On-ice Special Tests in Relation to Various Indexes of Aerobic and Anaerobic Capacity in Polish League Ice Hockey Players

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Abstract

The main goal of this study was to determine the predictive value of the indexes of aerobic and anaerobic endurance in relation to the specific on-ice tests performed by hockey players. Our subjects included ice hockey players who were members of the Polish Hockey League. Based on our data, we have identified significant correlations between maximal power obtained from the Wingate test and certain aspects of the special physical fitness test, specifically the 30m forward sprint, 6 × 9 turns and 6 × 30 m endurance tests. Significant correlations of the above-mentioned special physical fitness tests were also observed with the aerobic capacity parameter VO2max. The athletes who were faster in 30 m forward sprint, 6 × 9 m stops, 6 × 9 m turns and Endurance (6 × 30 m) tests achieved higher power values in the Wingate test and showed higher VO2max.

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Key words: Wingate test; VO2max; ice hockey tests

1. Introduction

Ice hockey is one of the most demanding and spectacular team games. Unfortunately, the level of hockey in Poland has been gradually declining for many years. Poor league causes problems with promotion of our national teams (both junior and senior teams) to elite levels (Roczniok et al., 2013). In every sports discipline are pointed out a number of values, which must contain the parameters defining the fitness level of players. This ensures...
optimal possibility of achieve the objectives of the training and the effective participation of the player in the
game. Sport scientist have used a multitude of tests to evaluate ice hockey players including anthropometry,
jumping, aerobic capacity and anaerobic power, as well as skating speed, agility and fitness (Cox et al., 1998;
Montgomery et al., 2000; Behm et al., 2005; Dreger and Quinney, 1999). Although some tests have been
performed on ice (Bracko, 2001) a majority of the literature reports data for off-ice tests, which might limit the
applicability of the results to on-ice performance or ability (Masaro et al., 1991; Montgomery, 1988). Ice
hockey is a physically demanding contact sport involving repeated bouts of high energy output, with shifts lasting
from 30 to 80 seconds (Green et al., 2004; Lau et al., 2001). Given the anaerobic nature of the sprint-based shifts
(69% anaerobic glycolysis) and the aerobic recovery (31% aerobic metabolism) between shifts and periods, as
well as the physicality of the game, success at the elite level requires players to develop well-rounded fitness
including anaerobic sprint ability, strength, power and endurance (Cox et al., 1995; Glaister, 2005).

Hockey is widely considered an aerobic activity accentuated with several repeated bouts of anaerobic exercise
(Carey et al., 2007).

A longitudinal study by Cox et al. (1995), gathered physiological data on over 170 players from the National
Hockey League (NHL) from 1980 to 1991. Over this time period VO₂max was found to increase from an average
of 54 ml/kg/min in 1980 to just over 62 ml/kg/min (N = 635) in 1991 for this group of studied players.
A similar longitudinal study by Montgomery (2006), looked at physiological data, including size, strength and
aerobic fitness of the Montreal Canadiens of the NHL, beginning in 1917. Compared to players from the 1920’s
and 1930’s, current players were an average of 17 kg heavier and 10 cm taller with an average BMI increase of
2.3 kg·m⁻¹. Aerobic fitness (VO₂max) was also found to increase from 54.6 to 59.2 ml/kg/min between 1992 and
2003, but the variability of the data made it impossible to determine if this increase was significant.

Therefore, measuring anaerobic endurance and anaerobic power of great importance for elite hockey players
based on which training has a greater influence on the physical performance of hockey players. The development
of an elite hockey training program should focus on improving each of the fitness components (i.e. flexibility,
strength etc.) and include some on-ice short intervals, multi-directional directional skating as well as puck,
technical skating and movement skills (Roczniok et al., 2012). Historically, coaching intervention has been based
on subjective observations of athletes.

