Sex differences in visceral adipose tissue volume among African Americans[1,2]

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ABSTRACT

Background: Men are believed to have more visceral adipose tissue (VAT) than women have, but studies in African Americans that measured VAT from a single computed tomography (CT) slice found no sex difference.

Objective: We used a serial-slice CT scan to investigate whether there is a sex difference in VAT volume among African Americans.

Design: Single-slice CT measurements of VAT area at lumbar spine L2-3 and L4-5 levels were taken in 110 African Americans (44 men, 66 women). In 59 subjects (24 men, 35 women), VAT volume was also measured with contiguous CT slices from the diaphragm to the iliac crest. Fat mass was determined by dual-energy X-ray absorptiometry.

Results: Men and women had similar ages ($\bar{x}$ ± SD: 36.1 ± 7.8 and 35.6 ± 7.8 y, respectively) and body mass indexes in kg/m^2 (29.5 ± 6.9 and 32.0 ± 8.9). The percentage of body fat was lower ($P < 0.0001$) in men (21.8 ± 7.3%) than in women (37.4 ± 7.9%). The VAT volume was greater ($P = 0.01$) in men (1443 ± 931 cm^3) than in women (940 ± 821 cm^3). There was no sex difference in unadjusted VAT area at L2-3 (men, 88.6 ± 63.5 cm^2; women, 57.2 ± 45.4 cm^2) or L4-5 (men, 65.6 ± 53.3 cm^2; women, 55.0 ± 38.3 cm^2). After adjustment for percentage of body fat or fat mass, men had larger VAT area at both levels ($P < 0.01$). After adjustment for body mass index, the sex difference in VAT area was detectable at L2-3 ($P < 0.001$) but not at L4-5 ($P = 0.22$).

Conclusions: VAT volume is greater in men than in women. Detection of sex differences in VAT area among African Americans on single-slice CT requires adjustment for body fat content. At L2-3, adjustment for body mass index alone is adequate to detect sex differences in VAT. *Am J Clin Nutr* 2002;76:975–9.

KEY WORDS African Americans, visceral adipose tissue, fat distribution, percentage body fat, total body fat content, fat mass

INTRODUCTION

Visceral adipose tissue (VAT) is positively correlated with triacylglycerol concentrations and negatively correlated with insulin-induced suppression of free fatty acids and insulin-mediated disposal of glucose (1–4). Therefore, VAT is a marker of atherogenicity. Compared with their female counterparts, African American, white, and Asian Indian men have higher triacylglycerol concentrations, less suppression of free fatty acids during an oral-glucose-tolerance test, and greater risk of cardiovascular disease (5, 6). It could thus be hypothesized that men in all 3 groups would have a greater VAT volume than women. For whites and Asian Indians, a sex difference in VAT has been documented (7, 8). Two large studies, the Coronary Risk Development in Young Adults (CARDIA) Study and the Health, Risk Factors, Exercise Training and Genetics (HERITAGE) Family Study, reported that there is no sex difference in VAT among African Americans (9, 10), but both of these studies reported a sex difference in VAT among whites.

The lack of a sex difference in VAT among African Americans reported by investigators from both the CARDIA and the HERITAGE studies is perplexing. However, aspects of the methods of those studies may have obscured sex-related VAT differences among African Americans. First, neither study made adjustments for body fat content in conjunction with sex comparisons of VAT. Such a correction may be particularly important for studies in African Americans because the sex difference in body fat content in African Americans is greater than that observed in whites (9). Second, the CARDIA and HERITAGE studies measured the VAT area in a single computed tomography (CT) scan slice at the L4-5 level of the lumbar spine. Our review of the literature found no studies that correlated single-slice VAT area with total VAT volume in African Americans. Such a possibility has been investigated in whites, and the results are conflicting. Some studies in whites that used serial-slice CT examinations found that the CT slice with the highest correlation with VAT volume was that at the L4-5 level, whereas others suggested that the best level for the slice was L2-3 (11–13). However, it remains undetermined which CT slice is the best correlate of VAT volume in African Americans.

The purpose of this investigation was 2-fold: first, to determine whether there is a sex difference in VAT among African Americans by measuring VAT volume and, second, to examine the relation of the VAT area at the L2-3 and L4-5 levels of the lumbar spine to VAT volume.

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Received August 17, 2001.

