Effect of Work Load Durations in Progressive Exercise Relationships between Lactate and Anaerobic Thresholds

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The purpose of this study is to investigate the effect of work load durations on the relationships between aerobic and anaerobic thresholds determined from gas exchange parameters, and lactate thresholds determined from blood lactate concentrations. Aerobic and anaerobic thresholds (Aer T, An T) were detected from the plot of changes in gas exchange parameters against increasing work load by a breath-by-breath system. Lactate thresholds (LT 1, LT 2) were detected from the plot of blood lactate level in the same manner as Aer T and An T. Ten normal subjects were studied doing progressive bicycle ergometer exercise (after 2 minutes warming-up at 0.5kp) until exhaustion under three experimental conditions (work load duration was increased every 1, 3 and 5 minute by 0.5kp respectively) in a random order. Neither aerobic nor anaerobic threshold expressed in V̇O₂ was significantly different despite of the different work load durations, but those data expressed as work load (kp) had significant differences with the different work load durations (for both Aer T and An T, p<0.01). Significant correlations were found between the average values of V̇O₂ at Aer T and LT 1 (for 3 min., p<0.05, for 5 min., p<0.01), and between An T and LT 2 (for all of 1, 3 and 5 min., p<0.01). These results suggest that Aer T and An T were well coincide with LT 1 and 2 under any experimental conditions studied here. Therefore, it seems that Aer T and An T determined from gas exchange parameters can be used as an index of the aerobic performance in man.

Key words: Aerobic threshold, Anaerobic threshold, Work load durations, Lactate threshold, Lactate release

INTRODUCTION

Maximal oxygen uptake (V̇O₂ max) was used as an objective index for indication of the endurance performance in man (Åstrand and Rodahl, 1970). Recently, anaerobic threshold has extensively been used, which was highly correlated to endurance performance (Farrel et al., 1979: Kumagai et al., 1982 : Tanaka et al., 1983), V̇O₂ max (Wasserman and McIlroy, 1973) and oxidative capacity in skeletal muscle (Ivy et al., 1980).

Wasserman et al. (1973) defined AT as V̇O₂ max or work rate at the point where blood lactate begins to increase at the resting level and/or ventilation increases nonlinearly during the incremental exercise. The anaerobic threshold is based on the theory of lactate production in tissues and skeletal muscles due to lack of oxygen and compensation by respiration.

Skinner and McLellan (1980), on the other hand, proposed the aerobic and the anaerobic thresholds where the process of energy liberation was divided into three phases with changes of blood lactate concentrations during incremental exercise. The term of aerobic and anaerobic thresholds in this study were based on Skinner and McLellan (1980).

However, it was reported that lactate and H+...
release from skeletal muscle to blood were dependent on work time (Bang, 1936; Hultman and Saltin, 1980), and were delayed (Jorfeldt et al., 1978). Therefore, the more release from beyond which lactate accumulated to blood should be expected as the prolonged work duration.

Hughes et al. (1982), Segal and Brooks (1979), Hagberg et al. (1982), and Yeh et al. (1983) expressed doubt on the relationships between the anaerobic threshold detected from gas exchange parameters and lactate threshold detected from the change of blood lactate concentrations.

The purpose of this paper was designed to investigate the effects of work load durations in the progressive exercise in the relationships between the lactate threshold and anaerobic threshold.

**METHOD**

Ten healthy male students participated voluntarily in this study. The subjects were informed of all the risks and stress of this study before giving their written consent of participation. Table 1 presents the physical characteristics of the subjects.

The work tests were performed in an upright position on a bicycle ergometer (Jonas Øglænd), after 2 minutes warming-up at 0.5kp and 50rpm up to exhaustion under three experimental conditions (work load duration was increased every 1, 3 and 5 minute by 0.5kp, respectively) in a random order.

During the tests, the subjects breathed through a mask by Hans Rudolph Inc. (dead space; 145mL). Expired O₂ and CO₂ concentrations were measured continuously from the mask with a Perkin Elmer MGA-1100 mass spectrometer. Expired air flow was measured with a fleisch #4 pneumotachograph. These signals underwent analog-to-digital conversion for the on-line breath-by-breath computation using a microcomputer by Micro Research Inc.. The parameters computed were oxygen consumption (VO₂), carbon dioxide (VCO₂), minute ventilation (VE), fractional concentration of the end tidal carbon dioxide (FETCO₂), fractional concentration of the end tidal oxygen (FETO₂), respiratory exchange ratio (RQ), VE/VCO₂, and VE/VO₂ according to Beaver et al. (1981).

