

Race and Gender Differences in the Relationships Between Anthropometrics and Abdominal Fat in Youth

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Objective: We examined the influence of race and gender on abdominal adipose tissue (AT) distribution for a given anthropometric measure including waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height (W/Ht) in youth.

Methods and Procedures: Subjects included healthy 62 black and 98 white youth. A single transverse image of the abdomen (L4–L5) was obtained using computed tomography.

Results: For a given BMI, there was a significant ($P < 0.05$) main effect of race and sex on the relationship between BMI and WC, such that boys and whites had a higher WC than girls and blacks. There was a significant ($P < 0.05$) main effect and interaction effect of gender on the relationship between WC and visceral AT, such that boys had a higher visceral AT than girls, and the difference was magnified with increasing WC. For a given WC, black boys and girls had higher abdominal subcutaneous AT (SAT) than white peers, wherein the magnitude of the difference is increased with increasing WC. For a given W/Ht, black boys had significantly ($P < 0.05$) lower visceral AT than white boys, but with no difference in girls. Black boys and girls had higher SAT than white peers, wherein the magnitude of the difference is increased with increasing W/Ht.

Discussion: Our findings demonstrate a significant race and gender differential in the abdominal AT distribution for a given BMI, WC, WHR, and W/Ht. Future studies should take these differences into consideration when developing race- and gender-specific anthropometric cut-offs for obesity and obesity-related health risks in youth.

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INTRODUCTION

Racial differences in the amount of visceral adipose tissue (AT) are well documented in adult populations. Previous studies have shown that for a similar degree of BMI, waist-to-hip ratio (WHR), or total adiposity, black adult men and women have less visceral AT than their white counterparts (1–6). It appears that this racial dimorphism of abdominal AT accumulation, in particular visceral AT, is present early in life. Goran *et al.* (7) reported that in a cohort of healthy prepubertal children (aged 4–10 years), the relative deposition of AT in the visceral region compared with the abdominal subcutaneous region was significantly lower in black children than in white children. Further, we (8) and others (9) previously demonstrated that despite having a similar total body adiposity, black obese adolescents have significantly lower visceral AT than white obese adolescents. As measurement of visceral AT is not routinely available, it is important to determine whether clinical surrogate measures of abdominal obesity can be used to accurately reflect abdominal AT distribution in black vs. white boys and

girls. Such information is of importance, given that (i) the recent International Diabetes Federation definition recommends using the 90th percentile cutoff of waist circumference (WC) as the main component of the metabolic syndrome in children and adolescents (10), consistent with criteria in adults and (ii) abdominal obesity-related health risks differ among different racial groups (8), especially against the backdrop of the recent trend of increasing WC and waist-to-height ratio (W/Ht) among US youths (11).

WC and WHR are commonly used to assess abdominal obesity and obesity related health risk. Recently, several studies have suggested the usefulness of W/Ht as a predictor of cardiovascular disease in adults (12,13) as well as in youth (14–16). The principle of this index is that height status has an influence on the magnitude of waist, thus there is a reasonable amount of central fat deposited for a given height (15). The value of 0.5 has been proposed as a cutoff to identify youth with obesity and obesity-related health risks (15). However, it is unknown how well W/Ht reflects abdominal AT, in

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particular visceral AT, accumulation in youth, and whether there is a racial difference in this relationship. Thus, the purpose of this study was to examine whether commonly used surrogate measures of abdominal obesity such as WC, WHR, and W/Ht accurately reflect abdominal AT distribution in black and white youth.

METHODS AND PROCEDURES

Subjects

Subjects consisted of healthy black ($n = 62$) and white ($n = 98$) children and adolescents, some of whom were reported previously (17,18), and whom participated in an ongoing research study examining race related differences in childhood metabolism, body composition, and obesity. Study participants were recruited via the general media. The investigation was approved by the Institutional Review Board. Parental informed consent and child assent were obtained from all participants before participation. All participants underwent physical examination and routine hematological and biochemical tests. No subjects were taking medications known to affect body composition (e.g., hormone therapy). All participants were admitted to the Pediatric Clinical and Translational Research Center (previously the General Clinical Research Center) at the Children's Hospital of Pittsburgh.

