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Physiological, physical and on-ice performance criteria for selection of elite ice hockey teams

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ABSTRACT: The purpose of this study was to examine physiological and physical determinants of ice-hockey performance in order to assess their impact on the result during a selection for ice hockey. A total of 42 ice hockey players took part in the selection camp. At the end of the camp 20 best players were selected by team of expert coaches to the ice hockey team and created group G1, while the second group (G2) consisted of not selected players (non-successful group Evaluation of goodness of fit of the model to the data was based on the Hosmer Lemeshow test. Ice hockey players selected to the team were taller 181.95±4.02 cm, had lower % body fat 13.17±3.17%, a shorter time to peak power 2.47±0.35 s , higher relative peak power 21.34±2.41 $W \cdot kg^{-1}$ and higher relative total work 305.18±28.41 $J \cdot kg^{-1}$. The results of the aerobic capacity test showed significant differences only in case of two variables. Ice hockey players in the G1 had higher VO_2max 4.07±0.31 $l \cdot min^{-1}$ values than players in the G2 as well as ice hockey players in G1 showed a higher level of relative VO_2max 51.75±2.99 $ml \cdot min^{-1} \cdot kg^{-1}$ than athletes in G2. Ice hockey players selected to the team (G1) performed better in the 30 m Forwards Sprint 4.28±0.31 s; 6x9 Turns 12.19±0.75 s; 6x9 stops 12.79±0.49 s and Endurance test (6x30 m stops) 32.01±0.80 s than players in G2. The logistic regression model showed that the best predictors of success in the recruitment process of top level ice hockey players were time to peak power, relative peak power, VO_2max and 30 m sprint forwards on ice. On the basis of the constructed predictive logistic regression model it will be possible to determine the probability of success of the athletes during following the selection processes to the team.

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INTRODUCTION

Defining the athlete's potential in team sports requires adequate methodology and statistical tools to be applied. Opportunities to employ tools of statistical analysis are ample, from the simplest taxonomic analyses to multidimensional exploration techniques for optimizing the recruitment process [1]. Also a variety of mathematical models or even artificial neural networks can be applied for optimization of selection at individual stages of sports advancement [2]. Therefore, application of the aforementioned methodology implies standardization of selection procedures so they could be used at every stage of the recruitment or/and selection process. However, it is noteworthy that in case of the selection process, the aim of applications created by means of econometric or statistical methods is to provide additional and useful information which helps with taking an optimal decision, yet it is the coach's responsibility. Ice hockey has been reported as physiologically demanding, particularly at the professional level [3, 4, 5]. It is one of the most spectacular team games. In addition, the game requires at times intense physical contact, aggressive play and exercise intervals at maximal capabilities [3]. When compared with other team sports, some authors have suggested that ice hockey predisposes an athlete to premature and chronic fatigue [6, 7]. This game is characterized by intermittent, high intensity bouts of skating requiring rapid acceleration and changes in velocity and direction, the potential for high-impact body contact, and the execution of a variety of skilled maneuvers [3, 4, 8, 9]. At the professional level, the game is characterised by intense repeated bouts of high energy output, with shifts lasting from 30-80 seconds, and seldom exceeding 90 seconds [3, 10, 11, 12]. Success at the elite ice hockey level requires players to develop fitness including anaerobic sprint ability (69% anaerobic glycolysis) as well as strength, power and endurance (31% aerobic metabolism) [3,12, 13]. The nature of the game also requires increased lean body mass and exceptional muscular strength [14]. Thus, ice hockey can be considered a sport in which total body fitness is necessary [3]. Identification of the physiological attributes of an athlete in a given sport discipline helps in the player's recruitment process and identifying athletes' strengths and weaknesses; furthermore, leads to the development of sport-specific training and testing. [15, 16, 17, 18]. The ability to identify elite versus non-elite potential of payers could influence a team's success. Therefore, effective classification of players based on physical characteristics and performance variables requires a critical analysis of the qualities deemed important for a particular sport discipline and subsequent selection and implementation of appropriate tests to assess those attributes [19]. Nowadays, there is a necessity to apply multidimensional analyses in sport sciences. It is especially relevant in the sport selection process. It is extremely difficult to designate a criterion with the aid of which one could present accomplishments of a particular player on a quotient scale. Therefore, the purpose of the present study was to examine physiological as well as physical profiles and on-ice performance of ice hockey players and their influence on success of being selected during the recruitment process to a top level Polish ice hockey team.

