APPENDIX A

Time Motion Analysis of Game Play
<table>
<thead>
<tr>
<th>Time Period</th>
<th>Players</th>
<th>5 University (Forwards)(^a)</th>
<th>3 University (Defensemen)(^a)</th>
<th>10 University(^b)</th>
<th>80 Junior(^c)</th>
<th>170 Midget(^c)</th>
<th>12 Old Timers(^d)</th>
<th>89 Minor League(^e)</th>
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<tbody>
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<tr>
<td>Bench time between shifts (s)</td>
<td>293±16</td>
<td>189±18</td>
<td>225±25</td>
<td>329</td>
<td>147.5</td>
<td>276.3±14.0</td>
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<td>Ice/shift time (s)</td>
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<td>146.3</td>
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<td>Bench/on-ice ratio</td>
<td>2.52</td>
<td>1.24</td>
<td>2.66</td>
<td>2.25</td>
<td>1.61</td>
<td>1.20</td>
<td>1.43</td>
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<tr>
<td>Playing time/game (s)</td>
<td>1152±54</td>
<td>1723±97</td>
<td>1471±84</td>
<td>1884</td>
<td>1032</td>
<td>1134</td>
<td>828</td>
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<td>Shifts</td>
<td>20.2±0.6</td>
<td>24.3±0.7</td>
<td>17.4±1.0</td>
<td>12.8</td>
<td>11.3</td>
<td>7.8±0.6</td>
<td>9.0</td>
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<tr>
<td>Playing time/shift (s)</td>
<td>57.9±2.5</td>
<td>73.1±4.7</td>
<td>85.4±3.1</td>
<td>86.9</td>
<td>139.1±10.5</td>
<td>94.9</td>
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<tr>
<td>Total stoppage time/shift (s)</td>
<td>58.2</td>
<td>79.3</td>
<td>62.3</td>
<td>59.4</td>
<td>75.3±8.8</td>
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<tr>
<td>Play stops/shift (s)</td>
<td>2.0±0.1</td>
<td>2.6±0.2</td>
<td>2.3±1.0</td>
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<td>3.5±0.3</td>
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<tr>
<td>Time/play stoppage (s)</td>
<td>29.1±3.3</td>
<td>30.5±4.1</td>
<td>27.1±1.4</td>
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<td>21.5</td>
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<tr>
<td>Playing time between stoppage (s)</td>
<td>29.5±0.8</td>
<td>28.5±0.3</td>
<td>39.7±2.6</td>
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<td></td>
<td></td>
<td>20.6±1.3</td>
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</table>

\(^a\) Data from Green et al. (1987a)  
\(^b\) Data from Green et al. (1976)  
\(^c\) Data from Léger (1980)  
\(^d\) Data from Montgomery & Vatzbedian (1979)  
\(^e\) Data from Paterson (1979)  

(Montgomery, 1988)
APPENDIX B

Physical Characteristics of Ice-Hockey Players
<table>
<thead>
<tr>
<th>Reference</th>
<th>Level of Play</th>
<th>Years of Experience</th>
<th>Age (yrs)</th>
<th>Stature (cm)</th>
<th>Mass (kg)</th>
<th>Body fat %</th>
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<tbody>
<tr>
<td>Houston &amp; Green (1976)</td>
<td>Minimum of 8</td>
<td>19.1±2.2</td>
<td>176.2±5.0</td>
<td>77.9±6.2</td>
<td>10.2±2.9</td>
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<tr>
<td>Forwards</td>
<td>Major Junior A &amp; University League (ice-hockey)</td>
<td>18.7±1.8</td>
<td>180.8±5.3</td>
<td>82.2±7.3</td>
<td>10.1±2.4</td>
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<td>Defense</td>
<td></td>
<td>19.5±2.7</td>
<td>176.5±4.6</td>
<td>72.9±7.9</td>
<td>9.6±4.2</td>
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<tr>
<td>Goalie</td>
<td></td>
<td>19-29</td>
<td>179.8±1.1</td>
<td>81.1±1.3</td>
<td>10.6±0.1</td>
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<td>Smith et al. (1982)</td>
<td>Canadian Olympic Ice-Hockey Team (n=23)</td>
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<td>Forwards</td>
<td></td>
<td>25.0±3.0</td>
<td>177.2±2.8</td>
<td>77.7±3.2</td>
<td>8.7±2.4</td>
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<td>Defense</td>
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<td>24.8±0.9</td>
<td>183.5±1.4</td>
<td>86.1±1.9</td>
<td>7.7±1.3</td>
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<tr>
<td>Goalie</td>
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<td>24.9±1.3</td>
<td>184.7±2.1</td>
<td>88.5±1.9</td>
<td>12.2±1.1</td>
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<td>Agre et al. (1988)</td>
<td>NHL (n=27)</td>
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<tr>
<td>Forwards</td>
<td></td>
<td>24.4±4.6</td>
<td>186.9±4.3</td>
<td>92.7±3.8</td>
<td>10.8±2.4</td>
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<tr>
<td>Defense</td>
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<td>24.7±2.6</td>
<td>187.7±4.8</td>
<td>93.9±4.2</td>
<td>12.1±2.5</td>
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<tr>
<td>Goal tenders</td>
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<td>27.3±4.5</td>
<td>184.2±3.1</td>
<td>84.1±4.6</td>
<td>13.5±3.1</td>
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<td>Smith et al. (1982)</td>
<td>NHL (n=31)</td>
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<tr>
<td>Forwards</td>
<td></td>
<td>4.68±2.69</td>
<td>12.18±2.05</td>
<td>153.05±14.38</td>
<td>44.41±12.30</td>
<td>18.37±5.5</td>
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<tr>
<td>Defense</td>
<td></td>
<td>3.80±1.74</td>
<td>10.95±0.55</td>
<td>143.43±8.3</td>
<td>36.44±7.13</td>
<td>19.7±4.1</td>
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<td>Boyle et al. (1994)</td>
<td>Competitive Field Hockey Players (n=9)</td>
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<tr>
<td>Elite Ice-Hockey Players (n=6)</td>
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<td>15.8±0.41</td>
<td>176.4±3.90</td>
<td>74.4±6.51</td>
<td>12.4±2.4</td>
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<tr>
<td>Bracko (2001)</td>
<td>Elite Women's Ice-Hockey Players (n=8)</td>
<td>17±6</td>
<td>176.2±2.3</td>
<td>68.9±6.4</td>
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<tr>
<td>Non-elite Women's Ice-Hockey</td>
<td>18±3</td>
<td>168.2±7.6</td>
<td>65.3±6.6</td>
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<tr>
<td>Players (n=15)</td>
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<tr>
<td>Bracko &amp; George (2001)</td>
<td>Women's Ice-Hockey Players (n=61)</td>
<td>4.60±2.18</td>
<td>12.18±2.05</td>
<td>153.05±14.38</td>
<td>44.41±12.30</td>
<td>18.37±5.5</td>
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<tr>
<td>Bracko &amp; Fellingham (2001)</td>
<td>Calgary Hockey Players &amp; American Hearing Impaired Hockey Association (n=19 female)</td>
<td>3.80±1.74</td>
<td>10.95±0.55</td>
<td>143.43±8.3</td>
<td>36.44±7.13</td>
<td>19.7±4.1</td>
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<tr>
<td>Calgary Hockey Players &amp; American Hearing Impaired Hockey Association (n=21 male)</td>
<td>5.0±0.89</td>
<td>10.75±0.65</td>
<td>140.92±4.11</td>
<td>35.66±4.32</td>
<td>7.58±2.24</td>
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<td>Calgary Hockey Players &amp; American Hearing Impaired Hockey Association (n=20 female)</td>
<td>4.25±2.27</td>
<td>12.75±0.54</td>
<td>158.6±1.07</td>
<td>46.97±7.95</td>
<td>17.43±3.71</td>
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<td>6.68±1.06</td>
<td>12.25±0.52</td>
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<td>48.28±8.54</td>
<td>6.80±3.41</td>
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<td>Calgary Hockey Players &amp; American Hearing Impaired Hockey Association (n=15 female)</td>
<td>5.96±3.03</td>
<td>14.55±0.46</td>
<td>164.85±5.94</td>
<td>58.83±5.92</td>
<td>19.88±4.85</td>
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<td>Calgary Hockey Players &amp; American Hearing Impaired Hockey Association (n=25 male)</td>
<td>9.0±1.63</td>
<td>14.65±0.26</td>
<td>166.69±9.99</td>
<td>56.92±9.61</td>
<td>13.8±2.96</td>
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<td>Hoff et al. (2005)</td>
<td>Elite</td>
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<tr>
<td>Junior Elite</td>
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<td>10+</td>
<td>24.2±4.7</td>
<td>179.9±6.1</td>
<td>84.2±8.1</td>
<td>16.6±4.0</td>
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<td>Behm et al. (2005)</td>
<td>Junior (n=30)</td>
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<tr>
<td>NHL Combines 2001 (n=74)</td>
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<td>17.9±0.5</td>
<td>185.5±4.3</td>
<td>88.8±6.3</td>
<td>10.2±1.6</td>
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<tr>
<td>NHL Combines 2002 (n=84)</td>
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<td>18.0±0.6</td>
<td>185.3±4.5</td>
<td>87.5±6.1</td>
<td>10.0±1.5</td>
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<tr>
<td>NHL Combines 2003 (n=92)</td>
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<td>18.0±0.6</td>
<td>186.1±4.4</td>
<td>87.5±7.6</td>
<td>9.5±1.6</td>
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</table>

Note: All measurements are in centimeters (cm) for stature, kilograms (kg) for mass, and percentages for body fat.
APPENDIX C

