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Sex and Ethnic Differences in the Relationship between Changes in Anthropometric Measurements and Visceral Fat in Adolescents with Obesity

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Objective To examine sex and ethnic differences in how baseline and changes in anthropometric measures relate with change in visceral fat with interventions in adolescents.

Study design Black and white adolescents (n = 143: body mass index [BMI] ≥85th percentile, 12-18 years) who participated in intervention studies (3-6 months) were included and had assessments of anthropometric measures (weight, BMI, waist circumference, waist-to-hip ratio [WHR], and waist-to-thigh ratio) and visceral fat at L4-L5 by magnetic resonance imaging before and after interventions.

Results At baseline, all of the anthropometric measures were positively associated with visceral fat ($P < .05$), with weight, waist circumference, and WHR having the largest variance explained (model adjusted R^2 = 0.35-0.47 vs 0.32-0.35). Blacks had 11.5-23.3 cm^2 less visceral fat compared with whites for a given anthropometric value. Girls tended to have less visceral fat for a given anthropometric value, but the sex differences were not consistently significant (range: 0.7-12.9 cm^2). Changes in waist circumference, BMI, and weight, but not WHR, remained significantly associated with changes in visceral fat. There were no sex differences, and much more minimal ethnic differences (<4.9 cm^2).

Conclusions At baseline, there are sex and ethnic differences in how anthropometric measures correlate with visceral fat. However, there were minimal sex and ethnic differences in how changes in anthropometric measures related with changes in visceral fat. Although all of the anthropometric measures were associated with visceral fat at baseline, waist circumference, BMI, and weight, but not WHR were associated with changes in visceral fat. *(J Pediatr 2019;213:121-7)*.

Trial registration Clinicaltrials.gov: NCT00739180, NCT01323088, and NCT01938950.

Sex and ethnic differences in body fat distribution are well documented in youth and adults.[1-5] For a given body mass index (BMI), female and white subjects are reported to have higher levels of percent body fat and lower waist circumference than male and black subjects, respectively.[6]

Similarly, there are significant sex[7] and ethnic[6] differences in abdominal fat distribution for a given waist circumference. In adults, it has been previously demonstrated that for a given weight loss, men with obesity lost more visceral fat and less subcutaneous fat than women.[8,9] These differences may be related to sex differences in hormones or adipose tissue receptor density that would influence lipolytic activity of adipose tissue.[10] As many of these changes occur over the course of puberty, it is unclear whether these sex differences are also present in adolescents who are in transition or recently fully mature. Anthropometric measures are often used as surrogates for adipose tissue measures that are generally more expensive and complicated to assess.

Therefore, the objective of this study was to examine the association between baseline and changes in anthropometrics and visceral fat in adolescents with overweight and obesity, and to determine if there are differences by sex and ethnicity.

Methods

This study is a secondary analysis of 143 black and white adolescent boys and girls with overweight and obesity who participated in 3 exercise-based intervention trials between 2007 and 2017 conducted at the University of Pittsburgh[11-13] (Clinicaltrials.gov: NCT00739180, NCT01323088, and NCT01938950) and who had complete baseline and follow-up information for BMI, waist circumfer-

BMI	Body mass index
WHR	Waist-to-hip ratio
WTR	Waist-to-thigh ratio
WHgtR	Waist-to-height ratio

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ence, and visceral fat. For all trials, participants were recruited via newspaper advertisements, flyers, and posters in the greater Pittsburgh area. Inclusion criteria for the two 3-month intervention trials[11,12] were 12-18 years of age, pubertal (Tanner stages III-V), nonsmokers, and sedentary (no structured physical activity in the 3 months prior to the study) and inclusion criteria for the 6-month trial[13] were 12-17 years of age, pubertal (Tanner stages II -V), nonsmokers, and sedentary (no structured physical activity in the 3 months prior to the study). Exclusion criteria for all trials included chronic conditions or medications that may influence glucose metabolism or body composition, and significant weight change (BMI >2-3 kg/m^2) in the 3 months prior to the study. All subjects were given a thorough physical examination by a nurse practitioner and routine hematologic and biochemical tests at the Pediatric Clinical and Translational Research Center at Children's Hospital of Pittsburgh of the University of Pittsburgh Medical Center. Participants self-identified as black or white. The investigation was approved by the University of Pittsburgh Institutional Review Board. Parental informed consent and child assent were obtained from all participants before study participation.

