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Fitness Profiling in Handball: Physical and Physiological Characteristics of Elite Players

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A B S T R A C T

The purpose of this study was to describe the structural and functional characteristics of elite Croatian handball players and to evaluate whether the players in different positional roles have different physical and physiological profiles. According to the positional roles, players were categorized as goalkeepers (n=13), wing players (n=26), backcourt players (n=28) and pivot players (n=25). The goalkeepers were older (p<0.01), and the pivot players were more experienced (p<0.01) than the backcourt players. The wings were the shortest players in the team. The pivots were tallest and heavier than the backcourt and wing players (p<0.01), whereas the backcourt players were tallest then wings (p<0.01). Goalkeepers had more body fat than the backcourt and wing players (p<0.01). The backcourt players had a lower percentage of body fat. The backcourt players were the quickest players in the team when looking at values of maximal running speed on a treadmill. The Goalkeepers were the slowest players in the team (p<0.01). The best average results concerning maximal heart rate were detected among the backcourt players. There were no statistically significant differences between the players' positions when measuring blood lactate and maximal heart rate. A strong negative correlation was found between body fat and maximal running speed (r=–0.68, p<0.01). Coaches are able to use this information to determine which type of profile is needed for a specific position. Experienced coaches can used this information in the process of designing a training program to maximize the fitness development of handball players, with one purpose only, to achieve success in handball.

Key words: *body composition, aerobic power, handball players*

Introduction

Handball is a sport which is rapidly gaining more and more popularity and this is inevitable. Americans are accustomed to watching such sports as football, basketball, soccer and baseball. Team handball, combining aspects of basketball, soccer and baseball, is one of the most popular sport in the world. The game is unique, with a rapid and physical yet simultaneously skillful and strategic style of play. Team handball originated in the Berlin Physical Education School in 1919 with Professor Carl Schelenz, and became an official Olympic Sport in 1972. Since its beginning team handball has developed into a very popular game in European countries, and is slowly becoming a recognized sport world wide. Team handball is played by six court players (three backcourt, two wings, and one line player or circle runner) and goalkeeper on each team, with two 30 minutes halves, on a court measuring 20x40 m. Long-term training processes in handball, along with appropriate selection, lead to the formation of an optimal, specific bio-motor structure responsible for achievement of top performance in handball[1]. Handball is very complex sport where successful performance depends on a number of basic abilities in particular strength, power, speed and endurance. Creativity in combination with speed and strength as well as coordination makes this sport very attractive but tough to play. The manifestation of these characteristics and their mutual interactions interest a large number of scientists around the world and force them to research this field[1]. During the past years coaches have recognized the value of scientific research and are becoming more and more open to scientific approaches and to results obtained from such researches. Handball has become one of the most interesting topics for researchers, due to various movement patterns and different level of abilities re-

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quired to achieve top level results[1–27]. To the authors´ knowledge this is the first study of its kind done on elite handball players (Olympic team members). In the last 15 years Croatia has presented a dominant style of play which has generated the greatest results in the history of handball. Since 1993 the Croatian national handball team has managed to win 12 medals, three gold medals form the Mediterranean Games (in 1993, 1997, 2001), a bronze (in 1994) and a silver medal (in 2008) at the European Championships, a bronze (in 1995), a gold (in 2003) and a silver medal (in 2005) at the World Championships. The greatest results of Croatian handball occurred at the Olympic games in Atlanta (in 1996) and in Athens (in 2004) where the national team won a gold medals at both (at the Olympic Games 2008 in China Croatian national team finished fourth). These results can be ascribed to the high level of physical fitness of the players who were submitted to well-planned and organized preparation cycles throughout the years. Raising the level of physical fitness, presents one of the key factors for successfulness. The measurement of physical (anthropometry, somatotypes) and physiological characteristics give a great insight into the current status of handball players and allows coaches to evaluate such players (selection) and to implicate the right training volume and intensity to raise their capabilities (preparation cycles programming). Anthropometrical measures of handball players were researched in several studies which point out specific positional differences in some measures[1,4,15,16,19]. Handball is a game with a large number of explosive movements, therefore the emphasis is on the anaerobic capacity of the players, and however the significance of the aerobic capacity should not be disregarded. The distance covered by players (running at different velocities or walking) according to their playing positions in a handball match has been the subject of the research of scientists around the world for some years[3–5]. One of the advantages of this study is the sample was conducted with Olympic team members (players who were tested and played at the Olympic Games 2004 and 2008).