Muscular Endurance, Flexibility & Speed Characteristics of Ice-Hockey Players
<table>
<thead>
<tr>
<th>Author</th>
<th>Level of Play</th>
<th>Yrs of Experience</th>
<th>Age (yrs)</th>
<th>Vertical Jump (cm)</th>
<th>Push-Ups (1 min)</th>
<th>Sit-Ups (1 min)</th>
<th>Sit &amp; Reach (cm)</th>
<th>40 Yard Dash (s)</th>
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<tbody>
<tr>
<td>Bracko &amp; Fellingham (2001)</td>
<td>Calgary hockey players &amp; American Hearing Impaired Hockey Association (n=19 female)</td>
<td>3.80±1.74</td>
<td>10.95±0.55</td>
<td>29.76±6.63</td>
<td>28.94±12.62</td>
<td>32.5±8.0</td>
<td>39.6±7.82</td>
<td>7.45±0.61</td>
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<td>Calgary hockey players &amp; American Hearing Impaired Hockey Association (n=21 male)</td>
<td>5.0±0.89</td>
<td>10.75±0.65</td>
<td>33.46±7.48</td>
<td>22.21±10.96</td>
<td>30.78±11.94</td>
<td>33.77±7.56</td>
<td>9.44±0.52</td>
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<td>Calgary hockey players &amp; American Hearing Impaired Hockey Association (n=20 female)</td>
<td>4.25±2.27</td>
<td>12.75±0.54</td>
<td>31.0±7.2</td>
<td>31.95±10.65</td>
<td>35.15±7.5</td>
<td>37.39±9.99</td>
<td>7.01±0.5</td>
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<td>Calgary hockey players &amp; American Hearing Impaired Hockey Association (n=31 male)</td>
<td>6.68±1.06</td>
<td>12.25±0.52</td>
<td>37.93±7.5</td>
<td>29.60±10.13</td>
<td>38.23±8.41</td>
<td>36.24±7.71</td>
<td>6.58±0.49</td>
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<td>9.0±1.63</td>
<td>14.65±0.26</td>
<td>44.43±8.14</td>
<td>37.44±11.55</td>
<td>42.72±7.11</td>
<td>39.28±8.75</td>
<td>6.40±0.42</td>
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<td>Bracko (2001)</td>
<td>Elite Females (n=8)</td>
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<td>25±5</td>
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<td>Non-Elite Females (n=15)</td>
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<td>19±2</td>
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<tr>
<td>Bracko &amp; George (2001)</td>
<td>Women's Ice-Hockey Players (n=61)</td>
<td>4.68±2.60</td>
<td>12.18±2.05</td>
<td>31.29±8.15</td>
<td>29.16±11.10</td>
<td>33.17±8.75</td>
<td>38.83±9.04</td>
<td>7.19±0.7</td>
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<td>Hoff et al. (2005)</td>
<td>Elite</td>
<td>10+</td>
<td>24.2±4.7</td>
<td>48.2±4.6</td>
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<td>Junior elite</td>
<td>7</td>
<td>17.6±0.9</td>
<td>43.6±3.6</td>
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<td>Vescovi et al. (2006)</td>
<td>NHL Combines 2001 (n=74)</td>
<td>17.9±0.5</td>
<td>67.2±8.3</td>
<td>Max 23.1±3.8</td>
<td>Max 39.6±22.8</td>
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<td>NHL Combines 2002 (n=84)</td>
<td>18.0±0.6</td>
<td>58.8±6.1</td>
<td>Max 27.1±5.9</td>
<td>Max 23.5±12.9</td>
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<td>NHL Combines 2003 (n=92)</td>
<td>18.0±0.6</td>
<td>56.1±9</td>
<td>Max 22.5±6.0</td>
<td>Max 16.5±10.5</td>
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APPENDIX D

Aerobic & Anaerobic Capacity of Ice-Hockey Players
<table>
<thead>
<tr>
<th>Reference</th>
<th>Level of Play</th>
<th>Age (yrs)</th>
<th>VO$_2$ max (ml kg$^{-1}$ min$^{-1}$)</th>
<th>VO$_2$ max Protocol</th>
<th>HR max</th>
<th>Anaerobic Lactate Capacity (mmol L$^{-1}$)</th>
<th>Anaerobic Lactate Capacity Protocol</th>
<th>On-Ice Anaerobic Power (w kg$^{-1}$)</th>
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<tbody>
<tr>
<td>Cunningham et al. (1976)</td>
<td>Highly Successful Competitive Players (n=15)</td>
<td>10.6±0.3</td>
<td>56.6±7.7</td>
<td>PWG$_{150}$ (50 rpm, 5 min loads, 150 kpm for supramaximal)</td>
<td>197±8</td>
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<tr>
<td>Houston &amp; Green (1976)</td>
<td>Major Junior A &amp; University League (n=48)</td>
<td>16-20</td>
<td>44.4-66.5</td>
<td>12.9 km h$^{-1}$; 1% increase in grade every minute</td>
<td>7.2-21.7</td>
<td>12.9 km h$^{-1}$ at 20% grade, La 5 &amp; 12 min post test</td>
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<td>Smith et al. (1982)</td>
<td>Canadian Olympic Team (n=23)</td>
<td>19-29</td>
<td>54.0±1.2</td>
<td>Continuous Monark cycle protocol starting at 150 watts, increased by 0.5 Kp every 2 minutes</td>
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<td>Agre et al. (1988)</td>
<td>NHL (n=27)</td>
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<td>Treadmill Bruce Protocol</td>
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<td>Goalies</td>
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<td>192±3.7</td>
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<td>Forwards</td>
<td>24.8±0.9</td>
<td>54.2±1.3</td>
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<td>Defensemen</td>
<td>24.9±1.3</td>
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<td>183±3.5</td>
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<td>Twist &amp; Rhodes (1993b)</td>
<td>NHL (n=31)</td>
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<td>Forwards</td>
<td>24.4±4.6</td>
<td>57.4±3.1</td>
<td>15.1±2.1</td>
<td>Modified 30 s Wingate Cycle ergometre protocol</td>
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<td>24.7±2.6</td>
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<td>14.9±1.8</td>
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<td>Goal tenders</td>
<td>27.3±4.5</td>
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<td>14.9±2.2</td>
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<td>Dreger &amp; Quinney (1999)</td>
<td>Elite females (n=8)</td>
<td>25±5</td>
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<tr>
<td>Bracko (2001)</td>
<td>Elite</td>
<td>24.2±4.7</td>
<td>57.4±4.7</td>
<td>Treadmill (inclination 6°), speed 6 km h$^{-1}$ increased by 1 km h$^{-1}$ every minute</td>
<td></td>
<td></td>
<td></td>
<td>6.63±0.42</td>
</tr>
<tr>
<td>Hoff et al. (2005)</td>
<td>Junior Elite</td>
<td>17.6±0.9</td>
<td>58.5±4.4</td>
<td>Discontinuous incremental treadmill (3 min stages, 90 s rest between stages; 9.7 km h$^{-1}$ with 0% grade, 9.7 km h$^{-1}$, 5%, increasing by 1.6 km h$^{-1}$ &amp; 1%)</td>
<td></td>
<td></td>
<td></td>
<td>5.5±0.27 (40 m)</td>
</tr>
<tr>
<td>Green et al. (2006)</td>
<td>National Collegiate (n=29)</td>
<td>59±4</td>
<td></td>
<td></td>
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<tr>
<td>Vescovi et al. (2006)</td>
<td>NHL Combines 2001 (n=74)</td>
<td>17.9±0.5</td>
<td>58.9±3.5</td>
<td>Cycle ergometre (70 rpm, starting at 2.0 kp, increasing by 1 kp every 2 min for first 3 levels, there after by 0.5 kp every 1 min at 80 rpm)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>NHL Combines 2002 (n=84)</td>
<td>18.0±0.6</td>
<td>55.9±5.7</td>
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<tr>
<td></td>
<td>NHL Combines 2003 (n=92)</td>
<td>18.0±0.6</td>
<td>57.7±5.2</td>
<td></td>
<td></td>
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<td>Reference</td>
<td>Group</td>
<td>n</td>
<td>Peak Power (W kg⁻¹)</td>
<td>30-second Anaerobic Endurance (W kg⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Smith et al. (1982)</td>
<td>Canadian Olympic Forwards 1980</td>
<td>15</td>
<td>11.7±1.0</td>
<td>9.6±0.6</td>
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<td>Canadian Olympic Defense 1980</td>
<td>6</td>
<td>11.5±0.4</td>
<td>9.6±0.9</td>
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<td>NHL Defense</td>
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<td>12.0±1.5</td>
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<td>40</td>
<td>12.0±1.2</td>
<td>9.1±5.5</td>
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<tr>
<td></td>
<td>NHL Goal Tenders</td>
<td>8</td>
<td>11.4±1.1</td>
<td>8.6±5.2</td>
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<td>Montgomery &amp; Dallaire (1986)</td>
<td>Montreal Canadians- Defensemen</td>
<td>12</td>
<td>9.8±1.1</td>
<td>8.2±0.3</td>
<td></td>
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<tr>
<td></td>
<td>Montreal Canadians- Forwards</td>
<td>6</td>
<td>10.3±0.4</td>
<td>8.7±0.7</td>
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<tr>
<td></td>
<td>Montreal Canadians- Goaltenders</td>
<td>3</td>
<td>10.6±1.0</td>
<td>8.3±0.1</td>
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<tr>
<td></td>
<td>Montreal Canadians 1981-82</td>
<td>27</td>
<td>9.9±0.7</td>
<td>8.3±0.3</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Montreal Canadians 1982-83</td>
<td>30</td>
<td>10.4±1.1</td>
<td>8.7±0.8</td>
<td></td>
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<tr>
<td>Watson &amp; Sargeant (1986)</td>
<td>University and Junior</td>
<td>24</td>
<td>10.1±1.0</td>
<td>7.7±1.0</td>
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<tr>
<td>Gamble (1986)</td>
<td>University</td>
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<td>11.5±0.6</td>
<td>9.2±0.5</td>
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<tr>
<td>Brayne (1985)</td>
<td>University</td>
<td>17</td>
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<td>9.0±0.7</td>
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</table>

Montgomery (1988)
APPENDIX E

Physical Activity Readiness Questionnaire (PAR-Q)

(Canadian Society for Exercise Physiology)
Physical Activity Readiness Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES to one or more questions
Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.
- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions
If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:
- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _______________________________________________________________________
SIGNATURE ___________________________________________________________________________ DATE____________________________________________________
SIGNATURE OF PARENT _______________________________________________________________________
or GUARDIAN (for participants under the age of majority) WITNESS ________________________________

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.
Physical activity improves health.

Every little bit counts, but more is even better – everyone can do it!

Get active your way – build physical activity into your daily life...

• at home
• at school
• at work
• at play
• on the way ...that’s active living!

Choose a variety of activities from these three groups:

Endurance
4-7 days a week. Continuous activities for your heart, lungs and circulatory system.

Flexibility
4-7 days a week. Opening reaching, bending and stretching activities to keep your muscles relaxed and joints mobile.

Strength
2-4 days a week. Activities against resistance to strengthen muscles and bones and improve posture.

Starting slowly is very safe for most people. Not sure? Consult your health professional.

For a copy of the Guide Handbook and more information: 1-888-334-9769, or www.paguide.com

Eating well is also important. Follow Canada’s Food Guide to Healthy Eating to make wise food choices.