Anthropometric measurement, and total and abdominal fat

Body weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, by using standardized equipment WC was obtained at the midpoint between the lowest rib and the iliac crest. These measurements were obtained by trained nurses at the Pediatric Clinical and Translational Research Center at the time of admission, and the average of two values was used in the analyses. BMI was calculated as weight (kg) divided by the square of height (m^2). The Centers for Disease Control and Prevention growth charts were used to calculate age- and gender-specific BMI percentiles (19). Total body fat was assessed

using dual-energy X-ray absorptiometry. Abdominal AT distribution was examined using a single slice computed tomography at the level of L4–L5. Both dual-energy X-ray absorptiometry and computed tomography methods were described by us previously (20).

Statistical analyses

Statistical procedures were performed using SAS version 8.2. Race and gender differences in the baseline characteristics were assessed using 2×2 ANOVA. General linear modeling was used to determine race- and gender-specific effects using multivariate regressions between the dependent (WC, visceral AT, and subcutaneous AT (SAT)) and independent (BMI, WC, WHR, and W/Ht) variables. Gender and race were entered as categorical variables, and visceral AT, SAT, BMI, WC, WHR, and W/Ht were entered as continuous variables. Non-linear independent terms (quadratic, cubic, square root, cubed root, and log) were tested in the model using stepwise regression. Appropriate gender-, race-, and gender-by-race interaction terms (linear and nonlinear terms) were tested in the multiple regression analyses. If the three-factor interaction effect (e.g., age \times race \times WC) was significant, further analyses were conducted within each gender separately. If the three-factor gender-by-race interaction term was not significant, a single model was used to determine gender and race differences in slope and intercept.

RESULTS

The characteristics of the study subjects are shown in [Table 1](#). Blacks and whites were similar in regards to anthropometric measurements (WC, WHR, and W/Ht) and abdominal AT distribution ([Table 1](#)). Among 160 subjects, 95 were normal-weight (e.g., BMI <95th percentile for age and gender) and 65 were overweight (e.g., BMI \geq 95th percentile for age and gender). In normal-weight group, blacks had significantly ($P < 0.05$) lower visceral AT (black boys: $11.0 \pm 1.4 \text{ cm}^2$; white

Table 1 Characteristics of the subjects

	Boys		Girls		Main effect	
	Blacks	Whites	Blacks	Whites	Race	Sex
<i>n</i>	32	52	30	46		
Age (years)	12.9 \pm 0.4	13.7 \pm 0.2	12.7 \pm 0.4	12.3 \pm 0.3		*
Weight (kg)	71.5 \pm 5.7	75.4 \pm 4.9	60.3 \pm 5.4	57.2 \pm 3.4	*	*
Height (cm)	157.5 \pm 2.4	164.6 \pm 1.6	151.9 \pm 2.0	152.3 \pm 1.8	*	*
BMI (kg/m ²)	27.9 \pm 1.8	26.9 \pm 1.4	25.1 \pm 1.8	23.9 \pm 1.1		*
Fat mass (kg) ^a	20.2 \pm 3.2	18.2 \pm 2.4	20.0 \pm 3.1	19.3 \pm 2.0		
Fat free mass (kg) ^a	42.4 \pm 2.2	44.2 \pm 1.9	35.9 \pm 2.0	33.7 \pm 1.3		*
Total adiposity (%) ^a	26.3 \pm 3.0	24.2 \pm 1.9	29.8 \pm 2.4	31.8 \pm 1.7		*
Waist (cm)	85.3 \pm 3.8	90.1 \pm 3.7	76.7 \pm 3.6	78.0 \pm 2.7		*
Hip (cm) ^b	93.5 \pm 4.0	95.4 \pm 2.9	88.9 \pm 4.3	89.7 \pm 3.0		
WHR ^b	0.87 \pm 0.01	0.90 \pm 0.01	0.84 \pm 0.01	0.84 \pm 0.01		*
W/Ht	0.54 \pm 0.02	0.54 \pm 0.02	0.50 \pm 0.02	0.51 \pm 0.01		*
W/Ht >0.5 (<i>n</i> , %)	19 (59%)	26 (50%)	13 (43%)	21 (46%)		
Visceral AT (cm ²)	42.8 \pm 6.9	54.6 \pm 6.6	34.0 \pm 4.9	35.6 \pm 3.3		*
Subcutaneous AT (cm ²)	295.9 \pm 48.5	296.4 \pm 38.6	251.0 \pm 46.0	245.9 \pm 28.3		
Abdominal AT (cm ²)	338.7 \pm 54.4	351.0 \pm 44.6	284.9 \pm 50.5	281.5 \pm 31.1		

Mean \pm s.e. of the mean.

