Ventilatory Threshold and Peak Exercise Response in Athletes With CP During Treadmill and Cycle Ergometry

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Little is known about the responses to graded exercise in athletes with cerebral palsy (CP). This study compared the ventilatory threshold (VT) and peak VO₂ among athletes with CP during treadmill and cycle ergometry exercise. Six (4 men, 2 women) track athletes with CP volunteered to participate in the study. Graded exercise tests on a treadmill and cycle ergometer were performed on separate days to assess VT and peak VO₂. Paired t tests were used to compare the two exercise modes. The VT, expressed as a percentage of peak VO₂, was significantly higher on the cycle ergometer than on the treadmill. The absolute VO₂ at the VT was similar during both testing modes, and peak VO₂ was significantly higher on the treadmill than on the cycle ergometer. Similar to responses seen in able-bodied individuals, the VO₂ at VT was similar during both modes of exercise, while the peak VO₂ was 10% lower on the cycle than on the treadmill. Cycle ergometer peak VO₂ in these athletes was higher than previous reports of individuals with CP for the cycle ergometer.

Cerebral palsy (CP) is characterized by nonspecific damage to the areas of the brain that control muscle tone and spinal reflexes (Shephard, 1990). Involvement can be as minimal as hemiplegia with full ambulation or as severe as total involvement of quadriplegia and the need for a motorized wheelchair. Muscle spasticity (61%) and athetosis (17%) are the two most common conditions present in competitors with CP (Sherrill, Adams-Mushett, & Jones, 1986). Sherrill et al. (1986) reported that 88% of all competitors with CP had a combination of at least three such conditions. While sport and fitness opportunities are increasing for individuals with CP, few reports of their physiological responses during exercise exist (Bhambhani, Holland, & Steadward, 1992; Fernandez, Pitetti, & Betzen, 1990; Lundberg, 1976, 1978).

Graded exercise testing is an important tool in the assessment of submaximal and maximal exercise capacity. Measures of submaximal and maximal capacity include the ventilatory threshold (VT) and peak oxygen uptake. The VT is defined as a disproportionate increase in pulmonary ventilation with respect to the increase in oxygen uptake (Froelicher, 1987). The nonlinear increase in ventilation has been linked to an excessive increase in anaerobic energy production (Wassermann, Hansen, Sue, & Whipp, 1987).

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However, there is some controversy concerning the relationship of pulmonary ventilation, and thus the VT, to an increase in anaerobic metabolism (Brooks, 1985; Davis, 1985).

Regardless, the VT is a reproducible, noninvasive physiological parameter that has been consistently related to submaximal exercise performance (Froelicher, 1987). The VT can be increased by exercise training (Wasserman et al., 1987). An optimal exercise intensity for training may be at or below the VT since intensities above the VT are associated with a high level of discomfort that may interfere with exercise duration (Froelicher, 1987).

The purpose of this study was to compare the VT and peak VO\textsubscript{2} of athletes with CP during treadmill and cycle ergometer exercise. The treadmill to cycle ergometer comparison was performed because of the controversy regarding the ability to use treadmill exercise in individuals with CP. Lundberg (1978) and Bhambhani et al. (1992) suggested that treadmill exercise may be difficult for individuals with CP due to balance or gait problems. In contrast, Fernandez et al. (1990) successfully used the treadmill ergometer as an exercise testing mode for individuals with CP. The treadmill would be the mode of choice for the testing of ambulatory athletes with CP who incorporate running into their training programs. Training guidelines may also be developed for this athletic group based on their metabolic responses to the two exercise modes.

**Methods**

**Subjects**

Members of the United States Cerebral Palsy Athletic Association’s (USCPAA) national track team were recruited as subjects for this study. At the time of the study, these athletes were participating in a training camp at a midwestern university in the U.S. All subjects competed in the 1992 Paralympics in Barcelona, Spain.

The subjects volunteered and gave informed consent for participation in the study after fully understanding the procedures, risks, and benefits. The research protocol was approved by the university’s Institutional Review Board. The athletes with CP were classified using the system of the Cerebral Palsy–International Sports and Recreation Association (CP–ISRA) (Mushett, 1992). The physical characteristics and CP class of each subject are contained in Table 1.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Sex</th>
<th>Age (yrs)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>CP-ISRA class</th>
<th>CP type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>16</td>
<td>63.3</td>
<td>178</td>
<td>7</td>
<td>Hemiplegia</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>19</td>
<td>67.2</td>
<td>177.8</td>
<td>8</td>
<td>Hemiplegia</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>25</td>
<td>82.5</td>
<td>190.5</td>
<td>7</td>
<td>Hemiplegia</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>18</td>
<td>50.4</td>
<td>166.3</td>
<td>6</td>
<td>Mod. Quadriplegia</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>33</td>
<td>48.0</td>
<td>125</td>
<td>7</td>
<td>Hemiplegia</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>34</td>
<td>64.7</td>
<td>167.6</td>
<td>8</td>
<td>Diplegia</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>24.2</td>
<td>62.7</td>
<td>167.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td>7.8</td>
<td>12.5</td>
<td>22.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1  Descriptive Variables of Athletes With Cerebral Palsy
Procedures