Blood samples were drawn with a capillary tube (containing heparin, fluoride and nitrite) from an earlobe prior to exercise and during the final 30 seconds of each step, and chilled for the subsequent analysis. The lactate in blood were measured by the automatic analyzer (Analox instrument LM3).

Aerobic and anaerobic thresholds were detected from the plots of changes in gas exchange parameters against increasing work load by a breath-by-breath system. The aerobic threshold (Aer T) was determined for each test using the work rate (kp) or VO₂ (ℓSTPD / min) at the point of departure from the linearity in VE, of a systemic increase in VE/ VCO₂ without the increase in VE/VO₂ and/or of an abrupt increase of FETCO₂. The anaerobic threshold (An T) was determined in the same manner as aerobic threshold at the peak point in FETCO₂ or the onset of decrease, and/or of a departure from the linearity in VE again.

From plots of the blood lactate concentrations against each work load, the broken point on the fitted line, was determined by the same manner, as mentioned above from plot of gas exchange parameter.

The 3-way ANOVA was performed to test statistical differences among the work load duration, between the Aer T and LT 1 or An T and LT 2, among the subjects and interactions between work load durations and thresholds. Differences were considered to be significant at p<0.05.

**Table 1 Physical characteristics of subjects**

<table>
<thead>
<tr>
<th>n</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>VO₂max (L/min)</th>
<th>VO₂max/weight (mL/kg/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>10</td>
<td>19.20</td>
<td>170.30</td>
<td>63.10</td>
<td>2.84</td>
</tr>
<tr>
<td>SD</td>
<td>1.14</td>
<td>7.64</td>
<td>6.86</td>
<td>0.25</td>
<td>5.73</td>
</tr>
</tbody>
</table>

**RESULTS**

Fig. 1 shows VO₂ of 1, 3 and 5 minute incremental
work tests, and as the longer work load durations were performed, the higher \( \dot{V}O_2 \) was obtained at the same work load (0.5kp, \( p<0.05 \), 1kp to 4.5kp, \( p<0.01 \)).

Fig. 2 shows the changes in blood lactate concentrations during 1, 3 and 5 minute incremental work tests. Significantly higher values in 3 and 5 minute work load durations as compared with 1 minute. These results suggest that \( \dot{V}O_2 \) and blood lactate concentrations for a given work rate differ with work load durations change.

Table 2 indicates that parameters measured at rest, at the Aer T, at the An T and at the maximum work rate during 1, 3 and 5 minute incremental work tests. No significant differences are observed in any of the gas exchange parameters, except the work rate and \( %\dot{V}O_2 \) max, at each work load.

Fig. 3 shows the regression representing relationships between the aerobic and anaerobic thresholds and between the lactate threshold 1 and 2. All of the tests seem to have a similar tendency.

Significant correlations were found between the average values of \( \dot{V}O_2 \) at Aer T and LT 1 (for 3 min., \( p<0.05 \), for 5 min., \( p<0.01 \)), and between the An T and LT 2 (for all of 1, 3 and 5 min., \( p<0.01 \)) (Fig. 4). These results (Fig. 3 and 4) suggest that the Aer T and An T well coincide with LT 1 and 2, respectively.

The results, summarized in table 3, indicate the

**Table 2** Variables measured at rest, at the Aer T, at the An T and at the maximum work rate during 1, 3 and 5 minute incremental work tests

