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Section III – Sports Training

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Physical Fitness And Performance of Polish Ice-Hockey Players Competing at Different Sports Levels

by

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The study aimed to determine the values of selected aerobic and anaerobic capacity variables, physical profiles, and to analyze the results of on-ice tests performed by ice-hockey players relegated to a lower league. Performance of 24 ice-hockey players competing in the top league in the 2012/2013 season was analysed to this end. In the 2013/2014 season, 14 of them still played in the top league (the control group), while 10 played in the first league (the experimental group). The study was conducted one week after the end of the playoffs in the seasons under consideration. The results revealed that only in the experimental group the analysed variables changed significantly between the seasons. In the Wingate test, significant changes were only noted in mean relative power (a decrease from 9.91 to 9.14 W/kg; p=0.045) and relative total work (a decrease from 299.17 to 277.22 J/kg; p=0.048). The ramp test indicated significantly lower power output in its final stages (364 compared with 384 W; p=0.034), as well as a significant decrease in relative VO2max (from 52.70 to 48.30 ml/min/kg). Blood lactate concentrations were recorded at the 3rd, 6th, 9th and 12th min of recovery after the ramp test. The rate of post-exercise recovery, ΔLA, recorded after the ramp test turned out to be significantly lower. The times recorded in the on-ice "6x30 m stop" test increased from 32.18 to 33.10 s (p=0.047). The study showed that playing in a lower league where games were less intensive, training sessions shorter and less frequent, had an adverse effect on the performance level of the investigated players. Lower VO2max recorded in the study participants slowed down their rates of post-exercise recovery and led to a significantly worse performance in the 6x30 m stop test, as well as lower relative power and relative total work in the Wingate test.

Key words: *team sports, recovery, on-ice tests, aerobic capacity, anaerobic capacity.*

Introduction

Ice-hockey is considered one of the most demanding and fastest team sport games. As the intensity of play has been observed to increase in recent years, the focus of training of ice-hockey players at the highest competitive level focused on muscle strength, aerobic capacity, anaerobic power, speed and agility (Bem et al., 2005; Montgomery, 2006; Quinney et al., 2008; Roczniok et al., 2013; Stanula et al., 2013). Ice hockey is a physically demanding contact sport involving repeated bouts of high energy output lasting from 30 to 80 s (Green et al., 2004; Lau et al., 2001; Montgomery, 1988). Professional ice-hockey games are characterized by intense bouts of play lasting from 45 to 60 s, rarely exceeding 90 s (Cox et al., 1995). Ice-hockey requires that the players have finely trained aerobic and anaerobic energy pathways. To play ice-hockey at the top level,

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intense glycolytic activity related to the bursts of intense muscular activity (69% anaerobic glycolysis) and exceptional aerobic power and endurance (31% aerobic metabolism) are required (Cox et al., 1995; Montgomery, 1988; Magiera et al., 2013). Moreover, when the intensity of an ice-hockey game is high, the actual engagement of the player's anaerobic systems may depend on the efficiency of his aerobic system. Aerobic processes play an important role in the resynthesis of energy substrates, which are necessary to exercise at high intensity (Roczniok et al., 2016; Stanula et al., 2014). Cox et al. (1995) analyzed detraining effects on the physiological profile of ice-hockey players during a competitive season. In this line, the present study was undertaken with the purpose of establishing if the relegation to a lower league resulted in lower values of selected aerobic and anaerobic capacity variables, influenced physical profiles and the results of on-ice tests in ice-hockey players.

Material and Methods

Participants

The experiment involved 24 ice-hockey players competing in the top league in the 2012/2013 season. In the 2013/2014 season, 14 of them still played in the top league (the control group), while 10 played in the first league (the experimental group). The research was conducted one week after the end of the playoffs in the seasons under consideration (April 2013, 2014). All the athletes possessed up-to-date medical examinations confirming proper health status and the ability to perform high-intensity exercise. The research project was approved by the Ethics Committee for Scientific Research at the Jerzy Kukuczka Academy of Physical Education in Katowice.

