DEVELOPING THE ENDURANCE ROWER

Presented By: Nick Clarke & Dr. Trent Stellingwerf
Date: 21st Nov 2015
Who am I?
Who am I?
WHAT DO WE NOW?

150 Years of Rowing
OXFORD-CAMBRIDGE BOAT RACE
WINNING TIMES 1845-2005

\[ y = -0.0331x + 83.872 \]

\[ R^2 = 0.6153 \]
FISA MEN’S CHAMPIONSHIP 1X WINNING TIMES 1894-2004

\[ y = -0.0137x + 34.292 \]
\[ R^2 = 0.5434 \]
MEASURING SPORT PERFORMANCE - HOW THIN CAN YOU SLICE?

CLINICAL RELEVANCE VS. PRACTICAL/APPLIED RELEVANCE...

0.38% difference

<table>
<thead>
<tr>
<th>Rank</th>
<th>Rowers</th>
<th>Country</th>
<th>Time</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Light, Rutledge, Byrnes, Wetzel, Howard, Seiterle, Kreek, Hamilton, Price</td>
<td>Canada</td>
<td>5:23.89</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Partridge, Stallard, Lucy, Egington, West, Heathcote, Langridge, Smith, Nethercott</td>
<td>Great Britain</td>
<td>5:25.11</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Hoopman, Schnobrich, Boyd, Allen, Walsh, Coppola, Inman, Volpenhein, McElhenney</td>
<td>United States</td>
<td>5:25.34</td>
<td></td>
</tr>
</tbody>
</table>
25-30% increase in average velocity over 150 years of competitive rowing (~2%/decade!)

What are the performance variables and how have they changed? (anthropometrical vs. physiological vs. psychological vs. equipment?)

How will future improvements be achieved?
CONTRIBUTION OF ROWING VARIABLES TO INCREASED VELOCITY OVER 150 YEARS

- Sliding Seat/Evolved Rowing Technique – 20%
- Increased Physical Dimensions - 10%
- Improved Training – 33%
- Improved Boat Design /reduced dead weight – 12%
- Improved hydrodynamic efficiency of oar – 25%

This is my best estimate of the relative contribution of the different performance variables addressed to the development of boat velocity over 150 years. Future improvements are probably best achieved by further developments in oar efficiency, and perhaps the return of the sliding rigger!
EVOLUTION OF TRAINING

Optimizing Rowing specific adaptation
Energy source comparisons across different events (**ALL** power-sports)

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>400</th>
<th>800</th>
<th>1500</th>
<th>5000</th>
<th>10000</th>
<th>Mar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerobic (%)</td>
<td>18</td>
<td>35</td>
<td><strong>52</strong></td>
<td>80</td>
<td>90</td>
<td>98</td>
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<tr>
<td>Anaerobic (%)</td>
<td><strong>82</strong></td>
<td><strong>65</strong></td>
<td><strong>48</strong></td>
<td>20</td>
<td>10</td>
<td>2</td>
</tr>
</tbody>
</table>

```
“Classic” Model
```

```
“Contemporary” Model
```

**Note:** “current” model determined using the latest methodology in oxygen kinetics, and with a much more elite subject population than the “classic” model, and where possible using field testing instead of laboratory testing.


Physiological / Technical Framework

Increase Propulsive Power
- Aerobic Capacity
  - Increased Physical Dimensions
- Anaerobic Capacity
  - Maximal Strength

Decrease Power Losses
- Decrease Drag Forces on Boat
  - Improve Technical Efficiency
  - Increase Propulsive Efficiency of oar/blade
  - Improved Training
DEVELOPMENTS IN TRAINING

### Relationship between training intensity and all training and recovery adaptations

#### Training Zone

<table>
<thead>
<tr>
<th>Training Adaptations</th>
<th>Zone 1 Active Recovery</th>
<th>Zone 2 Long Endur.</th>
<th>Zone 3 Steady State</th>
<th>Zone 4 Lactate Thresh.</th>
<th>Zone 5 VO2max</th>
<th>Zone 6 Anaerobic Capacity</th>
<th>Zone 7 Neuro-M Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased Plasma Volume</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Increased Muscle Mito. Enzymes</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Increased Lactate Threshold</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Increased Glycogen Storage</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hypertrophy Slow Twitch Fibers</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Increased Muscle Capillarization</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Fiber Conversion Type II b to II a</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Increased Stroke Vol. / Cardiac Output</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Increased VO2max</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Increased high energy phosphates (ATP &amp; PCr stores)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Increased lactate tolerance</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hypertrophy of fast twitch fibers</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Increased neuromuscular power</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