The subjects reported to the laboratory on three separate occasions. Their first visit consisted of an orientation session to familiarize them with the exercise testing modalities and the respiratory apparatus used for the measurement of VO₂. Each of the next two visits required the subjects to perform a maximal graded exercise test on either the treadmill or the cycle ergometer. The duration between these tests was 48 hours for each subject, and the order of testing between the two modes was counterbalanced. All testing was administered in the late morning prior to lunch. Each subject participated in an early morning workout the same day and rested approximately 2 hours between the morning workout and the testing.

Before testing began, the athlete was prepped for a CM-5 ECG by having three disposable electrodes attached to the chest. A portable defibrillator-ECG machine (Physio-Control Lifepak 9, Redmond, WA) was used to record the ECG. This single lead ECG was used for the measurement of heart rate during exercise. The respiratory apparatus, as described below, was fitted to each subject.

During the treadmill (Quinton 18-60, Seattle, WA) graded exercise test, the subject started walking at 3.0 mph and progressed by 1.0 mph every min until 7.0 mph was reached. Thereafter the speed remained unchanged while the grade was raised in 2% increments every minute. The cycle ergometer graded exercise test was performed on an electrically braked cycle ergometer (Lode, Groningen, Holland). The subject pedaled at 60 rpm with no resistance for 1 min. The resistance then increased in a step fashion by 20 W·min⁻¹. Both the treadmill and cycle ergometer tests were terminated at the subject’s volitional fatigue or at a test termination point such as chest pain, abnormal blood pressure changes, or abnormal electrocardiogram changes (American College of Sports Medicine, 1991).

During each test the subject breathed through a two-way respiratory valve (Hans Rudolph 2700, Kansas City, MO) with a nose clip in place. Inspiratory air volume was measured by a dry gas meter (Parkinson-Cowan CD-4, Birmingham, England) while the fractional concentrations of oxygen (Applied Electrochemistry S-3A, Sunnyvale, CA) and carbon dioxide (Beckman LB-2, Yorba Linda, CA) in the expired gas were measured by rapid response analyzers. Both the dry gas meter and gas analyzers were on-line with an integrated computer program (Rayfield Instruments, Waitsfield, VT) and computer (Apple Ile, Cupertino, CA) for the determination of VO₂ and other respiratory variables. The gas analyzers were calibrated prior to each test with a gas of known concentrations using the Micro-Scholander technique (Cameron, 1986).

Ventilation (Vₑ), VO₂, and heart rate were recorded every 30 s. The VT was determined for each test from computer generated plots of Vₑ/VO₂ versus VO₂ and Vₑ/VCO₂ versus VO₂ by three experienced, independent observers using criteria established by Davis (1985). The observers were blind to the athlete and exercise mode when examining the data. There was agreement on the choice of the VT between at least two of the three observers in every case. A third observer varied on 3 of 12 cases (25%). This variance was resolved by discussion between the three observers.

Means for the VO₂ at the VT (L·min⁻¹), relative percentage of the VT to peak VO₂, peak VO₂ (ml·kg⁻¹·min⁻¹), and peak heart rate were compared between the two exercise modes using a paired t test. Statistical significance was set at p < .05.

Results

All 6 athletes with CP were able to achieve a 7-mph running pace on the treadmill test. The treadmill grade at test termination varied 6–12%. Test termination due to volitional fatigue was reported by all athletes. The total time for the treadmill test varied 8–11
Table 2 Ventilatory Threshold and Peak Exercise Response Comparisons

<table>
<thead>
<tr>
<th>Mode</th>
<th>VO₂ @ VT (L·min⁻¹)</th>
<th>Ventil. Thresh.* (% peak VO₂)</th>
<th>Peak VO₂* (ml·kg⁻¹·min⁻¹)</th>
<th>Peak HR (bpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treadmill</td>
<td>2.31</td>
<td>68.0</td>
<td>55.7</td>
<td>189.2</td>
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<tr>
<td></td>
<td>SD 0.48</td>
<td></td>
<td>6.7</td>
<td>8.0</td>
</tr>
<tr>
<td>Cycle</td>
<td>2.43</td>
<td>77.5</td>
<td>50.1</td>
<td>187.8</td>
</tr>
<tr>
<td></td>
<td>SD 0.54</td>
<td></td>
<td>4.1</td>
<td>11.4</td>
</tr>
</tbody>
</table>

*<p < .05, treadmill vs. cycle.