The purpose of this study was to describe the structural and functional characteristics of elite Croatian handball players and to evaluate whether players in different positional roles have different physical and physiological profiles.

Materials and Methods

Ninety-two elite male handball players, twenty two were members of the Olympic team, volunteered to participate in the study. Some of the subjects were members of the Croatian National Team, and all of them provided written consent in accordance with the Declaration of Helsinki. At the Scientific Board Meeting the Faculty's Ethics committee approved the study protocol. The subjects could withdraw from the study at any time. The characteristics of the sample are presented in Table 1.

Subjects

The subjects were informed about the test protocol, without being informed of the aim of the study. At the time of the experiment, their average weekly training programs included 10–12 training sessions a week (each session lasting about 90 minutes), mainly handball training and occasionally running on a track or muscular strength training. The cohort studied was comprised of goalkeepers, wing players, backcourt players and pivot players. All the players from the Olympic team in 2004 and 2008 were tested and players playing in First Croatian League. Testing took place in period of four years from 2004–2008. The testing lasted for two days. The fist day the morphological characteristics were measured. The second day the players´ physiological parameters were tested. The tests were performed between 9 a.m. and 2 p.m. After the completion of the VO_{2max} test the subjects underwent the measurements of maximal blood lactate concentration. During the test the air temperature ranged from 20°C to 23°C. The physical load at given intensities was monitored by heart rate monitors. The subjects were given advice about their diet. All subjects had a similar diet (55% of calories were derived from carbohydrate, 25% from fat, and 20% from protein). In the period of 24 hours before the experiment, the subjects did not participate in any prolonged exercise.

Design

Upon entering the laboratory the morphological characteristics were measured. According to the instructions of the International Biological Program[28], the following anthropometrical variables were measured: body height, body mass and skinfold thickness. In the process of morphological measurement the players were interviewed about their playing experience, playing position with medical records taken into consideration; only healthy players were allowed to participate in the study. Body height, leg and hand length and hand spam were measured using the anthrop meter to the nearest 0.5 cm. Body mass was obtained to the nearest 0.1 kg using the balance beam scale (Seca, German engineering and technology). The skin fold thickness at seven sites (triceps,

TABLE 1
GENERAL DESCRIPTIVE PARAMETERS OF THE SAMPLE

	Age	Height (cm)	Weight (kg)	Body fat (%)	HR_{max}	VO_{2max} (mL/kg/min)	Years in training
$\bar{X}$±SD	26.4±3.8	192.1±8.2	96.0±8.3	11.2±3.4	191.2±8	54.0±4.1	14.7±5.2

*that maximal oxygen uptake (VO_{2max}) as well as maximal heart rate (HR_{max}) were measured by progressive treadmill test to exhaustion) subscapularis, midaxilaris, anterior suprailiac, chest, abdomen and thigh) were measured (John Bull Caliper) by a trained technician. The average of three measurements was used to represent the skin fold thickness. The percentage of fat was determined according to the athlete-specific equation of Jackson and Pollock[28]. The final test was one minute incremental maximal exercise tests on a motor-driven treadmill (Run Race, Technogym, Italy) with 1.5% inclination. A portable breath-by-breath gas analysis system (Quark k4 b2, Cosmed, Italy) was used for respiratory gas exchange monitoring. The heart rate was monitored using a heart rate monitor (Polar Vantage NV, Polar, Finland). The maximal exercise test was interrupted when a plateauing of oxygen consumption was noted or when the subject perceived volitional fatigue. For this purpose, four physiological parameters were calculated and analyzed (VO_{2max}, HR_{max} – maximal heart rate, MRS_{AT} – maximal running speed,, HR_{AT} – heart rate at anaerobic threshold). After the completion of the test the subjects underwent the measurement of maximal blood lactate concentration using a simplified blood lactate test meter (Lactate Pro™ LT-1710). The study was funded by the Faculty of Kinesiology University of Zagreb and Sport diagnostic center – Zagreb at the Faculty of Kinesiology.