#### Fatigue profile, risk of injury and over-training

- Total Adaptive Impact: 3, 13, 23, 27, 26, 16, 9
Relationship between training intensity and overall aerobic training effect

Overall training effect (increase in aerobic fitness)

Z1
Z2
Z3
Z4
Z5 Physiological strain / Fatigue / Injury / Illness potential
Z6

Max. tolerable Training volume

Arbitrary units

Exercise intensity (% of maximal steady state power)
“POLARIZED” TRAINING
Lactate Threshold Model
- Emphasizing training between the 1st and 2nd lactate/ventilatory thresholds.
- Lower training volumes, higher intensities
- Most training done at or near threshold

Polarized Model
- Emphasizing a large volume of training below the first lactate or ventilatory threshold combined with significant doses of training with loads eliciting 90–100% of VO2max.
- Larger training volumes
- Some work done at threshold

Training Intensity (% VO2max) or Training Zone
Zone 1       Zone 2       Zone 3

Training Frequency

VT
LT
MLSS

VT
LT
MLSS
Polarized Training …is it even new, or now just supported by sport science?

Arthur Lydiard’s Training Approaches in the 1960’s:
 Massive training volumes, even for 800m runners (e.g. Peter Snell, Olympic Gold Medalist and WR holder) + large focuses of hill running and drills.
Polarized Training – “Norwegian” Approach

Norwegian Endurance Successes
(pop. 4.6 million)

303 Total Medals in Winter Olympic Games (with ~60% from XC Skiing & Speed Skating)
VS.
253 Medals in Winter Games for USA; 145 Medals in Winter Games for Canada;
308 Medals in Winter Games for USSR/Russia

Grete Waitz
Olympic Silver
World Champs Gold
4 World Records
9-Time NYC Marathon Winner

Ingrid Kristiansen
World Champs Gold
2 European Champs
5 World Records (5000m To Marathon)

Bjorn Daehlie
8-time Olympic Champ
9-time World Champ
29 Olympic & World Champs Medals from 1991-1999

Johann Olav Koss
4-time Olympic Champ
3-time All-Around World Champ
10 World Records
Athletes and Polarized Training


"Many authors claim that endurance training is only effective if it is done at a lactate concentration between 2.5 and 3.5 mmol/l (18, 31, 33) or four mmol/l (1, 14). The results of most intensity checks done in the field show that coaches generally assume that long distance training should be done at a lactate concentration of about 3 mmol/l or just under 4 mmol/l. However, the results of our lactate measurements (Table 1) conflict with this assumption. The athletes examined by us seem to choose lower and more tolerable training intensities depending on their individual feelings. These intensities, which are chosen for purely subjective reasons, seem to be more effective for the improvement of the athletes’ endurance than the intensities suggested by the coaches which are based on theoretical concepts. If necessary the athletes could sustain a load intensity corresponding to a lactate concentration of 3.5 mmol/l for 45 minutes, but they found it very hard. Higher intensities were felt as very exhausting. Despite its unscientific character, this observation is typical of the quality of their subjective load perception. Training at an intensity corresponding to a lactate concentration of 4 mmol/l in order to achieve a better effectiveness can no longer be justified physiologically."
A polarized reversed periodization (short to long quality) approach?

**Lactate Threshold Model**
- Emphasizing training between the 1st and 2nd lactate/ventilatory thresholds.
- Lower training volumes, higher intensities

<table>
<thead>
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<tbody>
<tr>
<td>VT</td>
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<tr>
<td>MLSS</td>
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<th>Training Intensity (% VO2max) or Training Zone</th>
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<tbody>
<tr>
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**Polarized Model**
- Emphasizing a large volume of training below the first lactate or ventilatory threshold combined with significant doses of training

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**Classic Approach**
- Long Intervals
- Medium-Length Intervals
- Speed-work

**Polarized Model**
- Short to Long (race pace)

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<tbody>
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</tr>
<tr>
<td>LT</td>
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<tbody>
<tr>
<td>Zone 1</td>
</tr>
</tbody>
</table>

