ANAEROBIC ENDURANCE CAPACITY IN ELITE SOCCER, HANDBALL AND BASKETBALL PLAYERS

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Abstract:

The aim of the study was to determine whether there was a difference in anaerobic endurance between soccer, handball and basketball players. One hundred fifty players (mean age: 22.35±4.31 years), 50 from each sport (mean age: soccer, handball and basketball players 23.54±4.19, 20.42±4.48, 23.10±3.63 years, respectively), pertained to the highest level of their sport in Croatia; some were even members of respective national teams. Participants undertook the 300 yard shuttle run test (300Y) and maximal blood lactate test (BL). Results showed that there were significant differences in both the 300Y and BL scores between the soccer, handball and basketball players. Basketball players achieved the best results in the 300Y test (57.04±3.41s), followed by soccer (57.06±2.27s) and then handball players (59.53±2.65sl). Post-hoc tests indicated that the soccer players (14.70±2.07) had significantly ($p<.05$) higher maximal lactate values (BL) than the handball players (13.70±1.83). It is not possible to say that these three sports require equal levels of anaerobic endurance, but it is certainly an important component of performance in each and every one of them. We have concluded that the required anaerobic abilities are different in all the three investigated sports, which means that the sport-specific demands could influence athletes' anaerobic capacity.

***Key words**: blood lactate, 300 yard shuttle*

Introduction

Performance in team sports depends on multiple factors including players' energetic capacity, consisting of anaerobic and aerobic abilities; tactics, technique and the motivation of athletes for maximum use of their potential on the sport field (Grujić, Lukač, Baćanović, Dimitrijević, & Popadić, 1998) where the quality of these interactions determines the result. These factors combine a complex functional system which is created and modified during physical activities (Sporis, Ruzic, & Leko, 2008b). Many studies have suggested that success in team-sport games appears to include high anaerobic capacity, not aerobic power alone (Al-Hazzaa, et al., 2001; Hoffman, 2008; Hoffman, Tenenbaum, Maresh, & Kraemer, 1996; Smith, Roberts, & Watson, 1992).

Activities in team sports such as soccer, handball and basketball are comprised of varying explosive movement patterns (like forward, side-to-side and backward shuffles), runs at different intensities (e.g., from joggs to sprints), kicks, tackles, turns, jumps, and sustained forceful muscle contractions to control the ball against defensive pressure (Kalinski, Norkowski, Kerner, & Tkaczuk, 2002). Nowadays many team sports require skills to be performed at very high speeds. This speed requirement may lead to decreased performance when the complex functional system fails to cope with these demands (Sporis, Ruzic, & Leko, 2008a). For this reason importance of anaerobic endurance, i.e. the body's potential for long-term performance at high intensity, is well recognized in elite sport (Iaia & Bangsbo, 2010). Sporis et al. (2008a) showed that prolonged motor performance at relatively high speeds leads to fatigue, a consequential decrease in technique and an unsatisfactory final outcome. For this reason anaerobic endurance training, which helps to delay the onset of fatigue as well as reduces the fatigue effect, can be beneficial.

Anaerobic endurance is in physiological terms the ability of all living beings' organs and systems, in particular the central nervous system, to function at high intensity, but it is also related to technique and degree of economy in movement. In addition to aerobic endurance, which is the term used when referring to the distance covered (Kemi, Hoff, Engen, Helgerud, & Wisløff, 2003), sports such as soccer require performance of anaerobic activities like sprinting and acceleration (Little & Williams, 2003). This principle also applies to handball and basketball that have similar but not exactly the same movement requirements predominately due to the respective size of playing areas. For example, in basketball a significant rule change has been introduced in 2000 by which the maximum duration of an offense was decreased from 30 seconds to 24 seconds, thus leading to an increase in speed of the game (Cormery, Marcil, & Bouvard, 2008). After certain rules' changes have been introduced to handball and the „fast throw-off" style of play has been adopted, the time for rest between phases of attack and defence has been reduced so that the game became even more dynamic and demanding. Handball players have been shown to run an average of 4000 meters, the majority of which is of high intensity with an average pulse of 175 bpm and lactate concentration of 7-9 mmol/L (Loftin, Anderson, Lytton, Pittman, & Warren, 1996). In sports with a large proportion of high intensity activities, the amount of lactate, a by-product of anaerobic glycolysis, could indicate the level of preparedness of an athlete (Sporis, et al., 2008b). Hence the level of lactate could be used as a performance indicator. By monitoring its levels within a training regime, athletes' performance can be optimized (Delamarche, et al., 1987).