Get Active Your Way, Every Day – For Life!

Scientists say accumulate 60 minutes of physical activity every day to stay healthy or improve your health. As you progress to moderate activities you can cut down to 30 minutes, 4 days a week. Add-up your activities in periods of at least 10 minutes each. Start slowly… and build up.

Time needed depends on effort

Very Light Effort
• Stooping
• Draining

Light Effort
• Light walking
• Volunteering
• Easy gardening
• Baking leaves
• Stretching
• Gardening
• Water sports

Moderate Effort
• Brisk walking
• Yoga
• Easy cycling
• Raking leaves
• Swimming
• Dancing
• Water aerobics

Vigorous Effort
• Jogging
• Fast walking
• Fast cycling
• Fast swimming

Maximum Effort
• Sprinting
• Racing

You Can Do It – Getting started is easier than you think

Physical activity doesn’t have to be very hard. Build physical activities into your daily routine.

- Walk whenever you can – get off the bus early, use the stairs instead of the elevator.
- Reduce inactivity for long periods, like watching TV. Get up from the couch and stretch and bend for a few minutes every hour.
- Play actively with your kids.
- Choose to walk, wheel or cycle for short trips.
- Start with a 10 minute walk – gradually increase the time.
- Find out about walking and cycling paths nearby and use them.
- Observe a physical activity class to see if you want to try it.
- Try one class to start – you don’t have to make a long-term commitment.
- Do the activities you are doing now, more often.

Benefits of regular activity:

- better health
- improved fitness
- better posture and balance
- better self-esteem
- weight control
- stronger muscles and bones
- feeling more energetic
- relaxation and reduced stress
- continued independent living in later life

Health risks of inactivity:

- premature death
- heart disease
- obesity
- high blood pressure
- adult-onset diabetes
- osteoporosis
- stroke
- depression
- colon cancer

For more information, please contact the:

Canadian Society for Exercise Physiology
202-185 Somerset Street West
Ottawa, ON K2P 0J2
Tel. 1-877-651-3755 • FAX (613) 234-3565
Online: www.csep.ca

The original PAR-Q was developed by the British Columbia Ministry of Health. It has been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gedhill (2002).

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APPENDIX F

Letters of Approval From University of Pretoria & University of Montréal Ethics Committees
Dossier No. 735

Département de kinésiologie

Montréal, le 26 septembre 2006

Monsieur Luc Léger
Professeur titulaire
Département de kinésiologie
CEPSUM, 2100 boul. Édouard-Montpetit
Bureau 7203

OBJET : Certificat d’éthique

Monsieur Léger,

Vous avez soumis le projet intitulé « Validité comparative de trois tests en patin à glace pour évaluer l’aptitude aérobie de hockeyeurs adultes » pour évaluation par le Comité d’éthique de la recherche des sciences de la santé (CÉRSS).

Je suis heureuse de vous informer que le Comité a jugé le projet conforme aux normes déontologiques. Un certificat d’éthique a donc été émis et vous est envoyé.

Le certificat d’éthique est émis pour une durée d’un an. À l’échéance, un suivi déontologique sera effectué, conformément aux normes de fonctionnement du Plan d’action ministériel en éthique de la recherche et en intégrité scientifique.

Il est aussi à souligner que vous devrez faire part au CÉRSS de toute nouvelle information (changement dans les connaissances scientifiques...) ou observation (événement négatif...) ou de tout changement au protocole expérimental, qui pourrait modifier le fondement éthique sur lequel repose votre projet de recherche.

Je vous prie de recevoir, Monsieur, l’expression de mes salutations distinguées.

Marie-France Daniel
Présidente
Comité d’éthique de la recherche des sciences de la santé
CEPSUM, 2100 Edouard-Montpetit, bureau 7211
 Téléphone : (514) 343-5624
 Télécopieur : (514) 343-2181
 Courriel : marie-france.daniel@umontreal.ca

p.j.
COMITÉ D'ÉTHIQUE DE LA RECHERCHE DES SCIENCES DE LA SANTÉ  
(CÉRSS)  
CERTIFICAT D'ÉTHIQUE  

Titre du projet : Validité comparative de trois tests en patin à glace pour évaluer l'aptitude aérobie de hockeyeurs adultes  

Sous la direction de : Monsieur Luc Léger  

Nom de l'étudiant : Madame Suzanne Kuisis  

À la réunion du 28 août 2006, 11 membres du CÉRSS étaient présents : la présidente, la vice-présidente, l'experte en éthique, l'experte en droit, un représentant du public, la représentante des étudiants, le représentant de la Faculté de pharmacie, la représentante de la Faculté de médecine dentaire, la représentante de l'École d'optométrie, la représentante de la Faculté des sciences infirmières, le représentant du Département de kinésiologie.  

Le Comité a jugé le projet mentionné ci-haut conforme aux règles d'éthique de la recherche sur les êtres humains.  


Le 26 septembre 2006.  

Marie-France Daniel  
Présidente  
Comité d'éthique de la recherche des sciences de la santé  
CEPSUM, 2100, Edouard-Montpetit, bureau 7211  
Téléphone : (514) 343-5624  
Télécopieur : (514) 343-2181  
Courriel : marie-france.daniel@umontreal.ca
31 January 2006

Dear Doctor van Heerden,

Project: Validation and normative establishment of the modified (skating) 20 Metre Multi-stage Shuttle-run Test
Researcher: SM Kuisis
Supervisor: Dr HJ van Heerden
Department: Biokinetics, Sport & Leisure Science
Reference number: 25519833

Thank you for your correspondence of 7 December 2005 regarding the above application for ethical clearance.

I have pleasure in informing you that the Research Proposal and Ethics Committee formally approved the above study at an ad hoc meeting held on 26 January 2006. The approval is subject to the candidate abiding by the principles and parameters set out in her application and research proposal in the actual execution of the research.

The Committee requests you to convey this approval to Ms Kuisis.

We wish you success with the project.

Sincerely

Prof Brenda Louw
Chair: Research Proposal and Ethics Committee
Faculty of Humanities
UNIVERSITY OF PRETORIA
RE: Ethics Certificate

Sir,

You submitted the project entitled “Comparative validity of three ice skating tests to evaluate the aerobic aptitude of adult hockey players” for assessment by the Ethics Committee of the Health Science Research Institute (CERSS).

I am glad to inform you that the committee considered that the project complied with deontological standards. Therefore, an ethics certificate has been issued and is being sent to you.

The ethics certificate is issued for a period of one year. At the end of the period, a deontological follow-up will be carried out, in accordance with the operating standards of the ministerial plan of action for research ethics and scientific integrity.

We wish also to emphasise that you will have to inform the CERSS of any new information (change in scientific knowledge…) or observation (negative event) or any change in the experimental procedure, which could modify the ethical basis on which your research project rests.

Yours faithfully

Marie-France Daniel
Chairlady
CERSS
CEPSUM, 2100 Edouard-Montpetit, office 7211
Tel. (514) 343-5624
Fax: (514) 343-2181
e-mail: marie-france.daniel@umontreal.ca
Title of the Project: Comparative validity of three ice skating tests to evaluate the aerobic aptitude of adult hockey players.

Under the direction of: Mr. Luc Léger

Name of student: Mrs Suzanne Kuisis

At the meeting of 28 August 2006, 11 members of the CERSS were present: the chairlady, the vice-chairlady, the ethics expert, the law expert, a representative of the public, a student representative, representatives of the faculty of pharmacy, a representative of the faculty of dental medicine, a representative of the optometry School, a representative of the faculty of nursing, a representative of the Department of kinesiology.

The committee considered that the above-mentioned project complied with the ethics rules of research on human beings.

The certificate is issued for the period from 26 September 2006 to 25th September 2007

26 of september 2006

Marie-France Daniel
APPENDIX G

Informed Consent

Please note that this document was originally in French (as all the subjects were French) and has been translated for examination purposes.
Voluntary consent Form
To take part in the study described below

TITLE OF STUDY:
COMPARATIVE VALIDITY OF THREE ICE SKATING TESTS TO EVALUATE THE AEROBIC APTITUDE OF ADULT HOCKEY PLAYERS

STUDENT RESEARCHER: Suzan KUISIS
Institution/Department: University of Montréal, Department of Kinesiology
Address: CP 6128, succ. Centre ville. MONTREAL H3C 3J7, Canada
Telephone: +1 (514)343 6111 Extension 3125
E-mail: suzan.kuisis@up.ac.za

MAIN RESEARCHER: Luc LEGER
Institution/Department: University of Montréal, Department of Kinesiology
Address: CP 6128, succ. Centre ville. MONTREAL H3C 3J7, Canada
Telephone: +1 (514)343 7792
E-mail: luc.leger@umontreal.ca

INTRODUCTION
Maximum oxygen consumption (VO₂ max) is a key parameter for performance in ice hockey. This is usually measured directly, in a laboratory where the subject is connected to a gas analyzer. Three new ice-skating tests to measure VO₂ max have recently been developed to make testing more specific to the sport, and that predict VO₂ max from the maximum speed reached during those tests that have progressively increasing speed. These new tests have been researched by different researchers on different groups of subjects. It is necessary to validate the new tests and to compare these new tests to determine the advantages and disadvantages of each test.
AIMS AND OBJECTIVES OF THE STUDY

The aims of this study are to:
1. assess the validity and suitability of three ice-skating tests and compare the three ice-hockey tests to determine their degree of concordance,
2. compare these tests to the measurement of VO₂ max obtained on the treadmill in the laboratory, and
3. compare a conventional 20-m shuttle running test in a gymnasium with the hypothesis that such a simple test would be as valid as more specific ice skating tests that require costly ice time.

TERMS FOR PARTICIPATION IN THE STUDY

Each subject must therefore be available for 5 tests within a 2 to 3 week period. The tests take place in a mixed order according to the first test the subject takes, in order to avoid any bias. No more than one test per day and no more than 3 tests on consecutive days will be performed as this will affect the results. The tests will consume approximately 2 hours of your time. The tests will take place at the Human Performance laboratory, gymnasium, and the ice arena at CEPSUM (University of Montreal). Tests will be conducted by the student researcher, Suzan Kuisis, who will be assisted by students.

