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Comparison of Maximal Oxygen Consumption Between Black and White Prepubertal and Pubertal Children

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ABSTRACT

The purpose of this investigation was to determine whether maximal oxygen consumption (VO_{2max}) differed between two selected groups of black and white children and whether a difference existed to determine whether it was related to hematologic profiles, body composition, and/or physical activity/inactivity level. Forty-five prepubertal and 42 pubertal, clinically normal black and white children participated. Dual-energy x-ray absorptiometry was used to determine body composition. A computed tomography scan of the abdomen was used to determine visceral adipose tissue and s.c. adipose tissue. Daily physical activity/inactivity was assessed by questionnaire. Black prepubertal and pubertal children had lower VO_{2max} values when compared with white children (28.8 ± 7.8 *versus* 35.0 ± 6.5 $mL \cdot kg^{-1} \cdot min^{-1}$, $p < 0.01$; 33.7 ± 6.4 *versus* 40.4 ± 10.2 $mL \cdot kg^{-1} \cdot min^{-1}$, $p < 0.05$; respectively). Black prepubertal and pubertal children had lower Hb concentrations ([Hb]) and hematocrits than white children (prepubertal: 12.1 ± 0.5 *versus* 12.8 ± 0.9 g/dL, $p < 0.001$; 35.6 ± 1.4 *versus* 37.4 ± 2.3%, $p < 0.01$, respectively; pubertal: 13.0 ± 0.9 *versus* 13.6 ± 0.7 g/dL, $p < 0.05$; 37.7 ± 2.5 *versus* 39.5 ± 2.1%, $p < 0.05$, respectively). In conclusion, these findings indicate that black prepubertal and pubertal children had lower VO_{2max} when compared with their white peers matched for age, pubertal stage, and body mass index. This difference in VO_{2max} could be attributed at least in part to comparatively lower [Hb] and more sedentary lifestyle in the black children. Further investigations should study Hb flow rate (a function of [Hb] × maximal cardiac output) in black and white children as it relates to VO_{2max}. **(*Pediatr Res* 56: 706–713, 2004)**

Abbreviations

BMI, body mass index
FFM, fat-free mass
[Hb], hemoglobin concentration
Hct, hematocrit
HR, heart rate
MAQ, modifiable activity questionnaire
RER, respiratory exchange ratio
VO_{2max}, maximal oxygen consumption

Previous investigations have noted differences in maximal oxygen uptake (VO_{2max}) between black and white children. Gutin *et al.* (1) reported that black boys and girls (aged 7–11 y) had lower VO_{2peak} when compared with white children of the same age. Arslanian *et al.* (2) and Ku *et al.* (3) observed that black prepubertal children had lower VO_{2max} values when compared with whites. Pivarnik *et al.* (4) found that black female adolescents had a 14% lower VO_{2max} when compared with white adolescents of the same age. Finally, Trowbridge *et al.* (5) reported that VO_{2max} was 15% lower in black prepubertal girls when compared with white prepubertal girls.

Possible factors that could account for the differences in VO_{2max} between black and white children are hematologic profiles, body composition, and physical activity levels. Pivarnik *et al.* (6) reported that black adolescent girls had lower Hb concentration ([Hb]) and VO_{2max} values than white adolescent girls. In this same context, Hunter *et al.* (7) reported that black women had lower VO_{2max} values than white women. This comparatively lower VO_{2max} was associated with a lower [Hb] in the black women (7). Relatively small decreases in [Hb] or total Hb mass can cause a reduction in Hb flow rate, subsequently reducing oxygen transport to the working muscles (7,8). Thus, a lower [Hb] may have contributed to the comparatively lower VO_{2max} observed in the black children studied in these previous investigations.

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Although evidence is relatively limited, differences in [Hb] and associated VO_{2max} values between blacks and whites have been observed in both adolescents and adults. However, no investigations have examined the effect of [Hb] on VO_{2max} in young black and white children classified as either prepubertal or pubertal using accepted Tanner staging criteria. As such, the experimental paradigm used presently attempted to control for the possible effect of pubertal status on both [Hb] and VO_{2max}.