A detailed description of the three exercise interventions was reported previously.[11-13] Briefly, participants in the aerobic exercise group used either treadmills or ellipticals at 50%-75% of VO_{2peak}, 3 times per week (60 minutes/session), for 3-6 months. Participants in the resistance group used weight machines and performed a series of 10 whole-body resistance exercises, 2 sets, 8-12 repetitions in the 3-month trial,[11,12] and 2 sets, 12-15 repetitions in the 6-month trial,[13] 3 times per week (60 minutes/session), for 3-6 months. Participants in the combined aerobic and resistance exercise group in the 6-month trial[13] performed 30 minutes of aerobic exercise on a treadmill or elliptical at a moderate intensity (50%-65% of VO_{2peak}) and performed a series of 10 whole-body resistance exercises (1 set, 12-15 repetitions), 3 times per week (60 minutes/session). Participants in the control group in the 3-month trial[11,12] were asked not to participate in the structured physical activities but to maintain their leisure time physical activity levels.

Exercise attendance was ≥90% in all 3 trials as shown previously.[11-13] During the intervention period, participants in all 3 trials were asked to follow a healthy weight maintenance diet (55%-60% carbohydrate, 15%-20% protein, and 25%-30% fat) to examine the independent effects of exercise on the changes in health risk factors.

Body weight was measured to the nearest 0.1 kg and height was measured to the nearest 0.1 cm. Waist circumference was measured at the level of the last rib, top of the iliac crest, and the umbilicus. Hip circumference was measured around the widest potion of the buttocks. For all circumferences, the average of 2 measures was used in the analyses. For the waist-to-hip ratio (WHR), waist-to-thigh ratio (WTR), or waist-to-height ratio (WHgtR), the waist at the iliac crest was used.

Visceral fat at L4-L5 was measured using a 3.0 Tesla MR scanner (Magnetom TIM Trio; Siemens, Erlangen, Germany) at the University of Pittsburgh Magnetic Resonance Research Center. As shown previously,[11,12] the subjects lay in the magnet in a prone position with their arms placed straight overhead. Magnetic resonance imaging data were transferred electronically to a stand-alone computer for analysis using specially designed image analysis software (Tomovision, Montreal, Canada), the procedures for which are fully described elsewhere.[14,15]

Participant baseline and change characteristics are presented stratified by sex and ethnicity as means ± SD for continuous variables and frequency and percentages for categorical variables. Sex and ethnic differences in baseline and change values were assessed using ANOVA with least squared differences post hoc tests. The relationship between anthropometric variables and visceral fat at baseline were assessed using general linear modelling, with adjustment for age, sex, ethnicity, intervention group, and Tanner stage. The relationship between changes in anthropometric variables and visceral fat was additionally adjusted for baseline values of visceral fat. For both regressions, sex by ethnicity by anthropometric 3-way and 2-way interaction effects were examined. All analyses were performed with commercially available software (SAS v 9.4; SAS Institute, Cary, North Carolina). *P* values of less than .05 were accepted to indicate statistical significance.

Results

Baseline characteristics stratified by sex and ethnicity are shown in **Table I**. There were no significant sex or ethnic differences in overall obesity ($P > .05$), with sex and ethnic differences in visceral fat at baseline ($P < .05$). Despite the differences in abdominal obesity at baseline, there were no sex or ethnic differences in the change values in BMI, waist circumference, or WHR ($P > .05$). The unadjusted scatterplots for baseline and changes in visceral fat with weight, BMI, waist circumference, WHR, WTR, and WHgtR are shown in **Figure 1** and **Figure 2**.

At baseline, all of the anthropometric measures were positively associated with visceral fat ($P < .05$), with waist circumference and WHR measures having the largest variance explained (model R^2 = 0.39-0.47 vs 0.32-0.35) (**Table II**) with adjustment for age, sex, ethnicity, intervention group, and Tanner stage. There were no significant 3-way sex × ethnic × anthropometric interactions or 2-way ethnic × anthropometric interactions with visceral fat at baseline ($P > .05$). There were significant main effects for ethnicity for all variables examined ($P < .04$), wherein black adolescents had 10.1-23.3 cm^2 less visceral fat compared with white adolescents for a given anthropometric value.

