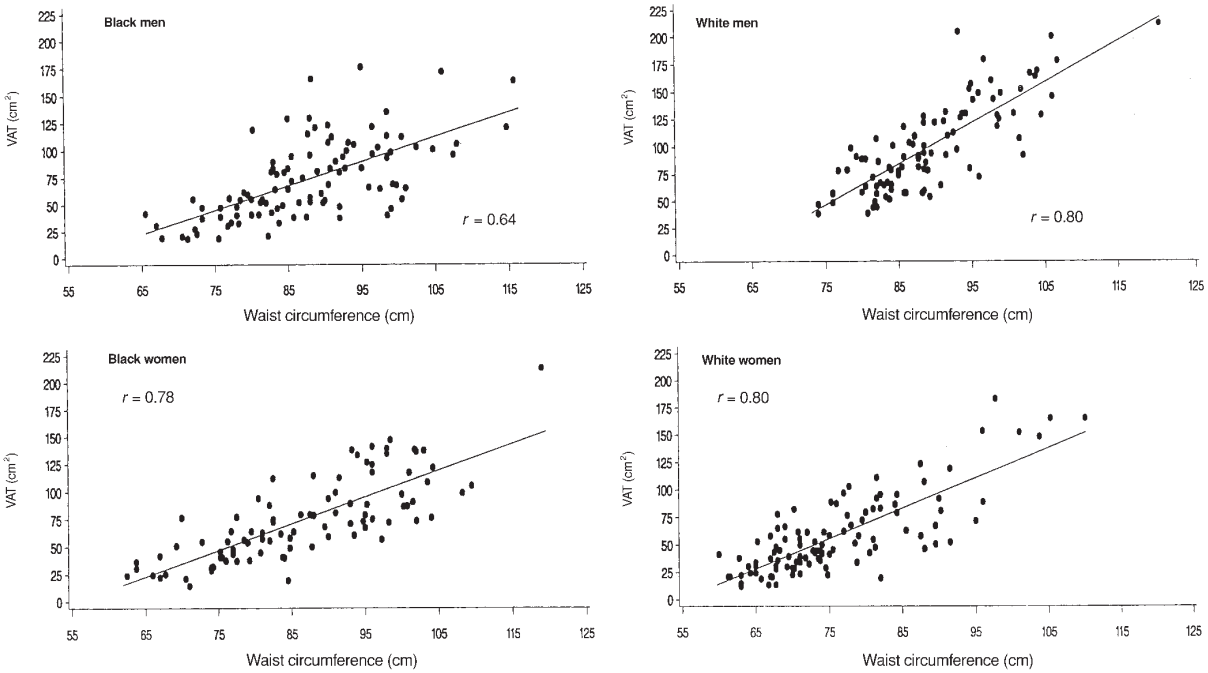

FIGURE 2. Relation between waist circumference and visceral adipose tissue (VAT) in black men (n = 100), white men (n = 96), black women (n = 90), and white women (n = 105).