Also, numerous investigations involving children have demonstrated that body composition influences aerobic fitness (1,6,9–12). Johnson *et al.* (11) found that an increase in aerobic fitness attenuated gain in body fat. Gutin *et al.* (1) reported that in children, percentage of body fat demonstrated an inverse relation with VO_{2max} and was also strongly correlated with risk factors for coronary artery disease and non–insulin-dependent diabetes. Finally, Pivarnik *et al.* found that black girls who had significantly higher body weight and body mass index (BMI) had significantly lower VO_{2max} values when compared with white girls of the same age (6). As such, the second objective of the present investigation was to compare the possible effect of different levels of body fat on VO_{2max} between black and white children.

Physical activity and physical inactivity are important behavioral determinants of overall health and may share an interactive mechanism with maximal aerobic power (13). Rowlands *et al.* (14) reported a positive relation between physical activity levels and aerobic fitness levels in children. Recently, it was reported that selected groups of black adolescents had lower levels of physical activity and higher levels of physical inactivity, quantified as hours of television watching, when compared with white adolescents (15–17). These lower levels of physical activity and greater levels of inactivity in black children may play a role in the higher prevalence of obesity and risk of type 2 diabetes when compared with white children (18). Trost *et al.* (19) found that inactivity, specifically television viewing, was associated with obesity in rural fifth-grade children. An extension of these findings leads to the expectation that comparatively lower levels of physical activity combined with higher levels of inactivity may, in part, account for differences in maximal oxygen consumption between black and white children. Therefore, the third objective of this investigation was to determine whether black/white differences in VO_{2max} could be explained by differences in various physical activity behaviors.

METHODS

Participants. Forty-five prepubertal (23 black, 22 white) and 42 pubertal (22 black, 20 white) clinically normal children participated in this study. Pubertal development was assessed by physical examination according to the criteria of Tanner (20) and confirmed by measurements of total testosterone in boys, estradiol in girls, and dehydroepiandrosterone-sulfate in both. All prepubertal children were determined to be in Tanner stage I of development, whereas the pubertal children were determined to be in the Tanner stages ≥II–IV of development. Some of the children had participated in an investigation reported previously (21,22). All participants were in good health on the basis of clinical history, physical examination, and hematologic profiles. All participants had normal glycosylated Hb values. No participants were receiving medications, and none were competitive athletes. Table 1 lists the clinical characteristics of the study participants.

Although a dietary recall was not obtained upon admission, all participants were carefully advised to follow a weight maintenance diet that contained 55% carbohydrate, 30% fat, and 15% protein for 1 wk before testing. 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. All studies were approved by the Human Rights Committee of Children's Hospital of Pittsburgh. Study participants were recruited through newspaper advertisements in the community. Research participants and parents or guardians gave written informed assent and consent, respectively, after receiving a thorough explanation of the research project.

Experimental design. All participants were admitted to the General Clinical Research Center in the early afternoon before testing. Provided the physical examination was considered clinically normal, participants 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.

Table 1. *Participant characteristics*

	Prepubertal (n = 45)		Pubertal (n = 42)	
	Black	White	Black	White
n	23	22	22	20
Sex (M/F)	10/13	10/12	12/10	11/9
Age (y)	9.9 ± 1.0	9.8 ± 1.2	12.3 ± 1.3	12.6 ± 1.1
Height (cm)	139.5 ± 7.0	139.3 ± 9.1	156.5 ± 9.0	153.2 ± 8.0
Weight (kg)	37.2 ± 10.4	34.8 ± 6.8	52.7 ± 12.5	47.6 ± 13.0
BMI (kg/m^2)	18.9 ± 3.9	17.8 ± 1.7	21.3 ± 3.7	20.2 ± 4.3
FM (kg)	8.7 ± 6.6	7.4 ± 3.4	12.1 ± 8.4	11.3 ± 8.4
FFM (kg)	26.6 ± 4.3	25.4 ± 4.1	37.4 ± 8.8	33.7 ± 6.2
BF (%)	20.7 ± 9.8	21.3 ± 6.5	22.5 ± 11.2	22.4 ± 11.0
VAT (cm^2)	20.2 ± 18.2	15.1 ± 10.5	21.0 ± 14.1	25.9 ± 21.1
SAT (cm^2)	101.9 ± 99.2	73.6 ± 40.8	123.3 ± 94.0	132.8 ± 131.0

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

Biochemical measurement. Blood samples were obtained from the antecubital vein after a 12-h overnight fast. Uncoagulated whole blood was immediately analyzed to obtain values for [Hb] and hematocrit (Hct). Hb was determined by the cyanide method using a Coulter Gen-S System (Beckman Coulter Inc., Atlanta, GA). The biochemical methods for total testosterone, estradiol, and dehydroepiandrosterone-sulfate are identical to what we have described in the past (23,24).

