Assessing maximal power capability of elite speed skaters: a comparison of laser, vertical jump and isokinetic power measures as predictors of time in 100-m speed skating sprints

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Introduction
Muscular power is associated with success in many sports. Practitioners often conceive of muscle power as a general capability that manifests itself in different mechanical forms. It may be defined as the ability to contract the muscles around a joint as fast as possible, and it may reflect in the net joint power (the product of the joint moment and joint angular velocity). In multi-segmental movements, joints are coordinated to maximize power output, which in turn exerts its effects on the center of mass (COM). During the push-off phase in skating and jumping the COM is accelerated mainly by knee joint extension (Van Ingen Schenau, de Groot, & de Boer, 1985). The dominant role of the knee extension power is attributed to the specific joint geometry in the lower extremities and attributed to temporal muscle constraints (Van Ingen Schenau, Bobbert, & van Soest, 1990). The similarities between the push-off in speed skating and in vertical jumps enable researchers to examine the major factors that contribute to the generation of maximal power in these skills based on a COM model (Houdijk, Bobbert, & de Koning, 1999). Compared to other tests, the vertical jump test is reliable (Ferreti, 1997) and often recommended to assess maximal power (Vanrenterghem & De Clercq, 1999). Vertical jumping is such a simple skill that it can be used as a maximal expression of power capability across a variety of sports. However, power-related variables that result from the vertical jump or other tests have not been associated with speed skating performance. The purpose of the study was to determine the strength of association between 100 m speed skating sprint times and the power measured during vertical jumps, isokinetic knee extension and speed skating starts.

Methods
Subjects and experimental design:
Twenty speed skaters at pre-national, national, and international levels, volunteered to participate in the study. Twelve were long-track skaters (3 females, 9 males) and 8 were short track skaters (3 females, 5 males). Table 1 below describes the present sample population.

Table 1: Mean (S.D.) values for age, weight and height of male (M) and female (F) long track (LT) and short track (ST) speed skaters

<table>
<thead>
<tr>
<th>Track</th>
<th>Gender</th>
<th>Age (ys)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT F</td>
<td>23.3 (4.8)</td>
<td>62.3 (9.5)</td>
<td>164.3 (4.8)</td>
<td></td>
</tr>
<tr>
<td>LT M</td>
<td>25.1 (3.3)</td>
<td>82.7 (9.2)</td>
<td>179.7 (6.3)</td>
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</tr>
<tr>
<td>ST F</td>
<td>21.7 (2.4)</td>
<td>58.3 (2.7)</td>
<td>163.8 (1.5)</td>
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</tr>
<tr>
<td>ST M</td>
<td>20.4 (2.2)</td>
<td>69.5 (7.3)</td>
<td>174.6 (6.5)</td>
<td></td>
</tr>
</tbody>
</table>

The volunteers performed five 100 m speed skating sprints (5-10 min rest between trials), followed by 15-20 maximal vertical jumps on a force plate (30 s rest between jumps), and 15 maximal isokinetic knee extensions with the left and the right lower extremities in 3 angular speeds (120, 180, 240 deg•s⁻¹; 3-5 min rest between sets of 5 movements).
**Apparatus:**
Photocells (Longines Ltd.) were used in conjunction with a high precision timer (TAG Heuer Ltd.), to measure 100 m sprint times. Displacement data during speed skating were collected using a Laveg laser device (Jenoptik, Optik Systeme GmbH; spatial accuracy =1 mm; temporal resolution =50 Hz). A custom-made force-measuring plate (range =0-5 kN; natural frequency =500 Hz) was used to collect ground reaction forces during the vertical jumps at a sampling rate of 500 Hz. Concentric knee flexion-extensions were carried out on an isokinetic dynamometer and sampled at 60 Hz (Biodex Medical Systems, Inc.). Torque-time profiles were limb-weight corrected. All data was processed off-line.