DESCRIPTION OF THE TESTS

STANDARD TEST ON TREADMILL

The treadmill test will be done in the Human Performance Laboratory of the Department of Kinesiology, at the University of Montréal also located in the CEPSUM. The maximum standard treadmill test with multiple stages will be approximately 10 to 20 minutes in duration according to each subject’s physical aptitude. This test begins at 10 km h⁻¹ (slow speed, easy for everyone); the speed increases with 1 km h⁻¹ after each 2 min stage. A nose clip will be worn and a mouthpiece is held in the mouth. During this test, the subject will be connected to a gas analyzer, the subject breathes through the mouthpiece, which containing a valve which directs the ambient air into the mouth at the time of the inspiration and the air expired into the system for means of analysis and calculation of the oxygen uptake (VO₂), a measure of the expenditure of energy. The mouthpiece and the valve are maintained in place by means of an adjustable headset. The subject also wears a nose-clip. Besides the slight discomfort, this system does not present any risk for the subject. The VO₂ measured within the last stage represents the maximum oxygen consumption of the subject (VO₂ max). This measurement of the aerobic aptitude is used as standard measurement to validate the field tests, in gymnasium and on ice.
FIELD TESTS IN THE GYMNASIUM AND ON ICE

Each subject must also do 4 other field tests, in a gymnasium (1x) or on ice with skates (3x). These tests are carried out in groups of 3 to 6 subjects. The duration of these tests is 10 to 20 minutes, but will depend on the physical aptitude of each subject. Each test is maximal and progressive, and is easier at the start and becomes more difficult. Subjects are required to give a maximal effort. Subjects will need to allow time for changing into full hockey kit and for a 5 minute explanation of each test.

The principle characteristics of each of the field tests are described in Table 1 below and shown in Figure 1.

Table 1. Characteristics of the maximal multistage running and ice skating tests.

<table>
<thead>
<tr>
<th>Source</th>
<th>20-m shuttle run</th>
<th>20-m shuttle skate</th>
<th>45-m shuttle skate</th>
<th>48.8 m shuttle skate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement technique</td>
<td>Shuttle Stop &amp; Go Gym Running</td>
<td>Shuttle Stop &amp; Go Ice Skating 1 hand on stick</td>
<td>Shuttle Stop &amp; Go Ice Skating 1 hand on stick</td>
<td>Shuttle Wide turn Ice Skating 1 hand on stick</td>
</tr>
<tr>
<td>Protocol Type</td>
<td>Max Multistage Continuous Linear 0 s 8.5 km h⁻¹ 0.5 km h⁻¹</td>
<td>Max Multistage Continuous Linear 0 s 10.0 km h⁻¹ 0.5 km h⁻¹</td>
<td>Max Multistage Intermittent Linear 30 s 12.6 km h⁻¹ 0.72 km h⁻¹</td>
<td>Max Multistage Continuous Curvilinear 45 s → 19.5 s* 0 s 15 s (11.7 km h⁻¹) -5 s (0.4 → 2.0 km h⁻¹)</td>
</tr>
<tr>
<td>Speed vs Stage</td>
<td>Linear 1 min</td>
<td>Linear 1 min</td>
<td>Linear 1 min</td>
<td>Linear 1 min</td>
</tr>
<tr>
<td>Stage duration</td>
<td>0 s</td>
<td>0 s</td>
<td>30 s</td>
<td>45 s → 19.5 s*</td>
</tr>
<tr>
<td>Rest interval</td>
<td></td>
<td></td>
<td>0 s</td>
<td>0 s</td>
</tr>
<tr>
<td>Initial speed</td>
<td>8.5 km h⁻¹</td>
<td>10.0 km h⁻¹</td>
<td>12.6 km h⁻¹</td>
<td>15 s (11.7 km h⁻¹)</td>
</tr>
<tr>
<td>Speed increase</td>
<td>0.5 km h⁻¹</td>
<td>0.5 km h⁻¹</td>
<td>0.72 km h⁻¹</td>
<td>-5 s (0.4 → 2.0 km h⁻¹)</td>
</tr>
<tr>
<td>Equipment</td>
<td>Running shoes</td>
<td>Full hockey gear (+ portable VO₂ system**)</td>
<td>Full hockey gear</td>
<td>Skates, Stick, helmet, gloves</td>
</tr>
</tbody>
</table>

* For the best results so far
Figure 1. Ice-skating tests

1. Kuisis 2001 Test

2. Leone Test

3. Faught Test

\[ y = 0.6693x + 10.233 \]
MEASUREMENTS TAKEN DURING THE TESTS

1. The performance score of the test is the number of completed stages
2. VO\(_2\) will be measured continuously during the standard treadmill test. The maximum value reached at the end of the test (VO\(_2\) max) is used as the standard to validate the maximum speed reached at the end of the field tests. The VO\(_2\) is measured by the collection of gases expired during the treadmill test, as described in the preceding section
3. Measurement of blood lactate will be used as an indication of the overall intensity of the tests, indicating the gross anaerobic contribution of the test. Lactate will be measured by pricking the finger and collecting a drop of blood, between 5 and 8 minutes of completion of each test. This procedure is similar to that used by people who monitor their blood glucose by means of a domestic glucose meter. The prick is a little painful, but it is without danger if one takes the precautions (sterilization)
4. Measurement of maximal HR at the end of each test to determine the respective intensity or difficulty of each test
5. The Borg Rated Perceived Exertion (RPE) is also used to establish the degree of difficulty of each test, and is subjectively established on a 6 to 20 point scale from "very very easy" to "very very difficult" and constitutes another classical indication of the overall difficulty of each test. This only takes a few seconds
6. Likert resemblance score is obtained on a subjective scale. Each test will be evaluated at 5 levels (questions), on a scale of 1 to 7 where subjects rate the similarity of the test to ice-hockey and the suitability of the test to evaluate aerobic fitness in ice-hockey players. This takes less than one minute to answer
7. During the tests on ice, the subjects will be filmed in order to try to develop indices of the level of skill and technique of stopping, starting, the skating of crossovers and turns. The technical level could then be used, with maximum speed, as a determinant in the prediction of VO\(_2\) max.

CONDITIONS OF PARTICIPATION

*Inclusion criteria*
1. healthy males aged between 18 and 50 years of age,
2. hockey players who have mastered their skating skills (start, stop, forward acceleration, skating turns and cross-overs)
3. be available for the duration of the study and to come to the University for all 5 testing sessions
4. read, understand and voluntarily sign an informed consent form describing the tests to be done
Exclusion criteria

1. Failure to meet inclusion criteria just described
2. Having a medical contraindication to exercise from his medical doctor or answer yes to any of the questions in the PAR-Q physical readiness questionnaire of the Canadian Society for Exercise Physiology
3. Injury during the testing period

ADVANTAGES IN PARTICIPATING

The evaluation of an athlete’s physical aptitude, whatever his speciality, forms part of the planning process of sport training. The evaluation of physical aptitude in athletes is a specialized process. By participating in this project you will obtain results regarding your aerobic capacity, which constitutes an important aspect of performance. We will also be able to discuss with you the strategies which are available to you to improve this parameter.

RISKS AND DISCOMFORT

In the course of those physical tests, you may experience great fatigue. All precautions are taken to ensure that the tests take place in the safest manner possible. The laboratory is equipped with an automated external defibrillator and researchers have obtained cardiopulmonary resuscitation certificates (the Head of the laboratory is also a certified CPR instructor, Arthur Long, 343 6111, extension 4238).

The PAR-Q questionnaire helps to minimize the risk of your participation, and eliminate subjects who are potentially at risk. The PAR-Q comprises a margin of error and the risks detected by the PAR-Q require confirmation by a doctor.

VOLUNTARY PARTICIPATION AND WITHDRAWL OR EXCLUSION FROM THE STUDY

Your participation is completely voluntary. You have a 48 h delay after: 1) you have filled in the PAR-Q, 2) acquainted yourself with the consent form, and 3) asked for additional explanations from the researcher and confirm your participation in the study, in order to give you time to ask for advice of a third party if need be.

If you wish to be included in the study, we will then ask you for your written consent by signing this form. If you no longer wish to participate, you are free to withdraw at anytime without prejudice and without having to justify your decision. If necessary, you must notify one of the two principal researchers identified at the beginning of this form.
You will be advised of all new information likely to make you reconsider your participation in the study.

COMPENSATION IN THE CASE OF HARM

The University of Montréal is required by law to compensate for prejudices/ injuries which may have been caused by your taking part in this study.

CONFIDENTIALITY OF INFORMATION

All the data and information concerning subjects will remain STRICTLY CONFIDENTIAL and will be saved in individual files identified by a rank number corresponding to the first test taken by all the subjects (from 1 to 30 in the order of inclusion), and subjects real identification will be kept in a separate file kept in another secure place accessible to the researchers only. Individual files will be stored for 7 years after the study to be destroyed thereafter.

The results can be obtained only from the principal researchers or the associated researchers, who are Suzan Kuisis, doctoral student responsible for the project (University of Pretoria, South Africa) and Luc Leger, professor responsible for supervising the project (University of Montreal). Authorized representatives of the ‘research institutions, government agencies or ethics committees can possibly ask to examine the personal data for ethical review or follow-up. The original data will be preserved in South Africa but the principal researcher also preserves an electronic copy of the captured data.

QUESTIONS ON THE STUDY (INFORMATION & EMERGENCY)

If you have any questions regarding the study, please communicate with the researchers:

Suzan KUISIS suzan.kuisis@up.ac.za Tel: +1 (514)343 6111 Extension 3125
Luc LEGER luc.leger@umontreal.ca Tel: +1 (514)343 7792

ETHICS

If you have any ethical problems or concerning the conditions of your participation this study, you can discuss it with the person responsible for the project, or explain your concerns to the president of the Ethical Council of Health Science Research, Marie-France Daniel, telephone (514) 343-5624.

After following this procedure, if you had serious reasons to believe that the answer brought is insufficient, you could enter into communication with the officials of the University, Mrs Marie-José Rivest (telephone (514) 343-2100).
SIGNATURES

TITLE OF STUDY:
Comparative validity of three ice skating tests to evaluate the aerobic aptitude of adult hockey players

MAIN RESEARCHER OR RESEARCHER RESPONSIBLE FOR THE STUDY :
(name in well formed letters):

I, (name of the participant in well-formed letters)..........................................................
declare that I acquainted myself with the attached documents of which I received a copy,
that I discussed it with (name of the investigator in well-formed letters)........................
and that I understand the aim, nature, advantages, risks and disadvantages of the study in question.

After some thought and a reasonable period of time, I freely consent to take part in this study. I know that I can withdraw at any time without any prejudice.

Signature of the participant.................................. Date ............................................
Signature of the parent if you are under 18 years of age
____________________________________________Date____________

I, (name of the investigator in well-formed letters)........................................................
declare that I explained the aim, nature, advantages, risks and disadvantages of the study
to (name of participant in well-formed letters)............................................................

