A Physiological Analysis of Ice Hockey Positions

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Ice hockey is characterized as an intermittent collision sport. Elite level hockey is fast and physical, placing demands on the athletes' aerobic and anaerobic energy systems, and strength, power and flexibility. Successful players are also very agile and technically skilled in skating, shooting, passing and checking (19).

Thirty-one National Hockey League (NHL) players were tested prior to the 1992-93 season to develop a physiological profile of professional hockey players and an analysis of position variations. Certain physiological parameters are utilized and manifested on the ice to different degrees. Physiological profiles of proven professional players also provides a basis for comparing athletes to help strength and conditioning coaches in program design and conditioning emphasis (18).

Anaerobic Power and Heart Rate

The goaltender position is characterized by quick, explosive movements that are short in duration, interspersed with periods of rest and sub-maximal activity. The goaltender relies on the aerobic system for recovery between these bouts of action, so that the player is prepared to defend against the next offensive attack.

Similarly, forwards use the aerobic system for recovery between their commonly high intensity shifts, and to supply energy for occasional sub-maximal efforts. Many defensemen are on the ice for almost 50 percent of the game, compared to an average of 35 percent for forwards (13). Defensemen, however, have a shorter recovery phase and higher off-ice heart rates than forwards (13). Defensemen, on average, play more frequently per game, and have less recovery time between shifts (5). On average, defensemen skate slower than forwards throughout a game, experiencing both periods of high intensity efforts and periods of submaximal activity. This is why defensemen generally have more playing time and play more shifts per game. Intensity and duration have a direct inverse relationship (16). Hence, the aerobic system becomes increasingly important with more playing time and longer shifts. It is also important for the defensemen's recovery, as they commonly have less time between shifts (20).

On-ice heart rates average 85 percent of maximum, peaking at 90 percent. Oxygen uptake averages 90 percent of VO\textsuperscript{2} max (13), but VO\textsuperscript{2} during skating is variable because of differences in each player's skating efficiency. (Heart rate and oxygen uptake have a linear relationship up to about 80 percent of VO\textsuperscript{2} max (at the lactate threshold), then a tailing off occurs.) On-ice energy expenditure cannot be predicted from simple velocity analysis. While skating velocity plays a part, skating efficiency, changes in acceleration, stop- and-starts, affect energy expenditure. Upper body activity (battling for pucks, checking, etc.) adds substantially to energy expenditure. Laboratory measures of VO\textsuperscript{2} max range from 50 to 60 ml/kg/min (1, 12, 14). Position differences are presented in Table 1 (14) are the result of a maximal oxygen uptake test on a treadmill (14).

Energy Depletion

The goaltender position is characterized by rapid, explosive, repetitive movements, drawing in large part on the ATP-PC system (making a save, clearing the puck). The lactic acid system (glycolysis) may, at times, also be important for the goaltender, when forced into the ready position for long periods of time and when required to make numerous saves in a short period of time. The defensemen also use the ATP-PC system during one-on-one confrontations or when retrieving the puck from the corner and moving it up the ice. The lactic acid system is utilized more by players in the defensive zone, especially when teammates are in the penalty box, or when leading offensive attacks. The rate of energy expenditure among forwards is higher than defensemen because forwards tend to cover more ice which requires more intensity. Forechecking and back-checking, racing up and down the ice, places demands on the anaerobic lactate system. While forwards experience more anaerobic activity than
defensemen (17), lactate accumulation is the same for defensemen and forwards. The defensemen's lactate level is the same as the forwards' even though they don't work as hard, because the rest periods to clear the lactate are shorter (3).

A modified 30-second Wingate bicycle ergometer test (resistance set at 90 gm.kg⁻¹) resulted in blood lactate values as high as 15.1 nmol/L (Table 2). Mid-game blood lactate levels measured only 8.7 mmol/L (4). Time-motion analyses reveal many changes in tempo during each individual shift. A typical hockey shift is characterized by short bursts of high intensity effort, followed by submaximal activity. These intermittent intense efforts result in substantial anaerobic glycolysis. Muscle glycogen depletion in the vastus lateralis (a muscle very active in the skating action) declined 80 percent throughout a game (21). Therefore, the relatively low on-ice lactate levels are likely due to elite players learning to optimize high intensity bursts (10), and are a result of the two or three interruptions in play within a typical shift. Continuous play averages 30 seconds (10), which is sufficient time for 60 to 65 percent of the phosphocreatine to be resynthesized and available for the next phase of the shift.

Forwards and defensemen have similar on-ice and off-ice lactate measures. Goaltenders experience only a small elevation in lactate from their pre-game level. Since hockey demands precise coordination of many muscle groups, a high concentration of lactic acid and excessive reduction of glycogen would ultimately hinder the execution of skills (15).