Accepted for publication December 12, 2001.

SUBJECTS AND METHODS

One hundred ten African Americans (44 men, 66 women) participating in a protocol to evaluate cardiovascular disease risk in healthy volunteers at the National Institutes of Health (NIH) in Bethesda, MD, were enrolled in this study. All of the women were premenopausal. Participants were born in the United States, and they each identified both parents as being of African descent. The study was approved by the Institutional Review Board of the National Institute of Diabetes and Digestive and Kidney Diseases. Before participating, the subjects signed an informed-consent document.

Subjects came to the NIH in the morning after a 12-h fast. The following tests were performed: a 75-g oral-glucose-tolerance test (Trutol 75; Custom Laboratories, Inc, Baltimore), an abdominal computed tomography (CT) scan, and a dual-energy X-ray absorptiometry (DXA) scan. Body weight was measured to the nearest 0.1 kg on a platform digital scale. Height was measured to the nearest 0.1 cm with a stadiometer. Waist circumference was measured at the level of the iliac crest by the same observer throughout the study (NGS).

Measurement of abdominal adipose tissue

The CT scan was performed with a HiSpeed Advantage or CT/I scanner (GE Medical Systems, Milwaukee). After an abdominal radiograph was obtained, slices were obtained with 10-mm collimation at the L2-3 and L4-5 levels of the lumbar spine of the subjects, who were in the supine position. The images at these levels were analyzed by the image-analysis software package available with the scanner. For each slice, the areas of the total abdominal adipose tissue, the VAT, and the subcutaneous abdominal adipose tissue (SCAT) were calculated. To assess the total abdominal adipose tissue, a region-of-interest cursor was used to trace the perimeter of the abdominal cavity. A fat-density mask was made of the resulting region of interest to include pixels with attenuation values ranging from −150 to −50 Hounsfield units. This range includes adipose tissue but not other soft tissue, bone, or air. We calculated the VAT by tracing the perimeter of the visceral cavity below the subcutaneous fat and obtaining a fat-density mask as above. The SCAT area was determined by subtracting the VAT area from the total abdominal adipose tissue.

Total VAT and SCAT volumes were measured in 59 consecutive participants with the use of 10-mm contiguous slices from the dome of the diaphragm to the iliac crest. These were analyzed with the MEDX image-analysis software (Sensor System, Inc, Sterling, VA) on a SUN workstation. A cursor is placed on the abdominal wall to allow the periphery of the abdominal cavity to be traced automatically with the use of edge-detection techniques. The perimeter of the visceral cavity below the subcutaneous fat is traced manually. Then a density mask inclusive of pixels with attenuation values between −150 and −50 Hounsfield units is created. The system calculates the VAT and SCAT areas separately for each slice. The results of the contiguous slices are added to yield total VAT and SCAT volumes.

Measurement of body fat

Dual-energy X-ray absorptiometry

Whole-body composition measurements were performed with a QDR 4500A dual-energy X-ray absorptiometer (Hologic, Inc, Bedford, MA) in the array mode with the use of software version 5.71A. The weight limit for the equipment was 136 kg; therefore, 6 subjects (3 men, 3 women) were ineligible for this scan.

Biolectrical impedance analysis

The percentage body fat (%BF) was measured in all 110 subjects by bioelectrical impedance analysis (BIA). Resistance and reactance were measured with a BIA device (Model no. 106; RJL Systems, Detroit). The %BF was determined with the use of WEIGHT MANAGER software, version 2.2 (RJL Systems).

The BIA measurements of %BF were adjusted to account for the 6 subjects in whom DXA scans could not be performed. With the DXA measurement of %BF used as the reference, the concordance between DXA and BIA measurements was 0.94 (14). However, there was a difference between the sexes ($P = 0.012$) in the relation of DXA to BIA. The adjustment equation for correction of %BF was 0.869 × BIA %BF − 0.43 in men and 0.869 × BIA %BF + 1.81 in women.