<table>
<thead>
<tr>
<th></th>
<th>rest</th>
<th>Aer T</th>
<th></th>
<th>An T</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR</td>
<td>LA</td>
<td>( \dot{V}O_2 )</td>
<td>WR</td>
<td>HR</td>
</tr>
<tr>
<td>min</td>
<td>beats</td>
<td>mmol</td>
<td>l/min</td>
<td>kp</td>
<td>beats</td>
</tr>
<tr>
<td>1</td>
<td>0.80</td>
<td>1.18</td>
<td>1.34 [2.2]</td>
<td>125.3</td>
<td>1.63</td>
</tr>
<tr>
<td>N=10</td>
<td>SD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8.0</td>
<td>0.42</td>
<td>0.17 [0.35]</td>
<td>10.32</td>
<td>0.31</td>
</tr>
<tr>
<td>N=10</td>
<td>X</td>
<td>1.42</td>
<td>1.32 [1.19]</td>
<td>125.9</td>
<td>2.02</td>
</tr>
<tr>
<td>5</td>
<td>6.77</td>
<td>0.33</td>
<td>3.86</td>
<td>0.22 [0.24]</td>
<td>7.49</td>
</tr>
<tr>
<td>N=10</td>
<td>X</td>
<td>1.32</td>
<td>1.32 [1.18]</td>
<td>128.6</td>
<td>2.18</td>
</tr>
<tr>
<td>3</td>
<td>11.61</td>
<td>0.87</td>
<td>0.17</td>
<td>0.26</td>
<td>9.98</td>
</tr>
</tbody>
</table>

* *P<0.05  **P<0.01*
Effect of Work Load Durations on Lactate and Anaerobic Thresholds

Fig. 3 Relationships between aerobic and anaerobic thresholds determined from the gas exchange parameters and lactate thresholds determined from blood lactate concentrations. Ordinates of upper 3 panels indicate LT 1, and those of lower ones, LT 2.

Fig. 4 The average values of $\dot{V}O_2$ at aerobic and anaerobic thresholds. The vertical bars indicate standard deviation. The statistical test is made for the correlation between AT and LT. LT and AT in this figure indicate thresholds determined from blood lactate concentrations and determined from respiratory gas exchange parameters, respectively.
significant differences by the 3-way ANOVA. This indicates that there were no significant differences between Aer T and LT 1 or An T and LT 2 when they were expressed in \( \bar{V}O_2 \). But, when they were expressed in work rate, there were significant differences.

**DISCUSSION**

It was reported that lactate threshold determined from blood lactate concentrations highly correlated aerobic threshold determined from the gas exchange parameters (Caizzo et al., 1982; Davis et al., 1976; Tanaka et al., 1983), but few studies reported relationships between anaerobic threshold and lactate threshold. In spite of the difference of work load durations, high correlations were observed between Aer T and LT 1, as well as An T and LT 2 in this study (Fig. 3).

Rusco et al. (1986), however, reported that at Aer T and An T the muscle/blood lactate ratio was 2-2.5 when the load increased by 15 W every 3 minutes until exhaustion. Tesch et al. (1982) and Jacobs et al. (1982) observed a similar ratio between muscle and blood lactate after 4 minutes of exercise at the An T. In contrast, Green et al. (1983) reported that it was 3-4 at the Aer T and 5-6 at the An T as an incremental progressive exercise regimen of a 15W increase every minute. This discrepancy of the above results can be explained by differences in exercise protocols. The same result was obtained in the present study which suggests that when the prolonged work load duration was performed, the higher blood lactate level was shown against the same work load (Fig. 2). This result is considered to be due to the delay of lactate release from the muscle to blood (Jorfeldt et al., 1978).

Linnarson et al. (1974) reported that a steady state of \( \bar{V}O_2 \) needed 1.5-2 minutes after increase of work load over extensive work rates. Thus, if work load duration is short, e.g. \(<1\text{min.}, \) before the adaptation in hemodynamics against one work load, it may be shifted to the next work load. However, it was reported that in spite of different work load duration, the Aer T and LT 1 occurred nearly at the same time as a result of the 1 and 4 minute incremental progressive exercise regimen (Wasserman and McIlroy, 1973; Yoshida, 1984). The present study obtained the same results at the Aer T, and demonstrated the occurrence of the An T nearly at the same time (Fig. 3 and 4). These results suggest
that the accumulation of blood lactate above resting level is a factor that leads to hyperventilation, when the delay of lactate release from the muscle to blood causes the delay of the ventilation control mechanism (Aunolar and Rusco, 1982).

The results suggest that the Aer T and An T well coincide with the LT 1 and LT 2 in any experimental conditions studied here. Therefore, it seems that the Aer T and An T determined from gas exchange parameters can be used as an index of the aerobic performance of man in a wide range of practical conditions.

REFERENCES
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(Received September 25, 1987)