The Effect of Various Cadences and Cycling Intensities on Blood Lactate and Skeletal Muscle Oxygenation as Measured by NIRS

Lisha Shastri
lisha.shastri@kcl.ac.uk
lisha@hst.aau.dk
Supervised by Dr Federico Formenti
MSc Space Physiology & Health
Introduction

- During exercise against a constant load, there is a linear increase in oxygen consumption of the muscle with duration of exercise (Zhang et al., 1991; Belardinelli et al., 1995).

- The increased oxygen demand stimulates the cardiovascular and respiratory systems:
  
  i. ↑ HR → ↑ Cardiac Output
  ii. ↑ ventilation rate, thereby promoting $O_2$ uptake and $CO_2$ expulsion.
  iii. Redistribution of blood towards the working muscle and increasing the venous return
  iv. Reflex vasodilatation of the vessels in the capillary bed and optimizing the $O_2$ supply to the muscle.

(Rowell, 1986; McArdle et al., 2015)
• Once the oxygen supply has reached its maximum after exhausting all the compensatory mechanisms, the muscle uses anaerobic metabolism to generate the ATP required (Wasserman et al., 2005).

• This point is called the Anaerobic or Ventilatory Threshold ($V_T$).

• With the anaerobic metabolism, comes the production of lactate. As the duration or intensity of the exercise increases, the production of lactate surpasses the tissue’s ability to utilize it, thereby reflecting in the rising blood lactate levels.

Figure 1: Lactate Threshold Identification: LT is considered the point at which blood lactate begins a sustained increase. LT is identified with an arrow. (Gaskill 2001)
Near Infra-Red Spectroscopy (NIRS)

PortaMon® (Artinis Medical Systems)
Size: 83.8 x 42.9 x 17.2 mm
Uses the wavelength of 763 and 853nm to measure the deoxygenated Hb (HHb) and Oxygenated Hb (OxyHb) respectively.

Ferrari et al., 2011
Introduction

• TSI decreases as cadence increases, when compared between 60 and 110 rpm (Skovereng et al. 2016).

• Whereas others have shown no such change (Ferreira et al. 2006).
Research Questions

1. To examine the oxygenation of the vastus lateralis at cadences of 30, 50, 70, 90 and 110 rpm at two different external power outputs, predetermined to be 70 and 90% of the ventilatory threshold.

2. The secondary aims of the study were to investigate the changes in the amplitude of oscillation of the TSI during the same protocols and to explore the relationship between lactate accumulation and the other NIRS parameters (OxyHb and HHb).
Methods

• 18 subjects were recruited but only 12 were able to complete the entire study.

• **Exclusion criteria**: BMI below 18 or above 30 kg.m\(^{-2}\), smokers, or anyone with a medical disorder that could affect the study (eg. Cardiorespiratory diseases)

• Each participant was called on two different days, at least 48 hours apart. Written informed consent was taken prior to the start of the trial.

• Participants were advised to avoid strenuous exercise 24 hours before and to refrain from any caffeine or alcohol intake for at least 12 hours before the trial.

*Institutional Ethical Approval (REC Reference Number: LRS-16/17-4097)*
Setup in the lab

1. Cycle Ergometer
2. NIRS
3. Lactate
4. Ventilatory parameters
5. Borg Scale (RPE)
6. ECG
Variables measured

1. Load and cadence on the cycle ergometer (Lode Corival Bike)
2. Ventilatory parameters- $\dot{V}O_2$, $\dot{V}CO_2$, $\dot{V}E$ and RER (Jaeger OxyCon Pro™)
3. ECG- Heart rate (HR)
4. Blood Lactate- Lactate Pro 2®
5. Skin fold thickness- using a caliper
6. Oxygenation of the vastus lateralis measured by NIRS (PortaMon®)
   - Tissue Saturation Index (TSI %)
   - Oxygenated hemoglobin (OxyHb)
   - Deoxygenated hemoglobin (HHb)
Protocol

Day 1: Determining the Ventilatory Threshold ($V_T$)

Defined by RER = 1

Cross checked with other methods like the V-Slope method, the breakpoint of $\dot{V}E/\dot{V}O_2$ and $\dot{V}E/\dot{V}CO_2$ (Amann et al. 2004).
Protocol

Day 1: Determining the Ventilatory Threshold ($V_T$)

Familiarization with the main trials on day 2
Protocol

Day 2: Main Trials

- 70% $V_T$
- 90% $V_T$
## Results

### Population characteristics

<table>
<thead>
<tr>
<th>Parameters</th>
<th>All participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>29 ± 10</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.75 ± 0.09</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>74 ± 11</td>
</tr>
<tr>
<td>Skin fold thickness (mm) (N=10)</td>
<td>8.0 ± 4.8</td>
</tr>
<tr>
<td>Gender - male</td>
<td>7 (58.3)</td>
</tr>
<tr>
<td>- female</td>
<td>5 (41.7)</td>
</tr>
<tr>
<td>Load at $V_T$ (W)</td>
<td>170 ± 62</td>
</tr>
</tbody>
</table>
## Results

Mean cadences maintained during the trials

<table>
<thead>
<tr>
<th>Trials</th>
<th>N = 12</th>
<th>Cadences (rpm)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
<td>50</td>
<td>70</td>
<td>90</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>70% $V_T$</td>
<td>34 ± 1</td>
<td>51 ± 1</td>
<td>70 ± 1</td>
<td>89 ±1</td>
<td>108 ± 2</td>
<td></td>
</tr>
<tr>
<td>90% $V_T$</td>
<td>35 ± 1</td>
<td>50 ± 2</td>
<td>71 ± 2</td>
<td>89 ± 1</td>
<td>109 ± 2</td>
<td></td>
</tr>
</tbody>
</table>
Figure showing the cardiopulmonary and metabolic response during the sub-$V_T$ trials.

* $P \leq 0.034$ when compared to the same cadence during the 70% $V_T$ trial using the Mann-Whitney U test

a, b, c, d: $P < 0.05$ when compared to 30, 50, 70 and 90 rpm respectively, during the same intensity of exercise, using the Wilcoxon's signed rank test.

HR: Heart rate; rpm: revolutions per minute; $V_T$: Ventilatory Threshold; $\dot{V}O_2$: Volume of oxygen consumed; $\dot{V}CO_2$: Volume of carbon dioxide exhaled.
Figure showing the mean RER and RPE during the two sub-$V_T$ trials.

* $P < 0.05$ when compared to the same cadence in the 70% $V_T$ trial using the Mann-Whitney U test.

a, b, c, d: $P < 0.05$ when compared to 30, 50, 70 and 90 rpm respectively, during the same intensity of exercise, using the Wilcoxon’s signed rank test.

RER: Respiratory Exchange Ratio; RPE: Rate of Perceived Exertion; $V_T$: Ventilatory Threshold; rpm: revolutions per min.
References


References


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