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Impact of Body Composition and Vo_2 Max on the Competitive Success in Top-Level Handball Players

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ABSTRACT

The purpose of the study was to determine the morphological and functional characteristics of 32 Serbian national U20 handball players (age 20.43±1.16y; training experience 8.12±1.89y) before European championship in Switzerland (2006) and to determinate their impact on competitive performance and outstanding success achieved. The results show that wing players differ from other players in morphological characteristics. Values for body height, weight, BMI, muscle mass and fat mass were significantly lower compared to the other playing positions. Extremely low values of maximal oxygen uptake (VO_2 max) were measured in all players (ranged from 2.68 to 4.66 $l \times min^{-1}$). Pivots had the highest VO_2 max in absolute values (3.76 $l \times min^{-1}$), and wing players in relative terms (40.83 $ml \times kg^{-1} \times min^{-1}$). Handball is characterized by high intensity intermittent play, followed by a number of walking breaks and quick substitutions. This makes possible to retain high playing intensity during whole match, because players can be given rest periods whenever needed. This will result in a high intensity game that does not necessarily require high VO_2 max. Competitive success in modern top-level handball might be more reliant on optimal tactical preparation than on the body composition and VO_2 max of an individual athlete.

Key words: *handball, body composition, VO_2 max, competitive success*

Introduction

Team handball is a high-intensity sport and one of the most physically demanding sport games[1]. This game, besides many contacts among the players, also consists of intense, intermittent movements such as running, jumping or short sprints[1]. Top-level handball players can be differentiated among themselves in the morphological space with respect to a particular playing position[2,3]. Time motion analysis of handball showed that different movement activities could be expected from players in different positions[4,5]. Numerous studies[3,5–7] showed that different movement demands among playing positions, could be one of the reasons for morphological and functional differentiation of players. Comparing the elite handball players with high performance athletes in other sports, those differences are even more manifested[8].

The importance of morphological and functional characteristics remains unclear. According to numerous researches, determination of morphological and functional characteristics have huge importance in the process of selection of handball players[3,9] and quality planning and programming of training[10]. Furthermore, recent studies reported that morphological and especially functional characteristics might have direct influence on sport performance[11–13]. Appropriate anthropometric characteristics with a high level of strength and power may provide an advantage in handball[3,14], by allowing better technical performance. Advantages in body height and body composition enable better energy transfer through kinematical chain during handball throws[10]. Moreover, according to Granados et al.[15], beside muscle strength and power, high levels of aerobic capacity represent primary conditions for successful competition performance in both male and female handball.

On the contrary, several studies[16–18] disproved the importance of aerobic capacity, especially the concept of VO_2 max in high-level competitive performance. Additionally, a number of studies on handball[19–21] highlighted the importance of anaerobic instead of aerobic characteristics in achieving high-level competitive results. More important-

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ly, recent studies[10,22] showed that aerobic capacity does not represent a limiting factor and that high value of VO_2 max is not necessary needed in top-level handball performance of today.

A study conducted by Lidor et al.[23] questions the usefulness and relevance of testing results in handball talent selection suggesting that results achieved had no prediction accuracy. However, Alexander and Boreskie[24] reported that despite the fact that testing procedures are standard part of athlete's screening, no studies have investigated connections among functional characteristics and the quantitative assessments of training and competition performance in top-level male handball players. Examination of these relationships could be of a great importance for optimal construction of the physical and sport-specific conditioning programs in improving competitive performance[3].

Therefore, this study was divided into two parts. The purpose of the first part was to determine morphological and functional characteristics of Serbian elite U20 handball players according to playing positions, and purpose of the second was to evaluate their impact on achieving high competitive results.

Materials and Methods

The study included sample of 32 Serbian national U20 handball players (age 20.43±1.16 and training experience 8.12±1.89 years). Distribution of the players across the playing positions was 4 goalkeepers, 14 back court players, 10 wing players and 4 pivots. The subjects were tested 2 weeks before the European U20 handball championship in Switzerland, 2006 where they achieved 4th place. Before any testing procedure, written inform consent was obtained from all subjects. The study has been performed in accordance with the Ethical standards of the Faculty of sport and physical education, University Belgrade[25].

