Body fat distribution in white and black women: different patterns of intraabdominal and subcutaneous abdominal adipose tissue utilization with weight loss\textsuperscript{1–3}

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ABSTRACT

Background: Intraabdominal adipose tissue (IAAT) is the body fat depot most strongly related to disease risk. Weight reduction is advocated for overweight people to reduce total body fat and IAAT, although little is known about the effect of weight loss on abdominal fat distribution in different races.

Objective: We compared the effects of diet-induced weight loss on changes in abdominal fat distribution in white and black women.

Design: We studied 23 white and 23 black women, similar in age and body composition, in the overweight state [mean body mass index (BMI; in kg/m\textsuperscript{2}): 28.8] and the normal-weight state (mean BMI: 24.0) and 38 never-overweight control women (mean BMI: 23.4). We measured total body fat by using a 4-compartment model, trunk fat by using dual-energy X-ray absorptiometry, and cross-sectional areas of IAAT (at the fourth and fifth lumbar vertebrae) and subcutaneous abdominal adipose tissue (SAAT) by using computed tomography.

Results: Weight loss was similar in white and black women (13.1 and 12.6 kg, respectively), as were losses of total fat, trunk fat, and waist circumference. However, white women lost more IAAT (P < 0.001) and less SAAT (P < 0.03) than did black women. Fat patterns regressed toward those of their respective control groups. Changes in waist circumference correlated with changes in IAAT in white women (r = 0.54, P < 0.05) but not in black women (r = 0.19, NS).

Conclusions: Despite comparable decreases in total and trunk fat, white women lost more IAAT and less SAAT than did black women. Waist circumference was not a suitable surrogate marker for tracking changes in the visceral fat compartment in black women. Am J Clin Nutr 2001;74:631–6.

KEY WORDS Overweight, obesity, weight loss, body composition, fat distribution, intraabdominal adipose tissue, waist circumference, African Americans, black women

INTRODUCTION

Intraabdominal adipose tissue (IAAT) is the body fat depot most strongly related to the metabolic abnormalities of obesity (1–4). In turn, weight reduction was used and recommended to reduce abdominal obesity and its associated health risks (5). Because of the methodologic difficulties in measuring IAAT, selected anthropometric measurements were recommended as surrogate markers for visceral adipose tissue (6). Waist circumference is commonly used because it correlates well with IAAT (7), even during weight loss (5, 8), and it appears to accurately reflect the relation between visceral adipose tissue and health-related risk (6, 9).

Because of racial differences in risk of obesity-related health problems (10–13), attention has focused on the association between risk factors and abdominal fat distribution patterns in white and black people (3, 4, 6, 9). Relative to their total fat mass or degree of obesity, black women and children have a lower distribution of adipose tissue as IAAT than as subcutaneous abdominal adipose tissue (SAAT) than do white women and children (3, 4, 6, 14, 15). IAAT is associated with different metabolic risk factors in black women than in white women (4) and may be less predictive of health risk in black women (6), although both groups of women may benefit from weight reduction (14).

Little is known about the effects of weight loss on relative changes in visceral and subcutaneous abdominal fat distribution in overweight white and black people. Nor is it known whether changes in waist circumference accurately reflect changes in abdominal fat distribution in these racial groups. Hence, the purpose of this study was to prospectively examine abdominal fat distribution patterns of overweight white and black women, before and after weight loss, relative to those of never-overweight control women.

SUBJECTS AND METHODS

Study subjects

Subjects were white and black premenopausal women between 20 and 46 y of age. Overweight subjects (23 white and 23 black)
had a body mass index (BMI; in kg/m²) between 27 and 30 (chosen to increase the likelihood that subjects could be reduced to a normal weight in a reasonable time frame) and a family history of obesity (BMI > 27) in at least one first-degree relative. Never-overweight control women (23 white and 15 black) reported always maintaining a BMI < 25 and having no family history of obesity in first-degree relatives (2 black control women had an overweight relative, but in each of these 2 cases they had ≥4 other lean first-degree relatives). Classification of subjects as black or white included the subjects’ indication that both their parents and grandparents were of that race. Normal glucose tolerance was determined on the basis of fasting and 2-h postprandial blood glucose concentrations measured after an oral glucose load. Subjects were nonsmokers, were sedentary, and had normal menstrual cycles. The study was approved by the Institutional Review Board for Human Use, and informed consent was obtained before study participation in compliance with the US Department of Health and Human Services Regulations for Protection of Human Research Subjects.