**A polarized reversed periodization (short to long quality) approach?**

**GP**

**SP**

**Comp**
**Polarized Training Continuum**

**ENDURANCE**
Aerobic Development (Capacity & Power) & Muscular Endurance

- Years to maximally develop but large ability to increase rate (nearly unlimited)

**ANAEROBIC THRESHOLD**
Lactate Power & Tolerance

- Weeks/months to maximize capacity (limited)

**PURE SPEED / STRENGTH**
Neuromuscular firing & Strength

- Days/weeks to develop and loose

---


**Moritani T. et al.** Neural factors versus hypertrophy in the time course of muscle strength gain. AJPM, 58(3): 115-130, 1979.

**Francis, C.** The Structure of Training for Speed. 2008.
Polarized Training Continuum

**ENDURANCE**
Aerobic Development (Capacity & Power) & Muscular Endurance

- Years to maximally develop but large ability to increase rate (nearly unlimited)

Maximal Cardiovascular Aerobic Development
- Long continuous training with lactates <1.5 to 2 mmol/L and moderate to low HRs.
  - e.g. cycling w/ high cadence over hrs; Higher stroke-rates, lower power over hrs (e.g. SR = 22 spm = 1320 sr/hr)

**ANAEROBIC THRESHOLD**
Lactate Power & Tolerance

- Weeks/months to maximize capacity (limited)

Muscular Endurance
- Prolonged muscle taxing exercise, with many repetitions, but enough rest to sustain.
  - e.g. many repetitions to fatigue in the weight-room; lower cycling rpms with large gear ratios; Low stroke-rates with full power (e.g. 16 spm = 960 st.hr)

Lactate Tolerance
- Very important physiological component to develop in mid-D / power athletes, however, this system is very limited in its total capacity. Emphasize more in weeks leading into targeted race performances.

**PURE SPEED / STRENGTH**
Neuromuscular firing & Strength

- Days/weeks to develop and loose

Race Pace Neural Firing
- Ensure ‘muscle memory’ of neural firing patterns associated with race speeds, cadence. (muscle is forgetful!); target technique at race pace for optimal refinement and adjustments

**In sports with high neural demand, be aware of CNS fatigue, which can take 48-72 hrs to recover from!**
Residual training effects

Aerobic endurance
Maximal strength
Anaerobic endurance
Strength endurance
Maximal speed

Short Adaptation of Peak Lactates and Lactate Tolerance

60 sec peak lactate tested in June; n=11 female Olympic rowers (2012)

**July 2**
4 x 70 sec / 10min recovery

**July 5**
4 x (4 x 45 sec / 30 sec) / 8min recovery

**July 9**
4 x 75 sec / 10min recovery

8.8 mmol/L
79% of Peak Lactate

11.2 mmol/L
102% of Peak Lactate
Polarized Training CASE-STUDY:
Olaf Tufte (Norwegian Rower, 2 x Olympic Gold)

2003-2004 Season with Olympics in August

~80hrs/month of aerobic work (= 3hrs/day!)

Intervals, Thresholds, and Long Slow Distance: the Role of Intensity and Duration in Endurance Training
Stephen Seiler¹ and Espen Tønnessen²
Sportscience 13, 32-54, 2009 (sportsci.org/2009/ss.htm)
STRENGTH TRAINING

To lift or not to lift?
That is the question
How Strong do Rowers need to be?

“In accordance with the force-velocity relationship a minimal (isometric) rowing strength of $53 \div 0.4 = 133$ kp ($1300N$) will be essential.” …at the start of a race

FORCES IN ROWING

»Isometric forces increase with performance level

– 204 kg International
– 183 kg National
– 162 kg club

41 current or former World rowing or sculling finalists provided written informed consent to take part in progressive incremental rowing tests on the ergometer, a maximal ergometer power test, and a maximal 2,000 m ergometer time trial.

- Power at Maximal Oxygen Consumption
- Maximal Force during 7 stroke test
- Maximal Wattage during 5 stroke test
- fat free mass (muscle mass!)

