RELATIONSHIP BETWEEN PHYSIOLOGICAL PARAMETERS AND TIME-TRIAL PERFORMANCE OVER 1, 2 AND 3 KM IN WELL-TRAINED RUNNERS

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**Introduction**

**Methods**

**Results**

**Discussion**

**Conclusion**

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**Physiological Factors Associated with Middle Distance Running Performance**

*Brandon (1995) Sports Med*

L. Jerome Brandon

Georgia State University, Atlanta, Georgia, USA

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**Determinants of 800-m and 1500-m Running Performance Using Allometric Models**

*Ingham et al. (2008) Phys Fit Perf*

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**Differential modeling of anaerobic and aerobic metabolism in the 800-m and 1,500-m run**

*Billat et al. (2006) J Appl Physiol*

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Previous studies often investigated physiological traits of elite athletes and athletes specialized in middle-distance running.

The subjects included 15 male middle-distance runners; 8 were specialists over 800-m and 7 over 1,500-m races. The two groups had

**Subjects**

Twenty-nine elite male runners participated in the study. These athletes were the best runners in Sweden at the time of the study and all belonged to the Swedish national team in their respective events. Twenty-seven of the

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*Ingham et al.* (2008) *Phys Fit Perf*

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“Using *samples restricted* (truncated) to contain only elite athletes or highly trained individuals *may result in biased results.*”

Participants

Sprinters (n = 6)

Middle-/ long-distance runners (n = 16)

(Ultra-)marathon runners (n = 3)

Mean Characteristics

- **Age:** 25.5 ± 4.7 years
- **Body mass:** 69.2 ± 6.4 kg
- **Body fat (%):** 11.3 ± 2.2%

- **$\dot{V}O_2max$:** 66.0 ± 5.71 mL·min\(^{-1}\)·kg\(^{-1}\)
- **RE:** 222.0 ± 11.1 mL·kg\(^{-1}\)·km\(^{-1}\)

Investigated Parameters

**Physiology**

1. Maximal oxygen uptake ($\dot{V}O_2max$)
2. Maximal fat oxidation (MFO)
3. Running economy (RE)
4. Fractional utilization of at $\dot{V}O_2max$ MLSS (%$\dot{V}O_2max$)
5. Maximal lactate accumulation rate ($\dot{V}La_{max}$)
6. Difference between resting and maximal post 100-m sprint lactate concentration ($\Delta La_{100}$)

**Performance**

7. Velocity associated with $\dot{V}O_2max$ ($v\dot{V}O_2max$)
8. Maximal lactate steady-state (MLSS)
9. Critical Velocity (CV)
10. Velocity associated with MFO ($Fat_{max}$)
11. Finite amount of energy that can be expended above CV ($D'$)
12. Anaerobic speed reserve (ASR)
13. Speed reserve ratio (SRR)
Experimental design

<table>
<thead>
<tr>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>medical check-up</td>
<td>100 m sprint test</td>
</tr>
<tr>
<td></td>
<td>incremental step test</td>
<td>ramp test</td>
</tr>
<tr>
<td></td>
<td>1st constant load test</td>
<td>2nd constant load test</td>
</tr>
<tr>
<td></td>
<td>2nd constant load test</td>
<td>3rd constant load test</td>
</tr>
<tr>
<td></td>
<td>1st time trial</td>
<td>2nd time trial</td>
</tr>
<tr>
<td></td>
<td>3rd time trial</td>
<td></td>
</tr>
</tbody>
</table>

Legend
- Recovery
- Incremental, sprint & ramp test
- Constant load tests
- Time trials if 2 or 3 constant load tests were necessary
Aerobic parameters ($\dot{\text{VO}}_{2\text{max}}$, MFO, RE) have increasingly positive influence

Anaerobic parameters ($\dot{\text{VLa}}_{\text{max}}, \Delta \text{La}_{100}$) had increasingly negative influence

No influence was found for %$\dot{\text{VO}}_{2\text{max}}$

**Figure 1** Correlation coefficients of physiological parameters and 100 m sprint and 1, 2, and 3 km TTs are displayed as solid dots and bars indicating respective confidence intervals.

