Maximal aerobic capacity in African-American and Caucasian prepubertal children

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The objective of this study was therefore to examine differences in aerobic capacity. By using the doubly labeled water technique, we were able to measure total energy expenditure (TEE) and calculate activity energy expenditure (AEE) to examine whether the energy cost of daily physical activity might contribute to ethnic differences in aerobic capacity.

METHODS

Protocol. Children were admitted to the General Clinical Research Center (GCRC) in the late afternoon for an overnight visit. On arrival, anthropometric measurements were obtained, and dinner was served at ~1700. An evening snack was allowed as long as it was consumed before 2000. After 2000, only water and noncaloric, noncaffeinated beverages were allowed until after the morning testing was completed. The following morning, resting energy expenditure (REE) was measured for 30 min, starting between 0600 and 0730. After testing was completed, the children were fed breakfast and allowed to leave. Two weeks later, the children arrived at the Energy Metabolism Research Unit at 0700 in the fasted state. Submaximal and maximal VO2 were determined by an all out, progressive treadmill test using a protocol appropriate for children. Body composition was determined by DEXA.

Subjects. A total of 94 healthy African-American (n = 60) and Caucasian (n = 34) children 5–10 yr of age completed the protocol. Children were recruited from the Birmingham, Alabama area by use of radio advertisements, flyers, and word of mouth. Children who were taking medications known to affect body composition or physical activity were excluded from the study, as were children diagnosed with Cushing's syndrome, Down's syndrome, type I diabetes, or hypothyroidism. The study was approved by the University of Alabama at Birmingham (UAB) Institutional Review Board for human use, and informed consent was obtained from all subjects before testing.
REE. REE was measured in all subjects in the early morning in the fasted state after subjects had spent the night at the GCRC. A Deltatrac Metabolic Monitor (Sensormedics), which was calibrated before each test against standard gases, was used for each REE measurement. During testing, all subjects were instructed to lie as still as possible. An adult-size canopy hood was used to collect the expired air for 20 min after a 10-min equilibrium period, and VO₂ and carbon dioxide production (VCO₂) were measured continuously during this time. Energy expenditure was calculated using the equation of de Weir (11).

Exercise testing. Subjects reported to the Energy Metabolism Research Unit at 0700 in the fasted state. After becoming familiar with the testing equipment, such as the mouthpiece and headgear, the children were allowed to practice walking on the motorized treadmill until they were able to walk without holding on to the railings. Subjects followed an all out, progressive, continuous treadmill protocol appropriate for children (3). The children walked for 4 min at 0% grade and 4 km/h, after which the treadmill grade was raised to 10%. Each ensuing work level lasted 2 min, during which the grade was increased by 2.5%. The speed remained constant until a 22.5% grade was reached, at which time the speed was increased by 0.6 km/h until the subject reached exhaustion.

VO₂ and VCO₂ were measured continuously via open circuit spirometry and analyzed with the use of a Sensormedics metabolic cart (model no. 2900, Yorba Linda, CA). Blood samples were collected at rest and during the last minute of each work level for measurement of heart rate, respiratory exchange ratio, and hemoglobin oxygen saturation. The intra-assay variation for triplicate analysis of samples at the laboratory is ~4% and 0.20 ‰ for deuterium and oxygen-18, respectively. Complete doubly labeled water was obtained for 62 of the 75 children.

Physical activity-related energy expenditure was estimated from the difference between TEE and REE. A correction for the thermic effect of food was necessary, since REE was measured in the fasted state. AEE was derived from the following equation: AEE = 0.9 × TEE — REE. The aforementioned equation makes an assumption of the thermic effect of food accounting for ~10% of TEE.