Statistics

The statistical Package for Social Sciences SPSS (v13.0, SPSS Inc., Chicago, IL) was used for the statistical analysis. Descriptive statistics were calculated for all the experimental data. The Kolmogorov-Smirnov test was used to test if the data are normally distributed. For comparison between the players positions we used the analysis of variance ANOVA. Statistical power and effect size were calculated using the GPOWER software[29,30]. The relationship between the morphological, physical and physiological characteristics was determined using the Person product-movement correlation coefficient. The results were accepted as significant at $p<0.05$.

Results

All the variables had normality distributed data. All the analyzed tests had high values of ICC (0.89–0.94). The effect size for the analysis of variance was medium ($f=0.25$) but statistical power was high (power=0.91). The goalkeepers were older ($p<0.01$), pivot players were more experienced ($p<0.01$) than the backcourt players. The wings were the shortest players in the team. The pivots were taller and heavier than the backcourt and wing players ($p<0.01$), whereas the backcourt players were taller than wings ($p<0.01$). The goalkeepers had more body fat than the backcourt and wings players ($p<0.01$). The backcourt players had a lower percentage of body fat. The backcourts were the quickest players in the team when looking at values of maximal running speed on the treadmill. The goalkeepers were the slowest players in the team ($p<0.01$). The best average results concerning maximal heart rate were detected among the backcourt players. There were no statistically significant differences between the players' positions when measuring blood lactate and maximal heart rate. A strong nega-

TABLE 2
PHYSICAL AND PHYSIOLOGICAL CHARACTERISTICS OF ELITE CROATIAN HANDBALL PLAYERS

Variable	Goalkeepers (n=13)	Wing players (n=26)	Backcourt players (n=28)	Circle runner (Pivot) (n=25)
Age (y)	28.6±5.0	25.3±4.2	26.2±3.7	28.2±0.9 ||
Professional experience (y)	13.4±2.1	18.2±1.4	9.5±2.1 $	18.4±3.6
Height (cm)	195.2±5.2 ‡	183.9±5.7	196.7±5.4 §	196.3±9.3 ||
Weight (kg)	100±8.8	89.1±6.5	96.7±5.4 §	107.6±7.9 ||
Body fat (%)	12.7±0.6 †	13.2±3.3	8.7±2.0 §	13.3±6.2
Arm span (cm)	199.9±6.1 ‡	185.8±7.5	197.8±6.4 §	199.0±1.9
Hand length (cm)	86.5±2.89 ‡	79.7±3.3	84.6±2.7 §	86.3±1.5
Leg length (cm)	112.7±3.1 ‡	104.1±5.3	111.3±5.6 §	110.9±3.8
Finger span (cm)	23.5.3±1.0	22.8±0.8	22.9±1.8	24.0±1.2 ||
Relative oxygen consumption VO_{2max} ($mL\ kg^{-1}\ min^{-1}$)	53.4±1.2	56.0±3.1	53.7±5.2	50.8±0.5 ||
Maximal heart rate, HR_{max} ($b\ min^{-1}$)	192.2±14.7	190.8±7.3	193.5±6.8	186.0±5.6
Maximal running speed MRS_{VT} (km/h)	15.6±0.5†	16.7±1.94	17.5±0.9	16.5±0.7
Blood lactate BL (mmol/L)	10.9±2.4	11.9±5.1	10.7±2.7	11.0±0.7

*Vales are expressed as $\overline{X}$±SD
‡ Statistically significant at $p<0.01$ for goalkeepers *vs*. wing
§ Statistically significant at $p<0.01$ for wings *vs*. backcourt
† Statistically significant at $p<0.01$ for backcourt *vs*. goalkeepers
$ Statistically significant at $p<0.01$ for backcourt *vs*. pivot
|| Statistically significant at $p<0.01$ for pivot *vs*. wings
Statistically significant at $p<0.01$ for pivot *vs*. goalkeepers

tive correlation was found between body fat and maximal running speed ($r=-0.68$, $p<0.01$) and relative oxygen consumption VO_{2max} ($r=-0.58$, $p<0.01$).