Calculation of percentage of muscle, bone and fat tissue was estimated according to the standard Matiegka's methodology[26]. This method involved the following measurements: 6 skinfolds (biceps, forearm – medial, maximum girth of forearm, thigh – halfway between trochanter and tibiale, calf – posterior in maximum girth of calf muscle, abdominal, chest – at height of 10th rib), body height, body weight, circumferences (of arm, forearm, thigh – mid, calf – maximum), width dimensions (epicondyles of humerus and femur, wrist and ankle). Body weight was measured to the nearest 0.1 kg using a digital Tanita scale (Tanita Corporation), and body height to the nearest 0.1 cm (Seca 214 Road Rod, Seca Corporation, Germany). Then, BMI was calculated using the formula: weight (kg) devided by square of height in meters (m^2).

Heart rate was measured using heart rate monitor (Polar S610, Finland). Maximal oxygen consumption (VO_2 max) was measured during a continuous treadmill test to exhaustion on a motorized treadmill (Technogym Runrace, Gambettola, Italy) using the modified Bruce protocol[27]. The treadmill speed was adjusted during the warm-up period to elicit a heart rate that was approximately 70% of age-predicted maximal heart rate. The speed of the treadmill was held constant during the test and the grade of the treadmill was increased two percent every two min until volitional fatigue. Expired air was collected and analyzed breath-by-breath with an automated on-line system (COSMED Quark b^2, Rome, Italy). Objective evidence that maximal rate of oxygen uptake had been achieved was the attainment of at least two of the following: plateau in oxygen consumption with increased exercise intensity, heart rate within 10 beats per min of age-predicted maximal heart rate and respiratory exchange ratio exceeding 1.10.

All data were set as mean (X) ± standard deviation (SD), with minimal and maximal values (MIN and MAX). The statistical analyses of data were carried out using one way analyses of variance (ANOVA), while differences between specific playing positions were obtained by the post-hoc analysis of variance (LSD test). Statistical significance was set at the $p<0.05$ level. All data were processed using SPSS software (15.0, SPSS Inc., Chicago, IL, U.S.A.).

Results

The basic descriptive analyses of morphological and functional characteristics of all players, as well as parameters of the one-way analyses of variance are shown in Table 1. Significant difference ($p<0.05$) was found in body weight, body height, fat mass, percentage of fat and muscle tissue.

Table 2 summarizes the differences between specific playing positions. A certain degree of variability was noticed within results. The results showed that wing players differ from other players in morphological characteristics. The value of their body height, weight, BMI, muscle mass and fat mass were significantly lower compared to the other playing positions. In relation to the pivots, wings showed a statistically significant difference in body weight ($p=0.009$) and amount and percentage of fat mass ($p<0.001$). Wing players compared with backs were significantly different in body height ($p=0.002$). Pivot were the heaviest players (95.41 kg), with the highest BMI (26.74 kg/m^2) and in relation to the backs they had significantly more fat mass ($p=0.002$). The greatest muscle mass was recorded in backs (46.01 kg or 51.22%), significantly higher compared to the pivots ($p=0.007$).

The largest homogeneity of morphological profiles was found between the goalkeepers and pivots. Goalkeepers were relatively high, with high values of body weight and fat tissue. It is interesting that they had the largest amount of bone tissue (14.18 kg), although no significant differences among the playing positions were found ($p>0.05$).

In addition, comparing the functional characteristics of the players, we have not found significant difference between the playing positions ($p>0.05$). Surprisingly low values of maximal oxygen uptake were measured in all players (ranged from 2.68 to 4.66 $l \times min^{-1}$). Pivots had the highest VO_2 max in absolute values (3.76 $l \times min^{-1}$) and wing players in relative terms (40.83 $ml \times kg^{-1} \times min^{-1}$).

TABLE 1
DESCRIPTIVE STATISTICS AND RESULTS OF ANOVA TEST OF MORPHOLOGICAL AND FUNCTIONAL VARIABLES IN 32 SERBIAN HANDBALL PLAYERS

Variables	$\overline{X}$±SD	MIN	MAX	F	p
Body height (cm)	190.70±5.23	179.50	200.50	4.158	.015
Body weight (kg)	88.44±8.98	88.00	106.00	3.296	.035
BMI (kg/m^2)	24.33±2.34	20.40	30.04	2.358	.093
Bone tissue (%)	16.74±0.99	15.26	18.65	1.428	.256
Bone tissue (kg)	14.72±1.30	12.14	17.53	1.689	.192
Body fat (%)	13.61±5.86	7.76	30.16	6.712	.001
Body fat (kg)	12.33±6.15	6.22	26.72	6.813	.001
Muscle mass (%)	50.44±2.57	43.18	54.47	1.493	.238
Muscle mass (kg)	44.59±4.87	35.36	53.02	3.323	.034
VO_2 max (l×min^{-1})	3.53±0.48	2.68	4.66	.869	.469
VO_2 max (ml×kg^{-1}×min^{-1})	39.98±4.62	32.65	54.10	.242	.866