Sex differences tended to be smaller with female subjects having 8.1-12.9 cm^2 less visceral fat than male subjects for a given BMI, iliac crest waist circumference, WTR, or WHgtR ($P < .05$), but no sex differences in visceral fat for a given

Table I. Participant characteristics stratified by ethnicity and sex

	White n = 66				Black n = 77			
	Male n = 36		Female n = 30		Male n = 28		Female n = 49	
	Baseline	Change	Baseline	Change	Baseline	Change	Baseline	Change
Characteristics	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age (y)	14.7 (1.6)		14.6 (1.6)		14.8 (1.7)		14.3 (1.7)	
BMI (kg/m^2)	33.6 (4.9)	−0.2 (1.6)	33.5 (4.5)	−0.4 (1.6)	34.6 (4.4)	−0.3 (1.1)	34.2 (4.1)	0.0 (1.5)
Weight (kg)	99.4 (18.5)	0.8 (5.3)	91.0 (13.9)	−0.5 (4.2)	97.4 (14.8)	0.7 (3.5)	91.8 (15.7)	0.7 (4.2)
Waist circumference at iliac crest (cm)	110.0 (12.1)	−1.2 (4.1)	110.9 (10.2)	−1.9 (3.4)	108.5 (11.4)	−1.9 (3.5)	108.3 (11.0)	−1.1 (3.4)
Waist circumference at last rib (cm)	101.7 (10.8)*	−0.9 (3.5)	96.6 (10.0)*	−1.9 (2.7)	99.6 (9.0)	−1.2 (4.0)	95.2 (9.5)	−0.6 (3.1)
Waist circumference at umbilicus (cm)	110.7 (12.1)	−0.6 (3.6)	106.9 (10.6)	−1.4 (4.3)	109.4 (11.5)	−1.8 (3.7)	105.7 (11.7)	−0.8 (3.6)
Mid-thigh circumference (cm)	63.8 (5.7)	−0.7 (2.2)	64.1 (4.8)	−1.1 (2.7)†	65.9 (6.2)	−0.6 (1.7)	64.7 (5.7)	0.2 (2.3)†
WTR	1.72 (0.12)†	0.00 (0.05)	1.73 (0.11)	0.00 (0.07)	1.65 (0.11)†	−0.01 (0.04)	1.68 (0.15)	−0.02 (0.07)
Hip circumference (cm)	112.0 (11.1)	−1.1 (2.4)	113.7 (7.1)	−1.0 (3.0)	110.0 (7.3)	−0.8 (1.8)	114.8 (9.9)	−0.8 (3.1)
WHR	0.98 (0.05)	0.00 (0.03)	0.96 (0.06)	−0.01 (0.02)	0.92 (0.06)	−0.01 (0.02)	0.93 (0.07)	0.00 (0.03)
Visceral fat at L4-L5 (cm^2)	87.5 (26.5)*,†	−8.0 (12.7)	75.5 (20.1)*,†	−8.7 (17.3)	63.2 (24.7)†	−8.4 (11.9)	57.4 (20.0)†	−7.7 (10.6)

Hip circumference and WHR were obtained in 69 subjects.
*Significant sex difference within ethnicity baseline or change value ($P < .05$).
†Significant ethnicity difference within sex baseline or change value ($P < .05$).

body weight or waist circumference at the last rib or umbilicus ($P > .05$). The only significant sex × anthropometric was for WHR wherein the sex difference was magnified with increasing visceral fat ($P = .04$).

As shown in **Table II**, changes in body weight, BMI, and waist circumference at all sites were significantly associated with changes in visceral fat (model adjusted $R^2 = 0.26$-34, $P \leq .0002$). Unlike at baseline, changes in WHR and WTR were not significantly associated with changes in visceral fat ($P > .05$). Changes in all of the waist circumference measures remained significantly associated with changes in visceral fat, but the variance explained was much more comparable with weight and BMI (model adjusted $R^2 = 0.26$-0.32 vs 0.32-0.34), but was stronger than the waist ratios (model adjusted $R^2 = 0.10$-0.22). There were no significant 3-way or 2-way sex × ethnic × anthropometric interactions with changes in visceral fat ($P > .05$). There were also no significant main effects for sex for any of the variables examined ($P > .05$). The only significant ethnic main effects were that black adolescents had 4.3 cm^2 less visceral fat for a given waist circumference at the last rib ($P = .03$) and 4.9 cm^2 less visceral fat for a given WHgtR ($P = .03$) than white adolescents.