Study design

Subjects were evaluated when overweight and again at normal weight under weight-stable, diet-controlled conditions at the University of Alabama at Birmingham General Clinical Research Center (GCRC). Before each evaluation, subjects were maintained in a weight-stable state for 4 wk, during the final 2 wk of which meals were provided through the GCRC to maintain macronutrient intake at 20% of energy as fat, 16% as protein, and 64% as carbohydrate. Subjects were then admitted to the GCRC for 4 d, during the follicular phase of the menstrual cycle. After subjects were discharged from the GCRC, the GCRC prepared all meals for weight reduction, providing 3347 kJ/d (800 kcal/d) and including Stouffer’s Lean Cuisine entrées twice daily (Nestlé Food Co, Solon, OH). Dietary adherence and body weight were monitored twice weekly until subjects lost >10 kg and reached a normal weight, defined as a BMI < 25. Although subjects were sedentary, no attempt was made to alter their physical activity patterns. On reaching a normal BMI, subjects repeated the protocol of 4 wk of energy balance and 4 d of GCRC admission. Never-overweight control women, who were recruited to be similar in age and BMI to the weight-reduced women, followed the identical protocol of 4 wk of energy balance and 4 d of GCRC admission.

Study procedures

Body composition was determined by using the 4-compartment model (16), which includes in the analysis bone mineral content, total body water, and total body density to take into consideration the fact that black women generally have a greater bone mineral content than do white women (17). The 4-compartment model includes the following density assumptions: 0.9 kg/L for fat, 0.99 kg/L for water, 3.042 kg/L for total mineral (osseous and cellular), and 1.34 kg/L for the unmeasured fraction of the body composed of protein and glycogen. The model is used to calculate the percentage of body fat from independent measures of total body density, total body water, and bone mineral content. Total body density was determined by weighing subjects underwater, and residual lung volume was measured simultaneously by closed-circuit oxygen dilution (18). Body weight was measured with an electronic scale while the subjects were in a fasting state and immediately after they had voided in the morning. The CV for body density of repeat tests on separate days in our laboratory is 0.3%. Total body water was determined by isotope dilution with the use of deuterium and 18O-labeled water as previously described (19). Briefly, a mixed dose of doubly labeled water was orally administered after collection of a baseline urine sample (10 mL). The isotope loading dose was ≈0.1 and 0.08 g 18O and D, respectively, per kg body mass. Two samples were collected on the morning after dosing, and an additional 2 samples were collected in the morning 14 d later. Samples were analyzed in triplicate for deuterium with the offline zinc reduction method (20) and for 18O with the equilibration technique (21), as previously described (22). Zero-time enrichments of deuterium and 18O were calculated from the intercepts of the semilogarithmic plot of isotope enrichment in urine versus the time after dosing. Isotope dilution spaces were calculated by using the equation of Coward et al (23). Total body water was taken as the average of the 18O dilution space divided by 1.01 and the deuterium dilution space divided by 1.04. Fat-free mass (FFM) was estimated from total body water by assuming that fat-free tissue has a hydration constancy of 73.2% (24–26), and fat mass was estimated from the difference between total body mass and FFM. Bone mineral content and regional body composition were determined by dual-energy X-ray absorptiometry (DPX-L; Lunar Corp, Madison, WI) with the use of software version 1.5g (Lunar Corp). Trunk fat mass was determined by using the separation point between the arms and trunk (at the glenohumeral joint) and the separation point between the legs and trunk (taken as an oblique angle through the neck of the femur). While the subjects were standing, their waist and hip circumferences were measured to the nearest 0.1 cm at the narrowest part of the torso and at the maximal extension of the buttocks, respectively, by the same investigator (BED) using a flexible tape.