**Muscle Fiber Distribution**

Goalkeepers (47.4 percent), defensemen (51.7 percent) and forwards (48.1 percent) all have similar Type I slow oxidative fiber distribution (7). Type I fiber distribution is similar for junior (50.2 percent), university (47.8 percent), and professional (50.1 percent) players (7). Data indicates that slow twitch muscle fiber composition of the vastus lateralis ranges from 20 to 71 percent (6) among junior, university and professional players. This is consistent with the description of hockey as a combination of fast bursts of activity, submaximal efforts and intermittent rest periods. It would seem ideal to have a greater percentage of Type II (fast twitch) fibers, however, both are needed in the leg muscles to accelerate and then to recover.

**Muscular Strength**

Forwards and defensemen generally are stronger than goalkeepers, as shown in the results of a hand grip dynamometer test and a maximal repetition 200-pound bench press in Table 2. Defensemen have historically scored higher than forwards on strength tests, however, as shown in Table 2, with the increased participation in off-ice conditioning programs, forwards and defensemen now have similar strength levels.

**Anthropometry**

Hockey players are mesomorphic in structure (20). Defensemen have typically been taller and heavier, likely due to position demands (8, 11). However, defensemen and forwards are now more similar in size, due to both player selection and strength training. Goaltenders possess a slightly greater percentage of body fat than forwards and defensemen. Table 2 displays mean percent body fat values. The mean percent body fat for

<table>
<thead>
<tr>
<th>Position</th>
<th>N</th>
<th>Weight</th>
<th>VO₂ max (mL.kg⁻¹.min⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forwards</td>
<td>27</td>
<td>87.1±5.6</td>
<td>57.4±3.1</td>
</tr>
<tr>
<td>Defensemen</td>
<td>40</td>
<td>90.2±4.3</td>
<td>56.8±3.9</td>
</tr>
<tr>
<td>Goaltenders</td>
<td>8</td>
<td>79.2±3.9</td>
<td>49.1±2.5</td>
</tr>
</tbody>
</table>

| Table 1. Mean VO₂ max and body weight values for National Hockey League players. |

| Age (yrs)    | 24.8±4.6 | 24.7±2.6 | 27.3±4.5 |
| Height (in)  | 73.6±1.7 | 73.8±1.9 | 72.5±1.2 |
| Weight (lbs) | 204.3±8.4 | 207.1±9.3 | 183.5±10.1 |
| Sum of six skinfolds (mm) (Ref 15) | 39.5±5.3 | 40.4±5.6 | 4.3±11.6 |
| Percent Body Fat | 10.8±2.4 | 12.1±2.5 | 13.5±3.1 |
| Anerobic power (Wingate Test) watt/kg in 5 sec | 13.4±1.2 | 13.1±1.5 | 12.7±1.1 |
| Anerobic capacity (Wingate Test) watt/kg 30 sec | 10.3±1.3 | 10.2±0.9 | 9.5±1.6 |
| Blood lactate (nmol/L) | 15.1±2.1 | 14.9±1.8 | 14.9±2.2 |
| Grip strength (kg, left + right) | 134.2±5.6 | 138.1±9.4 | 121.5±8.4 |
| 200 lb bench press (max reps) | 12.2±0.3 | 14.0±3.3 | 4.3±2.1 |
| Controlled sit ups (max 100) (ref 15) | 59.0±21.0 | 72.0±16.0 | 58.0±8.2 |
| Hip flexion (degrees) (ref 9) | 123.5±7.2 | 126.5±8.6 | 134.5±10.3 |
| Hip extension (degrees) (ref 9) | 48.5±5.1 | 48.0±5.0 | 52.5±4.8 |
| Trunk flexion (cm) (ref 15) | 45.0±7.4 | 44.2±6.9 | 52.5±4.8 |

| * X (= or - S.D.) |

**Table 2. 1992 pre-season physiological profiles of NHL veterans.**

Forwards and defensemen generally are stronger than goalkeepers, as shown in the results of a hand grip dynamometer test and a maximal repetition 200-pound bench press in Table 2. Defensemen have historically scored higher than forwards on strength tests, however, as shown in Table 2, with the increased participation in off-ice conditioning programs, forwards and defensemen now have similar strength levels.
goalies is 13.5, compared to 10.8 for forwards and 12.1 for defensemen.

Flexibility

Goalies perform better on trunk flexion, hamstring flexibility and hip flexion tests. This is expected because of the physical demands of the position, and coaches emphasize stretching for goalies.

In the past, NHL defensemen were characterized as leaner, taller, heavier, stronger and possessing more anaerobic power and capacity than forwards and goalies. Physiological profiles were more a result of the on-ice demands of each position, and most players did not take part in off-ice conditioning. Physiological assessments indicate an increase in off-ice conditioning, as athletes at each position have made improvements in specific parameters (14). This brings the physical capabilities of athletes at each position closer together, and produces a stronger, more powerful and flexible hockey player with a superior conditioning base.

References