Discussion

To the authors' knowledge, this study has provided a most comprehensive comparison between the different positional roles in top-level handball players to date. As expected, the results of this study have shown that there is a strong correlation between body composition, aerobic fitness and positional roles in elite handball. The average age of top Croatian handball players is 29.4±2.8 which is in agreement with previous investigations[1,4,15]. In the present study we found that pivot players are the oldest and most experienced players in the team. Today professional handball players do seem prepared to stay in the game for longer than they used to. The fact that pivot players are the oldest, and most experienced players in the team, may be related to the specific requirements of the position, and its unique tasks during a game (e.g. assisting, defending and attacking always under pressure). Different types of body size and proportion between team positions may constitute important prerequisites for successful participation in handball. In our study, we found that wing players are significantly shorter than pivots, backcourt players and goalkeepers which is in accordance with the results of a previous study[18]. Significant differences were found between the pivot players and wing players in weight in favor of pivot players, the same differences were found between the pivot and backcourt players also in favor of pivot players. If we examine the handball game we can conclude that the game involves physical contact whit the intention of scoring a goal. The physical attributes of the pivot players could help them to dominate in defense (covering opponents' best players) and attack (creating free space for backcourt players)[15]. In defense a shorter pivot can cover a large area thanks to his well developed agility in all ways. However, short pivot is required to have a well developed explosive power so that he could successfully block offensive shots either from the ground or from the (mid) air. On the other hand, the wings and backcourt players with a lower mass, height and body fat percentage are the most skillful players and are used to set attacks that are sometimes completed by taller players the pivots. Data on height, body mass, and body composition from our study of Croatian handball players' national Olympic team suggest that players vary widely in body size. These parameters are not an essential factor for success in handball; moreover, they might determent the playing positional role[1,15,16]. A particular body size in handball may be an advantage in certain match play situations, but a disadvantage in others. In variable finger span we found statistically significant differences between the pivot and wing players. It is known that the throwing velocity is highly dependant of a players' ability to produce power[17–19]. Higher values in variable finger span mean better ball control and better accuracy when throwing at the goal. An over arm throw either during a ground shot or jump shot in team handball is a very fast movement and has been the subject of many studies[20–25]. Due to the importance of the thrown ball velocity, many studies were oriented to the effects of different training programs to improve throwing power of elite handball players[11,25–27]. The question concerning whether to characterize handball as an aerobic or anaerobic sport has been the subject of debate. The system SAGIT which is based on artificial sight methods, to measure the cyclic movement of the players made it possible to analyze the game of handball. The relative positive error was between 0.2 m and 0.6 m, average velocity error was $0.6 ms^{-1}$. Players covered on average a distance of 4790 m at the analyzed match. Sprints amounted to 7% of playing time, 25% was spent in fast running, 31% in slow running and all of 37% walking or standing still. The players were active 53% of the playing time at a level above 70% effort. Only 2% of the playing time was spent at maximum effort and 5% at low effort. SAGIT is a new measurement technology and ensures a satisfactory level of validity and precision to evaluate the covered distance at a handball match[3]. We can conclude that handball is dominantly an aerobic sport. Anyone professionally involved in handball is aware of the games high aerobic demands, but anaerobic power is crucial for success in handball. Handball is still often perceived as an aerobic-anaerobic sport. Most action is done in aerobic conditions with anaerobic activities make a difference between wining and losing. The estimated maximal oxygen uptake of the Croatian handball players was about $58 mL\ kg^{-1}min^{-1}$. This data correspond to data collected on Slovenian handball players[3]. Significant differences were found between the pivot and wing players in maximal oxygen uptake values. The highest values of VO_{2max} were observed among the wing players. These differences were expected because of the wings specific task during a match. Wing players cover the largest distance during a match, compared to the pivots and backcourt players. In the phase of transition between defense and attack, they are the only players who run from one goal line to other goal line (approx. 35 m *per* transition), while the pivot players have to run from one 6 m goal area to the other 6 m goal area. Meaning they have to run 12 meters less during each turnover. Significant differences were found between the backcourt players and goalkeepers in variable MRS. Differences were in favor of backcourt players. These differences were expected when examining specific goalkeepers' task, which must be realized in the goal area. For goalkeepers a good reaction time and flexibility are the dominant factors for success. A strong negative correlation was found between maximal running speed, relative oxygen consumption VO_{2max} and body fat. Physics is a very important factor of success in handball. A handball player demands the ability to sustain physical effort, mostly discontinuously, over 60 minutes, some of which is at high intensity. Any unnecessary body weight has a negative effect on the manifestation of a player's ability in particularly, a player's endurance. Players who have more body fat than appropriate will become tired much faster during a game than those players with optimal amount of body fat, also these players will run slower during the second period of the game. Handball is a very difficult sport, because all action is done with an opponent. When comparing it to basketball or soccer, handball is much more a body contact sport like rugby. This constant duel is much more exhausting than running and sprinting without out contact from an opponent. The dominance of Croatian handball players at international competitions is probably not due to the players' superior physical and physiological parameters but because handball comprises a variety of individual and collective skills that are executed in the context of competitive play. It is more than obvious that other components of handball (e.g. technique, tactics, and strategy of the coach) play a key role in the final handball result. All this requires further investigation. Success in handball is dependent on how different individuals blend to become an effective playing unit. Also coaches' different strategies in playing style could have a large impact on the physiological requirements of handball players.