Statistical evaluation

On the basis of the work of Snehalatha et al (8), who examined sex differences in VAT among 21 women and 19 men assuming a mean and variation similar to those in our population, we formulated our study of 24 men and 35 women to have a power of 95% with an α value of 0.05. Data are presented as means ± SDs. Before the statistical comparisons were made, variables found not to be normally distributed were log transformed or, in the case of SCAT, transformed by square root. Analyses of the data were conducted with paired and unpaired *t* tests as appropriate. For unpaired *t* tests, SD testing was done to confirm homoscedasticity. A P value < 0.05 was considered significant. Regression analyses were performed separately with total VAT volume, VAT area at the L2-3 level, and VAT area at the L4-5 level as the dependent variables and with age, %BF, fat mass, and body mass index (BMI; in kg/m^2) as the independent variables. Additional regressions for VAT volume were performed for men and women separately with %BF, fat mass, and BMI as the independent variables. Concordance and Pearson's correlation coefficients were calculated for analyses of agreement between specific variables with STATA 6 software (STATA, College Station, TX).

RESULTS

The results of the oral-glucose-tolerance test showed that none of the participants had diabetes, and all had normal fasting glucose concentrations. The glucose concentration at 2 h showed that 15 women and 6 men had impaired glucose tolerance (15). Fourteen of the women with impaired glucose tolerance were classified as obese. There were no significant differences in either VAT or fat mass in the obese women with and without normal glucose tolerance. Of the 6 men with impaired glucose tolerance, 3 were overweight and 3 were classified as obese. The number of men with impaired glucose tolerance was too small for meaningful comparisons with the men with normal glucose tolerance.

The mean ages as well as measures of body fat composition and fat distribution of all subjects are shown in **Table 1**. There were no significant sex differences in age, BMI, or waist circumference, but there were significant sex differences in %BF, fat mass, and VAT volume. There were no sex differences in VAT area at either the L2-3 or the L4-5 level.

Additional sex comparisons were performed with adjustments for age plus either %BF, fat mass, or BMI. With these adjustments, there was a significant sex difference in total VAT volume and VAT area at the L2-3 level (**Table 2**). For the VAT area at the L4-5 level, the sex difference was significant with adjustment for either %BF

TABLE 1
Demographic characteristics and body composition of the subjects[1]

	Men (n = 44)	Women (n = 66)
Age (y)	36.1 ± 7.8	35.6 ± 7.8
Impaired glucose tolerance (%)	14 (n = 6)	23 (n = 15)
Weight (kg)	95.2 ± 22.8	86.3 ± 25.5[2]
Height (cm)	179 ± 6.3	163 ± 6.9[3]
BMI (kg/m^2)	29.5 ± 6.9	32.0 ± 8.9
Waist circumference (cm)	96.8 ± 17.5	98.4 ± 18.2
Percentage body fat (%)	21.8 ± 7.3	37.4 ± 7.9[3]
Fat mass (kg)	21.3 ± 12.1	34.0 ± 16.5[3]
Lean body mass (kg)	70.3 ± 12.6	50.3 ± 9.8[3]
VAT volume (cm^3)[4]	1443 ± 931	940 ± 821[5]
VAT area (cm^2)		
L2-3	88.6 ± 63.5	57.2 ± 45.4
L4-5	65.6 ± 53.3	55.0 ± 38.3

[1] x ± SD. All variables except age, height, and percentage body fat were log transformed before analysis; VAT, visceral adipose tissue.
[2,3,5] Significantly different from men: [2] P = 0.03, [3] P < 0.0001, [5] P = 0.01.
[4] Results are for 24 men and 35 women.

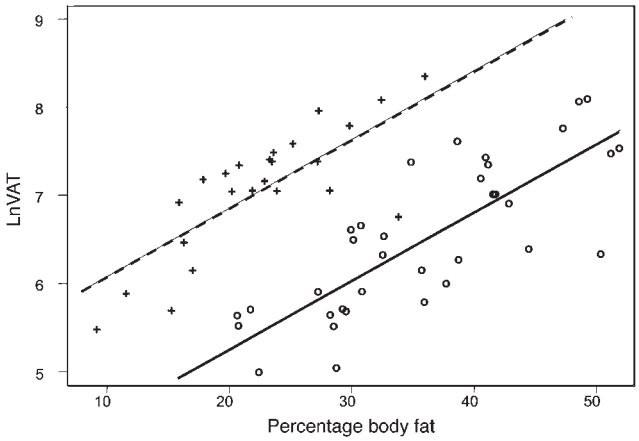

FIGURE 1. Relation between predicted (men, - - -; women, ——) and observed (men, **+**; women, **o**) values of log-transformed visceral adipose tissue (VAT) and percentage body fat. Predictions were derived by regressing lnVAT volume on percentage body fat for men and women separately. Men: r = 0.80, P < 0.001; women: r = 0.79, P < 0.001.

or fat mass but not for BMI. The relationships in men and women, determined by regression analyses using VAT volume as the dependent variable and %BF, fat mass, or BMI as the independent variable, are shown in **Figures 1–3**. There were no sex differences in the slopes of the regression lines, but the men had significantly higher y intercepts (P < 0.001 for all).