*Intersection of confidence intervals with zero corresponds to p-values exceeding 0.05.*
**Figure 2** Forward stepwise regression models of physiological parameters for sprint and TT velocity are displayed including coefficient of determination ($R^2$), change of $R^2$ and relation to inferior model ($\Delta R^2$), residual standard error (m·s$^{-1}$), probability of alpha error (p). Akaike's Information Criterion (AIC) was used for successive selection of added variables.
**Figure 3** Correlation matrix displaying correlation coefficients for all physiological parameters. * indicates probability of alpha error below 0.05
• **High relevance of \(\dot{V}O_2\text{max for middle-distance running}\)** is congruent with previous research (Brandon, 1995; Ingham et al., 2008; Billat et al., 2006)

• Evidence exists, that \(\%\dot{V}O_2\text{max might not play such a decisive role}\) as previously assumed in **endurance running** (Joyner & Coyle, 2008; Støa et al., 2010, Gordon et al., 2017)

• It could be assumed that **MFO indicates general status of endurance performance** rather than directly influencing middle-distance running (Maunder) (Maunder et al., 2018)

• **Few studies have investigated influence of anaerobic variables** directly (Schnabel & Kindermann, 1983; Sandford et al., 2019a, Sandford et al., 2019b, Bellinger et al., 2021)
Influence of anaerobic metabolism on sprint and time-trial performance

• Anaerobic metabolism enables **higher total rates of energy release** *(Robergs et al., 2004, Hanon et al., 2019)*

• **Muscular acidosis** as a result of anaerobic energy release is **detrimental for endurance performance**

• **Fast-twitch fibers** involved in high-intensity running are **more prone to fatigue** *(Lievens et al., 2020)*
Limitations

• **Applicability** of results for more homogenous cohorts remains unknown

• Difficulties in valid assessment of anaerobic power and capacities (Noordhof et al., 2018, Buchheit & Laursen, 2013)

• Investigated “anaerobic” parameters might not solely reflect influence of anaerobic metabolism but other characteristics such as muscle typology etc. (Lievens et al., 2020)

Future Directions

• **Training intervention studies** are needed to further understand modulation of anaerobic parameters and endurance performance through exercise prescription

• Studies investigating underlying mechanisms of detrimental effects of anaerobic metabolism on endurance performance
Conclusions

• **Aerobic variables** (\(\dot{V}O_2\) \(_{\text{max}}\), MFO, RE) **have an increasingly positive influence** on time trial performance

• **Anaerobic variables** (\(\dot{V}L_a\) \(_{\text{max}}\), \(\Delta L_a\) \(_{100}\)) **have an increasingly negative influence** on time trial performance

• **Beneficial and detrimental effects of anaerobic metabolism** might be in balance in maximal running lasting approximately three minutes

• **Regular monitoring of anaerobic parameters** might be of special interest for middle-distance runners and coaches
Supplementary Data
<table>
<thead>
<tr>
<th>Time-trial</th>
<th>Model</th>
<th>$R^2$</th>
<th>$\Delta R^2_{adj}$</th>
<th>Resid. Std. Error</th>
<th>$p$</th>
<th>AIC</th>
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<tbody>
<tr>
<td>100 m</td>
<td>$D'$</td>
<td>0.48</td>
<td></td>
<td>0.35</td>
<td>&lt; 0.001</td>
<td>-39.85</td>
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<tr>
<td></td>
<td>$D' + CV$</td>
<td>0.53</td>
<td>0.05</td>
<td>0.34</td>
<td>0.002</td>
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<td>1000 m</td>
<td>$\text{vVVO}_2\text{max}$</td>
<td>0.58</td>
<td></td>
<td>0.23</td>
<td>0.0001</td>
<td>-57.53</td>
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<td>$\text{vVVO}_2\text{max} + D'$</td>
<td>0.76</td>
<td>0.18</td>
<td>0.18</td>
<td>&lt; 0.0001</td>
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<tr>
<td></td>
<td>$\text{vVVO}_2\text{max} + D' + CV$</td>
<td>0.97</td>
<td>0.21</td>
<td>0.06</td>
<td>&lt; 0.0001</td>
<td>-106.84</td>
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<td>2000 m</td>
<td>CV</td>
<td>0.80</td>
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<td>0.16</td>
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<tr>
<td></td>
<td>$CV + D'$</td>
<td>0.98</td>
<td>0.18</td>
<td>0.05</td>
<td>&lt; 0.0001</td>
<td>-118.70</td>
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<tr>
<td>3000 m</td>
<td>CV</td>
<td>0.97</td>
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<td>0.06</td>
<td>&lt; 0.0001</td>
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<tr>
<td></td>
<td>$CV + D'$</td>
<td>1.00</td>
<td>0.03</td>
<td>0.02</td>
<td>&lt; 0.0001</td>
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### Participant characteristics