Table 1 Correlation coefficients for determinants of rowing speed over 2,000 m on the ergometer. $W_{O2\text{max}}$ Power at maximal oxygen consumption, $F_{max}$ maximal force during 7 stroke test, $W_{max}$ maximal power during 5 stroke test, $m_l$ fat free mass, $W_{\text{mmol}^{-1}}$ power at a blood lactate concentration of 2 mmol L$^{-1}$, $W_{\text{mmol}^{-1}}$ power at a blood lactate concentration of 4 mmol L$^{-1}$, $\dot{V}O_{2\text{LT}}$ oxygen consumption at lactate threshold, $m_b$ body mass, $W_{\text{LT}}$ power at lactate threshold, $\dot{V}O_{2\text{LT,LS}}$ oxygen consumption at lactate threshold determined by least sum of squares, $h$ height, $SL$ stroke length, $m_f$% percentage body fat, $[La^-]_{b,max}$ maximal blood lactate concentration, $\dot{V}O_{2\text{max}}$ (ml) $\dot{V}O_{2\text{max}}$ relative to body mass, $LT_{%2}\dot{V}O_{2\text{max}}$ oxygen consumption at lactate threshold as a percentage of maximal oxygen consumption, $m_t$ mass of fat, $HR_{\text{max}}$ maximal heart rate
"Moderate number of repetitions (3-4 sets of 5-3 reps at 75-90% 1RM) not to failure provides a favorable environment for achieving greater enhancements in strength, muscle power, and rowing performance"
## PERFORMANCE AND STRENGTH

<table>
<thead>
<tr>
<th>Date</th>
<th>Body weight</th>
<th>Squat</th>
<th>Bench Pull</th>
<th>Deadlift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter 2010</td>
<td>75.1 kg</td>
<td>68.1 kg</td>
<td>50.6 kg</td>
<td>93.3 kg</td>
</tr>
<tr>
<td>Spring 2012</td>
<td>78.4 kg</td>
<td>100.9 kg</td>
<td>62.3 kg</td>
<td>128.2 kg</td>
</tr>
<tr>
<td>Fall 2014</td>
<td>80.4 kg</td>
<td>111.3kg</td>
<td>68.6 kg</td>
<td>143.9 kg</td>
</tr>
<tr>
<td>Rio 2016</td>
<td>81.5 kg</td>
<td>126 kg</td>
<td>75 kg</td>
<td>145 kg</td>
</tr>
</tbody>
</table>

- At the 2009 World Championships the W8+ finished 9th (last)
- 2012 Olympic the W8+ finished second
PERFORMANCE AND STRENGTH

Men

<table>
<thead>
<tr>
<th>Chronological Age</th>
<th>16-18</th>
<th>18-20</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>24</th>
<th>25+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench Pull (kg) (1.2x BW)</td>
<td>61</td>
<td>68</td>
<td>80</td>
<td>86</td>
<td>98</td>
<td>109</td>
<td>119</td>
</tr>
<tr>
<td>Squat (kg) (1.7 x BW)</td>
<td>95.7</td>
<td>114</td>
<td>132</td>
<td>144</td>
<td>152</td>
<td>158</td>
<td>168</td>
</tr>
<tr>
<td>Deadlift (kg) (1.9x BW)</td>
<td>104</td>
<td>118</td>
<td>141</td>
<td>154</td>
<td>167</td>
<td>178</td>
<td>188</td>
</tr>
<tr>
<td>Training Age</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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Women

<table>
<thead>
<tr>
<th>Chronological Age</th>
<th>16-18</th>
<th>18-20</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>24</th>
<th>25+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench Pull (kg) (1.1x BW)</td>
<td>47</td>
<td>52</td>
<td>56</td>
<td>61</td>
<td>69</td>
<td>78</td>
<td>87</td>
</tr>
<tr>
<td>Squat (kg) (1.6 x BW)</td>
<td>72</td>
<td>85</td>
<td>98</td>
<td>106</td>
<td>112</td>
<td>117</td>
<td>126</td>
</tr>
<tr>
<td>Deadlift (kg) (1.8x BW)</td>
<td>86</td>
<td>96</td>
<td>105</td>
<td>114</td>
<td>123</td>
<td>133</td>
<td>142</td>
</tr>
<tr>
<td>Training Age</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

McNeeley, 2005
Ability to express levels of FORCE:

Production
Reduction
Stabilization

Repair/Prevent muscle imbalances
Training Variety – Fun (thanks Noel)
Maintain lean body mass
Positive changes in stroke

Improve balance
Improve core stability and strength

Reduce and rehab injuries
Sequencing of body segments

Appropriate ranges of motion

Improved stretch-shortening cycle
April 26 2013 – Blue = Left; Red= Right
THE REAL QUESTION: WHAT IS THE MISSING PIECE(S)?

