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Comparison of Maximal Oxygen Consumption between Obese Black and White Adolescents

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ABSTRACT

Abstract The purpose of this investigation was to determine whether maximal oxygen consumption (VO_{2max}) differed between clinically obese black and white children and if a difference existed to determine whether it was related to hematological profiles and/or physical activity/inactivity levels. Twenty-three black and 21 white adolescents were matched for age, BMI, and Tanner stage (II-V). Body composition was determined by DEXA and CT scan. Daily physical activity/inactivity was assessed by questionnaire. VO_{2max} was assessed using the Bruce treadmill protocol. Black participants had significantly lower VO_{2max} and $VO_{2maxFFM}$ values when compared with white adolescents (26.1 ± 4.2 *versus* 29.9 ± 3.1 mL · kg^{-1} · min^{-1}; 48.3 ± 8.8 *versus* 55.6 ± 5.2 mL · $kg_{FFM}{}^{-1}$ · min^{-1}, respectively). Black adolescents also had significantly lower Hb concentrations ([Hb]) than white children (12.7 ± 1.3 *versus* 13.4 ± 0.7 g/dL). Black adolescents were more physically inactive than their white peers. VO_{2max} correlated with [Hb] for the combined groups. Obese black adolescents had lower VO_{2max} compared with white children and this difference was explained, in part, by the lower [Hb] observed in the black participants. Further investigations should study Hb flow rate (a function of [Hb] · maximal cardiac output) and physical activity/inactivity patterns in obese black and white children as it relates to VO_{2max}. **(*Pediatr Res* 58: 478–482, 2005)**

Abbreviations

BMI, body mass index,
VO_{2max}, maximal oxygen consumption,
[Hb], hemoglobin concentration,
HR, heart rate,
RER, respiratory exchange ratio,

Numerous investigations have demonstrated that there is a difference in VO_{2max} between black children compared with white children (1–8). We recently reported that VO_{2max} was significantly lower in nonobese black prepubertal and pubertal children when compared with white children matched for age pubertal stage and BMI (8). Several factors have been associated with the differences in VO_{2max} between black and white youth these include hematological profiles (4–6,8), physical activity levels (5,7–10), and body composition (1,6). In our previous investigation, we concluded that the comparatively lower VO_{2max} in black children was partly attributed to a lower Hb concentration ([Hb]) and higher physical inactivity levels (8). While evidence is extremely limited, differences in [Hb] and associated VO_{2max} values between blacks and whites have been observed in both healthy children and adults. To our knowledge, no investigations have examined the effect of [Hb] on VO_{2max} in young obese black and white adolescents.

Obesity has been associated with significant health problems in the pediatric age group and is an important risk factor for adult morbidity and mortality (11–13). Obesity in children and adolescents is widely recognized as a contributing factor to various conditions such as: impaired glucose tolerance; type 2 diabetes; hyperlipidemia; hypertension and reduced cardiorespiratory/aerobic fitness (14–17). In addition, comparatively lower levels of cardiovascular/aerobic fitness may interact with one or more of these clinical states, further exacerbating their clinical sequelae.

Therefore, the purpose of this follow on investigation was to determine whether VO_{2max} differed between clinically obese black and white children and whether a difference existed to determine whether it was related to hematological profiles and/or physical activity/inactivity levels.

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METHODS

Participants. Twenty-three clinically obese [BMI ≥ the 95th percentile for age and sex] black and 21 white adolescents aged 10.9 to 16.8 y participated in this study. Pubertal development was assessed by physical examination according to the criteria of Tanner (18). All study participants were determined to be in Tanner stages ≥ II–V of development. Some of the subjects had participated in an investigation reported previously (19). All subjects were in good health based on clinical history, physical examination and hematological profiles. All subjects had normal glycosylated Hb values. No subjects were receiving medications and none were competitive athletes. Table 1 lists the clinical characteristics of the study participants.

Study participants were recruited through newspaper advertisements in the community. All studies were approved by the Human Rights Committee of Children's Hospital of Pittsburgh. Research participants and parents/guardians gave written informed assent and consent after receiving a thorough explanation of the research project. All children were studied in the General Clinical Research Center at Children's Hospital of Pittsburgh and at the Center for Exercise and Health-Fitness Research at the University of Pittsburgh.

Experimental design. All subjects were admitted to the General Clinical Research Center in the early afternoon before testing. Participants were advised to follow a weight maintenance diet containing 55% carbohydrate, 30% fat, and 15% protein for 1 wk before testing. After admission to the General Clinical Research Center subjects were transported to the Center for Exercise and Health-Fitness Research at the University of Pittsburgh where a physical activity questionnaire and VO_{2max} test were administered.