MATERIALS AND METHODS

The study sample consisted of ice hockey players participating in team selection camps in may 2012. In the 2012/2013 season, the team played in the top division of Polish ice hockey league. A total of 42 male ice hockey players took part in the selection camps at the end of which 20 players were selected to the team and created the group 1 (G1). G2 was a group of hockey players who cut from the selection camp (22 participants). 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. The authors of this study declare no conflict of interest.

Research design

Data collection was conducted in May, 2012. Tests lasted three days for each ice hockey player. On the first day, body measurements were made. Body height was determined including barefoot height ($\pm$ 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 weight measurement was taken in the morning (09.00-10.00 a.m.), 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 0.88 to 0.99. Three hours after breakfast, each athlete performed the 30-s Wingate test to determine anaerobic capacity. The test and a 5 min warm-up ride were performed on an electromagnetically braked cycloergometer (Excalibur Sport, Lode). The 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 the resistance adjusted to the athlete's body mass ($0.08\ \mathrm{Nm \cdot kg^{-1}}$). 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 48h of rest, all subjects preformed a ramp ergocycle test (T30x1) ($30\ \mathrm{W \cdot min^{-1}}$) with the workload increasing linearly ($0.5\ \mathrm{W \cdot s^{-1}}$) until volitional exhaustion, to establish maximal oxygen uptake (VO_2max) and to evaluate the anaerobic threshold. Each ramp test was started with the resistance set at 30W and pedal frequency varied between 70 to 80 rpm. In this phase, capillary blood samples were drawn to determine lactate concentration before and immediately at the end of the T30×1 as well as after the 3rd, 6th, 9th and 12th min of recovery. During the T30×1 protocol the following variables were constantly registered: heart rate (HR), minute ventilation (VE), oxygen uptake (VO_2) and expired carbon dioxide (CO_2), 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 ($\Delta VO_2 \leq 100\ \mathrm{mL \cdot min^{-1}}$ 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 set according to each subject.

After 48h of rest, during the last day of testing involving an on-ice test, subjects wore full hockey equipment except for the stick. Special physical fitness tests on ice were carried out in order to provide information on speed and endurance of the athlete: 30 m Sprint Forwards, 30 m Sprint Backwards, 6 × 9 m Stops, 6 × 9 m Turns, Endurance (6 × 30 meters). 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 10.0. Basic descriptive statistics were calculated, and all variables were examined for normal distribution. The Student t test for independent variables was used to evaluate the mean differences. Logistic regression was applied to establish the relationship between success at selection camps (where 0 = not selected, 1 = selected) as predictor variables. The obtained model was built on the whole data set without differentiation on a learner and test group. In order to verify error of the model three-fold cross validation was used. Evaluation of the goodness of fit of the model to the data was based on the Hosmer Lemeshow test, ROC curve and the AUC ratio (Area under curve). Statistical significance was set at $p < 0.05$.

RESULTS

Table 1 shows age, body height, body mass, BMI, and content % body fat.

The results of the anaerobic capacity test (30s Wingate test) are presented in table 2. Ice hockey players selected to the team (G1) had a shorter time to peak power (s) ($p=0.01$) compared to hockey players in G2 ($p=0.01$). Relative peak power ($\mathrm{W \cdot kg^{-1}}$) in the G1 was higher ($p=0.001$) compared to hockey players in G2 as well as

TABLE 1. Basic statistical characteristics of the two groups of hockey players – related to age and somatic variables

	G1		G2				
	N	Mean ± SD	N	Mean ± SD	t	df	p
Age [years]	20	24.70 ± 3.53	22	24.82 ± 6.68	-0.07	40	0.94
Body height [cm]	20	182.9 ± 4.02	22	179.18 ± 5.22	1.91	40	0.04
Body mass [kg]	20	78.48 ± 7.15	22	80.20 ± 9.27	-0.67	40	0.51
BMI	20	24.19 ± 1.52	22	24.94 ± 2.39	-0.89	40	0.38
Body FAT [%]	20	13.17 ± 3.17	22	16.53 ± 4.65	-2.23	40	0.03

Note: G1 – nominated group; G2 non-nominated group; BMI – body mass index;