» What is the limiting factor?
» Is it strength, technique, engine?
» You need to find out!
Case Study

104kg
385 W@ 2mmol
18:21 6k
5:43 2k
5 x 195kg Deadlift
Case Study

After training phase:
- Performance decrease
- 104 to 107 kg (~3kg lean mass)
- 340 W @ 2mmol
- 18:49 6k
- 5:57 2k

Pattern Recognition:

- Program type?
- Athlete type?
- How strong is strong?
TOOLS TO ASSESS RESPONSE TO TRAINING
“Ideal/Target” vs. “Actual” Distribution

Z1 Aerobic / SS / Recovery
Z2 Aerobic Power
Z3 Threshold
Z4 VO2max
Z6 Anaerobic Capacity
Z6 Neuromuscular / Speed / Strength

Exercise Intensity (% of maximal steady state power or velocity)

minutes of training / week

Optimal Profile

ACTUAL
ASSESSING TRAINING LOAD OR TRAINING EFFECTIVENESS

No plan / Trial & Error

Measuring "Actionable" Outcomes & relying on sound coaching experience!

Sweet Spot

Measuring Everything
Polarized Training...CASE-STUDY: Michael East (UK 1500m Runner)

Ingham, S.A.; B.W. Fudge & J.S. Pringle. The change in training distribution, physiological profile and performance for a male international 1500m runner. ACSM, 2011, Abstract.

Prescribed Vs actual difference
- 18% in year 1 and 2.8% in year 2 (P<0.001) for low intensity training
- High intensity training was performed close to the prescribed intensity each year

Training distribution
- Shift toward more low intensity training
- Less medium intensity training
- More high intensity training from year 1 to 2 (figure 1).

Performance (figure 3)
- 0.9% for year 1
- 1.4% for year 2
- 0.5% during the two years prior to support.
TARGETING TRAINING ZONES

2mmol/L = Aerobic threshold
4mmol/L = Anaerobic threshold
6mmol/L = PO/Speed Of 6k ERG in PEAK condition

<table>
<thead>
<tr>
<th>Intensity zone</th>
<th>VO₂ (%max)</th>
<th>Heart rate (%max)</th>
<th>Lactate (mmol.L⁻¹)</th>
<th>Duration within zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>45-65</td>
<td>55-75</td>
<td>0.8-1.5</td>
<td>1-6 h</td>
</tr>
<tr>
<td>2</td>
<td>66-80</td>
<td>75-85</td>
<td>1.5-2.5</td>
<td>1-3 h</td>
</tr>
<tr>
<td>3</td>
<td>81-87</td>
<td>85-90</td>
<td>2.5-4</td>
<td>50-90 min</td>
</tr>
<tr>
<td>4</td>
<td>88-93</td>
<td>90-95</td>
<td>4-6</td>
<td>30-60 min</td>
</tr>
<tr>
<td>5</td>
<td>94-100</td>
<td>95-100</td>
<td>6-10</td>
<td>15-30 min</td>
</tr>
</tbody>
</table>
TARGETING TRAINING ZONES

Lactate Step Test – Feb. 14th, 2012

<table>
<thead>
<tr>
<th>Power Output (watts)</th>
<th>Lactate (mmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>180</td>
<td>1.3</td>
</tr>
<tr>
<td>211</td>
<td>0.9</td>
</tr>
<tr>
<td>240</td>
<td>1.1</td>
</tr>
<tr>
<td>271</td>
<td>1.3</td>
</tr>
<tr>
<td>301</td>
<td>2.3</td>
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<tr>
<td>331</td>
<td>3.8</td>
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<tr>
<td>361</td>
<td>Max = 14.8</td>
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<tr>
<td>390</td>
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</table>
### Calculated Training Target Zones