Discussion

This study showed that regardless of widespread opinion, high competitive results in top-level handball might be achieved despite player's inappropriately low level of VO_2 max and high body fat. Majority of present studies on elite handball players originate from the Croatian authors[2,3,5,7,28,34]. To our knowledge, the connection between the anthropometric, morphological and functional variables with competitive performances in handball has not been analyzed in scientific papers. This is the first study that will analyze the importance of these variables in

TABLE 2
MEAN VALUES AND POST-HOC ANALYSIS OF VARIANCE (LSD TEST) FOR MORPHOLOGICAL AND FUNCTIONAL VARIABLES ACCORDING TO PLAYING POSITIONS.

Variables	$\overline{X}$±SD				Significant difference					
	G	W	B	P	G-W	G-B	G-P	W-B	W-P	B-P
Body height (cm)	191.15±2.71	187.08±4.92	193.61±4.38	189.08±5.71				**		
Body weight (kg)	92.05±7.6	82.28±8.1	89.83±8.69	95.41±5.8	*			*	**	
BMI (kg/m^2)	25.17±1.66	23.53±2.40	23.97±2.16	26.74±2.25					*	*
Bone tissue (%)	16.20±0.40	17.27±0.89	16.60±0.93	16.45±1.50						
Bone tissue (kg)	16.59±4.55	14.17±1.11	14.79±1.27	15.69±1.64						
Body fat (%)	17.81±3.69	10.49±3.07	12.35±3.98	21.65±9.72	*	*			**	**
Body fat (kg)	16.59±4.55	8.70±2.96	11.34±4.82	20.58±8.91	*	*			**	**
Muscle mass (%)	49.36±2.84	51.00±1.60	51.22±1.64	47.38±4.80					*	**
Muscle mass (kg)	45.48±5.14	41.98±4.44	46.01±4.63	45.25±5.72				*		
VO_2 max (l×min^{-1})	3.55±0.42	3.34±0.51	3.59±0.44	3.76±0.61						
VO_2 max (ml×kg^{-1}×min^{-1})	38.49±2.53	40.83±6.53	39.92±2.43	39.58±7.43						

G-goalkeepers; W-wings; B-backs; P-pivots, * indicates $p<0.05$; ** indicates $p<0.01$

TABLE 3
COMPARISON OF MORPHOLOGICAL AND FUNCTIONAL CHARACTERISTICS OF DIFFERENT HANDBALL TEAMS.

Reference	Teams	Age (years)	Height (cm)	Body mass (kg)	Body fat (%)	Muscle mass (%)	VO_2 max ($ml \times kg^{-1} \times min^{-1}$)
	Serbian U20 team	20.41±1.10	190.70±5.23	88.44±8.98	13.61±5.86	50.44±2.57	39.98±4.62
Hassan et al. (2007)	England	20±2.0	174.2±5.4	77.5±11.5	13.4±5.4	47.8±8.0	N/A
	Kina	25.0±3.0	190.0±7.4	85.4±10.0	9.6±2.8	54.5±8.8	N/A
	Japan	26.0±2.0	185.4±6.7	80.6±3.9	9.2±2.0	49.0±5.9	N/A
	Korea	25.0±2.0	184.6±5.3	85.4±8.7	11.2±2.7	54.7±6.8	N/A
	Kuwait	26.0±3.0	181.6±5.0	87.6±10.3	12.9±4.3	55.3±10.5	N/A
	Saudi Arabia	25.0±3.0	182.1±7.0	75.8±8.1	10.3±2.8	46.0±6.0	N/A
Gorostiaga et al. (2005)	Spain - national team	31.0±3	188.7±8	95.2±13	13.8±2	N/A	N/A
	Spanish III division players	22.2±4	183.8±7	82.4±10	11.6±3	N/A	N/A
Rannou et al. (2001)	France - national team	22.7±0.6	177.0±1.4	74.0±2.0	13.2±0.9	N/A	57.7±3.1
	International players	23.9±1.2	190.0±1.2	79.4±0.8	12.0±0.4	N/A	58.7±0.9
Vuleta & Gruić (2009)	Croatian national champion	26.9	192.6	95.6	13.6	N/A	53.2
Sporiš et al. (2010)	Elite Croatian players	26.4±3.8	192.1±8.2	96.0±8.3	11.2±3.4	N/A	54.0±4.1
Chaouachi et al. (2009)	Tunis - national team	24.3±3.4	189±5.5	88.6±7.5	15.4±3.7	N/A	52.83±5.48

achieving high competitive results in top-level handball. Therefore, in compare to the referent group presented in Table 1, morphological and functional characteristics of different handball teams are shown in Table 3.

