The predictive value of various anaerobic capacity indices in relation to specific on-ice performance tests in ice hockey players

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Abstract: The objective of the research was to compare and evaluate the level of anaerobic fitness among four groups of elite Polish ice hockey players, ie., U-16, U-18, U-20 and a senior team using on-ice and off-ice anaerobic fitness tests. The authors evaluated the differences in anaerobic fitness of the teams using the 30-second Wingate test and on-ice tests. Analysis indicated that the mean score of the U-16 was significantly different than that of the U-18, U-20 and senior teams. Absolute maximum power (Pmax) was significantly different $F(3.86) = 10.74$, $p<0.01$ in the U-16 and U-20 and senior teams. The analysis of the *total work* (W) completed during the 30-second Wingate test yielded similar results and revealed statistically significant differences $F(3.86) = 19.60$ $p<0.01$ between U-16 and the most experienced teams, ie., the U-20 and senior team. The same statistical analyses were performed for the 5x54m test variables. We observed statistically significant intergroup differences in on-ice test results $F(3.86) = 218.87$, $p<0.01$. The Pearson product-moment coefficient revealed two statistically significant correlations between the variables of the 30-second Wingate test and 5x54m on-ice test. These findings confirmed our hypothesis that anaerobic capacity represented by several selected variables of the Wingate test should be significantly higher in an "older" and more experienced group. Results of on-ice test all show statistically significant differences; more experienced groups achieved better results. These data might be useful for controlling the training process and provide extensive information about athletes. Thus, training strategies best suited for particular competitors could be created and applied.

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1. Introduction

Ice hockey is one of the fastest team sports played today. Good skating skills, stick operation and puck mastery make the game very spectacular. Ice hockey is characterized by high-intensity intermittent skating, rapid changes in velocity and duration, and frequent body contact. Achieving championship performance in ice hockey requires a high level of conditioning and coordination. Several authors have investigated the importance of anaerobic fitness as dominant in game efficiency while the level of aerobic fitness is necessary for training preparation and the recovery process (Carey et al., 2007). The rules and the character of the game demands very high level of anaerobic fitness. Repeated short-term high-intensity shifts on ice are separated by recovery times on the bench. The typical player performs for 15 to 20 minutes of a 60-minute game. Each shift on ice lasts from 30 to 80 seconds with 4 to 5 minutes of recovery between shifts. The intensity and duration of a particular shift determines the extent of the contribution from aerobic and anaerobic energy systems. The high intensity bursts require the hockey player to develop muscle strength, power, and anaerobic endurance (Montgomery 1988). Importance of anaerobic fitness in ice hockey game and its influence on game efficiency is confirmed in researches of many authors (Seluyanov & Sarsaniya 1991; Sochaet al., 2006; Farlinger et al., 2007; Burr et al., 2008). Several tests have been used when estimating the level of anaerobic fitness: on-ice tests including the S-cornering test, 35 m sprint test, 5 x 54 m shuttle run test, modification of "beep test"; and off-ice test (laboratory) progressive bike or treadmill test, jump and sprint tests as well as other variations (15 – 45 sec) of the Wingate test (Farlinger et al., 2007; Vescovi et al., 2006; Durocher et al., 2010). Laboratory off-ice tests give clear and comprehensive information about physical and physiological parameters of a player, but do not shed much light on specific technical skills which, combined with anaerobic fitness, determine the player's efficiency on ice. On the other hand, researchers believe that on-ice tests, frequently used by coaches, exhibit some limitations including the fact of skating time being the only variable measured, and lack of data on the physical and physiological characteristics of anaerobic capacity. Since most of the findings reported have been obtained during off-ice tests, they cannot be easily applied to on-ice performance (Cox et al., 1995; Montgomery, 1988; Vescovi et al., 2006). The question is which group of tests is more useful for qualified sport, and which of them gives more accurate information for selection and training control. The objective of the research was to compare and evaluate the level of anaerobic fitness among four groups of elite Polish ice hockey players, ie., the U-16, U-18, U-20 and a senior team using on-ice and off-ice anaerobic fitness tests. The authors estimated the differences in anaerobic fitness of the teams using the 30-second Wingate test and on-ice tests. Our first hypothesis was that more experienced teams should demonstrate higher level of anaerobic fitness in both on-ice and laboratory tests with regard to each variable under consideration. The other hypothesis was that, because of the anaerobic character of both tests, the correlations between the results should be significant. We attempted to establish which anaerobic fitness test provides the most adequate and useful determinants of ice hockey players selection and training.