Signature of the investigator ................................. Date ............................................
APPENDIX H

Order of Testing
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APPENDIX J

Borg Rating of Perceived Exertion Scale
Borg Scale

Rating of Perceived Exertion

6
7 Very, very light/ Très, très facile
8
9 Very light/ Très facile
10
11 Fairly light/ Assez facile
12
13 Somewhat hard/ Assez difficile
14
15 Hard/ Difficile
16
17 Very hard/ Très difficile
18
19 Very, very hard/ Très, très difficile
20
APPENDIX K

Likert Scale
Likert scale

Q1 Similarity of basic skating skills (not puck handling) of test compared to those of a hockey game
LOW   HIGH
1  2  3  4  5  6  7

Q2 Resemblance between the maximal intensity of the test & maximal intensity of a hockey game
LOW   HIGH
1  2  3  4  5  6  7

Q3 How is the test suited to evaluate aerobic fitness of hockey players
LOW   HIGH
1  2  3  4  5  6  7

Q4 How is the test suited to evaluate overall fitness (including muscular and cardiovascular fitness) of hockey players
LOW   HIGH
1  2  3  4  5  6  7

Q5 How is the test suited to evaluate overall hockey ability (fitness and technical (skating) skills) of hockey players
LOW   HIGH
1  2  3  4  5  6  7
Validity of 3 ice skating aerobic field tests for hockey players.

Kuisis, Suzan Mary\textsuperscript{1}, Léger, Luc\textsuperscript{2}, van Heerden Hendrik, Johannes\textsuperscript{1}, Bekraoui, Nabil\textsuperscript{2}, and Long, Arthur\textsuperscript{2}

\textsuperscript{1}University of Pretoria, South Africa and \textsuperscript{2}Université de Montréal, Canada

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\texttt{skuisis@mweb.co.za}
Abstract

Three aerobic maximal multistage ice skating tests have recently been introduced: 1) MS20MST, a continuous 20 m stop-and-go; 2) SMAT, an intermittent 45 m stop-and-go; and 3) FAST, a continuous 48.8 m shuttle with wide turns. In a paired design, the aim was to compare MS20MST, SMAT, and FAST to each other and to treadmill VO_{2,max} and to the 20 m gym aerobic shuttle run (20 MST) in order to assess the relative validity of these tests to predict maximal aerobic power (VO_{2,max}), to determine which test is best suited to do so and best rated by subjects, and to determine if these on-ice skating tests are any better than the over-ground 20 MST in 25 adult ice hockey players. Similitude with the intensity of hockey game and suitability as an aerobic test for ice-hockey was determined with a subjective 7-point Likert resemblance scale. FAST showed the lowest (p<0.05) Borg RPE, maximal lactate, HR_{max}, and ratings on the Likert Scale. Compared to treadmill VO_{2,max}, correlations were 0.74, 0.73, 0.41 and 0.84 for MS20MST, SMAT, FAST and the 20 MST, respectively, and 0.75, 0.78, 0.53 and 0.94, respectively with maximal treadmill speed. FAST is less valid than MS20MST and SMAT, and it’s lower HR_{max} and LA_{max} values do not support that test. Correlations between MS20MST, SMAT and 20 MST were approximately 0.7 but lower between these tests and FAST (approximately 0.4). MS20MST or SMAT protocols should be used if ice time is available, alternatively the gym 20 MST.

Keywords: Aerobic power, Skating, Ice-hockey, Modified Skating 20 MST, SMAT, FAST, test, validity, shuttle
Introduction

Maximal aerobic power is a key parameter for sport performance even for a highly anaerobic and high-speed intermittent sport such as ice hockey (Montgomery, 2006). VO$_2$max values are also specific to the muscles used and the type of activity used by subjects in their training regimen (Léger et al., 1980, Mc Ardle et al., 1978), and demonstrated that as compared to runners, ice-hockey players had a 15% greater mechanical efficiency while skating on the ice and a 7.9% lower mechanical efficiency on the treadmill (Léger, Seliger & Bassard, 1979). Sport specific tests are thus highly valued and have been applied in many sports such as endurance running (Léger & Boucher, 1980), intermittent running sports such as soccer and basketball (Léger et al., 1988), cross-country skiing (Doyon et al., 2001; Vergès et al., 2006), badminton (Chin et al., 1995), cycling (Ricci & Léger, 1983; Marion & Léger, 1988), swimming (Lavoie et al., 1985; Monpetit et al., 1981), water polo (Rechichi et al., 2000), and soccer (Nicholas, Nuttall & Williams, 2000; Labsy et al., 2004).

In an attempt to make laboratory testing more specific to ice-hockey, Montgomery's group from McGill University in Montreal (Nobles et al. 2003) developed a skating treadmill protocol. The skating treadmill is more “skating specific” than running or cycling, because it mimics the skating movement and solicits same muscle groups; it is also easier to control the speed and distance on a skating treadmill (vs. ice field tests). However the skating treadmill has many disadvantages (grade skating alters the mechanics of skating and increases resistance, low accessibility, high cost, individual testing and non-competitive environment, lack of wind resistance, and higher temperature).
Recently three new skating tests to assess aerobic fitness have emerged, namely the Skating Multistage Aerobic Test (SMAT, Leone et al., 2007), the Modified Skating MST (MS20MST, Kuisis, 2003), and the Faught Aerobic Skating Test (FAST, Petrella et al., 2007). The validity of these three ice-skating field tests is, however, not always obvious since the reported statistical indices (r and SEE) are quite different, probably because they were obtained for different age and gender groups, sometimes with small groups of subjects, wearing different equipment, and using different types of protocols. Among the newly introduced tests, required skating ability and skills are different. Direction changes in the MS20MST and SMAT rely on stop-and-go while FAST requires a wide turn and cross-over skating. Thus with a paired design, the aim of the study was to compare MS20MST, SMAT, and FAST to each other and to a treadmill VO$_2$max criterion in order to determine the best aerobic skating test; to determine which test is rated by the players as being the best suited and most functional test, and finally to compare each test to the 20 MST (Léger et al., 1988) to determine if these on ice skating tests are any better than the over-ground 20 MST that does not require costly ice time.

Materials and methods

Subjects and experimental protocols

Adult male ice-hockey players (n=26) of various fitness and ice-hockey levels gave their informed consent to participate in the study approved by the ethics committee of the university approximately six weeks before the start of the ice-hockey competitive season.
Only 16 subjects were able to free themselves to complete all five tests (Table 1). All testing facilities, Human Performance Laboratory, Indoor track and Ice arena (55 m x 26 m), were located in the university fitness center (CEPSUM, University of Montreal). Subjects performed five maximal multistage aerobic tests on separate days, and were not permitted to participate in more than one test per day on any two consecutive days, where after a minimum period of 24 hours rest was required before the next test. All five tests were however completed within three weeks. Due to the fact that there were up to four subjects participating in the field tests at the same time, test order could not be totally randomized. However, test order was mixed as much as possible to avoid any systematic ordering of the tests. All ice-tests were done on resurfaced ice. Field tests are detailed in Table 2.

Warm-up before running tests (treadmill and 20 MST) consisted of four to five minutes low intensity jogging (6-8 km h\(^{-1}\)), followed by five minutes of stretching. Upon completing the running tests, subjects recovered actively for four to five minutes by walking. Warm-up procedures for all ice protocols (MS20MST, SMAT and FAST) consisted of five minutes of submaximal skating around the outer perimeter of the ice (alternating direction), followed by a few easy stop and go drills, for the MS20MST and SMAT. Finally four to five minutes of stretching was performed. Upon completing the skating tests, subjects recovered actively for four to five minutes by skating slowly and gliding around the ice. Before any of the field tests were begun, the compact disc of the specific test was played, consisting of a brief explanation of the test, leading to a
countdown of the start. Set-up, procedures, and termination criteria were used as specified by the respective authors.

**Dependent variables and methods**

**Heart rate (HR)**

HR was continuously measured with a Polar pulse monitor (Polar Electro, Kempele, Finland). Submaximal HR values were recorded at 15 s intervals. Maximal HR value was recorded at the end of each test as an indication of the overall difficulty or intensity of each test.

**Blood lactate**

A Lactate Pro (Arkray, Inc, Kyoto, Japan) was used to assess finger prick (capillary) lactate between five and eight minutes of recovery. Blood lactate was considered another indication of the overall intensity of the tests, indicating the gross anaerobic contribution of the test.

**Borg Rate of Perceived Exertion Scale (RPE)**

The Borg Rated Perceived Exertion (RPE) (Borg, 1970) was subjectively established on a 6 to 20 point scale for every test upon termination of the test to determine the final perceived intensity of the tests.

**Likert Resemblance Scale**
A resemblance score was obtained on a subjective seven point Likert (1932) scale (one being the lowest possible score and seven being the highest possible score, for all questions, the higher the score, the better the result, indicating, for example, greater similarity between the test and an ice-hockey game or greater suitability of the tests to assess aerobic fitness in adult ice-hockey players); after the completion of each test. Each of the tests performed by the subjects was evaluated at five levels:

1. the similarity of the technical skating skills (excluding stick/puck handling) of the test with those of the hockey game,
2. the resemblance between the maximal intensity of the test and maximal intensity of the hockey game,
3. how the test is suited to evaluate aerobic fitness of the hockey players,
4. how the test is suited to evaluate overall fitness (including cardiovascular and muscular fatigue) of the hockey players, and
5. how the test is suited to evaluate overall hockey ability (fitness and technical skating skills) of the hockey players.

$\text{VO}_{2\text{max}}$

$\text{VO}_2$ was measured every 30 s with the open circuit method (Moxus Modular $\text{VO}_2$ system, AEI Technologies, Pittsburgh, Etats-Unis) during the laboratory treadmill running test. The $\text{VO}_2$ system was calibrated with standard reference gases and for volume approximately five minutes prior to each treadmill test. $\text{VO}_2$ values were recorded every 30 s. This protocol was a continuous multistage test with initial speed set at 10 km·h$^{-1}$ with 1 km·h$^{-1}$ increment per stage (two minutes) thereafter. The subject ran
until volitional exhaustion, and the highest VO\(_2\) achieved (VO\(_2\) peak) was considered VO\(_2\)\(_{\text{max}}\). VO\(_2\)\(_{\text{max}}\) values for field tests were also estimated using original regression equation (Table 2).