Although, soccer, handball and basketball require similar movement patterns, they are performed under different conditions, hence physiological requirements would be expected to be different in relation to both load and intensity (Meckel, Gottlieb, & Eliakim, 2009). During a 90-minute game, elite-level soccer players run about 10 km at an average intensity close to the anaerobic threshold (80-90% of maximal heart rate) (Stolen, Chamari, Castagna, & Wisloff, 2005). Basketball players cover about 4000-5000 m, at mean heart rates of 171/min or 91% of the maximal heart rate during a game (Abdelkrim, El Fazaa, & El Ati, 2007). Factors such as court or field surface, number of participants, and size of playing area would be likely to determine differences among the sports. On the other hand, these sports also have similar requirements as regards players' fitness such as high levels of anaerobic endurance and anaerobic energy capacity, although the sports are dominated by aerobic activity, the key situations of matches are taking place in anaerobic conditions (Abdelkrim, et al., 2007; Bangsbo, Nørregaard, & Thorsoe, 1991; Sporiš, Vuleta, Vuleta Jr., & Milanović, 2010). This has becoming increasingly true in the last decade when changes of playing style, rule changes and new tactical options have resulted in increased pace and speed of these game (Sporis, Jovanovic, Omrcen, & Matkovic, 2011). The changes which occurred in handball elicited the need to focus the training process on speed characteristics.

Kalinski et al. (2002) have found, on the sample of 316 elite athletes, statistically significant difference in their anthropological status. Also, the same authors concluded that the athletes who specialized in handball and basketball attained the greatest relative and absolute anaerobic capacity, and the greatest relative mean power. Relative mean power and anaerobic capacity of soccer athletes were the lowest among the investigated elite athletes.

The aim of this study was to determine whether there is a difference between soccer, handball and basketball players in anaerobic endurance parameters measured by a 300 yard shuttle run test and the maximal blood lactate test.

Methods

Subjects

The investigation was carried out during the summer of 2011 still in the competitive season. During the study period all the players participated in their regular training programs. The coaches were informed about the experimental procedures and the possible risk and benefits of the project. The subjects gave written consent to participate in this study. It is important to emphasize that training periodization is not the same for the sports analysed in this study so the testing of players was not conducted at the same time.

One hundred fifty players (mean age: 22.35±4.31 years) were analysed, 50 from each sport (mean age of: soccer, handball and basketball players was 23.54±4.19, 20.42±4.48, and 23.10±3.63 years, respectively). All pertained to the highest level quality of their sport in Croatia; some being even members of their respective national teams (Table 1). The same testing protocol was applied to each participant, in which, besides the main results, the basic anthropometric parameters (body height and body mass) were recorded. The study was approved by the Ethical Committee of the Faculty of Kinesiology, Zagreb, Croatia, according to the recommendations of the revised Declaration of Helsinki.

Anthropometric data

Body height (cm) was measured by a body height meter model SECA (Germany) (precision of 2 mm; range 130-210 cm). The player in the plane (Frankfurt Horizontal) and mass (kg) were recorded by a weighing machine model SECA (Germany) (precision 0.2 kg; range 2-130 kg). The percentage of body fat was estimated by measuring skinfold thickness (sum: subscapular, tricipital, suprailiac, abdominal, thigh and lower leg) using skinfold callipers (Harpenden, British Indicators, LTD), with accuracy of 0.2 mm.