W/Ht, waist-to height ratio; WHR, waist-to-hip ratio.

^aIn boys, $n = 29$ and $n = 44$ in blacks and whites, respectively; in girls, $n = 28$ and $n = 45$ in blacks and whites, respectively. ^bIn boys, $n = 29$ and $n = 48$ in blacks and whites, respectively; in girls, $n = 28$ and $n = 42$ in blacks and whites, respectively. * $P \leq 0.05$. No race \times sex interactions were found in subject characteristics.

boys: $18.0 \pm 2.8 \text{ cm}^2$; black girls: $18.6 \pm 2.6 \text{ cm}^2$; white girls: $23.9 \pm 2.4 \text{ cm}^2$) and SAT (black boys: $42.6 \pm 5.3 \text{ cm}^2$; white boys: $69.3 \pm 8.9 \text{ cm}^2$; black girls: $101.8 \pm 14.3 \text{ cm}^2$; white girls: $133.8 \pm 14.7 \text{ cm}^2$) independent of sex (all shown as mean \pm s.e.m.). In overweight group, boys had significantly ($P < 0.05$) more visceral AT than girls, wherein white boys ($94.0 \pm 7.5 \text{ cm}^2$) had a greater ($P < 0.05$) visceral AT than black boys ($70.9 \pm 8.1 \text{ cm}^2$) (all shown as mean \pm s.e.m.). The overweight groups did not differ in terms of SAT ($P > 0.10$).

Effect of race on the relationship between BMI and WC

WC was significantly ($P < 0.01$) associated with BMI independent of gender and race. There was a significant curvilinear relationship between BMI and WC (Figure 1), wherein the slope (e.g., interaction) was significantly greater in boys than girls ($P < 0.05$), but was not significantly different by race ($P > 0.1$). For a given BMI, there was a significant ($P < 0.05$) main effect of race and gender on the relationship between BMI and WC, wherein boys and whites had a higher WC than girls and blacks, respectively.

Effect of race on the relationship between WC and abdominal AT distribution

There was a significant linear relationship between WC with visceral AT and WC with SAT independent of gender and race ($P < 0.05$). There was a significant ($P < 0.05$) main effect and interaction of gender on the relationship between WC and visceral AT ($P < 0.05$), such that boys had a higher visceral AT than girls at WC $> 82 \text{ cm}$, and the difference was magnified with increasing WC (Figure 2a,b). For SAT, there was a significant ($P < 0.05$) main effect of gender, and a race interaction effect on the relationship between WC and SAT (Figure 2c,d). In other words, for a given WC, black boys and girls had higher abdominal SAT than their white counterparts, wherein the magnitude of the difference is increased with increasing WC ($P < 0.05$).

Effect of race on the relationship between WHR and abdominal AT distribution

WHR was significantly ($P < 0.05$) correlated with visceral AT (Figure 3a) and SAT (Figure 3c) in white boys only. WHR was

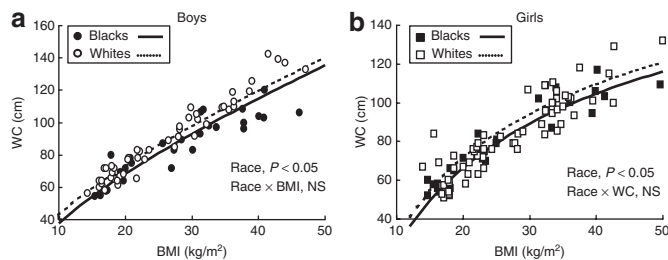


Figure 1 Relationships between BMI and waist circumference (WC) in blacks vs. whites. (a) White boys: $WC \text{ (cm)} = (1.57 \times BMI) + (21.80 \times \ln(BMI)) - 23.4$ (Model $R^2 = 0.96$); black boys: $WC \text{ (cm)} = (1.57 \times BMI) + (21.80 \times \ln(BMI)) - 28.3$ (Model $R^2 = 0.88$). (b) White girls: $WC \text{ (cm)} = (-0.30 \times BMI) + (64.06 \times \ln(BMI)) - 114.5$ (Model $R^2 = 0.89$); black girls: $WC \text{ (cm)} = (-0.30 \times BMI) + (64.06 \times \ln(BMI)) - 119.4$ (Model $R^2 = 0.91$).

not correlated with visceral AT in black boys, white girls or black girls ($P > 0.10$).