2. Material and Methods

Elite ice hockey players of the Polish national teams in four age categories: U-16 (n=27), U-18 (n=20), U-20 (n=23) and the senior team, ie., high-skilled players (n=21), participated in the study. In each age group, the investigations were carried out in 3-4 times in the same period of annual training cycle. Only field players (defenders and forwards) were recruited to take part in the tests; the research was conducted before the World Championships. All participants were healthy and did not report any musculoskeletal disorders. They all gave informed consent to participate in the experiment.

A 30-second Wingate test, was used to determine anaerobic fitness under laboratory conditions (off-ice test). The test variables were registered with MCE v2.2 computer software. The test effort was preceded by a 5-minute warm-up on the cycle ergometer. For each study subject the load was set at 75g/kg of total body mass. The following variables were analyzed: absolute maximum power (W), relative maximum power (W/kg), total work (kJ). The 5 x 54m shuttle run was selected as the on-ice test. The players were studied during an all-out exercise with sticks on a standard European ice rink. The test was preceded with a 30-minute warm-up, and was performed between days 3 and 7 after the laboratory test. The study was approved by the Bioethics Committee for Scientific Research at the Academy of Physical Education in Katowice.

Data analysis was performed using STATISTICA version 9.0 (StatSoft, USA). One-way ANOVA and a group of post-hoc tests were used to estimate intergroup differences regarding all variables under investigation. The Pearson product-moment correlation coefficient was calculated for all variables.

3. Results

The results of the 30-second Wingate test and 5 x 54 m shuttle run test are shown in Figures 1-4. While the parameters of the Wingate Test showed the highest values in the U-20 and senior teams and were comparable, shuttle test results were clearly the best in the senior team. Since all analyzed groups had normal distribution of variables, one-way ANOVA was conducted to compare the level of on-ice and off-ice anaerobic fitness in the four study groups. A significant difference ($F(3.86) = 10.59$, $p<0.01$) in Relative peak power - Pmax [W/kg] was observed between the U-16 and the remaining groups. The *Tukey HSD post-hoc test* (Fig. 1) showed that the mean Pmax score of the U-16 (M=10.24, SD=0.63) was significantly lower than that of the U-18, U-20 and senior teams (M=11.05 SD=0.92; M=11.46 SD=0.87; and M=11.54 SD=0.81, respectively).

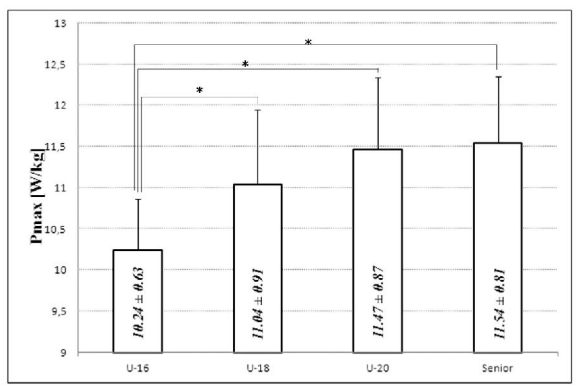

*Fig. 1. The mean and standard deviation Pmax [W/kg]. Significant differences when: * p<0.01*

Absolute maximum power (Pmax [W]) showed a statistically significant difference, ie. $F(3.86) = 10.74$, $p<0.01$, The *Tukey HSD post-hoc test* also showed (Fig. 2) that the mean Pmax score the U-16 (M=782.40, SD=81.95) was significantly lower than that of the U-20 and senior teams (M=919.43 SD=117.09 and M=926.38 SD=96.20, respectively).

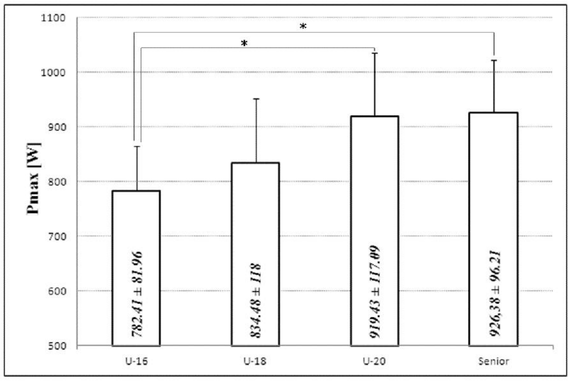

*Fig. 2. The mean and standard deviation Pmax [W]. Significant differences when: * p<0.01*