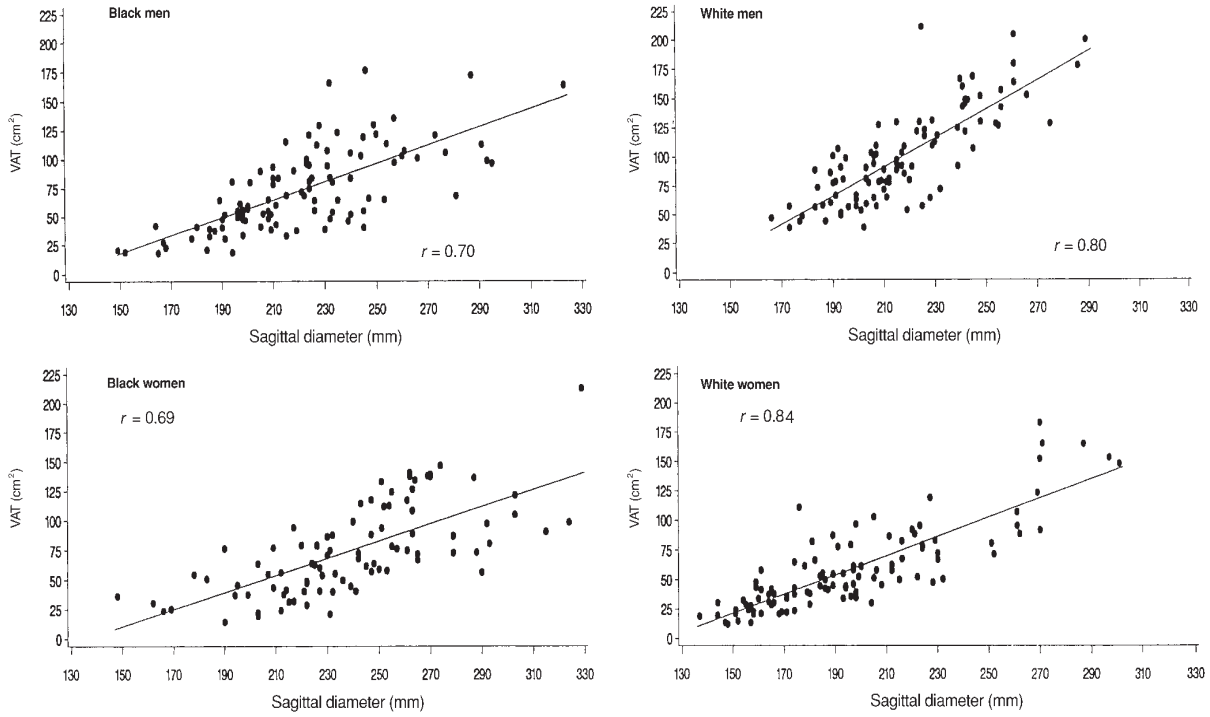

FIGURE 3. Relation between sagittal diameter and visceral adipose tissue (VAT) in black men (n = 100), white men (n = 96), black women (n = 90), and white women (n = 105).

when adjusted for total percentage fat, total body fat, BMI, or WHR. SAT was significantly higher in black women than in white women when adjusted for percentage body fat, total body fat, and WHR, but significantly lower when adjusted for sagittal diameter. SAT did not differ significantly between groups when adjusted for BMI or waist circumference.

Predictors of VAT

Because VAT differed among subgroups, even after adjustment for total adiposity, we examined the ability of anthropometric variables to predict amount of VAT. The univariate relations for each subgroup between the 4 predictor variables (total percentage fat, waist circumference, sagittal diameter, and

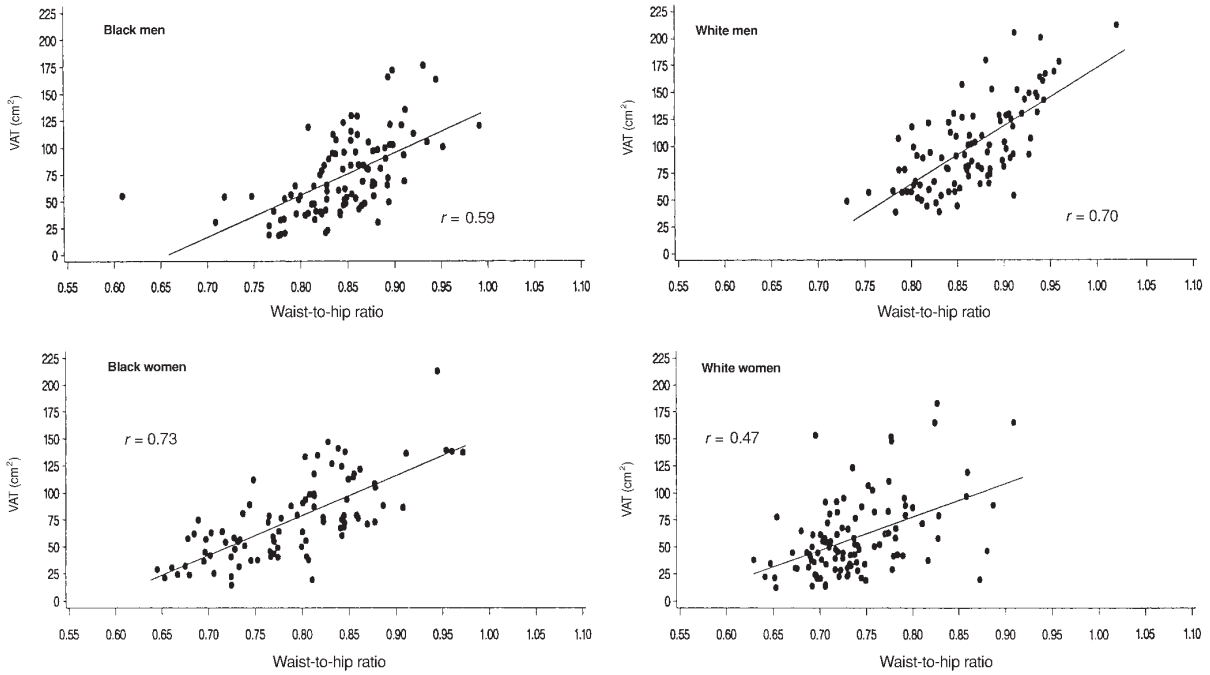

FIGURE 4. Relation between waist-to-hip ratio and visceral adipose tissue (VAT) in black men (n = 100), white men (n = 96), black women (n = 90), and white women (n = 105).