Statistical analysis

Statistical analyses were performed using Statistica software (6\(^{\text{th}}\) Edition, www.statsoft.com). Descriptive statistics (mean ± SD) were conducted for all variables. Multiple regression analysis was employed to construct an equation to predict VO\(_2\)\(_{\text{max}}\) from the MS20MST using direct VO\(_2\)\(_{\text{max}}\) from the treadmill test as the dependant variable and maximal MS20MST speed, height and weight, as the independent variables. Comparisons of maximal values of different variables (VO\(_2\)\(_{\text{max}}\), HR\(_{\text{max}}\), Speed max, Lactate\(_{\text{max}}\), test duration, Borg RPE max, and Likert scores) were done with a repeated one-way ANOVA to assess similarity in physiological difficulty of each test on the 16 subjects that completed all the tests. A posteriori test (Tukey) was used to determine exactly where the differences existed. Pearson correlation coefficients were also estimated for each variable in every test. Regression analysis (scatter plot, Pearson correlation and SEE) were applied between direct treadmill VO\(_2\)\(_{\text{max}}\) and maximal speed for each of the four tests to establish predictive model, to determine the external validity and to compare validity of each field test in a pairwise design (n=16 to 23).

Another purpose was to establish pairwise equivalence between field tests. Since conventional regression analysis assumes that one variable is independent and the other, dependent, which is not the case when you compare two different field tests and, since, two non algebraically equivalent regressions are obtained depending on the subjective
choice of the dependent variable, another approach was taken which would yield a bisectrix regression in the middle of the two others (Andersen et al., 1986). It is like considering perpendicular least squares to the regression line, instead of vertical ones. To get that regression, the slope $b$ of the conventional regression has to be divided by the $r$ value (new slope $b = \frac{\text{conventional slope}}{r}$) and to obtain the new intercept $a$, the average values of $X$ and $Y$, have to be entered in the equation ($Y = a + b \times X$) using new slope $b$. SEE was obtained using predicted value of that non conventional regression model: \[ \text{SEE} = \sqrt{\frac{\sum (Y_{\text{observed}} - Y_{\text{predicted}})^2}{(n-2)}}. \]

**Results**

**VO}_{2\text{max prediction from MS20MST.}**

Among potential and pertinent predictors of VO$_{2\text{max}}$ such as MS20MST maximal speed, weight and height, only the MS20MST maximal speed ($X$, km h$^{-1}$) was retained by the stepwise multiple regression as a significant predictor of VO$_{2\text{max}}$ ($Y$, ml kg min$^{-1}$):

\[ Y = -33.337 + 6.24 \times X, \quad r = 0.74, \quad \text{SEE} = 5.93 \text{ (11.2%), } n = 21 \quad \text{EQ-1} \]

**ANOVA comparisons between tests for each variable.**

Anova and a posteriori Tukey tests revealed significant differences between tests (Figures 1 and 2). Maximal speed was progressively higher from the MS20MST, SMAT and FAST (13.7, 17.9, 20.3 km h$^{-1}$, $p<0.01$). Concerning duration of on-ice skating tests, it increased from MS20MST, to FAST, and to SMAT (5.62, 8.03 and 11.73 min, $p<0.01$). Maximal HR was higher during the treadmill test than during FAST (189.9 and 183.4 bpm, $p\leq0.01$) and also higher during SMAT than FAST (189.1 and 175.8, $p\leq0.05$). No
other maximal HR difference was observed. Using the 6 to 20 RPE Borg scale, FAST was also subjectively perceived to be less difficult than any of the other four tests (15.1 vs. 16.9 and above, \( p \leq 0.05 \)). With regards to maximal lactate, SMAT was higher than treadmill, FAST and 20 MST lactate (12.0, 9.3, 10.2 mM respectively, \( p \leq 0.001 \)) and MS20MST lactate higher than FAST lactate (11.33 and 9.19 mM, \( p \leq 0.05 \)).

The predicted 20 MST VO\(_{2\text{max}}\) was significantly lower than the other tests except for the SMAT (48.4 vs. 51.8 to 54.0 ml kg\(^{-1}\) min\(^{-1}\), \( p < 0.05 \), Figure 1).

Subjective ratings among the five tests are shown in Figure 2. When subjects rated the similarity of the skating skills (Q1) required by the test as compared to those required during a hockey game (excluding puck handling), both running tests yielded lower ratings than the three ice skating tests. And within the 3 ice skating tests, FAST scores were lower than MS20MST scores. MS20MST and SMAT are the best tests to mimic skating skill.

With regard to the similarity of the intensity of the tests to the game of ice-hockey (Q2), MS20MST and SMAT are again the best with treadmill and FAST as the worst and 20MST in the middle (\( p < 0.05 \)).

When tests were rated according to their suitability to evaluate aerobic fitness (Q3), and with regard to the suitability to evaluate overall fitness (Q4), FAST is trailing again with the lowest score while only being significantly lower than SMAT.
Lastly, with regard to suitability of the test to evaluate overall hockey ability (fitness and skating skills), treadmill and 20MST yield lower scores than the three skating tests while the skating tests were not significantly different from each other.

Correlation and standard error of the estimate between each field test and the treadmill criterion test.

Results of criterion treadmill test could be expressed in VO$_2$$_{\text{max}}$ units (ml kg$^{-1}$ min$^{-1}$) or maximal speed units (km h$^{-1}$). In general, correlations between maximal speed attained in field tests with criterion treadmill test are slightly better when results of the treadmill test are in speed units (Table 3). For example, for the 20MST, correlation was 0.84 with VO$_2$$_{\text{max}}$ units and 0.94 with speed units. That being said, ranking the tests according to their correlation yielded the same pattern whether VO$_2$$_{\text{max}}$ or maximal speed units are used. Using VO$_2$$_{\text{max}}$ units for example, we can see that FAST test is much less correlated with the treadmill test ($r=0.41$ with a SEE of 7.53 ml O$_2$ kg$^{-1}$ min$^{-1}$ or 14.7% of treadmill VO$_2$$_{\text{max}}$ mean) than the two other skating tests, MS20MST and SMAT ($r=0.74$ and 0.73 with SEE=5.93 and 5.65 ml kg$^{-1}$ min$^{-1}$ or 11.2 and 11 %, respectively). With an $r$ value of 0.84 and SEE of 4.69 ml kg$^{-1}$ min$^{-1}$ or 9.02%, the running gym test, 20MST, is the best field test, assuming treadmill VO$_2$$_{\text{max}}$ is a proper criterion. Finally, the maximal speed attained on the treadmill compared to VO$_2$$_{\text{max}}$ obtained during the same test yielded a correlation of 0.84 with a SEE of 4.72 ml kg$^{-1}$ min$^{-1}$ or 8.95%. These $r$ and SEE values were obtained using the maximum number of subjects for each comparison (n=17...
to 23) but almost the same \( r \) and SEE values were obtained using only data from the same 16 subjects that did all the tests.

Scatterplots of the treadmill test as a function of each one of the three ice skating tests clearly demonstrates that to achieve the same aerobic fitness level on the treadmill, one has to skate at high speed in the FAST, medium speed in the SMAT and low speed in the MS20MST. (Figure 3).

**Inter-correlations between field tests.**

Table 4 reports correlations and SEE values between maximal speeds attained in each of the four field tests. Only two ice skating tests, MS20MST and SMAT, compare well to each other (\( r=0.84 \) and \( \text{SEE}=0.50 \) or \( 0.58 \ \text{km h}^{-1} \) depending on which test is considered as the dependent variable). The FAST is much less related to the two other ice skating tests (\( r=0.58 \) or \( 0.61 \) for MS20MST and SMAT respectively with \( \text{SEE} \) up to \( 1.89 \ \text{km h}^{-1} \) or 9.25%). Even the 20MST, a running gym test, is better correlated to the two other ice skating tests (\( r=0.83 \) and \( 0.87 \) for MS20MST and SMAT, respectively. with \( \text{SEE} \) less than \( 0.73 \ \text{km h}^{-1} \) or 5.83%). Equivalence regression coefficients are given in Table 4.
Discussion

Random error of field tests.

One purpose of this study was to establish a regression for the adaptation of 20MST, a gym shuttle run test, for an on-ice application, the MS20MST. EQ-1 indicates good accuracy ($r=0.74$ and SEE=$5.93$ ml kg$^{-1}$ min$^{-1}$ or 11.2%). This is slightly lower accuracy than the one obtained between treadmill VO$_2$ max and maximal speed attained during the same treadmill test ($r=0.838$, SEE =4.72 ml kg$^{-1}$ min$^{-1}$ or 8.95%). Treadmill VO$_2$ max was considered the criterion test because of its universal use and because similar VO$_2$ are obtained on the treadmill and on the ice (Leger et al., 1980). There are however some specific adaptations that may explain such a lower correlation. Measurement of VO$_2$ max on ice may have been a better choice to validate skating tests at least to know which skating test elicits the highest VO$_2$ max values using portable equipment. Ice skating is much more skill oriented than running and that may also explain lower correlation. To improve accuracy, we plan to investigate some easily measurable biomechanical indices such as the limb frequency at a set speed as was done for swimming (Lavoie et al., 1985).

On the other hand, although entered in the regression model we used, weight and height of the subjects were not retained as significant predictors. On the other hand, age and gender were not even considered as potential co-predictors because we feel this is inappropriate since, even though general accuracy may increase, it introduces systematic bias. Taking gender and age as co-predictors will just ensure that the average difference in gender or average age effect is automatically applied leading to systematic underestimation of females that really have same VO$_2$ max than males. In a direct test, male and female terminating at the same stage generally have the same VO$_2$ max
notwithstanding small differences in mechanical efficiency or measurement errors. With
regard to measurement errors, these are more frequent than we think with automated
metabolic systems (Babineau et al., 1999) and that is confirmed by the better correlations
obtained between maximal treadmill speed (instead of VO$_2$max) vs. maximal speed
achieved in other field tests (Table 3).

Compared to MS20MST, SMAT has similar accuracy (vs. treadmill VO$_2$max, $r=0.73$ and
SEE=11%) while FAST has much lower one ($r=0.41$ and SEE=14.7%). This is a bit
lower than correlations reported for SMAT in younger 14.7 year old subjects ($r=0.83,$
SEE=7.0%, Leone et al., 2007) and for FAST in 17-19 juniors players ($r=0.67$, Faught et
al., 2003) and in a large sample (n=532) of mixed age male and female players (9-22 year
old, $r=0.71$ and SEE=12.9%, Petrella et al., 2007). In the latter study however, $r$ is higher
because other predictors were included in the regression (weight, height and gender) and
because of a wide range of data while SEE, less sensitive to that, is similar to the one
found in our study. With the same data, correlations for each age subgroup vary between
0.42 to 0.63; also, for 179 male players aged 19 and above, $r$ was 0.42, very similar to the
one obtained in our study. The FAST may thus be less valid because, instructions on how
to negotiate the change of direction at each end of the course are not standardized enough
and also because, the terminal point is less reliable in a test where the speed increases
exponentially with time (as opposed to a linear increase) and a small difference in
motivation could make a large difference in the final results of FAST and negatively
affects the correlation with treadmill VO$_2$max.
Equivalence between field tests

In our study, FAST was also not well correlated to the other field tests ($r<0.67$, table 4).