However, several studies have shown that such observations are not only unreliable but also inaccurate.
Although the benefits of feedback and the knowledge of results are well accepted, the problems of highlighting
memory and observational difficulties result in the accuracy of coaching feedback being very limited. Nowadays
there is the necessity to apply the multidimensional analyses in sport sciences. It is especially relevant in sport
selection process. It is extremely difficult to designate a criterion with the aid of which one could present
accomplishments of a particular player in a quotient scale (Roczniok et al., 2008). Statistical and mathematical
forecasting methods are becoming more and more significant in this area. Opportunities to employ tools of
statistical analysis are wide, from the simplest taxonomic analyses, multidimensional exploration techniques for
optimizing the recruitment process, we have the possibility of grouping objects and find subsets of more
homogenous taxonomic units (Roczniok, Rygula and Kwaśniewska, 2007), through to application of a variety of
mathematical models or even artificial neural networks for optimization of selection at individual stages of sports
advancement.

The goal of the present study was to determine the predictive value of the indexes of control of anaerobic and
aerobic endurance in relation to specific tests performed by ice hockey-players in terms of their strength, speed,
power, as well as speed and strength endurance. The objectives of this research rested in posing the following
questions: Are there any significant correlations between the parameters of anaerobic capacity and special
physical fitness tests? Are there any significant correlations between the parameters of aerobic capacity and
special physical fitness tests? What is the strength and direction of these relationships?
2. Material and methods

In order to verify the above-mentioned objectives, investigation was carried out in March 2011, on 26 hockey players from the Polish Hockey League, who were members of the HC GKS Katowice team. Aerobic capacity test was conducted on the basis of ramp test protocol. During the test, each athlete performed a ramp ergocycle test (T30x1) (30 W per 1 min) were work load increased linearly (0.5 W per 1 s) until volitional exhaustion, to establish VO$_2$max. Each ramp test was started with a resistance set at 30 W and pedal frequency was individual. In this phase, capillary blood samples were drawn to determine lactate concentration before and immediately at the end of the T30x1 as well as after the 3rd, 6th, 9th and 12th min. During the protocol the following variable oxygen uptake (VO$_2$) (MetaLyzer 3B-2R, Cortex) was used (Czuba et al., 2010).

After 24 h of rest, all of the hockey players preformed the 30-second Wingate test to determine anaerobic capacity on an ergocycle. The Wingate test was performed with the resistance of the cycloergometer adjusted to the athlete’s body weight (0.8 Nm/kg). All of the athletes were instructed to cycle as quick and powerfully as possible throughout the entire test’s duration. All tests were performed on an ergocycle Excalibur Sport (Lode).

In addition to the above-mentioned tests, special physical fitness tests on ice were also carried out. A set of measurable hockey skills which provide information on speed and endurance were used, composed of the 30 m Forward Sprint, the 30 m Backward Sprint, 6 × 9 m Stops, 6 × 9 m Turns, and an Endurance Test (6 × 30 meters). Lap time was performed based on a set of photocells (Microgate).

Descriptive statistics were calculated to include mean ± standard deviation (SD) and min and max values with all of the variables examined for normal distribution. In order to answer the research questions set out in this study, Pearson’s linear correlation analysis was also carried out.

This study was approved by the Bioethics Committee of Scientific Research at the Academy of Physical Education in Katowice. The authors of this study declare no conflict of interest.

3. Results

The average values of the physiological variables and performance measurements taken in this study are presented in Table 1.

| Variables                  | Mean | SD | Min | Max |
|---------------------------|------|----|-----|-----|
| Special tests on ice      |      |    |     |     |
| 30 m Forward Sprint (s)   | 4.47 | 0.29| 4.08| 5.10|
| 30 m Backward Sprint (s)  | 5.73 | 0.82| 4.95| 7.62|
| 6 × 9 m Turns (s)         | 12.15| 0.78| 11.08|13.65|
| 6 × 9 m Stops (s)         | 12.78| 0.60| 11.69|13.72|
| Endurance (6 × 30 m) (s)  | 33.09| 2.28| 31.02|38.40|
| Pmax (W)                  | 20.41| 3.39| 12.64|25.03|
| Pmax (W/kg)               | 1637.19| 381.62| 1036.14|2328.20|
| Anaerobic Capacity        |      |    |     |     |
| LArest (mmol/l)           | 1.89 | 0.34| 1.22| 2.29|
| LA4 (mmol/l)              | 9.69 | 1.52| 6.46| 11.96|
| HRmax (bpm)               | 180.15| 167.00| 194.00|7.25|
| VO2max (ml/kg/min)        | 50.77| 43.00| 57.00|3.82|
Based on the analyses conducted on the measured variables (Tab. 2), significant negative correlations between the indexes of anaerobic capacity and the special physical fitness tests on ice were observed only between maximal power (measured in Watts per kilogram) and the variables: 30m Forward Sprint (s), 6 × 9 m Turns, Endurance (6 × 30 m). A correlation was also observed between LA4’ and the variable Endurance (6 × 30 m). In the case of other variables of anaerobic capacity, no statistically significant relationships with the special physical fitness tests on ice were observed.