Testing procedure

The 300 yard shuttle run test (300Y) estimates the level of anaerobic power ability and therefore belongs to the group of tests that measure functional ability of athletes (Arthur & Bailey, 1998). The test is performed in a sports hall or outdoors. Two 1-meter-long parallel lines are drawn 22.84 meters apart. The athlete begins at the starting line on a signal by a timekeeper and runs 12 lengths at maximum speed ensuring that s/he steps on the line before turning around and running back to the next line. The timekeepers record the split times of every length covered as well as the final result. The concentration of blood lactate (BL) is obtained from the blood samples drawn out after the first, third and fifth minute following the 300 yard test. The highest recorded result is taken as the maximum concentration of blood lactate (BL). Blood samples were taken from the finger tip of the left hand. The Lactate Scout analyser (LS, SensLab GmbH, Germany) was used for lactate analysis. 132 participants consented to blood lactate being measured because only 32 basketball players were tested.

Statistical analyses

The statistical Package for Social Sciences SPSS (v17.0, SPSS Inc., Chicago, IL) was used for the statistical analysis. Kolmogorov-Smirnov test was used to test if data were normally distributed. Descriptive statistics was calculated for age, body height and body weight along with the maximum concentration values of blood lactate and 300 yard test scores. One-way univariate analysis of variance (ANOVA) was used to assess differences between soccer, handball and basketball players in all the variables. When a significant F value was achieved, appropriate Tukey's *post hoc* test procedures were used to locate the difference between the means. The data are expressed as means±standard deviation. Statistical significance was set at p<.05.

Results

Kolmogorov-Smirnov test showed that data was normally distributed. Table 1 shows that the basketball players were, as expected, on average the tallest athletes (197.15±9.53 cm) as well as the heaviest (94.44±12.20 kg). The youngest on average were the handball players (20.42±4.48 years).

The comparison of the results of testing the maximum anaerobic performance of athletes from different team sports revealed significant differences in values of the measured variables (Table 2). The 300 yard shuttle run test took on average 57.88±3.04 seconds to perform with the best results achieved by the basketball players 57.04±3.41 s, followed by the soccer players 57.06±2.27 s and, finally, the handball players 59.53±2.65 s (Table 1). *Post hoc* tests revealed that handball players were significantly

Table 1. Descriptive statistical parameters for team sports

	N	All Mean±SD (min-max)	Soccer (n=50) Mean±SD	Handball (n=50) Mean±SD	Basketball (n=50) Mean±SD
Age (years)	150	22.35±4.31 (16–35)	23.54±4.19	20.42±4.48	23.10±3.63
Body height (cm)	150	188.99±9.92 (168.00–218.00)	182.16±7.06	187.66±6.42	197.15±9.53
Body mass (kg)	150	86.96±12.29 (59.50–119.30)	79.21±7.09	87.22±11.90	94.44±12.20
BL (mmol/L)	132	14.06±2.14 (9.00–21.10)	14.70±2.07*#	13.70±1.83*	13.65±2.47#
300Y (s)	150	57.88±3.04 (51.07–65.64)	57.06±2.27*	59.53±2.65*¶	57.04±3.41¶

BL - blood lactate; 300Y- 300 yard shuttle run; * statistically significant difference between handball and soccer; ¶ statistically significant difference between handball and basketball; # statistically significant difference between soccer and basketball

Table 2. Differences between players of soccer, handball and basketball

	Sum of Squares	df	Mean Square	F	Sig.
Age	285.17	2	142.59	8.41	.00
Body height (cm)	5750.17	2	2875.09	47.37	.00
Body mass (kg)	5807.81	2	2903.90	25.54	.00
BL (mmol/l)	32.11	2	16.06	3.65	.03*
300Y (s)	205.78	2	102.89	12.90	.00*

BL - blood lactate; 300Y- 300 yard shuttle run; * statistically significant difference p<.05

slower (p<.01) than the soccer and basketball players in parameters of anaerobic capacity. No significant difference (p>.05) was found between the soccer and basketball players in anaerobic capacity values (300 yard shuttle run test).