Statistical analysis. All statistical analyses were performed using SAS (SAS Institute, Cary, NC; SAS for MS Windows; Release 6.10). A two-way analysis of covariance (ANCOVA) design was used to test for the main effects of gender and ethnicity, as well as for the interactive effect of ethnicity by gender. Because gender did not affect the major outcome variables, all subsequent analyses were combined into two groups (African-American and Caucasian). The main outcome variables were resting VO₂, submaximal VO₂ and VO₂max, with soft lean tissue mass as the covariate. After adjustment for soft lean tissue mass, fat mass and leg soft tissue mass were entered into the model to determine if either total body fat or regional soft lean tissue mass distribution explained differences in VO₂ between the two ethnic groups (African-American and Caucasian).

To determine if either TEE or AEE contributed to the difference in aerobic capacity, each was entered separately into the model after adjustment for total soft lean tissue mass and fat mass.

RESULTS

Descriptive statistics for the four subgroups (African-American and Caucasian males and females) are shown in Table 1. All groups were similar in age. A significant gender difference was found for both total body weight (P < 0.05) and total fat mass (P < 0.001), with females

Table 1. Descriptive statistics

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<thead>
<tr>
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<th>Caucasian</th>
<th>African-American</th>
<th>2-Way ANOVA Results</th>
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<tbody>
<tr>
<td></td>
<td>Males (n = 13)</td>
<td>Females (n = 18)</td>
<td>Males (n = 17)</td>
</tr>
<tr>
<td>Age, yr</td>
<td>7.7 ± 2.4</td>
<td>8.2 ± 1.2</td>
<td>7.6 ± 1.4</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>28.5 ± 7.5</td>
<td>40.3 ± 12.7</td>
<td>30.8 ± 13.0</td>
</tr>
<tr>
<td>Total LTM, kg</td>
<td>20.8 ± 3.7</td>
<td>23.5 ± 5.0</td>
<td>22.1 ± 4.6</td>
</tr>
<tr>
<td>Leg muscle mass, kg</td>
<td>6.9 ± 1.7</td>
<td>8.3 ± 1.8</td>
<td>8.1 ± 1.7</td>
</tr>
<tr>
<td>Total FM, kg</td>
<td>7.2 ± 4.4</td>
<td>14.9 ± 7.8</td>
<td>7.6 ± 6.6</td>
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</tbody>
</table>

All values are means ± SD. ANOVA, analysis of variance; LTM, lean tissue mass; FM, fat mass; NS, not significant.
being heavier and having greater fat mass than males. However, soft lean tissue mass was similar among all four subgroups. Data for $\dot{V}O_2$ in absolute terms are summarized in Table 2. No significant influence of gender or ethnicity was observed for resting $\dot{V}O_2$ or submaximal $\dot{V}O_2$, but a significant effect of ethnicity was found for $\dot{V}O_{2\text{max}}$ ($P < 0.01$). African-American children had absolute peak $\dot{V}O_2$ values that were 15% lower than those of the Caucasian children. The lower $\dot{V}O_{2\text{max}}$ was seen in both males and females. There were no significant effects of gender or ethnicity on maximum respiratory exchange ratio or maximum heart rate (Table 2). Submaximal heart rate was significantly higher ($P < 0.05$) in females, and submaximal respiratory exchange ratio was significantly greater ($P < 0.05$) in African-Americans (Table 2). Caucasian males had significantly longer treadmill times than their African-American counterparts ($P < 0.01$), and the same was true for females ($P < 0.01$; Table 2).

Resting $\dot{V}O_2$, submaximal $\dot{V}O_2$, and $\dot{V}O_{2\text{max}}$ were related to soft lean tissue mass in both African-American and Caucasian children. Resting $\dot{V}O_2$, submaximal $\dot{V}O_2$, and $\dot{V}O_{2\text{max}}$ are plotted as a function of soft lean tissue mass in Fig. 1. For resting $\dot{V}O_2$ adjusted for soft lean tissue mass, there were no significant differences in either slopes or intercepts between African-American and Caucasian subjects (Fig. 1A). For submaximal $\dot{V}O_2$ adjusted for soft lean tissue mass, there were also no significant differences in either slopes or intercepts between African-Americans and Caucasians (Fig. 1B). For $\dot{V}O_{2\text{max}}$, the regression slopes adjusted for soft lean tissue were not significantly different, but the intercepts were significantly different ($P < 0.05$), with the African-American children demonstrating lower adjusted $\dot{V}O_{2\text{max}}$ (Fig. 1C). Similarly, the lower $\dot{V}O_{2\text{max}}$ persisted in African-American children after data were adjusted for leg soft lean tissue mass (Fig. 2). The lower $\dot{V}O_{2\text{max}}$ in African-American children could not be explained by differences in body fatness. When total fat mass was entered into the model, in addition to soft lean tissue mass, the lower adjusted $\dot{V}O_{2\text{max}}$ values persisted in the African-American group ($1.23 \pm 0.025$ vs. $1.39 \pm 0.031$ l/min; $P < 0.01$; Table 3).