Research design

Data collection was conducted in April 2013 and April 2014. Tests lasted three days for each ice hockey player. On the first day, body measurements were made. Body height was determined including barefoot height (± 0.1 cm) using a wall mounted stadiometer. Body composition was estimated using an 8-electrode bioimpedance analysis device (InBody 720, Biospace). All the measurements were taken by a certified representative of MEDfitness, a sole distributor of the InBody body composition analyzer in Poland. Body mass and composition measurements were taken in the morning (09.00-10.00 am), two hours after a light breakfast. The participants did not exercise or take any medication prior to the measurements, which were performed at a temperature of 21°. The ICC for the body composition analysis varied from 0.84 to 0.97. Three hours after breakfast, each athlete performed the 30 s Wingate test to determine anaerobic capacity. The test and a 5 min warm-up were performed on an electromagnetically braked cycloergometer (Excalibur Sport, Lode). Resistance during the warm up was set at 1 W per 1 kg of body mass and pedal frequency of approximately 70 RPM. The Wingate test was performed with resistance adjusted to athlete's body mass ($0.08 \text{ Nm}\cdot\text{kg}^{-1}$). Capillary blood samples were drawn at rest and after the 4th and 8th min of the test to determine lactate concentration. All of the ice hockey players were instructed to cycle as quickly and forcefully as possible throughout the 30 s test.

After 48 h of rest, all subjects performed a ramp ergocycle test (T30x1) ($30 \text{ W}\cdot\text{min}^{-1}$) with a progressive workload ($0.5 \text{ W}\cdot\text{s}^{-1}$) until volitional exhaustion, to establish maximal oxygen uptake (VO_{2max}) and determine the anaerobic threshold. Each ramp test was started with the resistance set at 30 W and pedal frequency between 70 to 80 rpm. In this phase, capillary blood samples were drawn to determine lactate concentration before and immediately after the end of the T30×1 as well as at the 3rd, 6th, 9th and 12th min of recovery. During the T30 × 1 protocol, the following variables were constantly registered: a heart rate (HR), minute ventilation (VE), oxygen uptake (VO_2) and expired carbon dioxide (CO_2), a respiratory exchange ratio (RER), breath frequency (BF) (MetaLyzer 3B-2R, Cortex). Maximal oxygen uptake (VO_{2max}) was assessed when the following criteria were met: (1) reaching a plateau in VO_2 with increases in the work load ($\Delta VO_2 \leq 100 \text{ mL}\cdot\text{min}^{-1}$ at VO_2 peak); (2) maximal respiratory exchange ratio $RER \geq 1.1$. All breath-by-breath gas exchange data were time-averaged using 15 s intervals to examine the oxygen plateau. All the ramp tests were performed on an ergocycle Excalibur Sport (Lode). Seat and bar height of the cycle ergometer were adjusted for each subject.

After 48 h of rest, during the last day of testing involving an on-ice test, subjects wore full hockey equipment except for the stick. Specific physical fitness tests on ice were carried out in order to provide information about the speed and endurance of the athlete: 30 m Sprint Forwards, 30 m Sprint Backwards, 6 × 9 m Stops, 6 x 9 m Turns, Endurance (6 × 30 m). Microgate Photocells (Bolzano, Italy) recorded the times of each sprint with accuracy of 0.01 s.

Statistical analysis

All statistical analyses were conducted using Statistica 12.0. Basic descriptive statistics were calculated. The Wilcoxon's matched pairs test for dependent variables was used to evaluate the mean differences. Statistical significance was set at $p < 0.05$.

Results

The analysis of research results started with the presentation and comparison of basic descriptive statistics of somatic variables.

No significant differences in the mean values of the variables were found, what indicated that playing in the lower league did not have a significant effect on somatic variables in the selected ice-hockey players. In the next step, the results of the 30 s Wingate test were analysed (Table 2).

Statistically significant differences were found only between the results in the experimental group for variables *Relative mean power* and *Relative total work*. Ice hockey players from the experimental group in the 2013/2014 season had lower values of relative mean power (9.14) compared to the results of the 2012/2013 season (9.91 $W \cdot kg^{-1}$; $p=0.04$) which they played at the top league. Analysis of the results of relative total work also indicated a statistically significant decrease in relative total work after a year spent in the lower league ($p=0.04$; Table 2). Further analysis related to aerobic capacity is presented in Table 3.