Blood lactate concentration showed low values in anaerobic-type sports such as handball and basketball. High blood lactate production has been observed in sports like soccer that is predominantly aerobic type of sport. *Post hoc* tests also revealed that the maximum BL levels were higher (p<.05) in the soccer players (14.70±2.07) than in the handball (13.70±1.83) and basketball players (13.65±2.47). There were no statistically significant differences (p>.05) in blood lactate concentration between the handball and basketball players (13.70±1.83 vs 13.65±2.47 mmol/L).

Discussion and conclusion

The aim of sport science is to find the weakest spot of every athlete and to apply adequate training protocol for maximum development of his/her biological potentials (Sporis, et al., 2008b). The present research was designed to investigate the difference between players from different team sports. Descriptive statistical parameters show that the players in this study have similar values of body mass (79.21±7.09 kg) and body height (182.16±7.06 cm) compared to previous research study (Wong, Chamari, Dellal, & Wisløff, 2009). However, the basketball players in our study were taller and had less body mass than previously found (Metaxas, Koutlianos, Sendelides, & Mandroukas, 2009). Furthermore the handball players differed from the previous study by Sporiš et al. (2010) in the measures of average body height 187.66±6.42 cm vs (192.1±8.2 cm) and weight 87.22±11.90 kg vs (96.0±8.3 kg), which was probably due to the fact that the handball players in our study were on average six years younger.

The basketball players were found to be significantly taller and heavier than the soccer players, which is easily explained by the specific anthropometric demands of basketball (Casajús, 2001; Metaxas, et al., 2009; Ostojic, Mazic, & Dikic, 2006; Reilly & Secher, 1990; Sallet, Perrier, Ferret, Vitelli, & Baverel, 2005). The highest values of blood lactate in our study were obtained for the soccer players. This can be explained by the fact that handball and basketball players produce less lactate under activity of the same intensity. The rate of lactate removal from the muscle cell is dependent on the adaptation to high intensity training which is stimulated by adrenaline concentration. A fast removal of lactate from the muscles allows further elimination, homeostasis consistency and a better tolerance to high intensity exercise (Billat, Sirvent, Py, Koralsztein, & Mercier, 2003). One possible reason for such differences is that the training process in handball and basketball is high-intensity oriented, focused on the development of anaerobic endurance that is indispensable for game performance. For example, Sporiš et al. (2010) found that handball players spent 7% of total movement time in sprinting and 25% of the time in high-speed running. Abdelkrim et al. (2007) demonstrated that basketball players spent 18% of total movement time in high intensity activity, whereas McMillan et al. (2005) found that soccer players spent only 10% of their movement time at this intensity level. Kohrt, O'connor, and Skinner (1989) showed significantly higher values of anaerobic capacity in athletes participating in anaerobic sport performances compared with those in the predominantly aerobic-type physical activities. This may be due to more frequent changes in movement course of play in handball and basketball than in soccer.

Tukey's *post hoc* test showed that the handball and basketball players had significantly lower blood-lactate values compared to the soccer players (p<.05). One explanation for this finding may be various tactical strategies employed during game as these can influence exercise intensity. Gerisch, Rutemoller, and Weber (1988) have observed higher mean blood-lactate values in players using 'man-to-man marking' compared to 'zone-coverage'. In this respect, basketball and handball players predominantly play „man-to-man" on a smaller playing area than soccer players. Therefore, more frequent and intensive activities are noted in basketball and handball. Anaerobic power and capacity show high values in anaerobic types of sports such as basketball and handball where players spend more time in anaerobic zone during matches (Gacesa, Barak, & Grujic, 2009). Smaller amounts of anaerobic energy production have been observed in team sports like soccer, which is predominantly an aerobic type of sports.