Body composition and abdominal adiposity. Body composition was assessed by dual-energy x-ray absorptiometry (21). S.c. adipose tissue was assessed by a 10-mm single axial computed tomography scan of the abdomen at the level of L4–5 lumbar vertebra as described by us previously (21). The volume of visceral adipose tissue was electronically calculated (25).

Physical activity assessment. Physical activity was assessed by a Modifiable Activity Questionnaire (MAQ) that separately measured physical, leisure-time activity and inactivity (26,27). Vigorous activity was defined by the question, "How many of the past 14 d have you done at least 20 min of exercise hard enough to make you breathe heavily and make your heart beat fast?" The participants had to choose from one of five answers (none; 1–2 d; 3–5 d; 6–8 d; 9 d or more), and their response was dichotomized according to our definition of vigorous activity, which was ≥1–2 d.

Physical inactivity, assessed from the question, "During a normal week, how many hours a day do you watch television and videos, or play computer or video games before and after school?" was defined as ≥4 h/d. Questions regarding television watching/video games/watching videos are standard when assessing children's physical activity and sedentary behavior in epidemiologic research. The specific question used in this study was taken directly from the Youth Risk Surveillance System questionnaire designed by the Centers for Disease Control and Prevention (28). In addition, the cut-point of 4 h or more of television/video/computer use is consistent with the cut-point used by the Centers for Disease Control and Prevention to identify "at risk" youth (28). Leisure-time activity was assessed by asking the participant to recall activities in which they participated at least 10 times over the past year (26,27).

VO_{2max}. VO_{2max} was indexed to total body mass (i.e., mL · kg^{-1} · min^{-1}) and fat-free mass (FFM; *i.e.* mL · kg$_{FFM}^{-1}$ · min^{-1}) and measured using the Bruce multistage treadmill protocol. This protocol is suitable for use with children ages 4 y and older (10). All tests were conducted on a Quinton (model Q-65) motor-driven treadmill. The test consisted of 3-min stages in which both belt speed and percentage grade increased according to a standard protocol (10). The attainment of VO_{2max} was accepted when the participants demonstrated any two of the following three criteria: *1*) a change in VO_2 of <2.1 mL · kg^{-1} · 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). 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 manufacturer's guidelines. Verbal encouragement was given to all participants to elicit a maximum effort.

Statistical Analysis. All statistical analyses were performed using SAS (SAS for Microsoft Windows: Version 8.0; SAS Institute, Cary, NC). Comparison of physiologic, hematologic, and body composition variables between black and white children were made using a two-tailed *t* test. Separate analyses were performed for the prepubertal and pubertal children. 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.

RESULTS

Characteristics for both prepubertal and pubertal participants are presented in Table 1. Biochemical and Hct measurements for all study participants are presented in Table 2.

Black prepubertal children had significantly lower VO_{2max} and $VO_{2maxFFM}$ values when compared with the white children (28.8 ± 7.8 *versus* 35.0 ± 6.5 mL · kg^{-1} · min^{-1}, $p < 0.01$; 37.9 ± 14.7 *versus* 47.3 ± 7.4 mL · kg$_{FFM}^{-1}$ · min^{-1}, $p < 0.05$, respectively; Table 3). Both VO_{2max} and $VO_{2maxFFM}$ were also lower in the pubertal black than white children (33.7 ± 6.4 *versus* 40.4 ± 10.2 mL · kg^{-1} · min^{-1}, $p < 0.05$;

