The Lactate Dilemma in Middle-Distance Training

USTFCCCA Convention 2014
Scott Christensen

• Stillwater, Minnesota, head coach for 30 years.
• 1997 National High School Champions (*The Harrier*).
• Four Stillwater alumni have broken 4:00 in the mile since 2003.
• Five year Lead Instructor in the USTFCCCA Academy.
• USA World Cross Country Team Leader 2003 and 2008.
Outline of Phoenix Presentation

• Introduction
• Scientific Theory
• Case Studies
• Training Schemes
• Take-Home Points
Oh No!!

Before 5 x 500

After 5 x 500

Pre-training

Post-training
Fatigue Defined

Fatigue is defined as the inability to **maintain** a given or expected power or work output.

Fatigue is the lead-up to exhaustion which is the inability to **continue** a given or expected power or work output.
Fatigue Manifestations

- A depletion of ingredients needed for respiration (CrP, carbohydrates, fats, oxygen, water, enzymes).
- An accumulation of negative byproducts from respiration (hydrogen ions, phosphate ions, carbon dioxide).
- A limitation at the multi-system interface (neuro-muscular junction).
Recovery from Fatigue

- Chronic fatigue: weeks to months of recovery time.
- Acute fatigue: seconds to days of recovery time.
Acute Fatigue Recovery → Days

Yakolev’s Model of Super-Compensation

Stimulus

A

B

Homeostasis

Compensation (recovery)

C

D

Supercompensation

Fatigue
Acute Fatigue Recovery → Minutes

Blood Lactate Levels

- Active Recovery

Blood Lactate (mmol/L) vs. Recovery (min)
Acute Fatigue Recovery → Seconds

Cellular Creatine Phosphate Recovery

% of CrP in Cell

Seconds

0 30 60 90 120 150 180

0 20 40 60 80 100
Brain

Heart Fatigue

Heart

Heart Fatigue

Myocardial Ischemia

Myocardial Ischemia

Muscle Fatigue

Mitochondria

Mitochondria

Anaerobiosis

Anaerobiosis

Hydrogen ions accumulate

Hydrogen ions accumulate

A. V. Hill

Model of Fatigue

A. V. Hill

Model of Fatigue
Fatigue in Middle Distance Runners

• Is it mainly glycogen depletion?
  or
• Is it mainly presence of lactate?
  or
• Is it mainly hydrogen accumulation?
Glycogen Depletion?

- Body stores about 490 g of carbohydrate.
- Total carbohydrate requirements to exhaustion:

<table>
<thead>
<tr>
<th></th>
<th>Anaerobic</th>
<th>Aerobic</th>
</tr>
</thead>
<tbody>
<tr>
<td>800</td>
<td>11 g</td>
<td>11 g</td>
</tr>
<tr>
<td>1500</td>
<td>11 g</td>
<td>24 g</td>
</tr>
</tbody>
</table>
Lactate Presence?
Pathways of Glucose Breakdown

• Aerobic → Pyruvate → Krebs Cycle

• Anaerobic → Pyruvate → Lactate → hydrogen ions lost → acidosis
Produced Blood Lactate Levels are Race Specific

<table>
<thead>
<tr>
<th>Distance</th>
<th>% Lactate Anaerobic</th>
<th>mmol/L Lactate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td>0.5%</td>
<td>0.8-1.8 mmol/L</td>
</tr>
<tr>
<td>30 meters</td>
<td>19%</td>
<td>2-5 mmol/L</td>
</tr>
<tr>
<td>100 meters</td>
<td>70%</td>
<td>14-16 mmol/L</td>
</tr>
<tr>
<td>200 meters</td>
<td>80%</td>
<td>18 mmol/L</td>
</tr>
<tr>
<td>400 meters</td>
<td>53%</td>
<td>24 mmol/L</td>
</tr>
<tr>
<td>800 meters</td>
<td>44%</td>
<td>21 mmol/L</td>
</tr>
<tr>
<td>1600 meters</td>
<td>19%</td>
<td>15 mmol/L</td>
</tr>
<tr>
<td>3200 meters</td>
<td>13%</td>
<td>12 mmol/L</td>
</tr>
</tbody>
</table>
Lactate Training Dilemma

• Single session mitochondrial damage from varying lactate →
• Yes, successful distance racing requires a High Lactate Response (HLR)
• But, successful distance racing requires a well developed aerobic energy system too.