<table>
<thead>
<tr>
<th>RCA Cat.</th>
<th>Description of Zone</th>
<th>Lactate (mmol/l)</th>
<th>Approx Split</th>
<th>Approx Power Targets (Wattage)</th>
<th>Approx Heart Rate Zone (bpm)</th>
<th>Approx Stroke Rate (spm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Easy Recovery or X-Training</td>
<td>~1</td>
<td>&lt; 01:40.9</td>
<td>&lt; 340</td>
<td>&lt; 162</td>
<td>&lt; 24</td>
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<tr>
<td>6</td>
<td>Basic Endur. / Aerobic Develop.</td>
<td>~1.5 - 2</td>
<td>01:40.9 - 01:39.0</td>
<td>340 - 360</td>
<td>162 - 166</td>
<td>24 - 24</td>
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<tr>
<td>5</td>
<td>Aerobic Capacity</td>
<td>~2 - 3</td>
<td>01:39.0 - 01:37.3</td>
<td>360 - 380</td>
<td>166 - 170</td>
<td>24 - 25</td>
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<tr>
<td>4</td>
<td>Anaerobic Threshold</td>
<td>= 4</td>
<td>01:34.3 - 01:32.9</td>
<td>417 - 437</td>
<td>177 - 181</td>
<td>27 - 27</td>
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<tr>
<td>3</td>
<td>Aerobic Power / Strength Endur.</td>
<td>~4 - 6</td>
<td>01:32.9 - 01:29.8</td>
<td>437 - 483</td>
<td>181 - 189</td>
<td>27 - 29</td>
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<tr>
<td>2</td>
<td>VO2max / 2k Race Pace</td>
<td>~8 - 14</td>
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</tr>
<tr>
<td>1</td>
<td>Anaerobic Capacity / Overmax</td>
<td>&gt; 10</td>
<td>-</td>
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</tbody>
</table>

**NOTE:** Keep in mind that these training zones are from one incremental test and there is variability between tests and modes of exercise (e.g. HR won't be the same for ergs and cycling). There is also day to day variability depending on several factors such as: fatigue, hydration, stress etc. This is why there is an approx range for power, HR, splits etc. given for each targeted training zone. Also, as you train and get fitter, you will normally progress to the top end, or above, the current given splits and wattage targets for a given lactate (see lactate curve). This is why we will periodically test throughout the year to make adjustments to these zones and to be sure training is progressing in a positive manner. If these zones feel way too hard or easy, then talk to your coach and/or physiologist to make some adjustments.
BLOOD LACTATE MONITORING

- Pre-Training
- Post-Training

% VO2max/HRmax/ Running or Cycling Speed

Lactate Threshold

Fatigue

Post-Training Lactate Threshold

Fatigue

Pre-Training Lactate Threshold
INTERPRETING LACTATE STEP TEST

**Anaerobic Development/Capacity**
(increased MAP and peak lactates)
- Lactate tolerance (buffering capacity)
- Fiber type distribution / enzymes
- Economy/efficiency of movement / skill
- Neuromuscular strength/power
- Mitochondrial development / density / capill.
- Cardiovascular development (VO2max)

**Aerobic Development/Capacity**
(lower lactates on low end of curve)
- Mitochondrial development / density
- Capillarization
- Cardiovascular development (cardiac-output / VO2)
- Neuromuscular endurance
- Fiber type distribution / enzymes
- Economy/efficiency of movement / skill
INTERPRETTING DATA

How much data is too much?
“ANAEROBIC” ENERGY SYSTEM
(GLYCOLYTIC OR SUBSTRATE LEVEL PHOSPHORYLATION)

GLUCOSE
(Carbohydrate)

Blood Stream

Muscle Cytoplasm

GLYCOGEN
(Stored Carbohydrate in Muscle)

Muscle Cytoplasm

Mitochondria and AEROBIC Energy

2 or 3 ATP’s

LACTIC ACID

PYRUVATE

2 or 3 ATP’s

ACEYTL CO-A

= 36 ATP’s

G-6-P
(Glucose-6-Phosphate)

(Overall Process called Glycolysis)
FORMULA 1
FORMULA 1
On Water Performance

“Top 3 inches” – immeasurable

2k/6k Erg

Power @ VO₂Max

Lactate Step VO₂Max

Economy
Technique
Co-ordination

Peak Power Strength 1RM
CONCLUSIONS

» Polarised Vs Lactate Threshold
  – Time/Experience dependent
  – Building evidence pro-polarised

» Strength & Conditioning – YES!