Table 2. *Biochemical and hematologic profiles of all study participants*

	Prepubertal (n = 45)		Pubertal (n = 42)	
	Black	White	Black	White
Total T (ng/dL)	6.1 ± 3.2	6.9 ± 3.0	262.6 ± 238.8	203.0 ± 212.6
Estradiol (pg/mL)	9.0 ± 1.4	7.1 ± 1.2	47.4 ± 30.0	34.3 ± 17.1
DHEAS (μg/dL)	45.0 ± 17.6	51.9 ± 32.7	117.7 ± 85.4	109.0 ± 64.9
[Hb] (g/dL)	12.1 ± 0.5*	12.8 ± 0.9	13.0 ± 0.9†	13.6 ± 0.7
Hct (%)	35.6 ± 1.4‡	37.7 ± 2.3	37.7 ± 2.5†	39.5 ± 2.1

All values are mean ± SD. Total T, total testosterone; DHEAS, dehydroepaindrosterone-sulfate. Total T in boys only and estradiol in girls only.
* $p < 0.001$ prepubertal black *vs* white.
† $p < 0.05$ pubertal black *vs* white.
‡ $p < 0.01$ prepubertal black *vs* white.

Table 3. *Maximal exercise responses*

	Prepubertal (n = 45)		Pubertal (n = 42)	
	Black	White	Black	White
RER	1.17 ± 0.16	1.18 ± 0.14	1.14 ± 0.07	1.16 ± 0.06
HR (beats/min)	186.7 ± 7.0	190.4 ± 8.6	194.0 ± 11.3	194.3 ± 9.8
VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	28.8 ± 7.8*	35.0 ± 6.5	33.7 ± 6.4†	40.4 ± 10.2
VO_{2FFM} ($mL \cdot kg^{-1} \cdot min^{-1}$)	37.9 ± 14.7‡	47.3 ± 7.4	45.8 ± 9.8§	55.2 ± 8.4
VO_2 (mL/min)	1064.6 ± 411.6	1193.8 ± 306.2	1780.3 ± 533.9	1876.4 ± 526.2

All values are mean ± SD.
* $p < 0.01$ prepubertal black *vs* white.
† $p < 0.05$ pubertal black *vs* white.
‡ $p < 0.05$ prepubertal black *vs* white.
§ $p < 0.01$ pubertal black *vs* white.

45.8 ± 9.8 *versus* 55.2 ± 8.4 $mL \cdot kg_{FFM}{}^{-1} \cdot min^{-1}$, $p < 0.01$, respectively; Table 3). No differences were observed within the prepubertal or pubertal groups when VO_{2max} was expressed in absolute terms (mL/min; Table 3). The maximum HR and maximum respiratory exchange ratio did not differ between racial groups within either the prepubertal or pubertal classifications (Table 3).

Black prepubertal children had significantly lower [Hb] when compared with white children (12.1 ± 0.5 *versus* 12.8 ± 0.9 g/dL; $p < 0.001$; Table 2). Similarly, [Hb] was lower in the black pubertal adolescents when compared with whites (13.0 ± 0.9 *versus* 13.6 ± 0.7 g/dL; $p < 0.05$; Table 2). In addition, black prepubertal children had significantly lower Hct values when compared with white children (35.6 ± 1.4 *versus* 37.4 ± 2.3%; $p < 0.01$; Table 2). Hct was also lower for the black pubertal children (37.7 ± 2.5 *versus* 39.5 ± 2.1%; $p < 0.05$; Table 2).

χ^2 analysis indicated ($p < 0.01$) that black prepubertal children engaged in less vigorous activity when compared with white prepubertal children (Table 4). In addition, black prepubertal children were more physically inactive ($p < 0.001$) than white prepubertal children (Table 4). Within prepubertal classification, past-year leisure-time physical activity measures did not differ between the black and white groups (Table 4). No differences were observed in any measure of physical activity or inactivity between the pubertal children (Table 4).

