Differences in 10 km running performance predicted from O₂ pulse in elite and trained runners.
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Objective
To examine the association of maximal oxygen uptake, stroke volume, and a-VO₂ difference, to critical speed and 10 km running performance.

Design
Observational, comparative.

Setting
Human Performance Laboratory, Faculty of Kinesiology, University of Calgary, Alberta, Canada.
Jack Simpson track, University of Calgary, Alberta.
Venue of the Forzani Mother's Day run, Calgary, Alberta.

Participants
Twelve trained male runners (26.5 ± 4.1 yrs; 69.6± 8.8 kg; 62.8 ± 6.4 ml·kg⁻¹·min⁻¹) volunteered to participate in five separate testing sessions and a local 10km run. Six runners were classified "elite" (10 km in 34:43 ± 1:45 min) and six were classified "trained" (10 km in 40:22 ± 1:51).

Methodology
VO₂ max Determination: The subjects performed a standard incremental test to exhaustion on a treadmill.Expired air was collected and analyzed using a metabolic measurement cart (Parvo-Med True Max).

Critical Speed: The subjects performed 3 maximal effort timed runs of 960, 2160, and 4080m. Results were graphed and extrapolated to predict 10km race time.

Cardiac Output: The subjects performed open-circuit acetylene breathing at selected intervals during 2 incremental treadmill tests. This technique involved breathing trace amounts of acetylene gas while inspired and expired air was continuously monitored by a mass spectrometer.

10 km Race Time: The subjects participated in a local 10km road race within 3 weeks of laboratory testing.

Main Outcome Measures
Cardiac Output (Q), oxygen consumption (VO₂), and heart rate (HR), were measured during 2 incremental treadmill tests. Stroke volume (SV) was calculated from the Q and HR data; arterio-venous oxygen difference (a-VO₂diff) was calculated from VO₂ and Q; and oxygen pulse (O₂ pulse) was calculated from VO₂ and HR. Results for VO₂, Q, HR, SV, a-VO₂diff, and O₂ pulse were compared between groups. When appropriate, values for each variable were compared to previously published values to assess validity.

Main Results (mean ± standard deviation)

<table>
<thead>
<tr>
<th>Group</th>
<th>10 km time (min)</th>
<th>VO₂max (ml/kg/min)</th>
<th>Critical speed (m/min)</th>
<th>O₂ pulse / kg (ml/bt/kg)</th>
<th>Stroke vol. (ml/beat)</th>
<th>a-VO₂ diff. (ml/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trained</td>
<td>40.22 ± 1:51</td>
<td>58.1 ± 3.89</td>
<td>261 ± 16.4</td>
<td>0.28 ± 0.01</td>
<td>142.7 ± 14.1</td>
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<tr>
<td>Elite</td>
<td>34.43 ± 1:45</td>
<td>67.5 ± 4.61</td>
<td>300 ± 8.5</td>
<td>0.31 ± 0.02</td>
<td>147.2 ± 14.3</td>
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</tr>
</tbody>
</table>

The elite group had significantly faster 10km run times (p < 0.001), higher VO₂ max values (p < 0.01), faster critical speeds (p < 0.001), and higher O₂ pulse (ml/bt/kg) (p < 0.05) than the trained group. 10 km performance was correlated with VO₂ max (r = 0.78) Critical speed, calculated from 3 shorter distance maximal timed runs, was strongly correlated to 10 km race time (r = 0.93), but over-predicted by 1:39 mins. There was a linear relationship between Q and VO₂:
Q = 5.76 VO₂ + 5.61 (r = 0.84). These values are similar to those of Barker et al. (1999). There was no significant difference between groups for SV, or a-VO₂ difference measured at critical speed intensity. O₂ pulse at race speed was only moderately correlated with 10 km race time (r = 0.57). Critical speed intensity occurred at 88 ± 0.05 % for both groups.

Commentary
The results demonstrate that 10 km performance was correlated with critical speed which supports previous studies. Thus, performance can easily be predicted from shorter maximal runs. Physiologically, our data demonstrates that a high VO₂ max is a fundamental requirement and that 10 km performance occurs at a high percentage of VO₂ max. Although we could directly measure cardiac output, we could not demonstrate an association between stroke volume or a-VO₂ difference and running performance. We have previously demonstrated a strong relationship between stroke volume and 20 km cycling performance. However, in running, other factors, such as running economy and/or biomechanical ability may play significant roles in determining actual performance. The calculated values of stroke volume and a-VO₂ difference were very similar to data reported in the literature, however, differences in body size may have been a confounding factor in demonstrating a difference between groups. Further research is required with a larger sample size.

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