Relative VO_{2max} (ml/min/kg) - relative maximal oxygen uptake. LA_{rest} (mmol · l^{-1}) – lactate concentration before the VO_{2max} test. LA_{max} (mmol · l^{-1}) – lactate concentration after the VO_{2max} test. $\Delta LA_{max-rest3'}$ (mmol · l^{-1}) - difference between the maximum concentration of lactate and lactate concentration in the 3rd min after the VO_{2max} test. $\Delta LA_{max-rest6'}$ (mmol · l^{-1}) - difference between the maximum concentration of lactate and lactate concentration in the 6th min after the VO_{2max} test. $\Delta LA_{max-rest9'}$ (mmol · l^{-1}) - difference between the maximum concentration of lactate and lactate concentration in the 9th min after the VO_{2max} test. $\Delta LA_{max-rest12'}$ (mmol · l^{-1}) - difference between the maximum concentration of lactate and lactate concentration in the 12th min after the VO_{2max} test.

Table 1

Basic values of the players' somatic variables by season

Variables	Level	Season 2012/2013			Season 2013/2014			*p*
		Mean	±	SD	Mean	±	SD	
Body height (cm)	Experimental	177.70	±	4.19	177.80	±	4.37	0.93
	Control	181.14	±	6.26	181.07	±	6.51	0.91
Body mass (kg)	Experimental	79.43	±	8.28	80.62	±	8.19	0.67
	Control	83.59	±	7.12	80.31	±	8.85	0.34
Body fat mass (kg)	Experimental	12.31	±	3.71	12.91	±	3.04	0.42
	Control	13.70	±	3.78	11.30	±	4.17	0.11
Body fat percentage (%)	Experimental	15.33	±	3.43	16.03	±	2.71	0.36
	Control	16.29	±	3.95	13.58	±	4.27	0.16

Table 2

Basic statistical characteristics of the players' anaerobic capacity by group and season

Variables	Level	Season 2012/2013 Mean ± SD	Season 2013/2014 Mean ± SD	*p*
Time to peak power (s)	Experimental	2.79 ± 0.60	2.79 ± 0.46	0.79
	Control	2.77 ± 0.66	2.77 ± 0.66	0.64
Relative Mean Power ($W \cdot kg^{-1}$)	Experimental	9.91 ± 0.81	9.14 ± 0.92	**0.04**
	Control	9.94 ± 0.85	10.04 ± 0.88	0.76
Relative Peak Power ($W \cdot kg^{-1}$)	Experimental	20.87 ± 1.92	20.01 ± 1.43	0.21
	Control	20.59 ± 3.03	20.91 ± 2.16	0.83
Relative Total Work ($J \cdot kg^{-1}$)	Experimental	299.17 ± 15.78	277.22 ± 26.37	**0.04**
	Control	298.21 ± 22.14	302.79 ± 21.25	0.69

Table 3

Basic statistical characteristics of the players' aerobic capacity by group and season

Variables	Level	Season 2012/2013 Mean ± SD	Season 2013/2014 Mean ± SD	*p*
Maximum power (W)	Experimental	384.60 ± 16.47	364.10 ± 21.96	**0.034**
	Control	387.21 ± 21.25	390.64 ± 20.12	0.89
RelativeVO_{2max} ($ml \cdot min^{-1} \cdot kg^{-1}$)	Experimental	52.70 ± 3.13	48.30 ± 3.20	**0.009**
	Control	52.57 ± 2.41	53.64 ± 4.81	0.71
LA_{rest} ($mmol \cdot l^{-1}$)	Experimental	1.17 ± 0.23	1.24 ± 0.41	0.90
	Control	1.27 ± 0.56	1.33 ± 0.50	0.76
LA_{max} ($mmol \cdot l^{-1}$)	Experimental	11.62 ± 1.13	10.91 ± 2.01	0.42
	Control	11.40 ± 1.79	10.73 ± 2.59	0.52
$\Delta LA_{max-3'}$ ($mmol \cdot l^{-1}$)	Experimental	-0.17 ± 1.04	-1.34 ± 1.18	**0.026**
	Control	-0.11 ± 1.30	-0.67 ± 1.38	0.50
$\Delta LA_{max-6'}$ ($mmol \cdot l^{-1}$)	Experimental	0.80 ± 1.36	-1.15 ± 1.23	**0.005**
	Control	0.52 ± 1.60	0.30 ± 1.68	0.76
$\Delta LA_{max-9'}$ ($mmol \cdot l^{-1}$)	Experimental	1.86 ± 1.27	-0.35 ± 1.35	**0.001**
	Control	1.39 ± 1.78	1.17 ± 1.77	0.94
$\Delta LA_{max-12'}$ ($mmol \cdot l^{-1}$)	Experimental	3.37 ± 1.12	0.71 ± 1.42	**0.0004**
	Control	2.61 ± 1.89	2.26 ± 1.75	0.58