Cross-sectional areas of IAAT and SAAT were determined by computed tomography with the use of a HiLight/HTD Advantage scanner (General Electric Co, Milwaukee) set at 120 kVp (peak kilovoltage) and 40 mA. We examined the subjects while they were in the supine position with their arms stretched above their heads. We obtained a single 5-mm scan for 2 s at the level of the fourth and fifth lumbar vertebrae because it was found that visceral fat area from a single scan is highly correlated with overall visceral volume (27). With the use of procedures established by Kvist et al (28), the attenuation range for adipose tissue was –30 to –190 Hounsfield units. Cross sections of adipose tissue were determined by using a computerized fat tissue-highlighting technique. IAAT and SAAT were measured by separating adipose tissue areas by encircling the muscle wall surrounding the abdominal cavity with a cursor. Tissue cross sections between –30 and –190 Hounsfield units in the respective areas were considered to be IAAT and SAAT. Both intra- and interobserver test–retest reliability had an r value of 0.99, with a CV of <2% on the basis of the reevaluation of 20 scans.

Statistical analyses

Descriptive statistics were calculated on all outcome variables by race groups. A 2 × 2 (weight loss × race) repeated-measures analysis of variance (ANOVA) on the first factor was used to test independent effects of weight loss and race on outcome variables. Post hoc tests were run independently on the white and black women by using paired r tests to examine the separate effects of weight loss on the mean ratios of IAAT to SAAT (IAAT/SAAT) in each race. Bonferroni corrections for additive α were made. A 2 × 2 (group × race) ANOVA was used to examine racial
RESULTS

The 46 overweight white and black women had an initial mean BMI of 28.8 ± 1.7. There were no significant differences in age, weight, BMI, percentage of body fat, FFM, total fat mass, or trunk fat mass between the races. After weight reduction, the mean BMI decreased to 24.0 ± 1.0 and we found no significant differences in weight loss between the races (13.1 kg, or 16.6% of initial weight, in the white women; 12.6 kg, or 16.1% of initial weight, in the black women). The mean duration of dietary restriction required for the subjects to achieve a weight loss of >10 kg and a BMI of <25 was 22 ± 7 wk for the white women and 25 ± 14 wk for the black women. The difference in mean duration was not significantly different between the races. Body weight, percentage of body fat, FFM, and fat mass decreased significantly; no significant differences were found in the weight-loss responses of the white and black women (Table 1).

Total fat mass decreased 33%, from an average of 30.8 ± 4.1 kg in the overweight state to 20.5 ± 3.9 kg in the normal-weight state. Losses of total fat mass were not significantly different in the white and black women (within 2%) (Figure 1). Trunk fat mass and waist circumference both decreased significantly, in parallel with total fat mass. That is, there were no significant differences in decreases in trunk fat (within 16% of each other) and waist circumference (within 7% of each other) between the races (Table 2).

The relation of trunk to total fat mass, expressed as their ratio, remained essentially unchanged before and after weight loss (white women: 0.48 and 0.44 before and after weight loss, respectively; black women: 0.45 and 0.44 before and after weight loss, respectively). Although all overweight women achieved a BMI of <25 in the weight-reduced state, their mean BMI was significantly higher than that of the control women (24.0 ± 1.0 compared with 23.4 ± 1.3). In contrast, we found no significant differences between the weight-reduced and control women in mean percentage of body fat (31.0 ± 4.5% and 31.7 ± 4.7%, respectively) or total fat mass (20.5 ± 3.9 and 19.6 ± 3.6 kg, respectively).

Whether they were in the overweight or weight-reduced state, white women had a higher waist circumference, a higher waist-to-hip ratio, and a greater cross-sectional area of IAAT than did black women. By contrast, the cross-sectional areas of SAAT were not significantly different between the races. IAAT and SAAT both decreased with weight loss, although the responses were significantly different between the races (Figure 2). Compared with the black women, the white women had a 77% greater decline in cross-sectional area of IAAT and a 26% lesser decline in cross-sectional area of SAAT (Table 2). Despite the overall decreases in both abdominal fat compartments, the net effect of weight loss was that white women had a significant decrease in the amount of IAAT relative to SAAT and that black women had a nonsignificant increase in the amount of IAAT relative to SAAT. The patterns of