TABLE 2. Basic statistical characteristics of the two groups of hockey players – related to anaerobic and aerobic capacity

		G1		G2				
		N	Mean ± SD	N	Mean ± SD	t	df	p
Anaerobic Capacity	Time to peak power [s]	20	2.47 ± 0.35	19	2.90 ± 0.60	-2.81	37	0.01
	Relative Mean Power [$W \cdot kg^{-1}$]	20	10.11 ± 0.86	19	9.64 ± 0.96	1.61	37	0.12
	Relative peak power [$W \cdot kg^{-1}$]	20	21.34 ± 2.41	19	18.28 ± 2.92	3.58	37	0.001
	Relative total work [$J \cdot kg^{-1}$]	20	305.18 ± 28.41	19	267.62 ± 69.78	2.22	37	0.03
	LA_{rest} [$mmol \cdot l^{-1}$]	20	1.54 ± 0.63	19	1.56 ± 0.54	-0.07	37	0.95
	$LA_{4'}$ [$mmol \cdot l^{-1}$]	20	11.16 ± 2.01	18	10.12 ± 1.77	1.68	36	0.10
	$\Delta LA_{4'\text{-}rest}$ [$mmol \cdot l^{-1}$]	20	9.62 ± 2.28	18	8.58 ± 1.84	1.53	36	0.14
Aerobic Capacity	HR [$beats \cdot min^{-1}$]	20	184.35 ± 10.23	22	182.23 ± 9.81	0.69	40	0.50
	VO_2max [$l \cdot min^{-1}$]	20	4.07 ± 0.31	22	3.81 ± 0.44	2.18	40	0.03
	Relative VO_2max [$ml \cdot min^{-1} \cdot kg^{-1}$]	20	51.75 ± 2.99	22	47.91 ± 3.04	4.12	40	0.0002
	RER	20	1.14 ± 0.07	22	1.11 ± 0.08	1.02	40	0.31
	VE [$l \cdot min^{-1}$]	20	144.50 ± 19.42	22	140.52 ± 32.98	0.47	40	0.64
	BF [$1 \cdot min^{-1}$]	20	50.46 ± 7.97	22	49.43 ± 9.40	0.38	40	0.70
	LA_{rest} [$mmol \cdot l^{-1}$]	20	1.57 ± 0.56	22	1.64 ± 0.43	-0.52	40	0.61
	LA_{max} [$mmol \cdot l^{-1}$]	20	10.67 ± 1.68	22	10.08 ± 2.12	1.00	40	0.33
	$\Delta LA_{max\text{-}rest}$ [$mmol \cdot l^{-1}$]	20	9.11 ± 1.69	22	8.44 ± 1.97	1.18	40	0.25
	$\Delta LA_{max\text{-}rest12'}$ [$mmol \cdot l^{-1}$]	20	2.61 ± 0.57	22	2.54 ± 0.88	0.32	40	0.75
Specific tests on ice	30m Sprint Forwards [s]	20	4.28 ± 0.16	21	4.59 ± 0.30	-4.18	39	0.0001
	30m Backwards [s]	20	5.37 ± 0.58	21	5.45 ± 0.58	-0.43	39	0.67
	6*9 Turns [s]	20	12.19 ± 0.75	20	12.88 ± 0.35	-3.74	38	0.0006
	6*9 stops [s]	20	12.79 ± 0.49	20	13.30 ± 0.52	-3.22	38	0.002
	Endurance (6*30m stops) [s]	20	32.01	21	33.88	-4.02	39	0.0002

Note: G1 – nominated group; G2 non-nominated group; $LA_{rest'}$ – Lactate concentration before the Wingate test, $LA_{4'}$ – Lactate in the 4th minute of recovery in the Wingate test, $\Delta LA_{4'\text{-}rest}$ – the difference between the 4th minute concentration of lactate and lactate concentration before the Wingate test. HR_{max} – max heart rate; VO_2max – maximal oxygen uptake; Relative VO_2max – relative maximal oxygen uptake; RER – respiratory ratio; V_E – minute ventilation; BF – breath frequency; LA_{rest} – Lactate concentration before the VO_2max test, LA_{max} – Lactate concentration after the VO_2max test, $\Delta LA_{max\text{-}rest}$ – the difference between the maximum concentration of lactate and Lactate concentration before the VO_2max test, $\Delta LA_{max\text{-}rest12}$' – the difference between the maximum concentration of lactate and Lactate concentration in 12th minute after the VO_2max test.