<table>
<thead>
<tr>
<th>Lactate present mmol/L</th>
<th>% damage of mitochondrial numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 mmol/L</td>
<td>3%</td>
</tr>
<tr>
<td>8-15 mmol/L</td>
<td>5%</td>
</tr>
<tr>
<td>16-25 mmol/L</td>
<td>8%</td>
</tr>
</tbody>
</table>
Adaptation to Lactate Producing Training Stimuli

- **Produce Less Lactate.** Lactate threshold velocity shifts closer to $\text{VO}_{2\ max}$ velocity due to improved economy.

- **Buffer More Lactate.** Improvement in the High Lactate Response (HLR) tolerance value.

- **Accumulate Less Lactate.** Increase the ability to drain the lactate from the cell more quickly.
Producing Less Lactate
(Astrand 2007)

Differences in Lactate Thresholds

Blood Lactate (mmol/L)

% VO2 max Pace

Untrained LT=65%
Trained LT=85%
Buffering More Lactate

- Specific training adds additional buffering agents to the blood and fluid around cells
- Altitude Effect limits stores of buffering agents like sodium bicarbonate (Paradox)
- Hemoglobin is a buffering agent
- Leads to a High Lactate Response (HLR)
Shifting the Lactate Threshold
(Astrand 2007)

High Lactate Response Curve

- **Blood Lactate (mmol/L)**
- **Speed (mph)**
- **Trained**
- **Untrained**
Accumulate Less Lactate

- Synthesis of more gated lactate channels out of muscle cell.
- Greater activation of lactate channels and response to lactate present.
- Increases lactate flow out of muscle cell. (Adaptation is the result of stress stimuli to FRAP1 gene and mTOR protein)
- Training stimulus at Critical Velocity pace (4 mmol/L or 10k pace)
mTOR Protein Pathways

GROW FACTORS

NUTRIENTS

CELLULAR STRESS

mTOR PROTEIN (FRAP1Gene)

Transcription Initiation Factor

PROTEIN MAKING

Cell Growth & Multiplication

New Blood Vessel Formation (Angiogenesis)

Digestion of Cellular Debris

Cell Metabolism

mTOR inhibitors
Rapamycin*, resveratrol
*Sirolimus FDA-approved drug
Translation to Broad Lactate Training Parameters

- **Training Zone 1**: 2.8 mmol/L to 4.0 mmol/L. 15 k pace to 10 k pace. **Shifting lactate threshold** is main adaptation.

- **Training Zone 2**: 4.0 mmol/L to 12.0 mmol/L, 10 k pace to 3 k pace. **Accumulating less lactate** (H\(^+\)) is main adaptation.

- **Training Zone 3**: 12.0 mmol/L to 23 mmol/L. 3 k pace to 400 meter pace. **Tolerating more lactate** (H\(^+\)) is main adaptation.
Case Studies
Eli Krahn LT Progression

12000 meter timed run

<table>
<thead>
<tr>
<th>Year</th>
<th>HR (bpm)</th>
<th>Lactate (mmol/L)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>169</td>
<td>3.15</td>
<td>4.88</td>
</tr>
<tr>
<td>2014</td>
<td>171</td>
<td>3.54</td>
<td>5.13</td>
</tr>
</tbody>
</table>
**Eli Krahn Lactate at vVO₂max**

5 x 1600 at 4:30, 4:30 rest (8:58 DP)

<table>
<thead>
<tr>
<th></th>
<th>Pre-Lactate (mmol/L)</th>
<th>Post-Lactate (mmol/L)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1600 #1</td>
<td>3.3</td>
<td>8.2</td>
<td>5.92</td>
</tr>
<tr>
<td>1600 #2</td>
<td>3.6</td>
<td>8.8</td>
<td>6.03</td>
</tr>
<tr>
<td>1600 #3</td>
<td>3.7</td>
<td>9.4</td>
<td>6.01</td>
</tr>
<tr>
<td>1600 #4</td>
<td>4.2</td>
<td>9.8</td>
<td>5.86</td>
</tr>
<tr>
<td>1600 #5</td>
<td>4.9</td>
<td>9.8</td>
<td>5.94</td>
</tr>
</tbody>
</table>
Eli Krahn at Special Endurance 2
8 x 400 at 58 seconds. 3 min recovery. Lactate in mmol/L