Effect of race on the relationship between W/Ht and abdominal AT distribution

There was a significant ($P < 0.01$) linear relationship between W/Ht and visceral AT independent of gender and race (Figure 4). In boys, blacks had 10 cm^2 less visceral AT than whites, for a given W/Ht ($P < 0.05$), whereas there were no significant differences in girls. Black boys and girls had higher

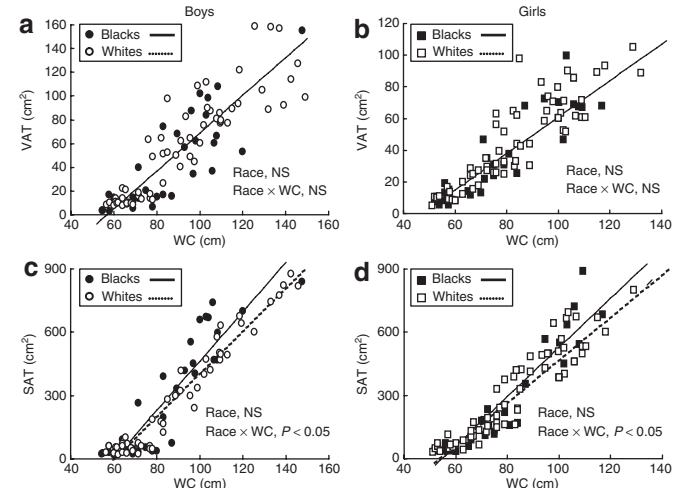


Figure 2 Relationships between waist circumference (WC) and abdominal adipose tissue in blacks vs. whites. (a) Boys: $VAT \text{ (cm}^2) = 1.59 \times WC - 90.3$ ($R^2 = 0.78$). (b) Girls: $VAT \text{ (cm}^2) = 1.15 \times WC - 54.3$ ($R^2 = 0.81$). (c) White boys: $SAT \text{ (cm}^2) = 10.12 \times WC - 612.0$ ($R^2 = 0.95$); black boys: $SAT \text{ (cm}^2) = 11.67 \times WC - 704.1$ ($R^2 = 0.81$). (d) White girls: $SAT \text{ (cm}^2) = 10.12 \times WC - 546.5$ ($R^2 = 0.87$); black girls: $SAT \text{ (cm}^2) = 11.67 \times WC - 638.6$ ($R^2 = 0.88$). SAT, abdominal subcutaneous adipose tissue; VAT, visceral adipose tissue.

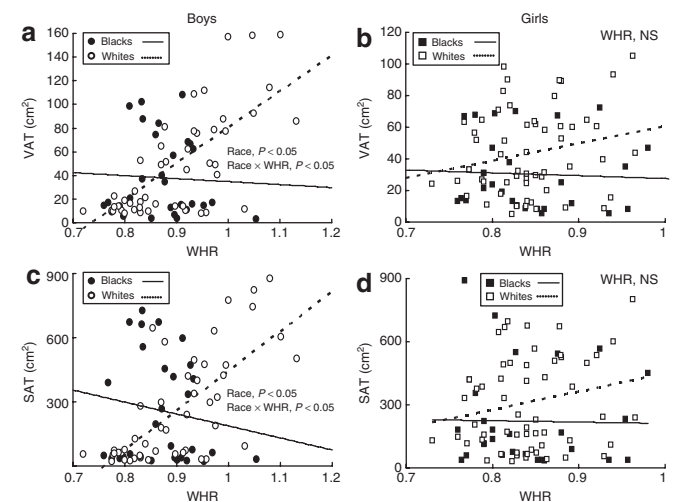


Figure 3 Relationships between waist-to-hip ratio (WHR) and abdominal adipose tissue in blacks vs. whites. (a) White boys: $VAT \text{ (cm}^2) = 305.1 \times WHR - 224.6$ ($R^2 = 0.41$). (b) Not significant independent of race. (c) White boys: $SAT \text{ (cm}^2) = 1848.0 \times WHR - 1404.4$ ($R^2 = 0.50$). (d) Not significant independent of race. SAT, abdominal subcutaneous adipose tissue; VAT, visceral adipose tissue.

