Aerobic Capacity or Aerobic Efficiency? A Look at Race Dependent Models

USTFCCCA Annual Meeting
Orlando 2012
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.
- USTFCCA Co-Lead Instructor in Endurance.
- USA World Cross Country Team Leader 2003 and 2008.
Outline of Orlando Presentation

- Scientific Theory
- Case Study Evidence
- Training Design Application
- Questions
Accepted Scientific Theory on Aerobic Capacity and Aerobic Efficiency
Why Run All Of Those Miles?

Zhou, Conlee, Jensen, et al. [MSSE 33(11)2001]

Aerobic Fitness and the Heart

Heart Rate (BPM)
Stroke Volume (ml/beat)

- Elite
- Trained
- Untrained
Combined Zone Races

All races from the 800 meters and longer have an aerobic and anaerobic component of energy contribution, and are called combined zone races.

Combined zone races have a comfort zone and a critical zone. The critical zone is where the race is won or lost.
# Energy Contributions at Max Effort


<table>
<thead>
<tr>
<th>Event</th>
<th>Duration</th>
<th>Aerobic</th>
<th>KCAL used</th>
<th>Anaerobic Glycolytic</th>
<th>KCAL used</th>
<th>Anaerobic Alactic</th>
<th>KCAL used</th>
<th>Total KCAL used</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 Meters</td>
<td>2 minutes</td>
<td>50 %</td>
<td>45</td>
<td>44 %</td>
<td>40</td>
<td>6 %</td>
<td>5</td>
<td>90</td>
</tr>
<tr>
<td>1600 Meters</td>
<td>4 minutes</td>
<td>70 %</td>
<td>100</td>
<td>28 %</td>
<td>42</td>
<td>2 %</td>
<td>3</td>
<td>145</td>
</tr>
<tr>
<td>3200 Meters</td>
<td>10 minutes</td>
<td>87 %</td>
<td>249</td>
<td>13 %</td>
<td>36</td>
<td>&lt;1 %</td>
<td>1</td>
<td>286</td>
</tr>
<tr>
<td>5000 Meters</td>
<td>15 minutes</td>
<td>92 %</td>
<td>372</td>
<td>8 %</td>
<td>32</td>
<td>&lt;1 %</td>
<td>1</td>
<td>405</td>
</tr>
<tr>
<td>10,000 Meters</td>
<td>30 minutes</td>
<td>95 %</td>
<td>700</td>
<td>5 %</td>
<td>30</td>
<td>&lt;1 %</td>
<td>1</td>
<td>730</td>
</tr>
</tbody>
</table>
Anaerobic Contribution in Distance Events (Duffield and Noakes 2010)
The toleration of disassociated Lactic Acid ($\text{C}_3\text{H}_5\text{O}_3^- + \text{H}^+$)
<table>
<thead>
<tr>
<th>Distance</th>
<th>Type</th>
<th>Lactate Tolerance</th>
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<tbody>
<tr>
<td>200 meters</td>
<td>Anaerobic capacity</td>
<td></td>
</tr>
<tr>
<td>400 meters</td>
<td>Anaerobic efficiency</td>
<td></td>
</tr>
<tr>
<td>800 meters</td>
<td>Anaerobic efficiency</td>
<td><strong>Lactate tolerance</strong></td>
</tr>
<tr>
<td></td>
<td>Aerobic capacity</td>
<td></td>
</tr>
<tr>
<td>1500 meters</td>
<td>Aerobic capacity</td>
<td><strong>Lactate tolerance</strong></td>
</tr>
<tr>
<td>5000 meters</td>
<td>Aerobic capacity</td>
<td><strong>Lactate tolerance</strong></td>
</tr>
<tr>
<td>10000 meters</td>
<td>Aerobic efficiency</td>
<td></td>
</tr>
</tbody>
</table>
What is Aerobic Capacity?
A Critical Understanding of VO\textsubscript{2 \text{max}} is Necessary in Aerobic Capacity

- Aerobic capacity improves due to cardiovascular development.
- Cardiac Output (Q) = HR x SV
- \( VO_{2\text{max}} = HR \times SV \times A-vO_2\text{ diff} \)
- \( HR_{\text{max}} = 207 - 0.7 \times \text{age} \)
- \( VO_{2\text{max}} \text{ pace HR is } \sim 88\% \text{ of } HR_{\text{max}} \)
**$VO_2_{max}$ Field Tests**

- **Buchfuhr** protocol: 10 min to exhaustion. (d)

- **Astrand** protocol: 2 miles at exhaustive pace. (t)

- **Taylor** protocol: 65% of date pace exhaustive 400 meters. (p)
### Percentage of VO$_2$ max as a Function of Race Velocity

<table>
<thead>
<tr>
<th>Event</th>
<th>% of VO$_2$ max</th>
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</thead>
<tbody>
<tr>
<td>800 Meters</td>
<td>120-136%</td>
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<tr>
<td>1500-1600 Meters</td>
<td>112-114%</td>
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<tr>
<td>3000-3200 Meters</td>
<td>102-100%</td>
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<tr>
<td>5000 Meters</td>
<td>97%</td>
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</table>
When Does Efficiency Become More Critical Than Capacity? [Rate vs. Economy]
Aerobic Efficiency
Training at the Thresholds

- **Aerobic threshold** pace occurs at about 70% of VO$_2$$_{\text{max}}$ pace. 50% fatty acids and 50% carbohydrate is the fuel.