Table 4

Basic statistical characteristics of the players' performance during on-ice tests by group and season

Variables	Level	Season 2012/2013			Season 2013/2014			p
		Mean	±	SD	Mean	±	SD	
30 m Sprint Forwards (s)	Experimental	4.38	±	0.17	4.42	±	0.21	0.99
	Control	4.24	±	0.14	4.23	±	0.10	0.98
30 m Sprint Backwards (s)	Experimental	5.50	±	0.79	5.57	±	0.87	0.92
	Control	5.29	±	0.29	5.29	±	0.29	0.96
6 x 9 Turns (s)	Experimental	12.16	±	0.79	12.15	±	0.76	0.96
	Control	12.65	±	0.45	12.62	±	0.44	0.78
6 x 9 Stops (s)	Experimental	12.75	±	0.65	12.81	±	0.79	0.75
	Control	12.82	±	0.47	12.79	±	0.43	0.85
Endurance (6 x 30 m stops) (s)	Experimental	32.18	±	1.05	33.10	±	0.70	0.80
	Control	31.97	±	0.81	31.81	±	0.60	**0.047**

Statistically significant differences with regard to aerobic capacity were also found only between the results of the experimental group. Ice hockey players from the experimental group in the 2013/2014 season had lower values of relative VO_{2max} (48.30) compared to the results of the 2012/2013 season (52.70 $ml \cdot min^{-1} \cdot kg^{-1}$; p=0.009) which they played at the top league. Analysis of the results of maximum power in the ramp test showed a statistically significant decrease in the maximum power after a year spent in the lower league (p=0.034; Table 3). Further analysis focused on blood lactate concentration. No significant differences were observed in the results of LA_{rest} and LA_{max} either in the experimental or the control group (p>0.05). Analysis of increases and decreases in the delta of blood lactate concentrate revealed that significant changes took place only in the experimental group. The rate of recovery in that group was significantly lower for all ΔLA values ($mmol \cdot l^{-1}$; p<0.05). In the next step, the analysis focused on the results of on-ice tests (Table 4).

No significant differences between the mean values (p > 0.05) were noted for the following variables: 30 m Sprint Forwards (s), 30 m Sprint Backwards (s), 6 x 9 Turns (s), 6 x 9 stops (s). Ice hockey players from the experimental group in the 2013/2014 season had worse values of endurance (6 x 30 m Stops) (33.10) compared to the results of the 2012/2013 season (32.18 s; p=0.047) which they played at the top league.