In the men, the VAT area at the L2-3 level was greater than that at the L4-5 level ($\bar{x}$ ± SD: 88.6 ± 63.5 and 65.6 ± 53.3 cm^2, respectively; P < 0.0001). In women, there was no difference in the VAT area at the 2 levels (57.2 ± 45.4 and 55.0 ± 38.3 cm^2, P = 0.42). For men, the Pearson's correlation coefficient for the VAT area at the L2-3 level and the VAT volume was r = 0.93 (P < 0.0001) and that for the VAT area at the L4-5 level and the VAT volume was r = 0.84 (P < 0.0001). For women, the Pearson correlation coefficient for the VAT area at the L2-3 level and the VAT volume was r = 0.97 (P <0.0001) and that for the VAT area at the L4-5 level and the VAT volume was r = 0.90 (P < 0.0001).

DISCUSSION

This study documents that VAT volume is greater in African American men than in African American women. Just as white and Asian Indian men have more VAT than do their female counterparts, African American men have more VAT than do African American women (7, 8).

In addition to sex differences in VAT, sex differences in body fat content are well documented in both African Americans and whites (6, 9, 10). Therefore, just as sex comparisons based on weight required adjustments of weight for height, sex differences in VAT are better assessed after adjustment for body fat content. Even though the sex difference in VAT volume was apparent without adjustment, the sex difference in VAT volume among African Americans was enhanced after adjustment for age and any one of the following: %BF, fat mass, or BMI (Table 2, Figures 1–3). The VAT areas at the L2-3 and L4-5 levels are often used as surrogate measures of VAT volume (11, 12, 16, 17). Before adjustments were made for age and body composition, the sex difference in the VAT areas at the L2-3 and L4-5 levels was not apparent (Table 1). But with adjustment for either %BF or fat mass, the sex difference in the VAT area at the L2-3 and L4-5 levels was clear. However, after adjustment for BMI, the sex difference in the VAT area was detectable only at the L2-3 level.

TABLE 2
Regression analysis of sex differences in visceral adipose tissue (VAT) measures after correction for age with percentage body fat, fat mass, or BMI[1]

	Regression analysis			
VAT measure and variable controlled for	Unadjusted R^2	Adjusted R^2	P for sex difference	95% CI for sex difference
VAT volume				
Percentage body fat (%)	0.71	0.69	<0.001	1.06, 1.75
Fat mass (kg)	0.64	0.62	<0.001	0.46, 1.09
BMI (kg/m^2)	0.63	0.61	0.003	0.17, 0.77
VAT area, L2-3				
Percentage body fat (%)	0.64	0.63	<0.001	1.35, 2.01
Fat mass (kg)	0.57	0.56	<0.001	0.57, 1.11
BMI (kg/m^2)	0.58	0.57	<0.001	0.25, 0.76
VAT area, L4-5				
Percentage body fat (%)	0.56	0.54	<0.001	0.68, 1.25
Fat mass (kg)	0.50	0.48	0.002	0.14, 0.60
BMI (kg/m^2)	0.48	0.47	0.22	−0.08, 0.35

[1] Age was controlled for in each analysis.

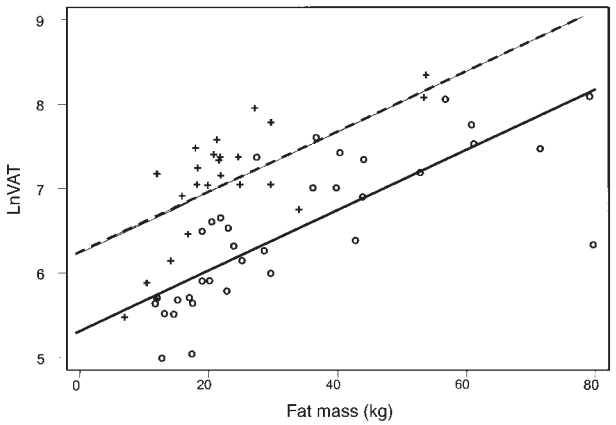

FIGURE 2. Relation between predicted (men, - - -; women, ——) and observed (men, **+**; women, **o**) values of log-transformed visceral adipose tissue (VAT) and fat mass. Predictions were derived by regressing lnVAT volume on percentage body fat for men and women separately. Men: $r = 0.72$, $P < 0.001$; women: $r = 0.76$, $P < 0.001$.