- **Lactate threshold** pace occurs at about 85% of VO$_2$$_{\text{max}}$ pace. 32% fatty acids and 68% carbohydrate is the fuel.
Aerobic Efficiency Dynamics

70-90% of VO\textsubscript{2} max
## Cell State Before and After 100/5000/12000

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After 100</th>
<th>After 5000</th>
<th>After 12000</th>
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</thead>
<tbody>
<tr>
<td><strong>Cellular ATP</strong></td>
<td>5 mmoL/kg</td>
<td>5 mmoL/kg</td>
<td>5 mmoL/kg</td>
<td>5 mmoL/kg</td>
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<td></td>
<td>5 mmoL/kg</td>
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<tr>
<td></td>
<td>5 mmol/kg</td>
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<tr>
<td><strong>Creatine Phosphate</strong></td>
<td>25 mmoL/kg</td>
<td>7 mmoL/kg</td>
<td>8 mmoL/kg</td>
<td>7 mmoL/kg</td>
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<tr>
<td></td>
<td>24 mmoL/kg</td>
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<tr>
<td></td>
<td>24 mmoL/kg</td>
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</tr>
<tr>
<td><strong>Carbohydrate (as glucose)</strong></td>
<td>56 mmoL/kg</td>
<td>18 mmoL/kg</td>
<td>68 mmoL/kg</td>
<td>35 mmoL/kg</td>
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<tr>
<td></td>
<td>70 mmoL/kg</td>
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<tr>
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<td>74 mmoL/kg</td>
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</table>
Carbohydrate Management

Factors

Glycogen Utilization in Working Muscle

![Graph showing glycogen utilization during different intensities of exercise.](image-url)
Muscle Glycogen Stores

800 meter runners tested
Muscle glycogen stores of 86.3 mmoL/kg of wet muscle weight

10000 meter runners tested
Muscle glycogen stores of 133.5 mmoL/kg of wet muscle weight
**VO₂ Kinetics to Steady State**

@16 km/hour (Paula Ratcliffe/General Population)

Jones and Berger 2008

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**Comparison of VO₂ Response**

![Graph showing VO₂ response over time for PR and GP populations.](image-url)
**VO₂\text{max}** Training Study

12 week Training Period

*(Helgerud et al, 2007)*

- **LSD:** CR for 45 min @70% VO₂\text{max}
- **LT:** CR for 25 min @85% VO₂\text{max}
- **15/15:** 47 reps @90% HR max, 15 s rest
- **4*4 min:** 4 min repeats @ VO₂\text{max}

Workout repeated twice per week, 40 mile weeks.
% Change VO2 max & Stroke Volume
(12 Weeks)
Helgerud et al, 2007, MSSE
Deena Kastor’s \( \text{vVO}_2 \text{ max} \) Development

- **Tested VO2 max:**
  - Age 22 (1995)  \( \text{VO2 max: 77.5 ml/kg/min} \)
  - Age 27 (2000)  \( \text{VO2 max: 80.5 ml/kg/min} \)
  - Age 32 (2005)  \( \text{VO2 max: 81.1 ml/kg/min} \)

- **Tested VO2 uptake at Lactate Threshold:**
  - Age 22 (1995):  \( 61.8 \text{ ml/kg/min (79%)} \)
  - Age 27 (2000):  \( 62.2 \text{ ml/kg/min (79%)} \)
  - Age 32 (2005):  \( 67.8 \text{ ml/kg/min (83%)} \)
## Stillwater Aerobic Capacity Development Case Study

<table>
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<tr>
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<th>vVO₂ 9</th>
<th>5K 9</th>
<th>vVO₂ 10</th>
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<th>5K 11</th>
<th>vVO₂ 12</th>
<th>5K 12</th>
<th>5K PR</th>
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# Stillwater Aerobic Efficiency Development Case Study

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<th>8k LT 9</th>
<th>5K 9</th>
<th>8k LT 10</th>
<th>5K 10</th>
<th>8k LT 11</th>
<th>5K 11</th>
<th>8k LT 12</th>
<th>5K 12</th>
<th>5K PR</th>
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</thead>
</table>
Training Design Applications for Aerobic Capacity and Aerobic Efficiency Development
Aerobic Efficiency Components

- Base mileage
- Longer tempo runs
- Aerobic intervals
- Long run
Aerobic Capacity Components

- Interval runs
- Repetition runs
- Shorter tempo runs
- \( VO_2 \text{ max} \) pace runs
- Long run
The 5 Paces of the Multi-Paced Training Scheme

- VO$_{2\,\text{max}}$ Run (800-3200 meters)
- Special Endurance 2 (300-600 meters)
- Special Endurance 1 (150-300 meters)
- Speed Endurance (60-150 meters)
- Speed (30-60 meters)
12 Day Multi-Paced Microcycle Aerobic Capacity Preparation

- Day 1: VO$_2$ max
- Day 2: Hills
- Day 3: Long Run
- Day 4: Special 1
- Day 5: Recovery Run
- Day 6: Race

- Day 7: Special 2
- Day 8: Tempo Run
- Day 9: Recovery Run
- Day 10: Speed Endur.
- Day 11: Recovery Run
- Day 12: Speed
9 Day Multi-Paced Microcycle
Aerobic Efficiency Preparation

- Day 1: VO$_2$ max
- Day 2: Hills or Speed
- Day 3: Recovery Run
- Day 4: Special 1
- Day 5: Recovery Run
- Day 6: Race
- Day 7: Long Run
- Day 8: Special 2
- Day 9: Tempo Run

Day pace intervals
Max effort intervals
Date pace continuous
Goal pace intervals
Date pace continuous
Date pace continuous
Date pace continuous
Goal pace intervals
Date pace continuous
More Endurance Information Available at the Following:

- The Complete Guide to Track and Field Conditioning for Endurance Events.
- Online courses in CC and the 800/1600

By Scott Christensen

http://completetrackandfield.com/scott-christensen