Conclusion

The results of the present study demonstrated the relationship between aerobic power and positional roles in handball. Profiling may be useful in a player's selection and the development of sport specific programs. It is important to consider which variables can be affected by conditioning (e.g. endurance capacity, body fat) and which cannot be affected (e.g. body size and proportion). The results of this study show there are differences in the physical and physiological characteristics in different positional roles of elite handball players. Handballs in different positional roles have special positional requirements which should reflect the differences. Coaches are able to use this information to determine which type of profile is needed for specific position. Experienced coaches can used this information in the process of designing training program to maximize fitness development of handball players, with one purpose only, to achieve success in handball.

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FIZIČKE I FIZIOLOŠKE KARAKTERISTIKE VRHUNSKIH HRVATSKIH RUKOMETAŠA

S A Ž E T A K

Cilj ovoga rada bio je opisati karakteristike elitnih Hrvatskih rukometaša, te utvrditi da li igrači na različitim pozicijama imaju različite fitness profile. Prema pozicijama igrači su podjeljeni u sljedeće skupine: golmani (n=13), krilni igrači (n=26), bekovi (n=28) i pivoti (n=25). Rezultati su pokazali da su glomani nastariji igrači (p<0,01) te da pivoti imaju veće igračko iskustvo od vanjskih (p<0,01). Krilni igrači su najniži igrači. Pivoti su veći i teži od vanjskih (p<0,01), dok su vanjski viši od krila ($p<0,01$). Golmani imaju veći postotak potkožnog masnog tkiva od vanjskih ($p<0,01$). Vanjski su igrači sa najmanjim postotok postkožnog masnog tkiva. Bekovi su ujedno i najbrži igraći u rukometu. Golmani su najsporiji igrači u rukometu. Najmanje vrijednosti maksimalne frekvencije srca imali su bekovi. Razlike između igračkih pozicija nisu dobivena na testu za procjenu maksimalne koncentracije laktata u krvi. Rezultati ovog istraživanja upućuju na negativnu korelaciju između maksimalne brzine tračanja i postotka potkožnog masnog tkiva ($r=-0,68$, $p<0,01$). Treneri mogu koristi ove informacije u vidu modelnih vrijednosti igrača s obzirom na specifičnost igračke pozicije. Iskusni treneri mogu koristiti ove informacije u procesu planiranja i programiranja treninga s ciljem poboljšanja fitness profila rukometaša te postizanja uspjeha u rukometu.