**Analysis:**
Correlation analyses were used to determine the relationship between 100 m speed skating times, mean peak power (mean P<sub>max</sub>) and velocity (mean V<sub>max</sub>). Jumping P<sub>max</sub> was obtained from the power curves resulting from the product F(t)•V(t). These data were normalized to body mass. Vertical power measurements were hypothesized to correlate negatively to 100 m sprint times and to the time-to-zero acceleration, but positively correlated to skating velocity. The significance level was set at ≤0.05.

**Results**
Correlation coefficients between normalized power, speed and temporal variables are shown in Table 2.

Table 2: Correlation coefficients between variables obtained from the timer, the laser device, the force plate and the isokinetic device (*p ≤0.05, **p ≤0.01, ***p ≤0.001)

<table>
<thead>
<tr>
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<th>1</th>
<th>2</th>
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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 100 m times</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 FP V&lt;sub&gt;max&lt;/sub&gt;</td>
<td>-0.842***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 FP rel. P&lt;sub&gt;max&lt;/sub&gt;</td>
<td>-0.763***</td>
<td>0.949***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 LSR mean V&lt;sub&gt;max&lt;/sub&gt;</td>
<td>-0.974***</td>
<td>0.764***</td>
<td>0.668**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 LSR mean P&lt;sub&gt;max&lt;/sub&gt;</td>
<td>-0.909***</td>
<td>0.920***</td>
<td>0.870***</td>
<td>0.850***</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 LSR time-to-zero Acc.</td>
<td>0.937***</td>
<td>-0.763***</td>
<td>-0.680***</td>
<td>-0.914***</td>
<td>-0.791***</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7 BDX 120 mean P&lt;sub&gt;max&lt;/sub&gt;</td>
<td>-0.618**</td>
<td>0.752***</td>
<td>0.706***</td>
<td>0.571**</td>
<td>0.707**</td>
<td>-0.598**</td>
<td>1</td>
</tr>
</tbody>
</table>

The linear trend between time and power is illustrated in the Figures 1,2 and 3 (power normalized to % of maximum for comparison purposes).
The linear relationship among variables was strong and statistically significant (Table 2) demonstrating that mechanical power measures can be associated with performance in events that require high muscular power. The data obtained during isokinetic knee extensions was more variable (Figure 3) compared to the other two methods of assessing power (Figure 1 and 2). Sprint time alone accounted for 82.32% of the variance in the general linear trend among power variables, as shown by a Principal Component Analysis. The results suggest that horizontal propulsive power and/or vertical jump power, but not isokinetic knee-extension power, could predict success in speed skating defined by the time from start to the 100-m line before the curve. The strong relationship of vertical velocity to horizontal speed skating velocity, speed skating power and 100 m sprint time reinforced the use of vertical jumps as a valid method to assess power of elite speed skaters.

Conclusion
The present research validated the use of different mechanical power estimates as indicators of speed skating performance in the 100 m sprint. Normalized peak power obtained in the vertical jump test appeared most valuable in predicting performance. In general, the mechanical measures used in this study could be assumed to reflect muscular power capability. Assessment of power capability is not dependent on skill in movements that share kinematics elements, but it is sensitive to the test used. Such a conclusion is further supported by the fact that vertical power in jumping and horizontal power in skating were strongly related, but knee extension power during isokinetic testing showed lower correlation coefficients. A possible explanation for the lower degree of association between the isokinetic method and sprint times could be its specificity. Isokinetic tests are anatomically specific, performed in one plane with a single limb, and limited to a single joint movement.

The laser device was introduced here to measure displacements of speed skaters. It allowed the calculation of the velocity-time profile, and subsequently, the calculation of horizontal power. The laser system has the advantage that feedback information could be immediately provided to coaches. For example, the time-to-zero acceleration, which showed strong and significant correlations with most parameters related to power. In conclusion, the vertical jump on a force plate is recommended as an off-season testing procedure to monitor changes in muscular power, while laser technology is recommended for assessing power capability for speed skaters when performing on ice.

References