The CARDIA and HERITAGE studies examined sex differences in VAT among African Americans and whites by comparing the VAT area at the L4-5 level in each group by sex (9, 10). The CARDIA and HERITAGE investigators found no sex difference in the unadjusted VAT area at the L4-5 level in African Americans. Therefore, they concluded that African Americans do not have a sex difference in VAT. We also found no sex difference in the unadjusted VAT area at the L4-5 level. However, our conclusion differs from theirs in that we believe there is a sex difference in VAT among African Americans. We made this judgment for 3 reasons. First, the VAT volume was different in men and women. Second, we found a significant sex difference in VAT area at the L2-3 and L4-5 levels after adjustment for body fat content. In the CARDIA and HERITAGE studies, the women had a higher BMI than the men did. In the CARDIA study, the sex difference in BMI among the African Americans was significant at a P value of <0.001. If smaller men are compared with larger women, the sex difference in VAT will be obscured. Third, a single-slice CT at the L4-5 level appears to be suboptimal for quantitating sex differences in VAT area among African Americans. For women, VAT areas measured at the L4-5 and L2-3 levels were similar. In contrast, the African American men had a smaller VAT area at the L4-5 level than at the L2-3 level. Therefore, a comparison of VAT areas at a level at which the men have a relatively small VAT area, without adjustment for body fat in African American men and women, obscured the sex difference.

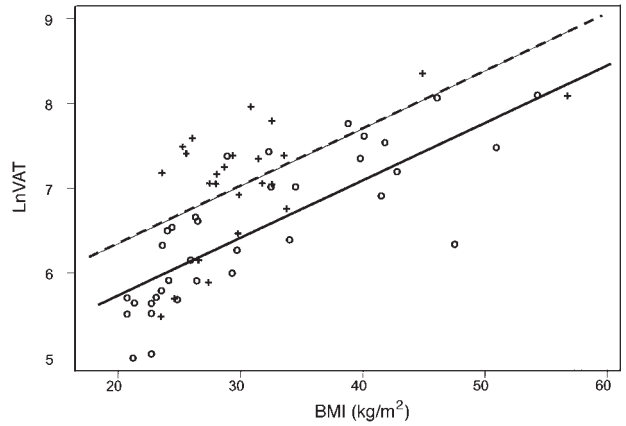

FIGURE 3. Relation between predicted (men, - - -; women, ——) and observed (men, **+**; women, **o**) values of log-transformed visceral adipose tissue (VAT) and BMI. Predictions were derived by regressing lnVAT volume on percentage body fat for men and women separately. Men: $r = 0.56$, $P < 0.005$; women: $r = 0.81$, $P < 0.001$.

In large studies, it is faster and more economical to obtain a single CT slice than a total VAT volume measurement. However, it remains undetermined as to which CT slice is the best surrogate measure of VAT volume in African Americans. In the current study, VAT area measurements at both the L2-3 and the L4-5 levels were highly correlated with VAT volume. Nevertheless, we favor the L2-3 level over the L4-5 level. With a slice from the L2-3 level, the sex difference in the VAT area could be detected with correction for BMI. But, with a slice from the L4-5 level, correction for BMI alone was not adequate to detect a sex difference, and correction for %BF or fat mass was required. The greater ease of correcting for sex differences in BMI than in body fat makes a CT slice at the L2-3 level, rather than one at the L4-5 level, a more attractive epidemiological tool.

In conclusion, VAT volume is greater in African American men than in African American women. In the examination of sex differences in VAT area in African Americans, a single-slice CT at the L2-3 level is superior to one at the L4-5 level. The reason for this is that, at the L2-3 level, the sex difference in VAT area is apparent after adjustment for BMI, but at the L4-5 level, adjustment for body fat content is required.

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