<table>
<thead>
<tr>
<th></th>
<th>Pre-Lactate</th>
<th>Post-Lactate</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 #1</td>
<td>3.3</td>
<td>14.1</td>
<td>59.0</td>
</tr>
<tr>
<td>400 #2</td>
<td>4.8</td>
<td>14.7</td>
<td>57.9</td>
</tr>
<tr>
<td>400 #3</td>
<td>5.6</td>
<td>14.7</td>
<td>58.2</td>
</tr>
<tr>
<td>400 #4</td>
<td>5.6</td>
<td>15.6</td>
<td>58.4</td>
</tr>
<tr>
<td>400 #5</td>
<td>5.3</td>
<td>15.5</td>
<td>57.7</td>
</tr>
<tr>
<td>400 #6</td>
<td>5.4</td>
<td>15.7</td>
<td>57.4</td>
</tr>
<tr>
<td>400 #7</td>
<td>5.6</td>
<td>16.7</td>
<td>58.3</td>
</tr>
<tr>
<td>400 #8</td>
<td>5.6</td>
<td>16.9</td>
<td>57.6</td>
</tr>
</tbody>
</table>
Eli Krahn’s 400 Meter Repeat Day

Tested Lactate Values

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Lactate (mmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td>18</td>
<td>21</td>
</tr>
<tr>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td>24</td>
<td>27</td>
</tr>
<tr>
<td>26</td>
<td>29</td>
</tr>
<tr>
<td>28</td>
<td>31</td>
</tr>
<tr>
<td>30</td>
<td>33</td>
</tr>
</tbody>
</table>
Training Schemes
12 Day Multi-Paced Microcycle

- **Day 1: VO₂ max**
  - **Date pace intervals** (10 mmol/L)
- **Day 2: Hills (strength)**
  - **Max effort intervals** (10 mmol/L)
- **Day 3: Recovery Run**
  - **Date pace continuous** (2 mmol/L)
- **Day 4: Special 1**
  - **Goal pace intervals** (16 mmol/L)
- **Day 5: Recovery Run**
  - **Date pace continuous** (2 mmol/L)
- **Day 6: Race**
  - **Date pace continuous** (15 mmol/L)
- **Day 7: Long Run**
  - **Date pace continuous** (2 mmol/L)
- **Day 8: Special 2**
  - **Goal pace intervals** (18 mmol/L)
- **Day 9: Tempo Run**
  - **Date pace continuous** (3 mmol/L)
- **Day 10: Speed**
  - **Max effort repetition** (2 mmol/L)
- **Day 11: Recovery Run**
  - **Date pace continuous** (2 mmol/L)
- **Day 12: Speed Endurance**
  - **Date pace intervals** (10 mmol/L)
Lactate Presence in the 12 Day Middle-Distance Microcycle

**Pre-competition Phase**

**Training Zone 1:** 5 days at <2.0 mmol/L (aerobic threshold)

1 day at 3.0 mmol/L (lactic threshold)

**Training Zone 2:** 3 days at 10.0 mmol/L

**Training Zone 3:** 3 days between 15-18 mmol/L
Special Endurance 2 (Day 8)

- Extent of work is 8 * 400 meters at near max effort on the track.
- Rest is 3 minutes.
- Time goal is 5 seconds faster then \textit{PRESENT DAY} 1600 pace.
- Training unit lactate range: 4-18 mmol/L
- 2 mile jog cool down.
Blood Lactate Recovery Following a Hard Running Effort
(18 mmol.)

Minutes of Active Recovery

Percent of Recovery
VO₂ max Workout (Day 1)

- Work is 8 x 800 meters @ Vigil protocol VO₂ max pace. Date specific.
- Total volume is 6400 meters.
- Done as an interval style workout. Rest equal to work.
- Training unit lactate range: 4-12 mmol/L
Speed Workout (Day 10)

• Work is flying 30 meter repeats on the track.
• Work is max effort.
• 4 minutes jog rest between repeats.
• Total max speed volume is 300 meters.
• Training unit lactate range: 2.0 mmol/L
• 4 mile easy run.
Take-Home Points

• Fatigue is the inability to maintain a high level of work.
• Middle-distance races are at a sub-maximal work rate.
• Fatigue in middle-distance runners is directly related to hydrogen ion build up.
• Produce less, buffer, or disperse hydrogen.
• Prescribe training sessions that stimulate all three areas of hydrogen presence.