Although we were confident that we reached a true $\dot{V}O_{2\text{max}}$ in the children who achieved two of the three criteria, it could be argued that children who reached three criteria may be more motivated in determining $\dot{V}O_{2\text{max}}$. Therefore, a subset of subjects ($n = 39$) who achieved all three of the physiological criteria for $\dot{V}O_{2\text{max}}$ were analyzed. When the relationship between leg soft lean tissue mass and $\dot{V}O_{2\text{max}}$ in this subset was plotted, the lower $\dot{V}O_{2\text{max}}$ in the African-American children persisted (Fig. 3). When the values were adjusted for leg soft lean tissue mass, the resulting $\dot{V}O_{2\text{max}}$ values of the African-American subjects remained significantly lower than those of the Caucasian children ($1.54 \pm 0.040$ vs. $1.27 \pm 0.044$ l/min, respectively, $P < 0.01$).

Adjusted means of TEE, REE, and AEE are shown in Table 4. There were no significant differences for TEE, REE, or AEE between the four groups. No significant effect of ethnicity was found for any of the dependent variables. To determine if TEE or AEE could explain the observed difference in $\dot{V}O_{2\text{max}}$ between the two groups of children, both variables were entered into the ANCOVA model separately in addition to soft lean tissue mass and fat mass. When TEE was entered into the model, the lower $\dot{V}O_{2\text{max}}$ persisted in the African-American children ($1.20 \pm 0.024$ vs. $1.38 \pm 0.028$ l/min; $P < 0.001$). When AEE was entered into the model in addition to soft lean tissue mass and fat mass, the lower $\dot{V}O_{2\text{max}}$ also persisted in the African-American children ($1.20 \pm 0.024$ vs. $1.38 \pm 0.028$ l/min, $P < 0.001$, in African-American and Caucasian children, respectively).

**DISCUSSION**

The main conclusion from this study is that $\dot{V}O_{2\text{max}}$ was 15% lower in the African-American vs. Caucasian prepubertal children. The lower aerobic capacity was also associated with decreased exercise endurance in the African-American children, as measured by treadmill time to exhaustion. Another indication of the lower fitness in general in the African-American children was that 25% of tested children, compared with 12% of Caucasian children, did not meet the criteria for a successful $\dot{V}O_{2\text{max}}$ test, possibly reflecting a reduced motivation for maximal exercise effort.

The significantly lower $\dot{V}O_2$ in African-American children was observed only at maximal exercise effort and was independent of soft lean tissue mass, total fat mass, and leg soft lean tissue mass. In other words, none of the independent variables we examined explained the ethnic difference in $\dot{V}O_{2\text{max}}$, and, in addition, the following table provides a summary of the results:

**Table 2.** Resting, submaximal, and maximal $\dot{V}O_2$ of African-American and Caucasian children

<table>
<thead>
<tr>
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<tr>
<td></td>
<td>Males (n = 13)</td>
<td>Females (n = 18)</td>
<td>Males (n = 17)</td>
<td>Females (n = 27)</td>
<td></td>
</tr>
<tr>
<td>Resting $\dot{V}O_2$, l/min</td>
<td>0.18 ± 0.03</td>
<td>0.19 ± 0.027</td>
<td>0.18 ± 0.028</td>
<td>0.18 ± 0.032</td>
<td>NS</td>
</tr>
<tr>
<td>Submax $\dot{V}O_2$, l/min</td>
<td>0.50 ± 0.11</td>
<td>0.63 ± 0.17</td>
<td>0.49 ± 0.13</td>
<td>0.54 ± 0.18</td>
<td>NS</td>
</tr>
<tr>
<td>Submax RER</td>
<td>0.80 ± 0.02</td>
<td>0.81 ± 0.02</td>
<td>0.86 ± 0.02</td>
<td>0.84 ± 0.01</td>
<td>NS</td>
</tr>
<tr>
<td>Submax HR, beats/min</td>
<td>118 ± 3</td>
<td>126 ± 3</td>
<td>121 ± 3</td>
<td>126 ± 2</td>
<td>Gender, P &lt; 0.05</td>
</tr>
<tr>
<td>$\dot{V}O_{2\text{max}}$, l/min</td>
<td>1.34 ± 0.28</td>
<td>1.49 ± 0.31</td>
<td>1.18 ± 0.31</td>
<td>1.23 ± 0.33</td>
<td>Ethnicity, P &lt; 0.05</td>
</tr>
<tr>
<td>Max RER</td>
<td>1.02 ± 0.04</td>
<td>1.02 ± 0.04</td>
<td>1.03 ± 0.04</td>
<td>1.05 ± 0.04</td>
<td>NS</td>
</tr>
<tr>
<td>Max HR, beats/min</td>
<td>198 ± 8</td>
<td>197 ± 7</td>
<td>192 ± 11</td>
<td>199 ± 8</td>
<td>NS</td>
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<tr>
<td>Treadmill time, min</td>
<td>15 ± 2.5</td>
<td>13 ± 3</td>
<td>13 ± 2</td>
<td>12 ± 2</td>
<td>Ethnicity, P &lt; 0.01</td>
</tr>
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Values are means ± SD. $\dot{V}O_2$, oxygen consumption; $\dot{V}O_{2\text{max}}$, maximal $\dot{V}O_2$; RER, respiratory exchange ratio; HR, heart rate. NS (P > 0.05).
tional regression analysis, ethnicity remained a significant and independent predictor of $\dot{V}O_{2\text{max}}$. The difference in aerobic capacity also was independent of physiological criteria for reaching $\dot{V}O_{2\text{max}}$ (heart rate >195 beats/min, respiratory exchange ratio >1.0 and/or plateauing of $\dot{V}O_2$), indicating that the ethnic difference was not due to differences in motivation during the treadmill test. Moreover, the ethnic difference in $\dot{V}O_{2\text{max}}$ was independent of habitual free-living physical activity-related energy expenditure.

Other body composition variables may play a role in the observed differences in aerobic capacity seen between the two groups. Previous studies have shown that the contribution of bone mass to fat-free mass may be greater in African-American than in Caucasian adults (26). One could speculate that the lower $\dot{V}O_{2\text{max}}$ found in the African-American children in our sample was due to the fat-free mass of the African-Americans containing more bone mass and less skeletal muscle compared with that of the Caucasian children. However, our analyses were done using soft lean tissue mass (bone excluded). Furthermore, the African-American and Caucasian children had similar amounts of skeletal muscle. Thus differences in bone mineral content of the African-American children and the Caucasian children were not a factor in the observed lower $\dot{V}O_{2\text{max}}$ in the African-American children.