Even the gym shuttle run 20MST is better correlated to the two other field tests ($r<0.83$, Table 4) and to treadmill VO$_2$max ($r=0.84$, Table 3), confirming its validity. In other words, to be ice skating specific either the MS20MST or SMAT could be used but the 20MST is a good alternative, particularly in developing athletes with whom the ice time is often limited. It is not excluded that another version of the FAST with stage of constant speed increment and constant stage duration would be more accurate.

Systematic differences between tests.

The MS20MST had the lowest maximal skating speed among the skating tests (Figure 3), and even if it correlated well with the treadmill speed, it may be questionable. Although the MS20MST is specific for ice-hockey with its frequent stop and go over a shorter distance than SMAT, it causes rapid muscular fatigue and limits subjects from attaining higher maximal speed. But as long as that speed is well correlated to VO$_2$max, the final speed is a good indicator of skating aerobic fitness although it does not correspond to speed where VO$_2$max is attained in steady state condition, the so called Maximal Aerobic Speed (MAS). Thus, with regards to maximal speed, the SMAT allows higher maximal speed, while maintaining a ice-hockey specific nature. When comparing the MS20MST to the SMAT, they have a similar speed increment per min, but the SMAT has a 30 s rest period after each one minute stage, and has a longer course (45 m as opposed to 20 m in the MS20MST), requiring a lower frequency in direction changes and acceleration phases. Thus to reach the same speed in the SMAT is easier and for the same VO$_2$max,
subjects reach higher speed in the SMAT. On the other hand, the FAST has no rest between stages, and has not stop-and-go pattern (the FAST is continuous and curvilinear), and the stages of the FAST become shorter and shorter meaning that the speed is increasing faster and faster (after every third length of the ice). In the FAST, subjects obtained much higher final skating speeds, as the course is continuous and curvilinear (without stop-and-go) and allows subjects to build up and maintain high skating speeds. In other words, as the test progresses the subjects have to maintain new speed for less time which enables them to reach higher speeds. So even if that was expected, it needed to be statistically confirmed and quantified which it has been done. This indicates that maximal speeds achieved in each of these three skating tests are different and each test imposes different stimuli and demands different skills from the subjects. Furthermore, since these maximal speeds are linked to the nature of the protocol, they do not reflect the difficulty of the test as they do not vary as lactate or RPE do between tests.

The duration of the treadmill test is the longest, probably because the treadmill protocol has the longest stage duration (2-min). With 2-min stages and 1 km h\(^{-1}\) increment per stage, steady state is attained at the end of each stage (Leger et al., 1998), a condition essential to obtain an unbiased measure of VO\(_2\) requirement and the so-called MAS. Although total SMAT duration is similar to treadmill one, this is due to introduction of a 30-s rest between stage and with 1-min stage added to a recovery rest, stage are not long enough to reach steady state. Similar problems affect all the field tests of this study but as long as we are solely interested in the prediction of VO\(_2\)max, the final speeds of these
field tests except FAST, appear to be good predictors. Coming back to total test duration, it is clear that MS20MST is the test with the shortest duration, making it the most time efficient. Thus, when ice-time is limited and expensive, it is still possible to administer an on-ice test, if it is time efficient, and for this purpose, the MS20MST would be the best.

In our study, only the FAST maximal heart rate was significantly lower than the treadmill one, while the two other skating tests also show a trend toward that. Others observed larger differences. Hence, Léger, Seliger & Bassard (1979) demonstrated lower maximal heart rates on-ice for both hockey players and runners (10 beats min$^{-1}$), compared to the treadmill test. Vergès, Flore & Favre-Juvin (2003) also found a significant difference in heart rate during laboratory treadmill running (195.3±6.8 beats min$^{-1}$) and field roller skiing (190.4±5.6 beats min$^{-1}$). It is possible that the larger active muscle mass while running versus skating explains these heart rate differences. On the other hand, Petrella (2006) found similar maximum HR during the FAST and treadmill test (190 beats min$^{-1}$ in both tests). We cannot explain these differences.

The MS20MST and the SMAT yielded the highest lactate values and FAST the lowest ones, indicating a higher anaerobic contribution in both the MS20MST and the SMAT, as compared to the FAST and the running tests. This may indicate that the MS20MST and the SMAT are more hockey specific than the other tests.

The perception of less physiological strain in the FAST (Figure 1) may be due to the fact that the FAST is curvilinear in nature (less muscular fatigue as it is continuous with no
stop-and-go), and allows subjects to build up speed gradually, and maintain that speed, before the skating speed becomes very fast, and subjects have to stop suddenly without having to sustain fatigue for a long time. It seems that the MS20MST and SMAT have similar perceived intensity despite longer test duration in SMAT. The skating tests are perceived to be easier, but physiologically, they are as taxing as the running tests. This perception may be due to the fact that ice-hockey players are more comfortable in and familiar with their training environment that with running, demonstrating the need for on-ice aerobic tests.

Predicted VO$_{2\text{max}}$ using original equation developed for SMAT and FAST yields similar values to the treadmill VO$_{2\text{max}}$ confirming the external validity of these two skating tests in terms of systematic errors. But as discussed before, FAST has much larger random errors than the two other skating tests.

Specificity of testing and practical aspects.

Testing players in their training environment more accurately reflects the muscular and metabolic demands of the sport, as well as specific adaptations from training (Daub, 1983). Due to the differences in efficiency between running and skating (Léger, Seliger & Brassard, 1979), it is preferable to test ice-hockey players on-ice. In 1976 Simard demonstrated that the best skaters had lower VO$_{2\text{max}}$ in the laboratory, showing that they were much more efficient on the ice and demonstrating that laboratory testing can yield inaccurate results. The availability of the three new skating field tests of aerobic fitness
provides the coach and sport scientist with the option of more specific on-ice field tests that are sometimes more time efficient.

Cycle ergometry, treadmill running and treadmill skating offer some variation of metabolically demanding exercise, but do not allow the participant to perform the same mechanics of skating on-ice (Petrella, 2007; Leone *et al.*, 2007). In an attempt to make the measurement of VO$_2$ max more sport specific for ice-hockey, Dreger & Quinney (1999) used a skating treadmill protocol. However, the high cost of such a piece of equipment and its availability may make it unsuitable. The MS20MST and the SMAT are very similar with regard to physiological demand (VO$_2$, HR, and lactate), RPE, and subjective suitability ratings (Likert scale), in which the skating tests consistently scored higher with regard to similarity to the game of ice-hockey, as well as suitability to assess aerobic and overall fitness in ice-hockey players. This clearly demonstrates the need for on-ice skating tests for the assessment of aerobic fitness in ice-hockey. Furthermore, these new tests allow testing many players simultaneously. In fact, Petrella (2006) states that the FAST can comfortably test up to eight ice-hockey players simultaneously, and that a full roster hockey team can be completely evaluated within a typical one hour practice session. When using the SMAT, between 10 and 15 players can be tested on-ice at the same time, depending on their body size (Leone, Léger & Comtios, 2006); the same applies for the MS20MST. These tests also require less time than laboratory treadmill testing, less equipment, and are less expensive, as they can be easily administered during a training session, wearing either complete (SMAT and MS20MST) or partial ice-hockey equipment (FAST).
Conclusion

The main purpose of this study was to assess and compare validity and specificity of three aerobic skating tests. For almost all measured variables, FAST has the lowest scores (correlation with treadmill VO$_2$max, correlations with the two other skating tests (even lower than the 20MST running test), maximal lactate, maximal heart rate, rated perceived exertion and Likert resemblance scores with the hockey game requirements). On the other hand, SMAT and MS20MST revealed similar and much better results as ice hockey specific tests and are to be preferred to the FAST.

Acknowledgment

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References


### Tables and Figures

#### Table 1: Subject Characteristics of the Sample Used (n=16)

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>Years of hockey (yrs)</th>
<th>Height (cm)</th>
<th>Weight in lab (kg)*</th>
<th>Weight with full kit (kg)**</th>
<th>FAST weight (kg)***</th>
<th>Treadmill VO₂max (ml kg⁻¹ min⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>32.1</td>
<td>22.0</td>
<td>176.7</td>
<td>78.7</td>
<td>88.6</td>
<td>73.0</td>
</tr>
<tr>
<td>SD</td>
<td>12.7</td>
<td>12.3</td>
<td>7.4</td>
<td>15.0</td>
<td>15.1</td>
<td>7.4</td>
</tr>
<tr>
<td>Minimum</td>
<td>20</td>
<td>3.0</td>
<td>165.0</td>
<td>56.7</td>
<td>67.0</td>
<td>64.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>59</td>
<td>54.0</td>
<td>193.4</td>
<td>117.10</td>
<td>129.0</td>
<td>80.0</td>
</tr>
</tbody>
</table>

* measured in the laboratory on a calibrated balance scale on the day of treadmill testing
** measured in the ice-arena on a bathroom scale with subjects wearing full kit and holding hockey stick, on the day of MS20MST or SMAT
*** measured in the ice-arena on a bathroom scale with subjects wearing a tracksuit, helmet, gloves and holding hockey stick
Table 2: Characteristics of the maximal multistage running & ice-skating field tests to be used in this study