For the total subject sample, VO_{2max} correlated with [Hb] ($r = 0.379$, $p = 0.0001$) and vigorous physical activity ($r = 0.249$, $p = 0.020$). An inverse relation was observed between physical inactivity and VO_{2max} for all participants ($r = -0.256$; $p = 0.017$). Stepwise multiple regression analysis was used to determine the relative contributions of race, [Hb], and sex in explaining the variance in VO_{2max} (Table 5, model 1). Both race ($p < 0.01$) and sex ($p < 0.001$) entered the model as significant predictors, combining to explain 60% of the variance in VO_{2max} for the prepubertal children and 55% of the variance in VO_{2max} for the pubertal children (Table 5, model 1). 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 5, model 2). Both race ($p < 0.01$) and sex ($p < 0.001$) entered the model as significant predictors, combining to explain 71% of the variance in VO_{2max} for the prepubertal children (Table 5, model 2). For the pubertal children, race ($p < 0.01$), physical inactivity ($p < 0.05$), and sex ($p < 0.01$) entered the model as significant predictors combining to explain 47% of the variance in VO_{2max} (Table 5, model 2).

DISCUSSION

The primary finding of this investigation was that clinically normal black children 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 children using HR and RER criteria. The similarities of maximum HR and RER between the two racial groups were consistent with previous investigations (1–6).

Table 4. *Physical activity and inactivity levels*

	Prepubertal (n = 45)		Pubertal (n = 42)	
	Black	White	Black	White
Vigorous physical activity				
None	12 (52.2%)*	4 (18.2%)	2 (9.1%)	3 (15.0%)
≥1 d	11 (47.8%)	18 (81.8%)	20 (90.9%)	17 (85.0%)
Physical inactivity				
<4 h/d	9 (39.1%)	21 (95.5%)	12 (54.5%)	14 (70.0%)
≥4 h/d	14 (60.9%)**	1 (4.5%)	10 (45.5%)	6 (30.0%)
Leisure-time physical activity (h/wk)	5.3 ± 5.3	6.5 ± 4.9	9.3 ± 8.3	7.4 ± 7.1

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 min of hard exercise. Physical inactivity was defined as the number of hours per day spent watching television and videos, or playing on the computer or video games.
* $p < 0.01$ prepubertal black *vs* white.
† $p < 0.001$ prepubertal black *vs* white.

Table 5. *Multiple regression models*

Outcome variable	Model 1							
	Prepubertal ($n = 45$)				Pubertal ($n = 42$)			
	r^2	Race	[Hb]	Sex	r^2	Race	[Hb]	Sex
VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	0.397*	−0.456*	−0.105	−0.490†	0.453*	−0.392*	−0.040	−0.571††

Table 5. *Continued*

Outcome variable	Model 2							
	Prepubertal ($n = 45$)				Pubertal ($n = 42$)			
	r^2	Race	[Hb]	Sex	r^2	Race	[Hb]	Sex
VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	0.390†	−0.433*	0.045	−0.467†	0.528†	−0.332*	−0.280‡	−0.562

PinA, physical inactivity. Independent variables are model 1, race + [Hb] + sex; model 2, race + PinA + sex. Values for all independent variables are β coefficients.

* $p < 0.01$.

† $p < 0.001$.

‡ $p < 0.05$.

Maximal oxygen uptake. The main conclusion from this investigation is that VO_{2max} was 18% lower in black prepubertal and 19% lower in black pubertal 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 14 to 20% lower VO_{2max} values in black compared with white children (1–6). However, our study is the first investigation that carefully matched racial groups of children with respect to age, pubertal stage, and BMI. In addition, previous investigations have observed VO_{2max} values ranging from 38.5 to 41.9 $mL \cdot kg^{-1} \cdot min^{-1}$ in white children and 31.7 to 37.4 $mL \cdot kg^{-1} \cdot min^{-1}$ in black children (1–6). The VO_{2max} values reported presently for both black and white children are generally consistent with these previously established ranges.

Several methods have been proposed to express VO_{2max} in children (29–32). Allometric scaling of VO_{2max} is of experimental interest when the paradigm compares individuals of differing body size, surface area, and maturity (29,31). Using allometric models, power functions ranging from 0.37 to 1.02 have been reported in developing children and adolescents (29–34). Pivarnik *et al.* (6) concluded that the race difference in maximal aerobic power in female adolescents existed when VO_{2max} was expressed in relative terms and allometrically scaled to body mass. To adjust for size differences within developmental groups, participants in the present investigation were allometrically scaled by body weight to the 0.75 power. This power function, based on previous research, is suitable to normalize body weight in prepubertal and circumpubertal children (31). VO_{2max} when allometrically scaled to body weight using a 0.75 power ($mL \cdot kg^{-0.75} \cdot min^{-1}$) was significantly lower in black prepubertal and pubertal children compared with white children (70.6 ± 19.3 *versus* 84.5 ± 16.1 $mL \cdot kg^{-0.75} \cdot min^{-1}$, $p < 0.05$; 90.4 ± 18.2 *versus* 105.0 ± 25.0 $mL \cdot kg^{-0.75} \cdot min^{-1}$, $p < 0.05$, respectively). These allometric analyses of VO_{2max} are consistent with previous reports (6,8,31,32,34) and indicate that differences in VO_{2max} between racial groups were not systematically biased by developmental factors.