<table>
<thead>
<tr>
<th></th>
<th>vMLSS</th>
<th>CV</th>
<th>Fat(_{\text{max}})</th>
<th>D(_{\text{max}})</th>
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<tbody>
<tr>
<td></td>
<td>[m·s(^{-1})]</td>
<td>[m·s(^{-1})]</td>
<td>[m·s(^{-1})]</td>
<td>[m]</td>
</tr>
<tr>
<td>SP (n = 6 / 4^*)</td>
<td>mean</td>
<td>3.53</td>
<td>4.15</td>
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</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.27</td>
<td>0.15</td>
<td>0.34</td>
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<tr>
<td>MD-LD (n = 16 / 15^*)</td>
<td>mean</td>
<td>4.33</td>
<td>4.78</td>
<td>3.23</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.41</td>
<td>0.37</td>
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<tr>
<td>M-UM (n = 3 / 1^*)</td>
<td>mean</td>
<td>4.37</td>
<td>4.95</td>
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<tr>
<td></td>
<td>SD</td>
<td>0.21</td>
<td>0.21</td>
<td>0.23</td>
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<tr>
<td>Total (n = 25 / 20)</td>
<td>mean</td>
<td>4.14</td>
<td>4.67</td>
<td>3.04</td>
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<tr>
<td></td>
<td>SD</td>
<td>0.50</td>
<td>0.41</td>
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<table>
<thead>
<tr>
<th></th>
<th>v(\dot{\text{VO}}<em>2)</em>{\text{max}})</th>
<th>v100</th>
<th>ASR</th>
<th>SRR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[m·s(^{-1})]</td>
<td>[m·s(^{-1})]</td>
<td>[m·s(^{-1})]</td>
<td></td>
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<tr>
<td>SP (n = 6)</td>
<td>mean</td>
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<tr>
<td></td>
<td>SD</td>
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<td>0.45</td>
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<td>MD-LD (n = 16)</td>
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<tr>
<td></td>
<td>SD</td>
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<td>0.36</td>
<td>0.37</td>
</tr>
<tr>
<td>M-UM (n = 3)</td>
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<td>1.72</td>
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<tr>
<td></td>
<td>SD</td>
<td>0.53</td>
<td>0.20</td>
<td>0.55</td>
</tr>
<tr>
<td>Total (n = 25)</td>
<td>mean</td>
<td>5.49</td>
<td>7.78</td>
<td>2.29</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.42</td>
<td>0.56</td>
<td>0.77</td>
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</tbody>
</table>
Figure 4 Conceptual data displaying correlation coefficients and confidence intervals of respective mean time-trial. Grey areas indicate time range of TOP50 (World Athletics, 2022) male and female performances in the 800 m, 1500 m and 3000 m SC running events.
Calculation of maximal lactate accumulation rate

\[
\text{maximal post-sprint lactate concentration} - \text{resting lactate concentration} \\
\frac{100\text{-m sprint time}}{\text{alactic time}}
\]
Non-normally distributed parameters

%\dot{\text{VO}}_2\text{max}
MFO
\dot{\text{VLa}}_{\text{max}}
ASR
SRR