Table 2. Correlations between the indexes of anaerobic capacity and the special physical fitness tests on ice

|                   | 30m Forward Sprint (s) | 30 m Backward Sprint (s) | 6 × 9 m Turns (s) | 6 × 9 m Stops (s) | Endurance (6 × 30 m) (s) |
|-------------------|------------------------|--------------------------|------------------|------------------|------------------------|
| Pmax (W/kg)       | -0.46*                 | -0.22                    | -0.62*           | -0.41            | -0.52*                 |
| Pmax (W)          | 0.01                   | -0.22                    | -0.27            | -0.43            | -0.28                  |
| LArest (mmol/l)   | -0.29                  | 0.24                     | 0.29             | 0.35             | -0.36                  |
| LA4 (mmol/l)      | -0.20                  | 0.11                     | 0.10             | -0.25            | -0.48*                 |

* significant correlations p ≤ 0.05

Pmax (W) – Absolute peak power, Pmax (W/kg) – Relative peak power. LArest’ (mmol/l) – Lactate concentration before the Wingate test. LA4’ (mmol/l) – Lactate in the 4th minute of recovery in the Wingate test. VO2max (ml/kg/min) – Relative VO2max. HRmax (bpm) – Max heart rate. LArest (mmol/l) – Lactate concentration before the VO2max test. LAmax (mmol/l) – Lactate concentration after the VO2max test. LA3 (mmol/l) – Lactate concentration in the 3rd minute of recovery in the VO2max test. LA6 (mmol/l) – Lactate in the 6th minute of recovery in the VO2max test. LA9 (mmol/l) – Lactate in the 9th minute of recovery in the VO2max test. LA12 (mmol/l) – Lactate in the 12th minute of recovery in the VO2max test.

Table 3. Correlations between the indexes of aerobic capacity and the special physical fitness test on ice

|                   | 30 m Forward Sprint (s) | 30 m Backward Sprint (s) | 6 × 9 m Turns (s) | 6 × 9 m Stops (s) | Endurance (6 × 30 m) (s) |
|-------------------|------------------------|--------------------------|------------------|------------------|------------------------|
| HRmax (bpm)       | -0.19                  | 0.40                     | 0.14             | 0.22             | -0.24                  |
| VO2max (ml/kg/min)| 0.16                   | -0.08                    | -0.55*           | -0.53*           | -0.57*                 |
| LArest (mmol/l)   | 0.03                   | -0.10                    | 0.06             | 0.44             | 0.19                   |
| LA max (mmol/l)   | -0.08                  | -0.41                    | 0.13             | -0.15            | -0.02                  |
| LA 3 (mmol/l)     | -0.41                  | -0.32                    | -0.07            | -0.24            | -0.31                  |
| LA 6 (mmol/l)     | -0.18                  | -0.35                    | -0.14            | -0.41            | -0.45*                 |
| LA 9 (mmol/l)     | -0.26                  | -0.33                    | -0.04            | -0.26            | -0.39                  |
In the case of relationships between the indexes of aerobic capacity and the special physical fitness test on ice (Tab. 3), significant negative correlations were observed only between \( V_{O2\max} \) with the variables: 6 x 9 m Turns, 6 x 9 m Stops and Endurance (6 x 30 m), correlation between LA6 and Endurance (6 × 30 m). As a side note, LA4 was previously used as an indicator of aerobic endurance in Green’s research (Dreger & Quinney, 1999). In the present study indicator of aerobic endurance is the LA 6. Coaches may prefer players who are leaner and have a lower lactate at a given \( V_{O2} \), which enables players to play at high intensity without fatigue. With regard to the other variables of aerobic capacity, no significant relationships with the special physical fitness tests on ice were found.

