Blood Lactate after Strenuous Exercise with and without Breath-holding

Noriaki Fujitsuka, Tetsuo Ohkuwa, and Miharu Miyamura*

Department of Physical Education, Nagoya Institute of Technology, Nagoya, 466 Japan
*Laboratory for Work Physiology, Research Center of Health, Physical Fitness and Sports, Nagoya University, Nagoya, 464 Japan

Summary  Lactic acid concentration of venous blood was determined in healthy male subjects after strenuous exercise with and without breath-holding. It was found that in all subjects the peak and total values of lactate during recovery was higher in the breathing run than in the breath-holding run, though the running time was the same.

Lactic production in exercise has been interpreted as an emergency process, taking place when the oxidative process is insufficient to meet the energy requirement. It has been found that in hypoxia the lactate formation takes place at a lower work load (Piper et al., 1966; Raynaud et al., 1974). However, Keul et al. (1972) observed that the resting lactate level decreased to about 70% during inspiration of a hypoxic mixture of 12.7% as compared with normal air. Similar changes were reported by Edwards (1936) and Hackel and Clowes (1956) who determined the lactate at the high altitude of 5.34 km or at a lower O₂ mixture (10% O₂). Concerning lactate in exercise, Hansen et al. (1967) observed significantly higher pyruvate levels (20-30%) with submaximal and maximal work loads during an acute exposure to an altitude of 4,300 m, though the lactate level apparently did not change in either hypoxia and normal conditions. The present study was carried out to examine the difference in the lactic acid concentration between short strenuous running with breathing and with breath-holding.

Methods. The subjects were 4 healthy males (laboratory staff) aged 28-35 years. All subjects were briefly informed about the experimental procedure. The subjects came to the laboratory on at least three separate days. On the first day all the subjects were familiarized with the equipment and the testing procedure. The actual testing was performed on the second and third days. On the second day, the subjects warmed up for a few minutes by running on a treadmill at a speed of 120–160 m/min and at a constant grade of 8.6%. This was followed by a 2-min rest, and thereafter exercise was performed on the treadmill at a con-
stant speed (250 m/min) with breath-holding; the exercise was continued until the subjects could not maintain breath-holding. On the third day, exercise was conducted by each subject at the same speed (250 m/min) without breath-holding for the same length of time that each subject had continued to run with breath-holding in the previous test. Both exercise tests were carried out for each subject on separate days; usually one week apart.

After exercise the subjects rested in a supine position; oxygen uptake and lactic acid were determined simultaneously during 60 min of recovery. The volume of expired gas was measured using a respirometer (Fukuda, type CR-50, Japan), and gas analysis was performed with a paramagnetic O₂ analyzer (Morgan, model S-3A, England) and an infrared CO₂ analyzer (Godart, capnograph, Holland). These analyzers were calibrated with two known calibration gases that had been checked by the Scholander micro-gas analyzer. Moreover, a needle with a three-way cock was inserted into the antecubital vein after exercise to draw a blood sample; approximately 3 ml of blood was drawn anaerobically into heparinized plastic syringes, and the concentration of the lactic acid was deter-

![Fig. 1. Changes of oxygen uptake (upper panel) and blood lactate (lower panel) after strenuous treadmill exercise with and without breath-holding.](image)

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BLOOD LACTATE AFTER BREATH-HOLDING RUN

mined by means of the enzymatic method as described by Hohorst et al. (1959).

Results and discussion. It was found in this study that the running time with
breath-holding for each subject ranged from 21 to 26 sec. This result may indicate
that the running time with breath-holding depends mainly on the total amount
of oxygen stored in the body (about 1,500 ml), because an oxygen requirement
of 3,000 to 4,000 ml/min may be reached during strenuous exercise, as described
by Keul et al. (1972).

Lundholm et al. (1963) observed that the enzymatic method of lactate deter-
mination was more specific and sensitive than the Barker and Summerson
(1941) method. They felt that because of large methodological errors, results of
the latter method should be evaluated with circumspection. For this reason we
chose the method described previously. Figure 1 shows a typical result (in the
case of subject H.I.) of change in the oxygen uptake and blood lactate after strenu-
os exercise with and without breath-holding. Furthermore, if the blood lactate
decreases logarithmically, lactate during recovery could be fitted best by an equa-
tion of the form, \( L = L_r + 10^{a-bt} \), where \( L \) is the lactic acid concentration at time
t, \( L_r \) the concentration of lactic acid in the blood at rest, 10\( a \) the extrapolated value
of excess lactic acid concentration in the blood at the beginning of recovery and
b the velocity constant (Margaria et al., 1933). Table 1 shows the data of each

<table>
<thead>
<tr>
<th>Subj.</th>
<th>Rest (mmol/liter)</th>
<th>Maximum (mmol/liter)</th>
<th>Total (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H.I.</td>
<td>BH 1.14</td>
<td>3.89</td>
<td>18.97</td>
</tr>
<tr>
<td></td>
<td>B 1.07</td>
<td>12.13</td>
<td>59.16</td>
</tr>
<tr>
<td>N.F.</td>
<td>BH 1.27</td>
<td>6.17</td>
<td>36.18</td>
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<td></td>
<td>B 1.17</td>
<td>8.91</td>
<td>52.25</td>
</tr>
<tr>
<td>S.H.</td>
<td>BH 1.36</td>
<td>3.31</td>
<td>15.53</td>
</tr>
<tr>
<td></td>
<td>B 1.52</td>
<td>9.55</td>
<td>44.80</td>
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<tr>
<td>Y.Y.</td>
<td>BH 1.33</td>
<td>8.03</td>
<td>51.96</td>
</tr>
<tr>
<td></td>
<td>B 1.54</td>
<td>8.68</td>
<td>56.16</td>
</tr>
</tbody>
</table>

BH, breath-holding run; B, breathing run.

subject in breathing and breath-holding runs estimated by the fitting process.
For a long time, the increase in lactate under conditions of oxygen deficiency was
considered to be an expression of an oxygen need in the total organism. As shown
in Table 1, however, the peak and total values of lactate during recovery, which
was calculated using the above equation, was higher in all subjects in the breathing
run than in the breath-holding run, though the running time and oxygen uptake
during recovery was the same. Although no definite explanation for lower lactate
after strenuous treadmill exercise with breath-holding can be presented on definite
physiological grounds, it may be related to the balance between disappearance and

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production of the lactate (Keul et al., 1967) because ISSEKUTZ et al. (1976) observed that the working muscle produces and utilizes lactate at the same time. In other words, it may be possible to assume that lower lactate after breath-holding runs is due to an enhancement of the lactate utilization in the working muscle during breath-holding run as an energy source. However, the possibility mentioned above will need further investigation.

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REFERENCES