» HARD WORK = SUCCESS
  – Monitor and adapt
  – Individualise
Thank you
"AEROBIC" ENERGY SYSTEM (OXIDATIVE PHOSPHORYLATION)

PYRUVATE → ACETYL CO-A

B-Oxidation breaks down FATS and produces Acetyl Co-A

CO₂

ADIPOSE (FAT) STORES

TCA CYCLE or KREBS CYCLE (series of 8 reactions)

CO₂

Inside Muscle Cytoplasm

Mitochondria

OXIDATIVE PHOSPHORYLATION = 36ATP’s

O₂ → H₂O
ANAEROBIC VS. AEROBIC SYSTEMS

**ANAEROBIC**

FUELS:
- Creatine Phosphate
- CHO (Glycogen)

1. VERY FAST ATP PRODUCTION
2. SMALL RESERVES OR CAPACITY AND RELATIVELY UN-TRAINABLE
3. NEGATIVE BY-PRODUCTS (IE. HYDROGEN ION (H+) ASSOCIATED WITH LACTATE PRODUCTION)

**AEROBIC**

FUELS:
- FAT
- CHO

1. ATP Generation for LONG periods of time at a decent rate.
2. High ATP production rate and increases with endurance training

** BOTH systems “turn-on” during sprinting, it’s just that the aerobic system doesn’t have time to become optimal and therefore the bulk of the energy produced is through the anaerobic system.**
Oxygen Debt Theory

Thus, VO2 “on” kinetics are relevant in middle-distance racing! (genetics, training, warm-up!)

Diagram:
- Oxygen deficit
- Resting O₂ consumption
- O₂ requirement
- Steady-state O₂ consumption
- EPOC

Time:
- Start exercise
- End exercise
- End recovery
ENERGY SYSTEMS FOR POWER ATHLETES

---

- **PCr-** (Phospho-creatine)
- **Aerobic- Oxidative Phosphorylation**
  - Fats & CHO
- **Anaerobic glycolysis**
- **Training**

---

(adapted from Martin & Coe: Training Distance Runners, Leisure Press, 1991)
Aerobic vs. Anaerobic

Aerobic energy production is generally presented as a rate

Absolute $\text{VO}_2\text{max}$

L (of oxygen) / min

Relative $\text{VO}_2\text{max}$

ml (of oxygen) / kg (body weight) / min
Aerobic vs. Anaerobic

--Anaerobic energy production is generally presented as a total capacity – which is limited.

Anaerobic capacity

mL (of equivalent oxygen) / kg (body weight)

(The rate of anaerobic energy production is essentially instantaneous)
Aerobic vs. Anaerobic

Consider this--- the total amount of energy that the anaerobic energy system can produce is equivalent to the amount of energy that the aerobic energy system can produce in about 90 seconds.
Question:

Which adaptation would have a greater affect on middle-distance / power-sport performance (~4 to 6min of racing)?

--A 10% increase in aerobic capacity (VO_2\text{max})

--A 10% increase in anaerobic capacity
Figure 3.15. Percentage improvements in 400, 800, 1500 and 3000 m performance following 10% improvements in either $\dot{V}O_2_{max}$, the rate of increase in $\dot{V}O_2$ (i.e. $\dot{V}O_2$ kinetics), anaerobic capacity or running economy.
Figure 3.8. Rate of oxygen uptake response for a 1500 m race in a typical middle-distance runner.
Energy systems for anaerobic based power athletes

- Rate of O₂ Uptake (ml/kg/min)

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</table>

- VO₂ Demand
  - ~110-130%VO₂max
  - 100% VO₂max

- VO₂ Supply
  - Favours Large Aerobic Capacities (r=0.79)
  - w/ high anaerobic/lactate tolerance (P/O at LT; R=0.86)
  - and maximal VO₂ ‘on’ half-time (R=0.50)

The aerobic strength model to power-sport and middle-distance training

- Power-sports are primarily aerobic events with >75% of the energy being aerobic in events >4min

- For most athletes (large variability), training that improves aerobic capacity/power (large volumes, years) and/or economy will have the largest benefit on power-sport (~2-10min) performance

- Improvements in anaerobic capacity are limited (and any improvements are quick) and will affect power-sports performance to a much smaller extent.
The aerobic strength model to power-sport and middle-distance training and performance

Cycling 4km-time trial pursuit (~4min) time “savings” resulting from a 5% improvement in:

<table>
<thead>
<tr>
<th>Factor</th>
<th>Time Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neuromuscular (Anaerobic) Power</td>
<td>~0.3sec (0.1%)</td>
</tr>
<tr>
<td>Anaerobic Capacity</td>
<td>~0.9sec (0.3%)</td>
</tr>
<tr>
<td>Aerobic Power</td>
<td>~3.8sec (1.4%)</td>
</tr>
</tbody>
</table>

(Calculations by Dr. Andy Coggan)
Counter argument….Don’t you need to work on developing lactate tolerance?