Discussion

Changes in body weight, BMI, and waist circumference, but not WHR, are significant correlates of visceral fat loss in response to an exercise intervention in adolescents with overweight and obesity. However, sex and ethnicity differences in how changes in anthropometric measures relate with changes in visceral fat are much more modest than at baseline. These findings suggest that both BMI and waist circumference should be used in the clinical setting to identify youth with increased visceral adiposity, regardless of sex and ethnicity.

The debate as to the optimal anthropometric measure for predicting visceral fat has been the topic of several investigations. Most commonly, BMI, waist circumference, and WHR are touted as the most strongly related with visceral fat[16] and health risk. However, fewer studies have examined changes in these anthropometric measurements with changes in visceral adiposity. As with others,[16-18] we demonstrate that body weight, BMI, waist circumference, and WHR are the most strongly related with visceral fat cross-sectionally. However, when examining changes, weight, BMI, and waist circumference clearly become the better correlates of visceral fat than WHR. In fact, changes in WHR were not significantly associated with changes in visceral fat, and of all the anthropometric measures examined in the present study, changes in WHR were most weakly related with changes in visceral fat. It has previously reported in adults that WHR is only significantly associated with changes in visceral fat in white men and not white women,[16] and that WHR is inferior to body weight for predicting changes in visceral fat.[18] WHR is often a stronger correlate of visceral fat and health risk because hip adjusted for waist independently reflects lower subcutaneous fat, muscle, and higher visceral fat.[19] However, with weight loss, fat is mobilized from both the abdominal and hip region.[8] Thus, depending on where the fat is preferentially mobilized from, WHR can increase, decrease, or have no change in response to weight loss.[16] Given the greater ease and repeatability of a single waist circumference measure vs both waist and hip circumference measurements, this study provides evidence that waist circumference or body weight may be a more clinical useful predictor of visceral fat in youth.

It is well established that visceral fat is an independent risk factor for insulin resistance, dyslipidemia, liver fat, and the metabolic syndrome in youth.[20-23] Sex[2,4,7] and ethnic[2,4-6] differences in fat patterning and visceral adiposity are also documented, and they exist early in life as they are apparent in youth as well as adults. Female sex and black ethnicity are well known to be associated with less visceral adiposity. In