Biochemical measurement. Blood samples were obtained, from the anticubital vein after a 12-h overnight fast. Uncoagulated whole blood was immediately analyzed to obtain values for [Hb]. Hb was determined by the cyanide method using a Coulter Gen-S System (Beckman Coulter Inc.Atlanta, GA).

Body composition and abdominal adiposity. Body composition was assessed by dual-energy x-ray absorptiometry. S.c adipose tissue was assessed by a 10-mm single axial computed tomography scan of the abdomen at the level of L_{4-5} lumbar vertebra as described by us previously (20). The volume of visceral adipose tissue was electronically calculated (21).

Physical activity assessment. Physical activity was assessed by the Modifiable Activity Questionnaire (MAQ) that separately measured physical, leisure-time activity and inactivity (22,23). Vigorous activity and physical inactivity were assessed exactly as described previously.8 Leisure-time activity was assessed by asking the subject to recall activities that they participated in at least 10 times over the past year (22,23).

Maximal oxygen consumption. Maximal oxygen consumption (VO_{2max}) was indexed to total body mass (*i.e.*, $mL \cdot kg^{-1} \cdot min^{-1}$) and fat free mass (*i.e.*, $mL \cdot kg_{FFM}^{-1} \cdot min^{-1}$) and measured using the Bruce multistage treadmill protocol. This protocol is suitable for use with children ages 4 y and older (8,24). All tests were conducted on a Quinton (model Q-65) motor-driven treadmill. The attainment of VO_{2max} was accepted when the participants demonstrated any two of the following three criteria: *1*) a change in $\dot{V}o_2$ of $< 2.1\ mL \cdot kg^{-1} \cdot min^{-1}$ with increasing exercise intensity at near-maximum higher treadmill stages, *2*) a respiratory exchange ratio (RER) of ≥ 1.05, and *3*) heart rate (HR) > 90% of the age-predicted maximum at the end of the exercise test (6–8). HR was measured continuously throughout the exercise test using a Polar Monitor System (Polar Electro, Inc., Woodbury, NY). Expired gases were collected and analyzed by open circuit spirometry in 15-s intervals using a Parvo Medics TrueMax 2400 metabolic measurement system (Salt Lake City, UT). The analyzer was calibrated with gases of known concentrations before each testing session according to the manufacture's guidelines. Verbal encouragement was given to all subjects to elicit a maximal effort.

Statistical analysis. All statistical analyses were performed using SPSS-PC (version 11.0; SPSS Inc, Chicago) and SAS (version 8.0; SAS Institute Inc., Cary, NC). Comparison of physiologic, hematological and body composition variables between black and white children were made with using an **unpaired** two-tailed *t* test. A χ^2 analysis was used to determine whether differences existed in the various physical activity measures between the subject groups. Because of multiple comparisons, *t* values were expressed using a Bonferroni-Dunn inequality adjustment. All data are presented as a mean ± SD. Pearson correlation coefficients were calculated to identify relations between selected variables. Multiple regression analysis was applied to evaluate multivariate relations.

Table 1. *Participant characteristics*

	Black	White
N	23	21
Sex (M/F)	14/9	11/10
Age (yrs)	13.3 ± 1.7	13.2 ± 1.6
Height (cm)	161.2 ± 7.4	162.0 ± 9.8
Weight (kg)	91.2 ± 18.3	87.2 ± 19.0
BMI (kg/m^2)	34.9 ± 5.6	32.9 ± 4.8
FM (kg)	37.8 ± 8.7	34.4 ± 9.4
FFM (kg)	47.1 ± 7.9	45.6 ± 10.2
BF (%)	42.9 ± 4.1	41.7 ± 6.0
VAT (cm^2)	63.2 ± 26.8	81.2 ± 27.6
SAT (cm^2)	518.1 ± 167.9	502.5 ± 142.3
[Hb] (g/dL)	12.7 ± 1.3*	13.4 ± 0.7

All values are mean ±SD. FM, fat mass; BF, body fat; VAT, visceral adipose tissue; SAT, subcutaneous adipose tissue.

* $p < .05$.

RESULTS

Characteristics for the initial pool of study participants are presented in Table 1. Three subjects (1 black and 2 white) failed to meet the criteria for VO_{2max} and were excluded from further data analysis.

Obese black adolescents had significantly lower VO_{2max} and $VO_{2maxFFM}$ values when compared with the white adolescents (26.1 ± 4.2 *versus* $29.9 \pm 3.1\ mL \cdot kg^{-1} \cdot min^{-1}$, $p < 0.05$; 48.3 ± 8.8 *versus* $55.6 \pm 5.2\ mL \cdot kg_{FFM}^{-1} \cdot min^{-1}$, $p < 0.05$, respectively; Table 2). No differences were observed between racial groups with respect to maximal HR or maximal respiratory exchange ratio (Table 2). Obese black adolescents had significantly lower [Hb] when compared with their white peers (12.7 ± 1.3 *versus* 13.4 ± 0.7 g/dL, $p < 0.05$; Table 1).