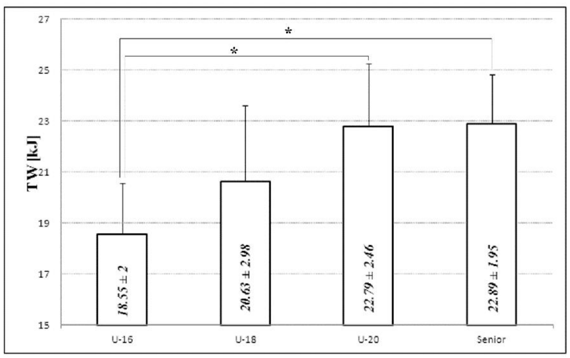

*Fig. 3. The mean and standard deviation TW [kJ]. Significant differences when: * p<0.01*

An analysis of the *total work* (Fig. 3) completed during the 30-second Wingate test yielded similar results and revealed statistically significant differences between the U-16 and the most experienced teams, ie., the U-20 and senior teams F(3.86) = 19.60 p<0.01 . The *Tukey HSD post-hoc test* also showed that the mean TW score of the U-16 (M=18.55 SD=2.00) was significantly lower than the mean scores of the U-20 (M=22.79 SD=2.46) and senior (M=22.89 SD=1.95) teams. All statistical analyses mentioned above showed higher values of 30-second Wingate test variables in the more experienced (older) group indicating better results.

The same statistical analyses were performed on 5x54m test variables yielding, however, quite different results. The results of the on-ice test (Fig. 4) differed significantly between the groups (F(3.86) = 218.87, p<0.01). The *Tukey HSD post-hoc test* indicated that U-16 results (M= 49.44, SD=1.53) were significantly different from those of the U-18 (M=44.97, SD=1.23), U-20 (M=44.03, SD=2.39) and senior (M=38.10, SD=0.68) teams. Only U-18 and U-20 results did not show statistically significant differences.

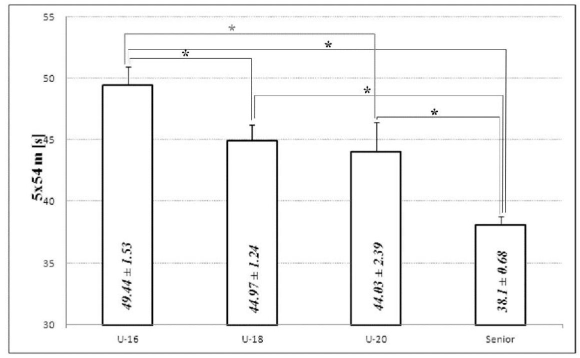

*Fig. 4. The mean and standard deviation 5x54 m [s]. Significant differences when: * p<0.01*

The Pearson product-moment correlations between the variables of the 30-second Wingate test and the 5x54m shuttle run test are presented in Table 1.

Table 1. Pearson product-moment correlations between the variables of the 30-second Wingate test and the 5x54m shuttle run test

		U-16	U-18	U-20	Senior
Team	Pmax [W]	-.06	-.03	-.36	-.37
	Pmax [W/kg]	-.02	-.04	-.43*	-.44*
	W [kJ]	-.07	-.06	-.40	-.36

* statistically significant values with p<0.05

Only two statistically significant correlations were observed. Firstly, relative maximum power of the U-20 (M=11.47, SD=0.87) and their results of the 5x54m shuttle run (M=44.03, SD=2.39) were significantly correlated (r=-0.43, p=0.04). Secondly, relative maximum power of the senior team (M=11.54, SD=0.81) and their results of 5x54m shuttle run on-ice test (M=38.1 SD=0.68) were also significantly correlated (r= -0.44, p=0.039).

4. Discussions

Anaerobic power and anaerobic endurance are of critical importance for elite ice hockey players, (Cox et al., 1995), making strength development an important component of a hockey training program. Although players are not required to meet certain physical challenges (when compared to other multiple sprint sports), power is required for acceleration, to maintain speed and for quick direction changes. Upper body strength allows players to shoot more powerfully and pass over a greater distance (Roczniok et al., 2012)

The problem of ice hockey players testing has been widely discussed by several researchers (Mascaro et al., 1992; Green et al., 2006; Burr et al., 2007; Carey et al., 2008; Durocher et al., 2010). The aim of this investigation was to estimate the applicability of on-and off-ice anaerobic tests for training control and selection. The obtained results allow a conclusion that off-ice tests used separately do not provide reliable information about anaerobic fitness and actual player's performance. Although off-ice tests yield comprehensive data on biochemical, physiological and mechanical potential of the organism, they do not take into account performance capabilities, e.g. agility and technical skills. Some specific skills can be observed only during game play; hence, the findings of laboratory tests alone are of limited value.