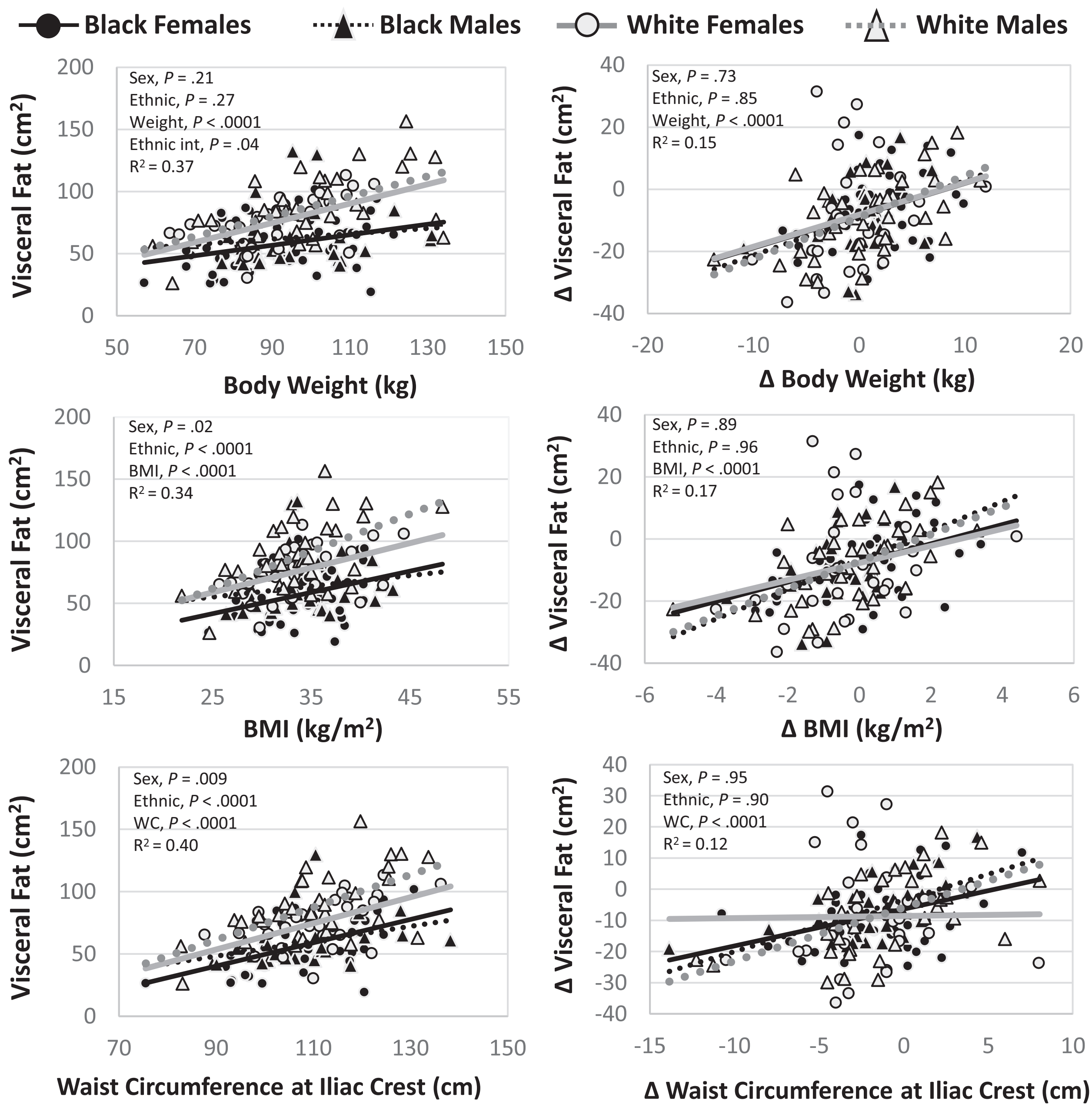

Figure 1. The unadjusted scatterplots for baseline and changes in visceral fat with body weight, BMI, and waist circumference in black and white boys and girls.

children and adolescents, the lower visceral adiposity in black may explain better lipid profile (eg, lower triglycerides and low-density lipoprotein cholesterol) and lower liver fat content compared with their white peers.[24,25] In adults, it is reported that changes in a given adipose tissue depot are related to their initial size.[8] Thus, men are typically reported to have greater visceral fat loss than women.[8,9] Reasons for these sex differences are unclear and may relate to differences in catecholamine-induced rate of free fatty acid mobilization from visceral fat and differences in the function of lipolytic beta 3-adrenoceptor sensitivity and antilipolytic alpha 2-adrenoceptor sensitivity.[10] Nevertheless, these appear to translate into only minimal differences in the way visceral fat is reduced with weight loss in black and white adolescents. For each kg weight loss, the difference in visceral fat loss between boys and girls was <1 cm^2, and only 3.8 cm^2 between blacks and whites. The health implications of this difference are unclear, but in men, a difference of 3.8 cm^2 would translate into a 0.01% higher odds for all-cause mortality risk.[26] Thus, the sex and ethnic differences that we observe are likely not clinically meaningful even if they were statistically significant.

Our findings are limited to black and white adolescent boys and girls with overweight and obesity. Whether our