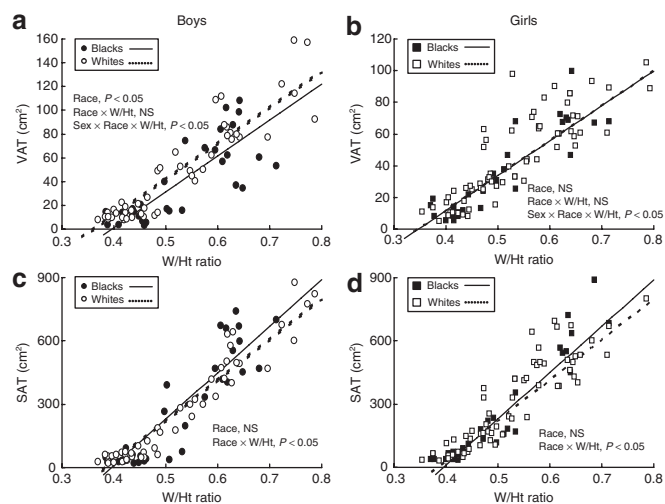


Figure 4 Relationships between waist-to-height ratio (W/Ht) and abdominal adipose tissue in blacks vs. whites. (a) White boys: VAT (cm^2) = $302.6 \times \text{W/Ht} - 109.8$ ($R^2 = 0.81$); black boys: VAT (cm^2) = $302.6 \times \text{W/Ht} - 120.1$ ($R^2 = 0.72$). (b) Girls: VAT (cm^2) = $220.3 \times \text{W/Ht} - 76.4$ ($R^2 = 0.80$). (c) White boys: SAT (cm^2) = $1923.8 \times \text{W/Ht} - 740.9$ ($R^2 = 0.93$); black boys: SAT (cm^2) = $2193.5 \times \text{W/Ht} - 866.5$ ($R^2 = 0.82$). (d) White girls: SAT (cm^2) = $1923.8 \times \text{W/Ht} - 740.9$ ($R^2 = 0.85$); black girls: SAT (cm^2) = $2193.5 \times \text{W/Ht} - 866.5$ ($R^2 = 0.89$). SAT, abdominal subcutaneous adipose tissue; VAT, visceral adipose tissue.

SAT than white peers, wherein the difference increased with increasing W/Ht ($P < 0.05$).

DISCUSSION

In this study, we observed a significant race and gender differential in the abdominal AT distribution for a given anthropometric measure of abdominal obesity. We demonstrated that (i) for a given BMI, boys and whites have a higher WC than girls and blacks, respectively, (ii) at higher WCs boys have a higher visceral AT than girls, (iii) independent of gender, blacks had higher abdominal SAT than whites for a given WC, wherein the difference increased with increasing WC, (iv) WHR is a significant correlate of visceral AT or SAT in white boys only, and (v) for a given W/Ht, black boys had significantly lower visceral AT than white boys, with no difference between girls, whereas black boys and girls had a higher SAT than whites. These findings suggest that race and gender differences should be considered when evaluating obesity and obesity-related health risks in children and adolescents, and in particular if one is to develop anthropometric cutoffs for identifying youth at risk of developing obesity related health risks.

Several adult definitions for the metabolic syndrome have a clinically appropriate measure of abdominal obesity. WC is often used as one of the obesity diagnostic criteria, but no consideration has been given to race differences except in the International Diabetes Federation definition (21). Recently the International Diabetes Federation provided a definition for the metabolic syndrome in youth where WC is a required component for the diagnosis of the metabolic syndrome (10). Thus, it may prove timely to consider race and gender related

differences in obesity parameters in youth and the potential need to account for them.