The results of our analysis show that the 30-second Wingate test is a valuable tool. Although a variety of on-ice skating tests have been developed, the off-ice Wingate test on a cycle ergometer (15 to 45 seconds) remains the most commonly used test for assessing anaerobic power and capacity in hockey players (Ebben et al., 2004). Each and every NHL or KHL entry draft involves the Wingate test to assess candidates' anaerobic capacity. Our hypothesis that the level of anaerobic fitness represented by selected variables of the Wingate test should be significantly higher in every "older" and more experienced group has been confirmed. The youngest U-16 players differed significantly from other groups regarding all laboratory variables under consideration. This finding is undoubtedly associated with the fact that strength and heavy athletic training is contraindicated in young individuals since such training could compromise further bone, muscle and joint growth. Therefore, considerable emphasis is placed on overall performance improvement and the development of high aerobic capacity (high VO_{2max}*), which* facilitates faster *recovery (increased rate of lactate utilization).*

Our results have also been confirmed by those reported by other authors (Glaister, 2005) who believe that aerobic and anaerobic capacity are important physiological characteristics for ice hockey players (Cox et al., 1995; Montgomery, 1998). Due to relatively short but intense work intervals in an ice hockey game (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; Montgomery, 1998). Even if such short shifts predominate in ice hockey, the physiological demands are not limited to anaerobic pathways. In fact, aerobic capacity is responsible for the recovery from such high intensity intermittent exercise and, therefore, acts as a buffer against fatigue and minimizes the attenuation of power output during subsequent shifts (Behm et al., 2005; Glaister, 2005). A transition from junior to senior levels involves the manipulation of the training load, ie., during the active season, the training volume decreases while its intensity increases. 18- and 20-year old NHL or KHL players are characterized by very well-developed muscle mass, aerobic and anaerobic capacity as well as skating and stick techniques. Senior training emphasizes reducing the time to maximum power production and increasing the glycolysis pathways, which allows high power outputs to be sustained for a long time. Hence, no significant differences were observed in the results of the 30-second Wingate test among our senior categories. Ice hockey is a physically demanding contact sport involving repeated bouts of high intensive effort, with a typical shift lasting approximately 30 to 80 seconds (Daub et al., 1983; Green et al., 2004; Lau et al., 2001). Given the anaerobic nature of these sprint-based phases (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 a well-rounded fitness level that includes anaerobic sprint ability, a strong aerobic endurance base, and high levels of muscular strength, power and endurance (Cox et al., 1995).

Our study participants were national age-group competitors, ie., the best ice hockey players in Poland with high aerobic and anaerobic capacity parameters. This might also account for the lack of differences between the U-18, U-20 and senior groups. Good skating techniques, anaerobic capacity, maximum power and time to maximum power production also play an important role during on-ice testing. The 5x54m on-ice test revealed significant differences between the U-16 and the remaining teams which might have been associated with better anaerobic capacity of the U-18, U-20 and the seniors. And, since our study participants performed a 40-second sprint, their glycolytic energy pathway, ie., the ability to sustain high power outputs for longer time, was also important. Unfortunately, the skill level of Polish ice hockey players has decreased considerably. Poor league causes problems with promotion of our national teams (both junior and senior) to elite levels. During the last Ice Hockey *World Championship Division I*, Polish senior and U-20 national teams still ranked in the middle whereas the U-18 was relegated to Division II, which proves the disastrous condition of Polish hockey. Following the reform in the system of playoffs which are to be implemented by IIHF, other national teams are also threatened with being downgraded to Division II, which is a counterpart of the third league (Roczniok et al., 2013). Consequently, the level of youth training has recently been quite poor resulting in incorrect skating techniques. Our U-16 category competitors did markedly worse compared to older teams as a result of weaker anaerobic capacity and worse skating technique. No significant differences in on-ice test results were found between the U-18 and U-20 suggesting comparable anaerobic capacity and skating technique of these groups. Significant differences in skating times were seen between the U-18, U-20 and the senior team competitors whose skating technique was definitely better.

An analysis of the Pearson product-moment correlation coefficients indicates significant negative correlations between relative maximum power and the 5x54m on-ice test results, but only regarding the U-20 (r=-0.43) and the senior team (r=-0.44), which has been confirmed by other researchers Roczniok et al. (2012) conducted a study on the U-20 and found significant negative correlations between an anaerobic capacity index, ie., maximum power (measured in Watts per kilogram) and the results of 6 × 9 m Hockey Stops, 6 × 9 m Turns, and an Endurance Test (6 × 30 m).

Thus, it can be concluded that along with a competitor's development and introduction of heavy athletic- and speed training, which is of key importance in ice jockey, correlations start to emerge between maximum power and the results of specific on-ice fitness tests (Behm et al., 2005).

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