The peak respiratory exchange ratio (RER) averaged 1.09 ± 0.05, suggesting maximal metabolic exertion by the athletes. The athletes achieved 97% of age-predicted maximal heart rate during the treadmill graded exercise test.

The cycle ergometer graded exercise tests produced peak work rates between 160 and 240 W (M = 213 ± 47 W). The test lasted 8–12 min before it was terminated due to volitional fatigue. The RER at peak exertion was 1.1 ± 0.08, with all but one athlete having a RER greater than 1.05. Thus, maximal metabolic exertion by each athlete was likely. The athletes achieved 96% of age-predicted maximal heart rate during the cycle ergometer test.

Table 2 contains the comparison of the VT and peak exercise responses between the two modes of exercise testing. The VT occurred at a similar absolute VO₂ (L·min⁻¹) value for the two testing modes, while the percentage of peak VO₂ at the VT was higher on the cycle ergometer, t(5) = 2.34, <p < .05. The peak VO₂ in ml·kg⁻¹·min⁻¹ achieved on the treadmill was significantly higher than the cycle ergometer peak exercise response for VO₂, t(5) = 4.48, <p < .05. The difference in peak VO₂ between modes was approximately 10%. Peak heart rate was not statistically different between the modes.

**Discussion**

The VT, expressed as a percentage of peak VO₂, was significantly higher during the cycle ergometer test than during the treadmill test. This difference was largely due to the peak VO₂ between the two modes. The cycle ergometer test resulted in a peak VO₂ that was lower than that measured during the treadmill test, while the absolute VO₂ at the VT was similar between the modes of exercise. It has been previously reported that the VT expressed as a percentage of peak VO₂ was higher on the cycle ergometer than on the treadmill and that the absolute VO₂ at the VT was similar between cycle and treadmill exercise for able-bodied populations (Davis et al., 1976). Thus, the athletes with CP had a similar VT response between cycle and treadmill exercise to that reported for able-bodied individuals.

The higher peak VO₂ found on the treadmill compared to the cycle ergometer is consistent with reports from other populations. The typical difference reported in peak VO₂ between the cycle and treadmill ergometers is approximately 10% (Smoldaka, 1987), which is similar to the difference reported in this study. These comparable results are not surprising since it has been consistently shown that athletes with disabilities
generally exhibit exercise responses similar to those exhibited by able-bodied individuals (DePauw, 1988).

Peak VO\textsubscript{2} on the cycle ergometer was higher in these athletes with CP than previously reported for maximal cycle ergometer exercise in subjects with CP (38.6–46.3 ml·kg\textsuperscript{-1}·min\textsuperscript{-1}) (Bhambhani et al., 1992; Lundberg, 1978). The treadmill peak VO\textsubscript{2} for these athletes was also higher than a previous report of 21.6 ml·kg\textsuperscript{-1}·min\textsuperscript{-1} for nonathletic, ambulatory individuals with moderate to severe CP during a maximal treadmill test (Fernandez et al., 1990). The fact that our subjects engage in athletic competition, train, and have minimal CP involvement may account for the large difference in peak VO\textsubscript{2} between our subjects and others with CP previously studied (Bhambhani et al., 1992; Fernandez et al., 1990; Lundberg, 1978). There are no known reports examining the VT in individuals with CP to support comparisons.

It is interesting to note that the treadmill peak VO\textsubscript{2} for 5 of the 6 athletes classifies them in the high category for peak VO\textsubscript{2} or aerobic capacity compared to norms listed for able-bodied individuals based on age and gender. The 1 remaining athlete was classified in the good category for peak VO\textsubscript{2} (American Heart Association, 1972).

During the cycle and treadmill testing no problems related to balance or gait that might affect exercise responses were noted for any of the athletes. Biomechanical analysis using videotaping during the testing, as part of a separate study on these athletes, consistently noted upper extremity asymmetry during treadmill exercise. However, no consistent lower extremity movement deficits were noted (Bahamonde, 1992).

In conclusion, the treadmill test yielded a higher peak VO\textsubscript{2} and lower relative VT than the cycle ergometer in these athletes. The treadmill protocol was not felt to be affected by any balance or gait problems. Generalizing these findings to exercise for individuals with CP may be limited by the subject number and by CP-ISRA Classifications 6–8. It may be interesting to compare athletes with CP to able-bodied individuals of similar age, gender, and performance level for the biomechanical and physiological economy of movement and the metabolic responses during exercise. These findings, along with the results of the present investigation, would provide information for the development of training programs as well as for the assessment of performance in individuals with CP.

References