Hematologic profiles. Our finding that [Hb] was lower in black children when compared with white children is consistent with previous investigations (35–37). Garn *et al.* (35) reported that black children had an average [Hb] ~1 g/dL lower than white children. Dallman *et al.* (36) also found that blacks had significantly lower Hb values, by ~0.5 g/dL, when compared with white or 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] and Hct values when compared with their white peers. This comparatively lower hematologic profile, although 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 (38). Rowland (8) 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. The present data are consistent with previously reported differences in hematologic profiles between black and white individuals (5–7). 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 hematologic profiles were associated with corresponding differences in VO_{2max}. Hunter *et al.* (7) reported that black women had significantly lower [Hb] and VO_{2max} values when compared with white women of the same age. Hunter *et al.* (7) concluded that the significantly lower VO_{2max} observed for the black subjects was associated with a lower [Hb]. The current investigation is among the first to observe differences in [Hb] and VO_{2max} between black and white prepubertal and pubertal children.

The average [Hb] and Hct values for both racial groups used presently fell within clinically accepted normal limits. Nevertheless, it is possible that the lower values in the black children resulted in lower oxygen transport to peripheral tissues and subsequently less oxygen extraction by exercising skeletal muscle during the treadmill test. The significant ($p = 0.0001$) 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 (39)]. Therefore, differences in Hb flow rate can cause differences in VO_{2max}. Assuming normal binding of oxygen with Hb, it is proposed that a lower Hb flow rate and oxygen transport in part accounted for the lower VO_{2max} in the black than white children.

Other possible mechanisms that contribute 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 (36). It has been reported that ~8 to 10 % of blacks in the United Stated have sickle cell trait (40). Dietary iron deficiency is by far the most common cause of a subnormal [Hb] among ethnic groups (41).

Body composition. Differences in body composition between blacks and whites have been reported for adult subjects (42) and in children (43,44). Increasing levels of body fat have been shown to correlate negatively with aerobic fitness as observed in cross-sectional studies (1). Furthermore, it has been demonstrated that increases in aerobic fitness may attenuate increasing levels of adiposity (11). Pivarnik *et al.* (6) reported that black adolescent girls had significantly higher FFM levels and lower VO_{2peak} than white adolescents. The present groups of black and white children did not differ with respect to their total body composition and abdominal adiposity. Hence, it is unlikely that VO_{2max} was differentially influenced by body adiposity in the present investigation. Furthermore, when VO_{2max} was expressed per unit of FFM, a significant race difference in maximal aerobic power remained.

Physical activity. Previous investigations have reported that aerobic fitness may be influenced by the level of physical activity and ethnicity (4,45). Physical activity and inactivity have been shown to have a significant effect on aerobic fitness in children (11,14,46). 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 (19,47,48). Bouchard and Malina (49) suggested that ~60% of the variance in fitness is influenced by environmental and behavioral factors. Qualitative measures of physical inactivity (*e.g.* television viewing) have been positively associated with being overweight and obese in prepubertal children (15,50–52). Physical inactivity has been related to decreases in physical activity and increases in body fat in children (15). By extension, higher levels of physical inactivity and associated body weight can lead to lower levels of maximal aerobic power.