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**TABLE 1**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overweight (n = 23)</th>
<th>Black (n = 23)</th>
<th>Normal weight (n = 23)</th>
<th>Black (n = 23)</th>
<th>P value</th>
<th>Inter-</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>37.0 ± 5.9</td>
<td>35.5 ± 5.9</td>
<td>38.9 ± 3.7</td>
<td>36.7 ± 3.5</td>
<td>&lt;0.001</td>
<td>0.75</td>
<td>0.63</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>79.1 ± 5.0</td>
<td>78.2 ± 8.9</td>
<td>66.0 ± 4.8</td>
<td>65.6 ± 7.7</td>
<td>&lt;0.001</td>
<td>0.47</td>
<td>0.57</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>29.0 ± 1.5</td>
<td>28.7 ± 1.8</td>
<td>24.0 ± 1.1</td>
<td>23.9 ± 0.9</td>
<td>&lt;0.001</td>
<td>0.32</td>
<td>0.63</td>
</tr>
<tr>
<td>Percentage body fat (%)</td>
<td>39.9 ± 3.7</td>
<td>38.3 ± 3.1</td>
<td>32.3 ± 4.6</td>
<td>29.8 ± 4.2</td>
<td>&lt;0.001</td>
<td>0.06</td>
<td>0.45</td>
</tr>
<tr>
<td>Fat-free mass (kg)</td>
<td>47.4 ± 3.9</td>
<td>48.4 ± 5.2</td>
<td>44.5 ± 3.4</td>
<td>46.0 ± 4.8</td>
<td>&lt;0.001</td>
<td>0.34</td>
<td>0.42</td>
</tr>
<tr>
<td>Fat mass (kg)</td>
<td>31.5 ± 3.7</td>
<td>30.1 ± 4.5</td>
<td>21.3 ± 3.5</td>
<td>19.7 ± 4.2</td>
<td>&lt;0.001</td>
<td>0.19</td>
<td>0.86</td>
</tr>
</tbody>
</table>

**FIGURE 1**

Mean (±SEM) changes in total fat mass, trunk fat mass, and waist circumference in 23 white and 23 black women measured in the overweight state and after weight reduction to the normal-weight state and in comparison with 38 race-matched (23 white and 15 black), never-overweight, control women. For each variable, the patterns of response to weight loss were not significantly different between the races.
Intraabdominal adipose tissue (IAAT), subcutaneous abdominal adipose tissue (SAAT), and waist circumference (cm) were measured in 23 white and 23 black women before and after weight loss, and in the normal-weight state and after weight reduction to the normal-weight state and in the combined group of normal-weight black and white women. Significant differences were found between the weight-reduced and control women in the amounts of IAAT (53.8 ± 23.9 and 49.8 ± 23.0 cm², respectively) or in IAAT:SAAT (0.26 ± 0.12 and 0.29 ± 0.10, respectively).

Anthropometric correlates of IAAT and SAAT are shown in Table 3. In cross-sectional analyses, waist circumference correlated significantly with IAAT in the overweight women (r = 0.70, P < 0.001) and in the combined group of normal-weight women (ie, weight-reduced plus control women; r = 0.66, P < 0.001). Furthermore, waist circumference and waist-to-hip ratio correlated significantly with IAAT within each weight-race subgroup. However, in the analyses of changes in response to weight loss, decreases in waist circumference correlated significantly with decreases in IAAT in the white women but not in the black women. Changes in the waist-to-hip ratio did not correlate with changes in IAAT in either race.

DISCUSSION

The results of this study indicated that the white women had significantly more IAAT and significantly more IAAT relative to SAAT than did the black women. These differences were present even though all the white and black women were premenopausal and were comparable in age, percentage of body fat, FFM, total fat mass, and trunk fat mass. These findings confirm those previously reported for men and women (3, 4, 6, 14, 29–31) and for children (15).

To our knowledge only a few other studies compared changes in abdominal fat distribution with weight loss in different racial groups. Conway et al (29) studied 10 white and 8 black women before and after weight loss and, in contrast with our results, found that IAAT and SAAT decreased similarly in the 2 races. On the other hand, in a study of 8 white and 8 black women in South Africa, van der Merwe et al (14) found that the white women lost one-half as much weight but almost twice as much IAAT as did the black women. Although they did not make a direct comparison of the absolute losses of intraabdominal and subcutaneous abdominal fat, their findings agree with ours; ie,
white women appear to mobilize more IAAT with weight loss than do black women.