**Fig. 1.** A: relationship between resting oxygen consumption ($\dot{V}O_2$) and soft lean tissue mass (LTM) in African-American (dashed line; $r^2 = 0.61$) and Caucasian (solid line; $r^2 = 0.65$) children. Slopes (0.0053 ± 0.00064 vs. 0.0048 ± 0.00065 l·min$^{-1}·$kg soft LTM$^{-1}$) and intercepts (0.065 ± 0.014 vs. 0.073 ± 0.015 l/min) were similar in both groups. B: relationship between submaximal $\dot{V}O_2$ and soft LTM in African-American ($r^2 = 0.52$) and Caucasian ($r^2 = 0.65$) children. Slopes (0.025 ± 0.0037 vs. 0.027 ± 0.0038 l·min$^{-1}·$kg soft LTM$^{-1}$) and intercepts (–0.051 ± 0.083 vs. –0.069 ± 0.089 l/min) were similar in both groups. C: relationship between maximal $\dot{V}O_2$ ($\dot{V}O_{2\text{max}}$) and soft LTM in African-American ($r^2 = 0.65$) and Caucasian ($r^2 = 0.83$) children. Slopes (0.056 ± 0.0063 vs. 0.061 ± 0.0052 l·min$^{-1}·$kg soft LTM$^{-1}$) were similar, but intercept was significantly lower in African-American children (–0.024 ± 0.14 l/min vs. 0.025 ± 0.12 l/min; $P < 0.05$).

**Fig. 2.** Relationship between $\dot{V}O_{2\text{max}}$ and leg soft LTM in African-American (dashed line; $r^2 = 0.64$) and Caucasian (solid line; $r^2 = 0.84$) children. Slopes were similar between groups (0.15 ± 0.12 l/min vs. 0.25 ± 0.10 l/min), but intercept was significantly lower in African-American children (0.15 ± 0.12 l/min vs. 0.25 ± 0.10 l/min).

**Table 3.** Adjusted means of resting, submaximal, and maximal $\dot{V}O_2$ in African-American and Caucasian children

<table>
<thead>
<tr>
<th></th>
<th>Adjusted for Soft LTM</th>
<th>Adjusted for FM and Soft LTM</th>
<th>Adjusted for Leg Soft LTM</th>
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<tbody>
<tr>
<td><strong>Resting $\dot{V}O_2$, l/min</strong></td>
<td></td>
<td></td>
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<tr>
<td>African-American (n=44)</td>
<td>0.18 ± 0.027</td>
<td>0.18 ± 0.032</td>
<td>0.18 ± 0.033</td>
</tr>
<tr>
<td>Caucasian (n=31)</td>
<td>0.18 ± 0.033</td>
<td>0.18 ± 0.032</td>
<td>0.18 ± 0.041</td>
</tr>
<tr>
<td><strong>Submaximal $\dot{V}O_2$, l/min</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>African-American (n=44)</td>
<td>0.53 ± 0.015</td>
<td>0.53 ± 0.013</td>
<td>0.54 ± 0.018</td>
</tr>
<tr>
<td>Caucasian (n=31)</td>
<td>0.56 ± 0.019</td>
<td>0.56 ± 0.016</td>
<td>0.54 ± 0.022</td>
</tr>
<tr>
<td><strong>Maximal $\dot{V}O_2$, l/min</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African-American (n=44)</td>
<td>1.23 ± 0.025*</td>
<td>1.23 ± 0.025*</td>
<td>1.20 ± 0.031*</td>
</tr>
<tr>
<td>Caucasian (n=31)</td>
<td>1.39 ± 0.031</td>
<td>1.39 ± 0.031</td>
<td>1.43 ± 0.042</td>
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</table>

Data are adjusted means ± SE. Values are adjusted with analysis of covariance for either soft LTM, total FM plus soft LTM, or leg soft LTM. *Significant influence of ethnicity, $P < 0.01$. 

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Habitual physical activity and exercise patterns may have a significant influence on aerobic capacity. Although there are many social and behavioral factors that determine physical activity habits, some studies have implicated ethnicity as a determinant of exercise patterns, with African-American and other ethnic minorities being less active than Caucasians (7, 8, 12). According to the 1990 Youth Risk Behavior Survey, female African-American students (grades 9–12) were the least likely to be vigorously active three or more times per week (9). We do not have any descriptive data regarding the physical activity patterns of the children, but we do have the daily AEE for the children derived from the doubly labeled water data. It is important to note that the AEE value represents only the average daily AEE and does not give any information about the intensity or duration of the activities performed by the children. There were no significant differences between the groups with regard to TEE or AEE. However, in additional analysis, we found that the relationship between VO\textsubscript{2max} and AEE was significant in the Caucasian children. In addition, African-American and Caucasian children had similar AEE values, but VO\textsubscript{2max} was lower in African-American children. Although we are not able to make a conclusive statement regarding this finding, these data suggest that the Caucasian children participated in activities at higher intensities. One limitation of the doubly labeled water technique is that, although AEE can be calculated, it gives no information regarding the type or intensity level of the activities, and thus further studies using more qualitative assessment of physical activity pattern are warranted.