<table>
<thead>
<tr>
<th></th>
<th>20-m shuttle run (20 MST)&lt;sup&gt;1&lt;/sup&gt;</th>
<th>20-m shuttle skate (MS20MST)&lt;sup&gt;2&lt;/sup&gt;</th>
<th>45-m shuttle skate (SMAT)&lt;sup&gt;3&lt;/sup&gt;</th>
<th>48.8 m shuttle skate (FAST)&lt;sup&gt;4&lt;/sup&gt;</th>
</tr>
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<tbody>
<tr>
<td><strong>Displacement technique</strong></td>
<td>Shuttle Stop &amp; Go Gym Running</td>
<td>Shuttle Stop &amp; Go Ice Skating 1 hand on stick</td>
<td>Shuttle Stop &amp; Go Ice Skating 1 hand on stick</td>
<td>Shuttle Wide turn Ice Skating 1 hand on stick</td>
</tr>
<tr>
<td><strong>Protocol Type</strong></td>
<td>Max Multistage Continuous Linear 1 min 0 s 8.5 km h&lt;sup&gt;-1&lt;/sup&gt; 0.5 km h&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>Max Multistage Continuous Linear 1 min 0 s 10.0 km h&lt;sup&gt;-1&lt;/sup&gt; ~0.5 km h&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>Max Multistage Intermittent Linear 1 min 30 s 12.6 km h&lt;sup&gt;-1&lt;/sup&gt; 0.72 km h&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>Max Multistage Continuous Curvilinear 45 s → 19.5 s 0 s 15 s (11.7 km h&lt;sup&gt;-1&lt;/sup&gt;) -5 s (0.4→2.0 km h&lt;sup&gt;-1&lt;/sup&gt;)</td>
</tr>
<tr>
<td><strong>Speed vs. Stage</strong></td>
<td>Max Multistage Continuous Linear 1 min 0 s 8.5 km h&lt;sup&gt;-1&lt;/sup&gt; 0.5 km h&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>Max Multistage Continuous Linear 1 min 0 s 10.0 km h&lt;sup&gt;-1&lt;/sup&gt; ~0.5 km h&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>Max Multistage Intermittent Linear 1 min 30 s 12.6 km h&lt;sup&gt;-1&lt;/sup&gt; 0.72 km h&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>Max Multistage Continuous Curvilinear 45 s → 19.5 s 0 s 15 s (11.7 km h&lt;sup&gt;-1&lt;/sup&gt;) -5 s (0.4→2.0 km h&lt;sup&gt;-1&lt;/sup&gt;)</td>
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<tr>
<td><strong>Stage duration</strong></td>
<td></td>
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<tr>
<td><strong>Rest interval</strong></td>
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<tr>
<td><strong>Initial speed</strong></td>
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<tr>
<td><strong>Speed increase</strong></td>
<td></td>
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<tr>
<td><strong>Equipment</strong></td>
<td>Running shoes</td>
<td>Full hockey kit (+ portable VO&lt;sub&gt;2&lt;/sub&gt; system**)</td>
<td>Full hockey kit</td>
<td>Skates, stick, helmet, gloves</td>
</tr>
</tbody>
</table>

**In experimental phase of original study only**

<sup>1</sup> VO<sub>2max</sub> (ml kg<sup>-1</sup> min<sup>-1</sup>) = -27.4 + 6.0 (running speed, km h<sup>-1</sup>) (Leger et al. 1988)

<sup>2</sup> VO<sub>2max</sub> (ml kg<sup>-1</sup> min<sup>-1</sup>) = -33.337 + 6.24*Speed (in km h<sup>-1</sup>). (This study, n=20)

<sup>3</sup> VO<sub>2max</sub> (ml kg<sup>-1</sup> min<sup>-1</sup>) = 16.151(maximal skating velocity in skating velocity is in m s<sup>-1</sup>)-29.375 (Leone et al. 2007)

<sup>4</sup> VO<sub>2max</sub> = {0.428(F-length)} - {0.348(weight in kg)} + {25.434(height in m)} - {11.09(gender, 1=male)} +27.196 (Petrella et al., 2007)
Table 3. Correlations and standard errors of the estimate predicting treadmill VO$_2$max and maximal speed from field test maximal speed.

<table>
<thead>
<tr>
<th>Treadmill (Y)</th>
<th>n</th>
<th>Predicted variable</th>
<th>r</th>
<th>SEE ml kg$^{-1}$ min$^{-1}$ or km h$^{-1}$</th>
<th>SEE %</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS20MST (X)</td>
<td>21</td>
<td>VO$_2$max</td>
<td>0.74</td>
<td>5.93</td>
<td>11.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Max speed</td>
<td>0.75</td>
<td>1.23</td>
<td>8.07</td>
</tr>
<tr>
<td>SMAT (X)</td>
<td>20</td>
<td>VO$_2$max</td>
<td>0.73</td>
<td>5.65</td>
<td>11.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Max speed</td>
<td>0.79</td>
<td>1.16</td>
<td>7.73</td>
</tr>
<tr>
<td>FAST (X)</td>
<td>20</td>
<td>VO$_2$max</td>
<td>0.41</td>
<td>7.53</td>
<td>14.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Max speed</td>
<td>0.53</td>
<td>1.59</td>
<td>10.6</td>
</tr>
<tr>
<td>20MST (X)</td>
<td>17</td>
<td>VO$_2$max</td>
<td>0.84</td>
<td>4.69</td>
<td>9.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Max speed</td>
<td>0.94</td>
<td>0.70</td>
<td>4.59</td>
</tr>
</tbody>
</table>
Table 4. Equivalence between field tests using regression model without dependant and independent variables.

| Independent variable (X) | Dependent variable (Y) | n  | r   | Y = a + b X* | SEE** | SEE%
|--------------------------|------------------------|----|-----|--------------|-------|------
| SMAT                     | MS20MST                | 20 | 0.84| -1.863      | 0.50  | 3.68 |
| MS20MST                  | SMAT                   |    |     | 2.149       | 0.58  | 3.24 |
| 20MST                    | MS20MST                | 16 | 0.83| 3.172       | 0.62  | 4.49 |
| MS20MST                  | 20MST                  |    |     | -3.780      | 0.73  | 5.83 |
| 20MST                    | SMAT                   | 17 | 0.87| 5.286       | 0.62  | 3.47 |
| SMAT                     | 20MST                  |    |     | -5.284      | 0.62  | 4.92 |
| FAST                     | 20MST                  | 17 | 0.67| 0.944       | 0.99  | 7.87 |
| 20MST                    | FAST                   |    |     | -1.648      | 1.73  | 8.51 |
| FAST                     | MS20MST                | 19 | 0.58| 4.056       | 0.89  | 6.51 |
| MS20MST                  | FAST                   |    |     | -8.643      | 1.89  | 9.25 |
| FAST                     | SMAT                   | 21 | 0.61| 6.863       | 0.95  | 5.32 |
| SMAT                     | FAST                   |    |     | -12.702     | 1.76  | 8.64 |

*b of this regression model is obtained dividing b of conventional model by r; then a is obtained substituting average values of Y and X and new value of r in: Y = a + bX.

**SEE = √((∑(Y_{observed} - Y_{predicted})²)/(n-2)) using predicted value with the new model.
Figure captions

Figure 1: Comparison of maximal values attained in investigated tests (n=16)

Figure 2: Comparison of resemblance scores with ice hockey for investigated tests on the
1 to 7 point Likert scale (1=no, 7=yes)

Figure 3. Scatterplots of maximal treadmill speed as a function of maximal speed of each
ice skating test
Figure 1: Comparison of maximal values attained in investigated tests (n=16)

Note 1: Lactate is in mmol L\(^{-1}\), RPE is on a scale of 6-20, Duration is in min, Final speed is in km h\(^{-1}\), HR is in beats min\(^{-1}\), VO\(_2\) max is in ml kg\(^{-1}\) min\(^{-1}\).

Note 2: HR and VO\(_2\) max are divided by 10 so they could be plotted on the same graph.

Note 3: Pairs of values joined by a vertical bar are different (p<0.05)
Figure 2: Comparison of resemblance scores with ice hockey for investigated tests
on the 1 to 7 point Likert scale (1=no, 7=yes)

<table>
<thead>
<tr>
<th>Tests</th>
<th>Mean Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treadmill</td>
<td>1.88</td>
</tr>
<tr>
<td>MS20MST</td>
<td>5.19</td>
</tr>
<tr>
<td>SMAT</td>
<td>4.75</td>
</tr>
<tr>
<td>FAST</td>
<td>4.13</td>
</tr>
<tr>
<td>20 MST</td>
<td>2.44</td>
</tr>
</tbody>
</table>

Q1 Similarity of basic skating skills (not puck handling) of the test compared to those of a hockey game
Q2 Resemblance between maximal intensity of the test & maximal intensity of a hockey game
Q3 How is the test suited to evaluate aerobic fitness of hockey players?
Q4 How is the test suited to evaluate overall fitness (including muscular & cardiovascular fitness) of hockey players?
Q5 How is the test suited to evaluate overall hockey ability (fitness & skating skills) of hockey players?

Note: Pairs of values joined by a vertical bar are different (p<0.05)
Figure 3. Scatterplots of maximal treadmill speed as a function of maximal speed of each ice skating test.
INTRODUCTION. Three multistage aerobic ice skating field tests have recently been introduced: 1) maximal continuous multistage stop and go 20-m shuttle skating test (Modified Skating 20 MST, MS20MST, Kuisis 2003), 2) maximal intermittent multistage 45-m ice skating shuttle test with stop and go (SMAT, Leone 2006), both using full ice hockey equipment; and 3) maximal continuous multistage 160ft (48.8m) ice skating shuttle test with wide turns wearing only gloves, hockey stick and helmet (FAST, Petrella 2006).

OBJECTIVES and METHODS. The relative validity of these 3 tests was assessed comparing maximal speed of these tests to VO2max (Moxus) and maximal speed of a multistage treadmill test and the gym 20-m shuttle run test (Leger 1988) in 25 adult ice hockey players of various fitness levels but with good skating skills.

RESULTS. Expectedly, maximal speed increased from MS20MST to SMAT and to FAST protocols but the later shows lowest Borg RPE and max lactate and heart rate (p<0.05, Repeated ANOVA and Tukey test). Similitude with the intensity of hockey game and suitability as an aerobic test for ice-hockey was also judged lowest by the subjects for the FAST test on a 7 points subjective scale. Compared to treadmill VO2max, correlations were 0.74, 0.73, 0.41 and 0.84 for MS20MST, SMAT, FAST and the 20-m gym test, respectively. Correlations were slightly better with treadmill max speed (0.75, 0.78, 0.53 and 0.94, respectively) due to small but common accuracy problem of VO2measure. Thus using treadmill test as a standard, the FAST is less valid than the 2 others skating protocols admitting that the ice skating protocol that elicits the highest VO2max values would be a better standard. Nevertheless lower HR max and LA max values for the FAST do not support that test. Correlations between the MS20MST, SMAT and 20-m gym tests were around 0.84 but lower between these tests and FAST (around 0.63).

CONCLUSIONS. Based on these results, it is recommended to either use MS20MST or SMAT protocols in elite players if ice time is available or the 20-m gym test otherwise. Future study is needed to identify which test yields highest VO2max values on ice.

REFERENCES:

Keywords: Aerobic Power, Skating, Icehockey