the G1 showed a higher level of relative total work ($J \cdot kg^{-1}$) than ice hockey players in G2 who were not selected to the team. For other variables, no significant differences between the mean values ($p > 0.05$) were found. Table 2 also reports parameters of the ramp ergocycle VO_2max test. Ice hockey players from G1 had significantly higher relative and absolute values of VO_2max than G2. For other variables evaluated by means of the ramp ergocycle VO_2max test, no significant differences between the mean values ($p > 0.05$) were noted. Ice hockey players in the G1 were faster in the 30 m Sprint Forwards (s) (p=0.0001); 6*9 Turns (s) (p=0.0006); 6*9 stops (s) (p=0.002) and Endurance test (6*30 m stops) (s) (p=0.0002) than players in the G2 who were not selected to the team.

Variables that predicted success at the selection camp for the team are shown in table 3. The prepared model indicates that only four variables: Relative peak power; relative VO_2max; Time to peak power and 30 m sprint forwards predicted success in the selection process for the team. The odds ratio of Relative peak power was 1,82, thus, with every one-$W \cdot kg^{-1}$ increase in relative peak power, ice hockey players were 1.82 times (82%) more likely to be selected to the team as well as with every one-$ml \cdot min^{-1} \cdot kg^{-1}$ increase

TABLE 3. Logistic regression predicting selection to the team from measured variables

	B	Standard error	Wald	p	Odds ratio	Lower 95% CI limit	Upper 95% CI limit
Relative peak power [$W \cdot kg^{-1}$]	0,6	0,31	3,62	0,047	1,82	0,98	3,36
Relative VO_2max [$ml \cdot min \cdot kg^{-1}$]	0,75	0,33	5,13	0,023	2,12	1,11	4,05
Time to peak power [s]	-4,66	2,3	4,09	0,043	0,01	0	0,87
30 m Sprint forwards [s]	-8,85	4,3	4,23	0,04	0,009	0	0,66

Note: B = estimated coefficient, CI = confidence limits.

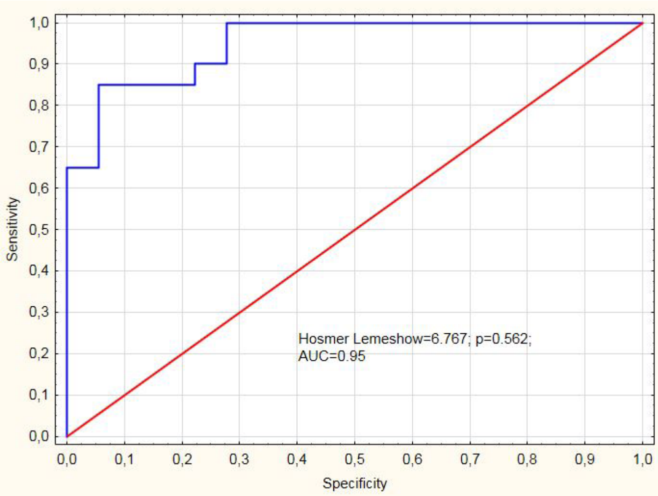

FIG. 1. Goodness-of-fit test for the logistic regression model

in relative VO_2max, ice hockey players were 2.12 times more likely to be selected to the team, etc. The basis for the use of the constructed models is technical verification. On the basis of the result of the Hosmer Lemeshow test (p=0.56), the ROC curve (Fig. 1) and area under the ROC curve (AUC=0.95) it was found that the resulting model was a good fit to the data.

