Fractional Utilization of Maximal Aerobic Capacity in Children 6 to 8 Years of Age

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Untrained 6- to 8-year-old children (N=80) served as subjects in a cross-sectional study of the fractional utilization of maximal aerobic power during submaximal running. Using the open-circuit method, the absolute oxygen demands of submaximal running were found to increase with age. When expressed relative to body weight, oxygen demands of submaximal running showed no statistically significant changes over the 3-year span. VO₂max increased 36.2%, which was proportionally greater than the percentage increase for either body weight (28.4%) or the absolute oxygen demands of submaximal running (22.9%). Thus, during the span of years studied there was a significant reduction in the fractional utilization of maximal aerobic power required to run at a fixed submaximal speed.

The adult pattern of running, featuring full leg action, a period of nonsupport, and the development of a consistent stride length is reasonably well established by the time a child is 6 years of age (8). After the adult pattern is achieved, speed and endurance increase with age throughout childhood and adolescence.

Endurance running performance depends to a significant extent on maximum aerobic power (VO₂max) (12). Astrand’s (1) cross-sectional study of boys revealed VO₂max (1·min⁻¹) among 16- to 18-year-olds to be more than double that of 7- to 9-year-olds, but when expressed relative to body weight (ml·kg⁻¹·min⁻¹) he found no significant difference. As the oxygen requirement of running is roughly proportional to body weight (1), it seems paradoxical that young children’s performance in distance running does not compare with that of older children who possess similar maximal aerobic power relative to body weight (9). After studying 14 boys (ages 10–15) for 22 months, Daniels and Oldridge (4) concluded that improvement in running performance was primarily a result of increased running economy, which they hypothesized was largely a function of growth.

These earlier studies utilized athletic children as subjects. It is also important to investigate the running economy of untrained normals because running tests have become a common component of fitness testing and the attributes measured...
need to be understood. The purpose of the present research was to investigate the running economy of untrained children ages 6–8 years. A cross-sectional approach was employed.

Methodology

University Human Experimentation Committee and school district approval, parental permission, informed consent, and medical clearance of the children (N=117) chosen to participate were obtained for the study. Elementary school personnel familiar to the students and representing both sexes were present during all testing and provided verbal assurance and encouragement for the subjects. Parents were notified of the testing time and date and were invited to attend.

Each subject was weighed and measured, had skinfolds (10) and vital capacity determined, and was asked to perform the running test on a motor driven treadmill. A portable treadmill had been located in the school’s multipurpose room and the children had practiced treadmill running for 3 weeks prior to the test. Pilot testing indicated that the youngest and least physically fit children could not accomplish treadmill running at speeds faster than 115 m•min⁻¹, thus treadmill speed was set and calibrated at 115 m•min⁻¹ for all testing.

Subjects first ran at level grade for 4 minutes; thereafter, grade was increased 2-1/2% per minute until volitional exhaustion was reached, usually in 7 to 9 minutes. Oxygen uptake was measured using the open-circuit method as described by Daniels (3) and Daniels and Oldridge (4). Nose clips were taped in place to avoid slipping. Expired air was collected in meteorological balloons. A collection covering the final 60 seconds at level grade was used to establish the oxygen demands of running at 115 m•min⁻¹. Minute collections made during every subsequent minute were analyzed to determine maximal oxygen uptake. Expired gas volumes were determined with a Parkinson–Cowan flowmeter. Gas samples were analyzed for CO₂ and O₂ content with Lloyd–Gallenkamp volumetric analyzers. Maximal oxygen consumption was determined using an increase of less than 2.1 ml•kg⁻¹•min⁻¹ in VO₂ with an increase in grade as the leveling criterion (13).

Subjects who either did not achieve leveling on the VO₂max test or who exhibited a respiratory exchange ratio above 0.98 during the 4th minute (thereby raising doubt about the presence of a steady-state condition during the “submaximal” portion of the test) were excluded from the data analysis. This procedure provided assurance that the VO₂max values were valid and that VO₂ measured during the 4th minute provided an acceptable measure of the oxygen demands associated with a running pace of 115 m•min⁻¹. These criteria were met by 80 subjects.

It would have been desirable to have a separate and extended test session for the submaximal run; however, this option was dismissed for two reasons. First, human experimentation concerns for minimizing stress to young subjects increased the attractiveness of a single test session. Second, work by Sady (11) on the transient oxygen uptake response at the onset of relative endurance exercise in prepubertal children suggests that oxygen demands of running should have stabilized by the time expired gases were collected.