χ^2 analysis indicated ($p < 0.05$) that obese black adolescents were more physically inactive than their white peers (Table 3). No between group differences were observed for measures of vigorous physical activity and leisure-time physical activity (Table 3).

For the total subject sample, VO_{2max} correlated with [Hb], sex and race ($r = 0.379$, $p < 0.01$: $r = -.350$, $p < 0.05$; and $r = -.319$, $p < 0.05$, respectively). No significant correlations were observed between any measure of physical activity and VO_{2max}. Stepwise multiple-regression analysis was used to determine the relative contributions of race, [Hb] and sex in explaining the variance in VO_{2max} (Table 4, model 1). Both race ($p < 0.05$) and sex ($p < 0.05$) entered the model as significant predictors, combining to explain 28% of the variance in VO_{2max}. A second stepwise multiple-regression analysis was used to determine the relative contributions of race, physical inactivity and sex in explaining the variance in VO_{2max} (Table 4, model 2). Both race ($p < 0.05$) and sex ($p < 0.01$) entered the model as significant predictors, combining to explain 25% of the variance in VO_{2max} (Table 4, model 2).

Table 2. *Maximal exercise responses*

	Black (n = 22)	White (n = 19)
RER	1.05 ± 0.08	1.08 ± 0.08
HR (beats/min)	189 ± 9	193 ± 6
VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	26.1 ± 4.2*	29.9 ± 3.1
VO_{2FFM} ($mL \cdot kg_{FFM}^{-1} \cdot min^{-1}$)	48.3 ± 8.8*	55.6 ± 5.2

All values are mean SD. RER, respiratory exchange ratio; HR, heart rate; VO_{2FFM}, oxygen consumption per fat free mass.

* $p < .05$.

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Table 3. *Physical activity questionnaire assessment*

	Black (n = 22)	White (n = 19)
Vigorous physical activity		
None	7 (31.8%)	8 (42.1%)
≥1 day	15 (68.2%)	11 (57.9%)
Physical inactivity		
<4 hrs/day	5 (22.7%)	10 (52.6%)
≤4 hrs/day	17 (77.3%)*	9 (47.4%)
Leisure-time physical activity (hrs/wk)	9.1 ± 5.5	11.5 ± 8.7

Number of participants (percentage within group), means ±SD. Vigorous physical activity was defined as the number of days in the past 14 spent doing 20 minutes of hard exercise. Physical inactivity was defined as the number of hours per day spent watching television and video's, or playing on the computer or video games.

* $p < .05$.

DISCUSSION

The primary finding of this investigation was that clinically obese black adolescents had significantly lower VO_{2max} levels when compared with white children matched for age, pubertal stage and BMI. The attainment of VO_{2max} was confirmed for both racial groups of adolescents using HR and RER criteria. The similarities of maximal HR and RER between the two racial groups were consistent with previous investigations (6–8,25).

Maximal oxygen uptake. The main conclusion from this investigation was that VO_{2max} was 13% lower in obese black children when compared with their white peers. The difference in VO_{2max} between black and white children was still present when VO_{2max} was indexed to FFM ($mL \cdot kg_{FFM}^{-1} \cdot min^{-1}$). Our findings are consistent with the previously reported 12% to 20% lower VO_{2max} values in black compared with white children (1–8). Gutin *et al.* (7) reported that obese black boys and girls (ages 13–16 y) had significantly lower VO_{2max} values when compared with white adolescents of the same age and body composition. However, our study is the first investigation that carefully matched racial groups of obese children with respect to age, pubertal stage, BMI and body composition. The VO_{2max} values reported presently for both of the black and white obese children are generally consistent with these previously established ranges.

Hematological profiles. Our finding that [Hb] was lower in black adolescents when compared with white is consistent with previous investigations (6,8,26,27). Garn *et al.* (26) reported that black children had an average [Hb] ~1 g/dL lower than white children. Dallman *et al.* (27) also found that black children had significantly lower Hb values, by ~0.5 g/dL, when compared with white and Asian children of the same sex and age.

One factor that may explain the race differences in VO_{2max} observed presently is that black children had significantly lower [Hb] when compared with their white peers. This comparatively lower hematological profile, while still within the clinically normal range, may have decreased central circulatory oxygen transport capacity producing a corresponding decrease in total body oxygen consumption at maximal exercise intensities (28). Rowland noted that relatively small changes in [Hb] or total circulating Hb mass have a profound effect on VO_{2max} in both adolescent boys and girls (29). The present data are consistent with previously reported differences in hematological profiles between black and white individuals of normal body weight (5–8,30). Pivarnik *et al.* (6) found that a selected group of black girls (mean age = 13.5 y) had venous [Hb] levels that were significantly lower than those of white girls and these differences in hematological profiles were associated with corresponding differences in VO_{2max}. In addition, we previously reported that significantly lower [Hb] was associated with a lower VO_{2max} in normal weight black prepubertal and pubertal children when compared with white children.8 The current investigation is, to our knowledge, among the first to observe an association between the lower [Hb] and VO_{2max} in obese black and white adolescents.