Highly developed anaerobic endurance is important in sports observed in this study, but importance of aerobic capacity should not be disregarded either. Aerobic condition might be essential since it improves lactate removal during recovery. Namely, the reduction in oxygen availability during high-intensity exercises is associated with a higher accumulation of lactate in blood and an impaired ability to maintain a high-power output (Balsom, Gaitanos, Ekblom, & Sjödin, 1994). In this respect handball would seem to require higher values of anaerobic endurance compared to soccer, but equal to that of basketball. However, the handball players were significantly slower (p<.01) in the 300 yard shuttle run test than the soccer and basketball players. In other words, the group of handball players achieved significantly poorer results in terms of anaerobic power test (Sporiš, et al., 2010). This may be explained with the fact that high intensity of handball play is being compensated with more frequent player substitutions during the game than in soccer.

Since the handball players were younger than the soccer and basketball players, and thus had probably fewer training sessions, was this the cause of the poor anaerobic endurance results? Perhaps a possible answer may be related to a smaller portion of anaerobic training in young athletes' sports preparation. This question is left open for further research. However, the anaerobic endurance test results here show that the current senior population of handball players, who were competing at the highest level of competitive sport in Croatia, were on average younger than the players of soccer and basketball.

The athlete sample size was big and representative enough to allow the determination of statistically significant differences between these three sports games.

An emphasis put on speed properties in conditioning preparation on speed properties of soccer, basketball and handball players could contribute to the improvement of technical and tactical performance of athletes. It should be stressed, however, that within these team sports games certain sports-specific principles exist by which athletes are selected for their playing positions. This paper has not assessed this aspect, but recognizes this as a challenge of future research. Also, it is not possible to ascertain the necessary levels of anaerobic endurance specific for the three sports observed. However, it is viable to infer that anaerobic endurance is an important component of sports performance in soccer, handball and basketball. The anaerobic endurance level of handball players, determined by the 300 yards shuttle run tests, was significantly lower than in soccer and basketball players of similar elite-quality-level.

The present study introduces potential values of anaerobic capacity for team sport athletes of soccer, basketball and handball at the elite level. These data should help coaches, and athletes alike, in the evaluation of players' anaerobic capacity and assist in the selection of athletes for elite level competition. Physiological profile of a particular team sport describes the required physical characteristics of athletes, which can then be used for talent identification and sport-specific training programs development. From the comparison of team sports such as handball, basketball and soccer we concluded that they require different anaerobic abilities, which means that the sport-specific demands could in turn influence athletes' anaerobic capacity.

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USPOREDBA KAPACITETA ANAEROBNE IZDRŽLJIVOSTI VRHUNSKIH NOGOMETAŠA, RUKOMETAŠA I KOŠARKAŠA

Cilj istraživanja bio je utvrditi postoji li razlika u anaerobnoj izdržljivosti između nogometaša, rukometaša i košarkaša. Stotinu i pedeset igrača (srednja dob: 22,35±4,31 godina), po 50 iz svakog sporta (srednja dob nogometaša 23,54±4,19, rukometaša 20,42±4,48 i košarkaša 23,10±3,63 godina), najkvalitetniji su u svom sportu u Hrvatskoj, a neki su bili članovi nacionalnih izabranih vrsta. Sudionici su izveli test 300 *yard shuttle run* (300Y) i izmjerene su im maksimalne vrijednosti laktata u krvi (BL). Rezultati su pokazali da postoje značajne razlike u rezultatima oba testa (300Y i BL) između nogometaša, rukometaša i košarkaša. Košarkaši (57,04±3,41 s) su ostvarili najbolje rezultate u testu 300Y, nakon čega slijede nogometaši (57,06±2,27 s), a zatim rukometaši (59,53±2,65 s). *Post hoc* testovi pokazali su da su nogometaši (14,70±2,07) imali značajno ($p<0,05$) veće maksimalne vrijednosti laktata (BL) od rukometaša (13,70±1,83). Ne može se reći da ta tri sporta zahtijevaju jednake razine anaerobne izdržljivosti, ali je ona svakako važna komponenta uspješnosti u svakom od sportova. Zaključili smo da su potrebne anaerobne sposobnosti različite u sva tri istraživana sporta, što znači da zahtjevi specifičnog sporta mogu utjecati na anaerobni kapacitet sportaša.

Ključne riječi: *laktati u krvi, test 300 yard shuttle*