The explanation for the greater loss of IAAT and lesser loss of SAAT in white women than in black women in our study is not evident. Differences in concentrations of circulating insulin between obese white women and obese black women may explain the different rates of utilization of body fat compartments with different insulin sensitivities (14). IAAT appears to be less responsive to insulin than does SAAT in terms of antilipolysis and stimulation of reesterification of fatty acids (32), and changes in insulin sensitivity with weight loss appear to correlate better with changes in IAAT than with either SAAT or total fat mass (33). Nevertheless, there are insufficient data to determine whether differences in insulin sensitivity between races and between adipose tissue compartments explain the racial responses we observed. Racial differences in the relation of sex hormone concentrations to body fat distribution may also provide an explanation for the different weight-loss patterns of the white and black women. Dowling and Pi-Sunyer (34) studied 42 adult women with comparable amounts of total body fat and categorized them according to upper- or lower-body obesity patterns based on waist-to-hip ratios. Their findings indicated that concentrations of sex hormone binding globulin were higher and percentages of free testosterone were lower in black women than in white women despite similar patterns of upper-body obesity. A subsequent study by Pi-Sunyer and coworkers (4) showed that after adjustment for the waist-to-hip ratio, black women had less visceral fat than did white women. Together, these data support the hypothesis that lower free testosterone concentrations are associated with less accumulation of visceral adipose tissue. However, these data do not suggest what would happen with changes in body weight because the investigators did not assess sex hormone and fat distribution patterns in response to weight loss. Another possible explanation is that during weight loss, energy is preferentially derived from the larger adipose tissue store. Hence, because they started with a greater IAAT store, the white women in our study would have used relatively more IAAT than would have the black women. Busetto et al (36) recently found this to be the case in a group of 6 morbidly obese women after surgically induced weight loss. That is, women with higher initial levels of IAAT lost more IAAT. In a recent review of 23 weight-loss studies that measured IAAT, Smith and Zachwieja (36) also reported that people with greater visceral fat mass lost more visceral fat relative to their loss of total body fat. Even if we could explain why a greater amount of IAAT was mobilized during weight loss in white women on the basis of their greater stores of IAAT, we could not explain why they deposit more IAAT than do black women during weight gain.

Because of the methodologic difficulties in measuring abdominal fat compartments, waist circumference was recommended as a surrogate marker for IAAT (5, 6, 9) and is considered to be preferable to the waist-to-hip ratio for this purpose (37). In cross-sectional analyses, Albu et al (4) found significant positive correlations of waist circumference and waist-to-hip ratio with IAAT in obese white and black women, as did Conway et al (7) in obese black women. In addition to confirming these findings in our overweight white and black women, we found that waist circumference and waist-to-hip ratio retained significant predictive power for IAAT in normal-weight women. For these anthropometric indexes to serve as a surrogate for IAAT, it is also important to know whether they accurately reflect changes in abdominal fat distribution with changes in body weight. Kamel et al (8) found significant correlations between decreases in waist circumference and, to a lesser extent, in waist-to-hip ratio and decreases in IAAT in 19 white women during weight reduction. Our data confirm the usefulness of waist circumference, but not of waist-to-hip ratio, for tracking changes in IAAT in white females. However, we found that neither waist circumference nor waist-to-hip ratio correlated with changes in IAAT in black women and, hence, may not be useful surrogate markers of visceral fat in black women undergoing weight change.

In summary, our findings indicate that even when total fat mass was comparable, white women had greater absolute amounts of IAAT than did black women, a difference that was present whether the women were obesity-prone or obesity-resistant, or overweight or normal-weight. With weight loss, the white and black women had similar reductions in total fat mass, trunk fat mass, and waist circumference, but the white women lost significantly more IAAT and significantly less SAAT than did the black women. After weight loss, the abdominal fat distribution patterns of both race groups regressed toward those of their control counterparts. Additional studies examining changes in metabolic risk factors with weight loss and gain are needed to understand the clinical significance of these disparate racial responses in abdominal fat utilization. Finally, although waist circumference and waist-to-hip ratio may be useful surrogate markers of IAAT for screening purposes, these anthropometric indexes may not be useful for tracking changes in the visceral fat compartment in black females. These findings suggest that there is a need to develop simple markers of dynamic changes in intraabdominal fat in black women.
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REFERENCES