There are several factors that we did not examine that could possibly explain the lower VO\textsubscript{2max} in the African-American children. Although the lower aerobic capacity in African-American children could not be explained by leg soft lean tissue mass (Fig. 2), it could have been due in part to differences in muscle fiber type in these two groups. African-American adult males have been found to have a greater percentage of type II, anaerobic fibers, and lower percentage of type I, aerobic fibers, compared with Caucasian males (1). Because fiber type and peak VO\textsubscript{2} have been shown to be significantly correlated in adults (4, 17), it is possible the lower proportion of type I fibers in African-Americans may limit the ability to perform continuous, endurance-type activities that require a steady rate of aerobic energy transfer (21). If these differences in fiber type also occurred in this sample of young children, they may have been responsible for all or part of the difference in reduced VO\textsubscript{2max} and treadmill time in the African-American children. This hypothesis could not be examined because muscle tissue from these children was not available.

Another factor that might explain our findings is ethnic differences in hemoglobin concentrations ([Hb]). When [Hb] levels are low, there is a decrease in the blood's oxygen carrying capacity and, consequently, a corresponding decrease in ability to perform even mild aerobic exercise (21). Pivarnik et al. (27) found that, in a group of African-American and Caucasian adolescent females (age = 13.5 yr), the African-Americans had [Hb] levels that were significantly lower than those of the Caucasian girls (13.0 ± 1.1 vs. 13.8 ± 0.9 g/dl; P < 0.01). Whereas the values were within normal physiological limits, it is unknown whether the lower [Hb] concentration contributed to a lower O\textsubscript{2} extraction during exercise (27).

The implications and clinical significance of the difference in the VO\textsubscript{2max} between African-American and Caucasian children cannot fully be defined, and it is difficult to generalize our findings to the general population. However, current epidemiological data indicate that low fitness is a powerful precursor of mortality in adults. Moderate levels of physical fitness exhibit a protective effect against the influence of such mortality predictors as smoking, hypertension, and hypercholesterolemia (5). It is unknown whether aerobic capacity or physical activity patterns in children would affect long-term adult health outcomes. However, it has been postulated that physical activity and/or fitness during childhood serves as the foundation for a lifetime of regular physical activity (6). Further research is war-
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Warranted both to determine habitual physical activity patterns of children of different ethnic and cultural groups and to find appropriate ways to educate and motivate children to adopt regular physical activity patterns. The long-term relationship between aerobic fitness and risk of obesity and other chronic diseases has yet to be determined in different ethnic groups.

In conclusion, VO₂max was significantly lower in African-American compared with Caucasian prepubertal boys and girls. This difference could not be explained by differences in body composition, including fat mass, total soft lean tissue mass, leg soft lean tissue mass, differences in body composition, including fat mass, and American compared with Caucasian prepubertal groups and to find appropriate ways to educate and motivate children to adopt regular physical activity patterns. The long-term relationship between aerobic fitness and risk of obesity and other chronic diseases has yet to be determined in different ethnic groups.

In conclusion, VO₂max was significantly lower in African-American compared with Caucasian prepubertal boys and girls. This difference could not be explained by differences in body composition, including fat mass, total soft lean tissue mass, leg soft lean tissue mass, differences in body composition, including fat mass, and American compared with Caucasian prepubertal groups and to find appropriate ways to educate and motivate children to adopt regular physical activity patterns. The long-term relationship between aerobic fitness and risk of obesity and other chronic diseases has yet to be determined in different ethnic groups.

REFERENCES