The average [Hb] values for both racial groups used presently fell within clinically accepted normal limits. Nevertheless, it is possible that the lower values in the obese black participants resulted in lower oxygen transport to peripheral tissues and subsequently less oxygen extraction by exercising skeletal muscle during the treadmill test. The significant ($p < 0.01$) positive correlation between [Hb] and VO_{2max} is consistent with this proposed mechanism. At maximal exercise intensities oxygen transport is a function of Hb flow rate [*i.e.*, [Hb] maximal cardiac output (31)]. Therefore, differences in Hb · flow rate can cause differences in VO_{2max}. Assuming normal binding of oxygen with Hb, we propose that a lower Hb flow rate and associated oxygen transport in part accounted for the lower VO_{2max} in the black participants.

Other possible mechanisms contributing to differences in [Hb] between black and white children could be genetic factors, such as sickle cell trait, dietary factors, such as iron deficiency, or some combination of these factors (27). It has been reported that ~8 to 10% of black individuals in the United Stated have sickle cell trait (32). Dietary iron deficiency is by far the most common cause of a subnormal [Hb] among ethnic groups (33).

Physical activity. Previous investigations have reported that aerobic fitness may be influenced by the level of physical activity and ethnicity (4,34). Physical activity and inactivity have been shown to have a significant effect on aerobic fitness

Table 4. *Multiple regression models*

	Model 1 (n = 41)				Model 2 (n = 41)			
Outcome variable	r^2	Race	[Hb]	Sex	r^2	Race	PinA	Sex
VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	.284*	−.296*	.209	−.316**	.359*	−.380**	−.060	−.381*

PinA, physical inactivity. Independent variables are model 1, race sex; model 2, race PinA sex. Values for all independent variables are coefficients.
** $p < 0.05$, * $p < 0.01$.

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in children (7,35,36). Gutin *et al.* (7) reported that obese black children were significantly less vigorously active when compared with their white peers and that this was significantly correlated to cardiovascular fitness ($r = 0.400$, $p < 0.001$). Although there are many social and behavioral factors that determine physical activity habits, some investigations have implicated ethnicity as a determinant of exercise patterns, with blacks and other ethnic minorities being less active than whites (36–38). Bouchard and Malina (39) have suggested that ~60% of the variance in fitness is influenced by environmental and behavioral factors. Qualitative measures of physical inactivity (*i.e.*, television viewing) have been positively associated with being overweight and obese in prepubertal children (9,10)

The black children in this study were more physically inactive when compared with their white peers. The data for these children are consistent with previous reports on minority adolescents (9,10,40). Although no between group difference was observed in leisure time physical activity or vigorous physical activity, it was speculated that the greater amount of physical inactivity, observed in the black children could in part, have resulted in a lower VO_{2max}. Based upon these findings it seems more likely that VO_{2max} was affected by both sedentary behaviors and hematological factors, rather than daily physical activity patterns. Further investigations are needed to more thoroughly evaluate the effect of daily physical activity patters on aerobic fitness in obese children.

Limitations of the current investigation include its restrictive sample, cross-sectional design and general reporting accuracy using the MAQ. However, these factors are assumed to have a limited impact on the conclusion reached. Because the investigation is cross-sectional in nature no causality can be determined. Further investigations should probe the relation between daily physical activity level and VO_{2max} in children of the age group studied.

Another possible factor, not examined in the present investigation that could have contributed to differences in [Hb] between black and white children could be differences in iron intake or in genetic traits. Both of these factors could have contributed to comparatively lower arterial O_2 content and ultimately lower tissue respiration during maximal exercise in the black group. Future investigations should examine these potential mediating hematological factors more thoroughly.

CONCLUSION

It should be emphasized that the present findings demonstrated that VO_{2max} was lower in obese black than white adolescents and that these findings must be considered representative only of the specific group of children tested. The difference in maximal aerobic power may be, at least in part, attributed to the lower [Hb] and higher levels of physical inactivity in the black children. The observed difference in VO_{2max} between the racial groups was independent of body composition and daily physical activity level. Follow-up investigations should study Hb flow rate in black and white children as it relates to racial differences in VO_{2max}. Also, further investigations should examine the possible role physical activity/inactivity patterns have in obese black and white children as it relates to VO_{2max}.

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