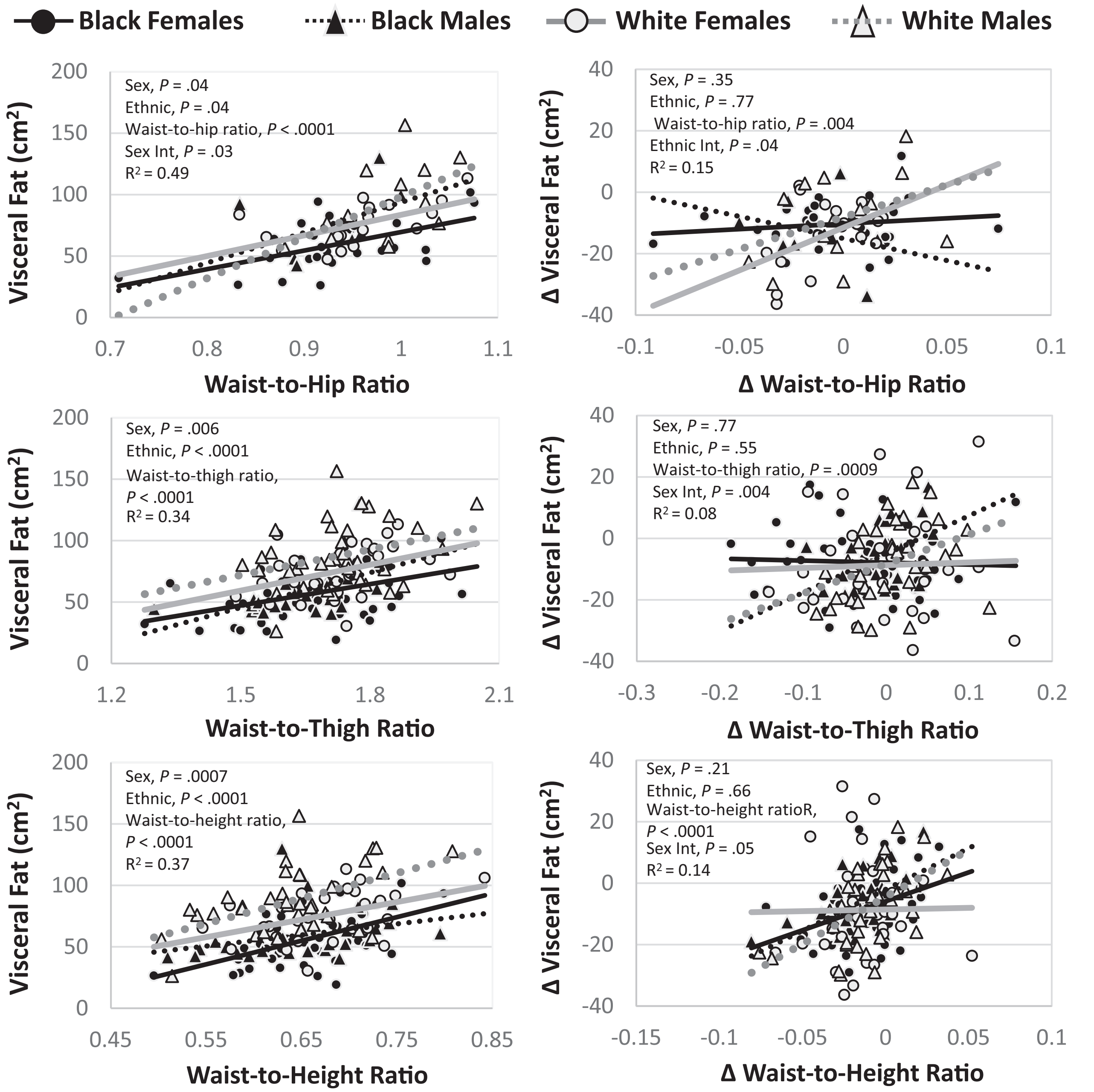

Figure 2. The unadjusted scatterplots for baseline and changes in visceral fat with WHR, WTR, and WHgtR in black and white boys and girls.

observation would remain true in other racial groups or prepubertal boys and girls is unknown. We had a smaller sample size for our analyses with WHR (n = 69) as the 3-month intervention studies[11,12] did not acquire hip measures. However, even when examining the associations for weight and waist circumference in the smaller sample, the magnitude of the associations and the variance explained remained similar. Further, although we controlled for exercise intervention type in our analyses, there may be differences in how fat is mobilized in response to different weight loss therapies that may differ by sex and ethnicity, such as diet, pharmacotherapy, or surgery. Finally, it is unclear whether the anthropometric measures examined would have similar associations with changes in metabolic risk factors.

Our study demonstrated that the significant sex and ethnic differences in the cross-sectional relationship between anthropometric measures and visceral fat are not significant modifiers of the relationship between change values. Thus, changes in simple anthropometric variables reflect similar changes in visceral fat in black and white boys and girls. ■

We thank all participants and their parents who participated in this study and the nursing staff of the Pediatric Clinical and Translational Research Center at Children's Hospital of Pittsburgh of UPMC for their outstanding care of the participants.