TABLE 5
Correlation (r^2)values for prediction of total visceral adipose tissue with adjustment for age and selected anthropometric variables or percentage body fat

	Black men	White men	Black women	White women
Waist circumference	0.44	0.64	0.62	0.66
Sagittal diameter	0.53	0.65	0.50	0.72
WHR[1]	0.37	0.49	0.53	0.26
Sum of skinfold thicknesses	0.36	0.30	0.36	0.59
BMI	0.26	0.49	0.41	0.61
Percentage body fat	0.53	0.37	0.25	0.54

[1]Waist-to-hip ratio.

WHR) and measured VAT are shown in **Figures 1–4**. In particular, waist circumference was a good predictor of VAT in all groups (Figure 2). However, there were significant sex × race effects ($P < 0.0004$) in both the slope and intercept of the regression lines. Shown in **Table 5** are the age-adjusted r^2 values for the prediction of total VAT. For black men, either sagittal diameter or percentage body fat provided the best prediction of VAT. Waist circumference had less predictive value. For black women, waist circumference had the best predictive value for VAT and sagittal diameter was a much weaker predictor. For white men and women, both waist circumference and sagittal diameter had good predictive value for visceral fat. Sagittal diameter was a slightly better predictor than waist circumference for white women. WHR, a commonly used means of estimating VAT, was a relatively weak predictor of visceral fat in all 4 subgroups, especially in white women.

DISCUSSION

We found a significant race × sex interaction in VAT in this population of young adults. The most striking result was that for any given body fatness, black men had significantly less VAT and significantly more SAT than did white men. Given the substantial amount of data obtained in white subjects suggesting that VAT influences risk of type 2 diabetes and cardiovascular disease independently of total adiposity, we must question whether black men are at the same risk of these diseases as white men with similar percentages of body fat. At present, there are not enough data for the black population, especially for black men, to assume that the relation between VAT and disease risk is similar to that seen in whites. Data obtained in black women suggest that the relation may not be the same, especially with regard to risk of type 2 diabetes (21). Although the epidemiologic literature provides some support that increasing overweight increases cardiovascular disease risk less in blacks than in whites (24), there is little support for this in relation to risk of type 2 diabetes (18, 25, 26). Because data on several cardiovascular disease and type 2 diabetes risk factors are being collected at the 10-y CARDIA follow-up, we will be able to address this question in future analyses.

The differences in VAT between black and white women in the present study are not as striking as those reported previously (20, 21). VAT was lower in black women than in white women only when adjusted for waist circumference or sagittal diameter, not when adjusted for total body fat or BMI. In previous studies VAT was found to be lower in black women than in white women when adjusted for BMI (20, 21). This discrepancy could be related to the different populations studied. Most other studies used small numbers of either lean or obese subjects, in whom the range of BMI was limited. One advantage of the data presented here is the wide range of BMI, making the results more generalizable to the overall population. SAT, however, was higher in black men and women than in whites even when adjusted for total body fatness. This may suggest that subcutaneous upper body fat contributes more to type 2 diabetes risk in blacks than in whites. Although this is consistent with previous work (27, 28), the issue deserves further study.

Waist circumference was a good predictor of visceral fat in all race and sex groups. The fact, however, that there were significant sex × race differences in both the slopes and intercepts of the regression lines relating waist circumference to VAT suggests that equations to predict VAT from waist circumference will need to be sex and race specific. When VAT cannot be measured directly by CT scanning or magnetic resonance imaging, waist circumference can provide a reasonable estimate of VAT in black and white men and women. Sagittal diameter was also a good predictor of VAT in all groups, but provided no advantage over waist circumference. However, sagittal diameters in this study were measured only from the CT image. WHR, which is commonly used to estimate VAT in population studies, provided a less precise estimate of VAT, particularly in black men and white women.

There is a great deal of interest in understanding how body fat distribution is regulated. The finding that there are racial influences on body fat distribution may provide an opportunity to use racial comparisons to better understand the physiologic and behavioral factors that influence body fat distribution.

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