Analysis of variance was used to determine the presence or absence of a main effect. Tukey HSD (14) tests were employed to isolate significant mean differences when the main effect was statistically significant.
Table 1
Descriptive Characteristics of the Group (N=80)

<table>
<thead>
<tr>
<th>Variables</th>
<th>6 yrs (n=26)</th>
<th>7 yrs (n=18)</th>
<th>8 yrs (n=36)</th>
<th>Contrasts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>120</td>
<td>4</td>
<td>126</td>
<td>5</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>23.2</td>
<td>3.7</td>
<td>24.0</td>
<td>3.5</td>
</tr>
<tr>
<td>BSA (m²)</td>
<td>0.80</td>
<td>0.07</td>
<td>0.92</td>
<td>0.08</td>
</tr>
<tr>
<td>Skinfold sum (mm)</td>
<td>57.</td>
<td>37.</td>
<td>57.</td>
<td>24.</td>
</tr>
<tr>
<td>Vital capacity (L)</td>
<td>1.15</td>
<td>0.32</td>
<td>1.30</td>
<td>0.28</td>
</tr>
<tr>
<td>Resting heart rate</td>
<td>91.</td>
<td>13.</td>
<td>86.</td>
<td>9</td>
</tr>
<tr>
<td>Max heart rate</td>
<td>201.</td>
<td>10.</td>
<td>198.</td>
<td>9</td>
</tr>
<tr>
<td>VO₂max (1·min⁻¹)</td>
<td>0.97</td>
<td>.18</td>
<td>1.05</td>
<td>.15</td>
</tr>
<tr>
<td>VO₂max (ml·kg⁻¹·min⁻¹)</td>
<td>41.8</td>
<td>6.0</td>
<td>44.0</td>
<td>6.0</td>
</tr>
</tbody>
</table>

aAge 6: 11 boys, 15 girls; age 7: 13 boys, 5 girls; age 8: 24 boys, 12 girls.
bDuBois (6).
cTotal of right tricep, left subscapular, right suprailiac, umbilical, right pectoral, and anterior right midthigh (10).
dSignificant (P<.01) between-group differences.

Results and Discussion

The descriptive data for the subjects (N=80) are depicted in Table 1. The values for boys and girls were not different, therefore the data were combined to eliminate redundancy and provide greater stability in the mean values. Age groupings were determined by placing subjects at the age of their nearest birthday. The data are cross-sectional, therefore the results contained herein reflect differences that are expressed in groups of different ages rather than changes occurring within subjects studied over an extended period.

Significant increases in height, weight, body surface area, skinfold sums, vital capacity, and VO₂max (1·min⁻¹) were observed across the 3-year span studied. The maximal heart rates were high, but slightly lower than those reported by Astrand (1). The mean values for maximal oxygen uptake (ml·kg⁻¹·min⁻¹) were much lower than those reported for the athletic subjects studied by both Astrand (1) and by Daniels and Oldridge (4).

The absolute (1·min⁻¹) oxygen demands of running at 115 m·min⁻¹ are depicted in Figure 1. Significant increases were observed across the 3-year period. Body weight also increased; therefore the change in absolute oxygen demand is not surprising.

Mean values for the oxygen demands (Figure 2) of submaximal running expressed relative to body weight (ml·kg⁻¹·min⁻¹) showed no statistically significant changes over the 3-year span of ages studied. Studying slightly older children, both Astrand (1) and Daniels and Oldridge (4) reported significant improvement
in economy of submaximal running with growth. Astrand’s cross-sectional study covered more athletic subjects and an age range extending well beyond the one featured in the current investigation. Daniels and Oldridge studied subjects who were engaged in running training, a condition not present in the children studied herein. This may explain the differences between data sets, as Ekblom et al. (7) have reported that oxygen demands of submaximal work are reduced following several months of training.

When the oxygen requirement of submaximal running is considered as a percentage of maximal aerobic power, an estimate of the relative workload or intensity is obtained (2). The changes observed over the 3-year period in fractional utilization of aerobic capacity (percent VO₂max) required to run at 115 m·min⁻¹ are depicted in Figure 3. A significant drop in percent VO₂max was

Figure 1 — Maximal aerobic power and submaximal oxygen demands (M±SE) of treadmill running. The differences among age group means are statistically significant (P<.001) for both variables.
found. Thus, the intensity of effort required to run at 115 m·min⁻¹ was greater for 6-year-olds than for 8-year-olds.

Previous studies conducted on athletic subjects suggest that young children are less economical during treadmill running than older children are, primarily because of their high stride frequency, which imposes an expensive utilization of energy per unit of time and results in greater oxygen demands per kg of body weight (5). The current investigation, which describes an untrained group, found no significant changes with age in oxygen demands (ml·kg⁻¹·min⁻¹) of submaximal running. Maximal aerobic power (1·min⁻¹) increased 36.2% while body weight increased only 28.4% over the 3-year age span. The absolute (1·min⁻¹) oxygen demands of running at 115 m·min⁻¹ increased by 22.9%, which was a proportionally smaller change than exhibited by either maximal aerobic power or body

Figure 2 — Maximal aerobic power and submaximal oxygen demands (M±SE) of treadmill running, relative to body weight. The differences among age group means are not statistically significant (P>.05) for either of the variables.
Figure 3 — Fractional utilization of aerobic capacity ($M \pm SE$) required for treadmill running at 115 m \cdot min$^{-1}$. The differences among age group means are statistically significant ($P<.01$).

weight. The net result was a growing spread between VO$_2$max (ml$\cdot$kg$^{-1}\cdot$min$^{-1}$) and the oxygen demands of submaximal work. The resulting decrease in percent VO$_2$max required to run at a given speed suggests a lower intensity of work experienced by older children and may provide a partial explanation for the improvement in running performance observed to accompany growth.

References


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