Table II. Sex and ethnic differences in the relationship between cross-sectional and changes in anthropometric measures and visceral fat

	Baseline							Change						
Characteristics	Anthro STD-β	*P*	Sex male vs female	*P*	Ethnicity white vs black	*P*	Model adjusted R^2	Anthro STD-β	*P*	Sex male vs female	*P*	Ethnicity white vs black	*P*	Model adjusted R^2
–			9.6	.03	21.1	<.0001	0.20			0.6	.79	3.9	.08	0.18
Weight (kg)	0.44	<.0001	3.1	.45	21.5	<.0001	0.35	0.42	<.0001	-0.4	.85	3.8	.06	0.34
BMI (kg/m^2)	0.37	<.0001	8.9	.03	23.3	<.0001	0.32	0.38	<.0001	0.3	.87	3.6	.07	0.32
Waist circumference (cm)														
Iliac	0.46	<.0001	8.1	.04	19.3	<.0001	0.39	0.29	.0002	0.5	.81	3.4	.10	0.26
Rib	0.56	<.0001	0.7	.85	18.9	<.0001	0.47	0.38	<.0001	0.4	.85	4.3	.03	0.32
Umbilicus	0.51	<.0001	3.3	.39	20.0	<.0001	0.44	0.28	.0002	0.8	.71	3.2	.14	0.26
WHR														
Male	0.63	.02	Sex-int	.04	11.5	.04	0.35	0.21	.08	4.9	.16	0.8	.76	0.10
Female	0.58	.0007	Sex-int	.04	-2.2	.87	0.35							
WTR	0.38	<.0001	9.4	.02	16.3	<.0001	0.32	0.11	.17	0.5	.83	2.5	.27	0.16
WHgtR	0.40	<.0001	12.9	.002	20.6	<.0001	0.35	0.24	.007	2.1	.36	4.9	.03	0.22

int, interaction; *STD-*, standardized.
β values are the difference in visceral adipose tissue per SD difference in the anthropometric variable.
Values for sex and ethnicity main effects are the differences between female and male and white and black, respectively.
Models adjusted for age, sex, ethnicity, intervention group, and Tanner stage.
There were no significant 3-way sex $\times$ ethnicity $\times$ anthropometric interactions for baseline or change values ($P > .05$).
There were no significant 2-way sex $\times$ anthropometric or ethnicity $\times$ anthropometric interactions for change values ($P > .05$).
WHR were obtained in 69 subjects.

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50 Years Ago in *The Journal of Pediatrics*

Termination of Night Feeding in Infancy

Beal VA. J Pediatr 1969;75:690-2

Termination of night feed is seen as a “parenting success.” Parents eagerly wait for the day when the child would achieve an 8-hour gap (during the night) between feedings. It was also believed that early introduction of solid feeds in the infant diet would promote night sleep. In 1969, Beal observed that the median age of achieving 8-hour span between night feedings in 95 infants was 1.25 months! The average age of introduction of solid foods varied between 0.5-5 months, with 86% of infants first receiving solid food before 3 months of age.

Fifty years later, the World Health Organization recommends introduction of solid foods only after 6 months of exclusive breastfeeding.[1] Early introduction of food is a health hazard, predisposing to increased morbidity and mortality in low/middle income countries. Studies also indicate very early introduction of solid foods (17 weeks) of high diversity may increase the risk of later allergy, predispose to childhood obesity, and serve as a risk factor for noncommunicable diseases of adulthood. Parents who feed top milk or solid feeds early need to realize that such infants are less likely to feed at night but not less likely to wake till the sleep pattern is established. Increasing calorie intake during the day is unlikely to reduce the night-time awakening. Thus, introduction of solid foods below 6 months of age may not help the child achieve night time awakening free status. A recent study on 715 infants 6-12 months age revealed that about 80% were still regularly awakening at least once a night.[2]

Arousal and sleep are complex neurophysiologic processes regulated by circadian rhythms and sleep wake homeostasis which appear by 10-12 weeks. This determines the duration and timing of sleep making sleep more structured, decreasing day naps, and altering sleep/wake pattern to gear toward day/night pattern by 6 months.[3] Effective behavioral routines reinforce this development. Though a universal physiologic process, differences in sleep patterns are influenced by culture, race/ethnicity, child temperament and development, parenting practices, and maternal depression, but not by diet.

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