DISCUSSION

The competitive sport analysis allows to observe some significant changes, especially when considering team sports with regard to motor abilities and physiological characteristics of athletes. Consequently, ice hockey is becoming a more and more demanding sport discipline what results in a significant increase of game intensity. All these changes have an influence on game spectacularity. Nowadays, ice hockey players have to be much better prepared with respect to their motor abilities and technical skills. Their psychological characteristics and tactical knowledge have to be very advanced so they can meet requirements set by this sport discipline and handle the stress. Athletes somatic variables such as body height, body weight, body mass index (BMI) or % body fat have a considerable influence on training strategy, as they can affect the technique and tactics for competition and athlete's specialization within a given discipline [20, 21, 22]. Based on the obtained results, with regard to body composition, significantly lower % body 13.17% was found in G1 group of hockey players than in the G2 16.53%. The observed anthropometric differences have important functional implications. The improved "physique", as indicated by a decrease in % body fat, would support the contention that there was an increase in lean mass of the players selected to the team in the present study. This increase would also assist in generating power and speed and positively influence outcomes of the physical nature of the game of hockey at the professional level [23]. In players selected to the team, a shorter time required to achieve maximum power 2.47 s and higher relative peak power 21.34 $W \cdot kg^{-1}$ were observed. Roczniok et al. [24] showed similar results in which youth ice hockey players selected to the team had significantly higher relative peak power than non successful players. In recent years, the most notable trends have consisted in increases in anaerobic peak power, height and VO_2max [3, 5, 12]. It was stated that athletes selected to the team had very high anaerobic power and capacity, with a mean value obtained during the Wingate test equaled to 305 $J \cdot kg^{-1}$. On the basis of the VO_2max test, absolute VO_2max along with relative VO_2max values were significantly higher in G1 (4.07 $l \cdot min^{-1}$ and 51.75 $ml \cdot min^{-1} \cdot kg^{-1}$, respectively). Other studies showed that VO_2max of elite hockey players ranged from 52-63 $ml \cdot min^{-1} \cdot kg^{-1}$ [5, 16]. Aerobic capacity is responsible for recovery from high-intensity intermittent exercise and will therefore buffer against fatigue and minimize the attenuation of power output during subsequent shifts [13]. The improvement of skating speed, particularly in the context of multiple repetitions of actions, should be a focus of training and conditioning programs and a criterion measure for selecting athletes to competitive teams [25]. Numerous studies point to a discrepancy between training intensity and the intensity of physical activity in a game situation [26, 27, 34]. Thus, specific physical fitness tests performed under game conditions are of great importance for the selection process. In the present study, such tests were carried out on ice. It was observed that hockey players selected to the team had significantly better results when compared to the hockey players who were cut. On the basis of the results of the logistic regression model, it was stated that prediction of the success in the recruitment process could be performed on the basis of 4 independent variables included in the model, i.e. 30 m sprint forwards on ice, time to peak power along with relative peak power obtained in the Wingate test and relative maximal oxygen uptake. Other studies have shown the importance of the factors included in the logistic regression model presented in this study. Being a successful player in professional ice hockey requires the player to perform high-intensity skating and at times rapidly change speed and direction, what requires a high level of anaerobic capacity [23,28]. Therefore, skating involves intermittent work, where maximal-intensity efforts of 3-5 seconds alternate with low-intensity efforts [3, 12, 23]. Roczniok et al. [24] in their research showed a logistic regression model for youth ice hockey players during a selection process to the hockey team in which body height and relative peak power were predictors of selection. Although researchers have clearly established the anaerobic nature of ice hockey, it is also clear that a well developed cardio respiratory fitness level is also important for professional players [3]. In a study conducted by Stanula a significant correlation between aerobic capacity measured by VO_2max and the fatigue index obtained during the 6 x 89 m shuttle test was identified [29]. This result is consistent with other findings reported on this topic [30, 31, 32]. Analysis of these findings leads to the conclusion that aerobic processes play an important role in the recovery, enhancing the resynthesis of energy substrates, which are necessary to exercise at high intensity. High aerobic capacity increases the ability to recover from repeated bouts of high intensity, and probably decreases lactate concentrations in response to higher LA utilization in slow twitch muscle fibers [19, 33]. The use of all variables included in the model is justified, however, in the last years the positive trend in aerobic fitness was less than that observed for anaerobic power, which underscores the relative importance of anaerobic fitness for professional hockey players [3]. In conclusion it can be stated that the findings of the present study allow to identify the variables which most influence the success during a selection process to an Polish elite ice hockey team. On the basis of the constructed logistic regression model it will be possible to determine the probability of success of the athletes following the selection processes to the team.

CONCLUSIONS

The main factors differentiating selected and cut players in this study were: % body fat, time to peak power, relative power, VO_2max and specific physical fitness on ice with the exception of 30 m sprint backwards. Based on of the logistic regression the results we found that the best predictors of success in the recruitment of top level ice hockey players were time to peak power, relative peak power, VO_2max and 30 m sprint forwards on ice.

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