Discussion

Ice hockey as a professional game is metabolically unique. It is physically demanding and requires finely trained aerobic and anaerobic energy pathways. If appropriate training addressing these areas is not applied detraining may occur, i.e. the deterioration of different physiological variables in ice-hockey players. Typically, hockey players train over the calendar year in 3 or 4 phases. These phases usually include some type of taper in the immediate off-season and a pre-season combination of aerobic and resistance training which attempts to maintain fitness gained earlier (Quiney, 1990). Lack of optimal training in the pre-season may bring players' VO_{2max} down and consequently reduce their rates of post-exercise recovery, a key determinant of ice-hockey players' performance. Analysis of the results obtained in the course of the study showed that a season played in the first league (lower level) caused detraining in the players in the experimental group that reduced their power output in its final stages in the ramp test from 384.60 to 364.10 W (p=0.034) and VO_{2max} from 52.70 to 48.30 ml·min^{-1}·kg^{-1} (p=0.009). Because of lower VO_{2max}, the rate of post-exercise recovery ΔLA mmol · l^{-1} at the 3rd, 6th, 9th and 12th min after the ramp test decreased as well. The players' maximal power output reduction may have been caused by decreased buffering capacity after a season played in the first league where intensity of play is much lower. The researchers have found that the aerobic system may be of prime importance for recovery (Czuba et al., 2009; Thoden, 1991; Zając et al., 2010, 2014). There are many mechanisms that can explain these results. Most of all, high aerobic power increases the ability to recover from repeated bouts of anaerobic exercise and probably decreases lactate concentrations in response to higher LA utilization in slow twitch muscle fibers (Tesch and Wright, 1983; Tomlin and Wenger, 2001). In other studies, a significant correlation between capillary density and blood lactate concentration was found, suggesting that an improved efflux of lactate resulted from increased capillary density (Tesch and Wright, 1983). Increased capillary density, as seen in endurance-trained individuals, provides a decreased diffusion distance between capillaries and muscle fibers, enhancing movement of oxygen and nutrients to, and the removal of H+ and lactate from the muscle (Holloszy and Coyle, 1984). Harris et al. (1976) and Colliander et al. (1988) showed that enhanced oxygen delivery to muscles post-exercise potentially accelerated the rate of PCr resynthesis, an oxygen-dependent process. A different study allowed to identify a significant correlation between aerobic capacity measured with VO_{2max} and the fatigue index (FI) obtained during the 6 x 89 m test (Stanula et al., 2014). The results of this study seem to indicate, therefore, that the recovery time and lactate clearance depend on the fitness level, the stage of training, active muscle mass, muscle fiber composition, nutritional status, the blood flow and fatigue (Basset et al., 1991; Cox et al., 1995; Koziris and Montgomery, 1991; Smith and Roberts, 1990). As a result of lower VO_{2max}, the players in the experimental group may be less efficient in carrying out the tactical directions of their coaches during a game, because a lower rate of post-exercise recovery and oxygen debt building-up with successive shifts on ice will increase their fatigue. The study also showed that a season played in the first league had a significant and negative influence on the variables of the players' performance measured in the 30 s Wingate test: relative mean power declined from 9.91 to 9.14 W·kg^{-1} (p=0.04) and relative total work from 299.17 to 277.22 J·kg^{-1} (p=0.04). The players' performance in the on-ice 6 x 30 m test was also significantly worse (p=0.047). The relative peak power and time to peak power recorded in the experimental group in the 30 s Wingate test were not significantly worse. A season played in the first league did not have a negative effect on the results of activities determined by the ATP-PCr system (maximal effort – exercise duration up to 5 s), in contrast with the results of activities determined by PCr+glycogen (O_2) metabolic processes (maximal effort – exercise duration up to 30 s). After a season in the first league, the players in the experimental group were found to have reduced glycolytic capacity. In the top league, a majority of game play is well below the LT (Cox et al., 1995; Stanula and Roczniok, 2014; Stanula et al., 2016). Ice-hockey players relegated to a lower (less demanding) league played at a considerably lower intensity. As a result, they had greater problems with coping with muscle acidification and their glycolytic capacity recorded during tests was lower. This allows to conclude that ice-hockey players who played a season in the first league and aspire to play again in the top league should have their training programs designed with the objective to improve their aerobic and glycolytic capacity. A useful tool seems to be high intensity interval training in normobaric hypoxia (IHT) as it has been demonstrated to be effective in increasing aerobic capacity and significantly improving post-exercise recovery. This has been confirmed in basketball players after 3 week of exposure to hypoxia (Czuba et al., 2013).

Conclusion

The study showed that playing a season in a lower ice-hockey league results in a significant decrease of physical fitness and performance. The maximal oxygen uptake of the players was reduced and the rates of post-exercise recovery after the ramp test were significantly lower. Variables of glycolytic capacity, i.e. relative mean power and relative total work in the 30 s Wingate test were also reduced. Furthermore, significant deterioration in the players' performance in the on-ice 6 x 30 m test was noted. To make it possible for the talented ice-hockey players to continue their careers, they should optimize their pre-season training, as observed in many top ice-hockey leagues in the world.

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