It is well known that in adults, whites are more susceptible to visceral obesity than blacks (2,4–6) for a similar degree of overall obesity. In women, whites have higher visceral AT than blacks after adjusting for BMI (4) or total adiposity (6) and this remains true even after significant weight loss (~17 kg) (5). Similarly, for any level of total body fatness as measured using hydrostatic weighing, Després *et al.* (2) reported significantly lower visceral AT levels in black than white men and women. In prepubertal youth, Goran *et al.* (7) demonstrated that black children have lower visceral AT than white children after controlling for abdominal SAT. In a longitudinal study, Huang *et al.* (22) reported that during a 3- to 5-year follow-up, the rate of increase in visceral AT was significantly greater in whites than blacks even after controlling for changes in SAT. In our study, no racial differences in visceral AT were observed for a given WC. Conversely, there were significant racial differences in the amount of abdominal SAT observed for a given WC. This suggests that the racial variations in abdominal AT distribution observed in previous studies (7,22) do not impact the clinical utility of WC to similarly identify increases in visceral AT in blacks and whites. As imaging techniques are not routinely available for the quantification of visceral AT and SAT, anthropometric measures are more clinically relevant for the assessment of visceral obesity. Visceral AT is clearly associated with deleterious health effects (23–25), and this study provides evidence to suggest that WC will provide similar estimates of visceral AT in blacks and whites and reinforces the utility of WC to be used as a clinical tool in racially diverse populations. In contrast with WC, we observed a racial difference in the association between W/Ht and visceral AT in boys and SAT with no gender differences. The clinical usefulness of this measure beyond that of WC alone in assessing abdominal AT distribution or health risk is currently unknown and warrants further investigation.

Previous data from our laboratory suggest that there are racial differences in the association between visceral AT and health risk (8). In black overweight/obese adolescents, lower visceral AT was associated with lower hepatic glucose production and better lipid profile than their white peers, yet the diabetogenic risks were higher in blacks than in whites (8). Others have demonstrated that blacks are more hyperinsulinemic and insulin resistant (26–30), and have higher incidence of type 2 diabetes (31) compared with whites. In contrast, whites have higher triglycerides (2,4,8) and prevalence of the metabolic syndrome than blacks (32,33). Some studies suggested that the lower visceral AT in black adults favors better plasma lipoprotein profiles (2,34), but not diabetogenic risk factors (e.g., fasting insulin and insulin sensitivity) compared with whites. These adult and pediatric findings are intriguing observations, and suggest that caution must be exercised when interpreting obesity related health risk outcomes taking into consideration not only race related differences in abdominal adiposity but also the differential contribution to metabolic alterations.

Although the deleterious effects of visceral AT on the risks of cardiovascular disease and type 2 diabetes are well known in both the pediatric and adult literature, the singular importance of visceral AT on health outcomes is controversial. Some suggest that SAT is a stronger correlate of insulin sensitivity than visceral AT in men (35,36). Kelley *et al.* (37) demonstrated that deep SAT in the abdomen is strongly associated with insulin resistance similar to that of visceral AT in men and women. Currently, the race differential on the relative contribution of different abdominal SAT depots (anterior, posterior, deep vs. superficial AT) to health risk is unclear in adults and pediatrics. Although speculative, higher abdominal SAT, in particular metabolically active deep SAT, in blacks may confer greater metabolic health risks than whites despite lower visceral AT. Further, increased diabetogenic risks in blacks may be influenced by other factors such as increased fat deposition in the skeletal muscle and pancreatic β -cells independent of visceral AT.

Recent studies report that the W/Ht is a strong correlate of cardiovascular disease in adult (12,13) and pediatric populations (14). McCarthy and Ashwell (15) suggested that height status in childhood influences the size of WC during growth/development and thus height should be considered when evaluating central obesity. However, we observed that both WC and W/Ht were strongly associated with visceral AT by a similar degree of magnitude in both blacks (WC; $r = 0.84$ in boys and 0.90 in girls, W/Ht; 0.85 in boys and 0.90 in girls) and whites (WC; $r = 0.90$ in boys and 0.90 in girls, W/Ht; 0.90 in boys and 0.89 in girls), and that both measures (WC and W/Ht) were better correlates than WHR independent of race. Nevertheless, our study provides evidence that WC is a useful marker of visceral AT in pediatrics when it is used by itself or in combination with height, but not with hip circumference.

Limitations of this study warrant mention. As this study was a cross-sectional analysis, we cannot infer that longitudinal increases in adiposity in black and white boys and girls would follow a similar pattern as those observed here. Further, WC and abdominal AT were not measured at the same anatomical landmark. Although both measures were assessed using commonly used anatomical locations for measuring WC and abdominal AT distribution, it is unclear how the associations observed here would be influenced if they were assessed at the same anatomical location.

In conclusion, we demonstrated a significant race and gender differential in the abdominal AT distribution for a given anthropometric measurement. Future studies need to consider these differences when developing race- and gender-specific anthropometric cutoffs for obesity and obesity-related health risks in youth, or in the development of metabolic syndrome criteria in childhood.

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DISCLOSURE

The authors declared no conflict of interest.

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