Aerobic model rationale: The goal is not to tolerate lactate build-up. The goal is to actually make less lactate in the first place, to make the lactate production rate less at race pace (this can be tested by a lactate step test).

**HOW??**

1) By increasing the aerobic contribution (increasing lactate threshold pace). Glycolysis (glycogen breakdown) can also be oxidized aerobically in the mitochondrial (do you want 3 miles to the gallon or 36 miles to the gallon?)

Also, anaerobic training can very quickly up-regulate lactate tolerance and transporters (just a few training sessions over weeks).
Middle-distance / power-based training: Aerobic strength model

The argument for long-aerobic / large volumes and threshold work:

-- Large aerobic volumes (very large!) cause continual blood pressure stress to drive capillarization and large energy deficits to stimulate mitochondria biogensis…which over time (years) can slowly develop a more aerobic profile.

-- Drops in muscle pH (acidosis) inhibits mitochondrial biogensis and mitochondrial enzymes.

-- Periodic work at threshold allows for the most stimulus to adapt the aerobic system.

-- Instead of viewing training as aerobic and anaerobic, view as “aerobic development” and “leg prep” (e.g. neuromuscular adaptation)
Middle-distance / power-based training: Neuromuscular development

Speed work / short-hills / plyometrics / weights are primarily used as neuromuscular leg prep and lower leg (track specific) strengthening, as opposed to anaerobic development.

-- Recruit fast twitch fibers
-- Reinforce biomechanics
-- Provide stress / stimulus for feet, Achilles and calves
-- Maintain muscle strength and mass needed for performance success
-- Keep kinetic chain strong to decrease injury rates
Developing VO2max

Key is time spent at VO2max

Example of longer intervals (5min on / 5min off)

Example of shorter intervals (90s on / 30s off)

The stress of shorter intervals (on VO2max) comes from shortening recovery, not increasing speed (beyond goal race pace)
Two types of middle-distance / power-based athletes

-- “Aerobic Diesel” (e.g. 5k / 1500m athlete)
  • ~2/3rds of athletes fall in this range.
  • More slow-twitch / oxidative muscle fibers.
  • Tend to show lower lactates during training, and not very high peak lactates at the end of a ramp / step test.
  • Tend to clear lactates quicker after high-intensity exercise.
  • Benefits strongly from an aerobic approach to training.
  • Need to carefully balance anaerobic stimulus, as need enough for lactate tolerance, but not so much to become stale.

-- “Glycolytic Whippet” (e.g. 800m / 1500m athlete)
  • More fast-twitch / glycolytic muscle fibers.
  • Tend to show higher lactate during training, and very high peak lactates at the end of a ramp test.
  • Tend to take longer to clear lactates after intense exercise.
  • Has the ability to tolerate lactate incredibly well.
  • Doesn’t handle aerobic approach quite as well, but still must complete -- can handle (and needs?) a bit more anaerobic training.
TRAINING RULES

1) 210-250 Km/week
   30-35 Km Per Day

2) Training "Twice A Day"
   Morning → 18-20 Km (1h 20')
   Afternoon → 15-16 Km (1h)
   6:30-10:00 o'clock
   16:30-18:30 o'clock

3) Long Distance
   3×30 Km  5×35 Km  2×38 Km  1/2×2 Km easy

4) Fartlek → 20/25 times → fast; slow
   1's slow is not jogging !!!!

5) Interval Training
   12×1000 sec 1'30"
   6×1000 sec 2'
   4×3000 sec 2'
   4×5000 sec 1 Km 3'45"/4'00"
   3×10 000 sec 1 Km 3'45"/4'00"

6) Sunday is not Holiday !!!!

7) Eat well; sleep well; don't use alcohol !!!!