4. Discussion and conclusion

At the elite hockey level, there has been a long-standing debate among scouts, coaches, strength conditioning specialists and physiologists as to the relative utility of on-ice tests for aerobic and anaerobic power prediction. Nonetheless, having access to ice-specific special physical fitness tests, which are good predictors of the most important indexes of aerobic and anaerobic capacity, might minimize the number of expensive off-ice tests and minimize disturbance to training cycles, particularly during the competitive season or play-offs (Roczniok and Kwaśniewska, 2007).

The obtained results allow us to identify the significant relationships between the indexes of anaerobic and aerobic capacity and these special physical fitness tests on ice. The athletes who were faster in 30m Forward Sprint, 6 × 9 m Turns, 6 × 9 m Stops, Endurance (6 × 30 m) tests achieved higher power values in the Wingate test and showed higher \( V_{O2\max} \). Significant negative relationships were also found between the level of lactate after the Wingate test and the variables Endurance (6 × 30 m). These results allow for the conclusion that higher degrees of acidification correspond to shorter trial times. Similar results were obtained when analysing the results of negative correlation between the acidification in the aerobic capacity test in the 6th minute and the variable Endurance (6 × 30 m). Green et al. (2006) conducted a study on an NCAA Division I hockey team and how their physiological profiles, including \( V_{O2\max} \), blood lactate, and percent body fat, related to their performance. Using a discontinuous protocol in which blood lactate was measured between three-minute stages of treadmill running, blood lactate levels averaged 8.9 ± 2.1 mmol·L\(^{-1}\) at the end of the fourth stage, the last stage completed by each of the subjects. This stage was tested at 12.9 km·h\(^{-1}\) and a seven-percent grade on the treadmill. Aerobic fitness (\( V_{O2\max} \)) accounted for 17% of the variance in performance, which was based on overall scoring chances while a particular player was on the ice. It was concluded that only \( V_{O2\max} \) significantly predicted performance.

The results presented here are also confirmed by those reported by other authors, which state that aerobic and anaerobic capacity are important physiological characteristics for ice hockey players. Because of the relatively short but intense work intervals found in an ice hockey game (from 30 to 60 seconds), the ability to produce anaerobic energy might dictate performance within a given shift when playing on ice (Cox et al., 1995; Montgomerry, 1988). Although a variety of on-ice skating tests have been developed, the Wingate test on a cycle ergometer (from 15 to 45 seconds) remains the most commonly used test for assessing anaerobic power and capacity in hockey players (Ebben et al., 2004). Even if such short shifts predominate in ice hockey, the physiological demands are not limited to anaerobic pathways. Aerobic capacity is responsible for the recovery from such high-intensity intermittent exercise and, therefore, acts as a buffer against fatigue and minimize the attenuation of power output during subsequent shifts (Glaister, 2005). For elite ice hockey players, anaerobic
power and anaerobic endurance is of critical importance (Montgomerry, 1988), making strength an important part of a hockey training program. Although players aren’t required to meet certain physical challenges (when compared to other multi-sprint sports), power is required for acceleration, maintain speed and quick direction changes. Upper body strength allows players to shoot more powerfully and pass over a greater range of distance.

All in all, the bio-energetic demands of the sport require heavy bouts of high-intensity whole-body exercise characterized by high-speed explosive skating and sudden changes of direction, coordinated with spontaneous bursts of muscular strength and power (Twist & Rhodes, 1993). In an average hockey game, there are typically 4–8 bursts of maximal skating per shift, leading to an average of 4–8 min/game of high-intensity bouts of maximal effort, and an average heart rate intensity of 70–90% of maximum heart rate (HRmax). The game of ice hockey does require approximately 18–22 min of both aerobic and anaerobic energy expenditure per game and repeated back-to-back sprints make speed and tolerance changes in acid-base balance an important characteristic of elite players.

The athletes who performed better in the 6 × 9 m Stops, 6 × 9 m Turns and Endurance (6 × 30 m) tests achieved higher power values in the Wingate test as well as showing higher VO2max. Therefore, the most important findings of this study suggest that the best predictors of aerobic and anaerobic capacity are the 6 × 9 m Stops, 6 × 9 m Turns, and Endurance (6 × 30 m) tests. Such knowledge might be considerably useful in the frequent control of training process, as well as providing much more information on athletes which can then be suited for more personalized forms of training.

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