The black prepubertal children in our study were more physically inactive when compared with their white peers. The data for these prepubertal children are consistent with previous reports on minority adolescents (15–17,53). Although no between-group differences were observed in leisure-time physical activity, it was speculated that the greater amount of physical inactivity, observed in the black prepubertal children, accompanied by lower levels of vigorous activity, could in part have resulted in a lower VO_{2max}. In support of this possibility, the multiple regression analysis indicated that race and sex accounted for a significant amount of the variance in VO_{2max} when examined for the total sample. However, when examining the pubertal children as a separate cohort, no differences were observed in any level of physical activity or inactivity. Therefore, it seems more likely that VO_{2max} was affected by the hematologic factors rather than daily physical activity patterns.

Skeletal muscle metabolic properties. Skeletal muscle contractile properties and corresponding muscle enzymatic activity may play an important role in explaining differences in VO_{2max} between black and white children. Ama *et al.* (54) reported that sedentary black adult men had a significantly higher percentage of type IIa (fast-twitch glycolytic) fibers and a lower percentage of type I (slow-twitch oxidative) fibers when compared with sedentary white men. They also found that when compared with their white peers, black men had higher concentrations of such regulatory enzymes as creatine kinase, hexokinase, phosphofructokinase, and lactate dehydrogenase (54). Hunter *et al.* (7) found that lower muscle oxidative capacity, measured by 31P-magnetic resonance spectroscopy, was related to lower VO_{2max} in black women when compared with white women. The interaction between skeletal muscle fiber type and metabolic enzymatic activity has been shown to be significantly correlated to VO_{2peak} (55,56) and VO_{2max} (7) in adults. Therefore, it is possible that the lower proportion of type I fibers reported in blacks, relative to whites, may result in comparatively lower tissue respiration and VO_{2max}. Suminski *et al.* (57) found that black men had lower VO_{2peak} when compared with white men and that this difference was attributed to differences in skeletal muscle oxidative metabolic properties. Although these factors were not directly examined in the present investigation, such a metabolic mechanism may have accounted in part for the lower VO_{2max} in the black children observed presently.

Limitations of the current investigation include its restrictive sample, cross-sectional design, and general reporting accuracy of 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. For example, it is possible that the direction of the relation is that increasing body fat leads to decreasing physical activity, which, in turn, leads to decreasing fitness level. However, as noted earlier, the correlation between activity and fitness in the present investigation is low. It is also recognized that the reverse relation is possible, *i.e.* low levels of VO_{2max} may cause low physical activity. Further investigations should probe the relation between daily physical activity level and VO_{2max} in children of the age group studied.

Some terms and phrases in the MAQ, as originally designed for use with adolescents, may have been cognitively inappropriate to allow the present group of young prepubertal children to recall their vigorous activity, leisure-time physical activity, and physical inactivity. We suggest the development of a more age-appropriate questionnaire to assess various types of physical activity/inactivity in children.

It is possible that the present black sample of children could have overestimated their physical activity. Although we did not have evidence that this actually occurred in the present investigation, we are aware of previous investigations in which black pubertal children reported higher levels of leisure-time activity and had significantly lower VO_{2max} values when compared with white children (3). We are also aware that the time of administration of the MAQ could have had an impact on the child's activity responses. For example, children who were assessed in the winter may have experienced more frequent bouts of physical inactivity when compared with the summer months. However, we had a relatively lower number of examinations in the winter months (December–February) compared with the fall (September–November) and spring (March–May) months.

Although the present investigation did recommend that all participants follow a weight maintenance diet, a dietary recall was not administered. This information could be useful in determining potential iron deficiencies and its effect on [Hb]. Another possible factor, not examined in the present investigation, possibly contributing to differences in [Hb] between black and white children could be differences in genetic traits. Both of these factors could have precipitated comparatively lower O_2 content and ultimately lower tissue respiration during maximal exercise in the black group. Future investigations should examine these potential mediating factors more thoroughly.

CONCLUSION

It should be emphasized that the present findings demonstrated that VO_{2max} was lower in black than white prepubertal and pubertal children and that these findings must be considered representative only of the specific group of children tested. This difference was attributed, at least in part, to lower [Hb] in the black children. The observed difference in VO_{2max} between the prepubertal racial groups was independent of body composition and physical activity level but was related to higher physical inactivity levels in the prepubertal black children. The observed difference in VO_{2max} between the pubertal racial groups was independent of body composition and 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 of skeletal muscle metabolic properties and bone mass architecture in accounting for racial differences in VO_{2max} in children.

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