Once determined, these parameters allow us to recognize factors that might tightly relate to competitive success. Previous studies[2,8] supported widespread concept that morphological and functional characteristics are important in successful handball performance. Morphological profiles of top-level athletes in handball are being characterized by well-balanced mesomorphic somatotype with a touch of ectomorphy. Numerous researches showed that body composition could distinctively influence a playing position determination[2,14,28]. Years ago, importance of body height, body weight and other anthropometric measures have been shown. Khosla[29] demonstrated that players on the Olympic Games were taller in medal-winning teams than in the others, and suggested that body height and body weight were of a big importance for successful handball performance. Study of Gorostiaga et al.[10] supported these results by stating that more powerfully built players represent an advantage in top-level handball. Also, Hassan et al.[14] research showed that successful teams at Asian games in 1994 were taller and had lower body fat than the less successful teams.

In compare with similar researches[10,14,21] tested Serbian handball players had higher values of body height (190.7±5.23cm), body weight (88.44±8.98kg) and body fat (13.61±5.86%) than British, French, Asian or Spanish division III handball players had (Table 3). Muscle mass percentage was higher than found in Saudi Arabian and Japanese handball athletes, but considerably lower than found in Chinese, Korean and Kuwait handball players. Although widely accepted as one of the most important anthropometric parameters for successful participation in handball, muscle mass as a factor might not necessary represent an advantage. Despite the highest values of muscle mass, Kuwaiti players did not perform well for the period of Asian games[14].

Testing functional characteristics of the cardiovascular system is standard part of sport diagnostic procedures. High value of maximal oxygen uptake might be a major determinant in achieving sport result in conditioning sports like running. Average reported values of VO_2 max for track and field athletes were from 60.2 $ml \times kg^{-1} \times min$ for sprinters[21], to 78.7 $ml \times kg^{-1} \times min$ for long distance athletes[30]. Opposite to track and field running, handball and other team ball sports are skill sports where technique and tactics are of a primary importance. Taking that into consideration, top-level handball players might not necessary require such high VO_2 max.

In the last few decades, reported values of VO_2 max for elite handball players were approximately 60 $ml \times kg^{-1} \times min^{-1}$ [19,31]. Twenty years ago, World champion handball players

had VO_2 max value of 55 ml×kg^{-1}×min^{-1} [24]. Nowadays mean reported values of maximal oxygen uptake are up to 60 ml×kg^{-1}×min^{-1} for top-level male[22], and up to 53.8 ml×kg^{-1}×min^{-1} for female handball players[32]. Compared to other top-level handball players, maximal oxygen uptake of Serbian U20 players was approximately 30% lower than in French national and international players[21], Tunisian national players[33] and Croatian elite handball players[2,34].

According to norms mentioned above, with VO_2 max of less than 40 ml×kg^{-1}×min^{-1}, Serbian U20 handball players should never reach worthy competitive success. However, even the study of Alexander and Boreskie[24], pointed a possible inquiry that handball players might not require such a high aerobic capacity for excelling in competition. Throughout analyze of high competitive results achieved and previous study, this paper challenges old sport training and testing concepts by offering possible explanation on a question: »How was possible for Serbian U20 national team, Croatian national champion and Tunisian national team, beside inappropriate morphological and functional characteristics (Table 3), to manage admirable competitive results?«

1) Serbian U20 team in 2005/2006 → 4th place at European U20 championship;
2) Tunisian National team[33] in 2005/2006 → 1st place in African championship and 4th place in World championship;
3) Croatian National champion[34] in 2007/2008 → 1st place in Croatian National league with 29/1/0 game win/draw/lose ratio.

Nowadays handball is characterized by high intensity intermittent play, followed by a number of walking breaks and quick substitutions. Based on previous researches, Gorostiaga et al.[10] has been reported that during an official match, handball players spent 25–30 minutes on the court covering from 1.1 to 3 km with total energy consumption of up to 800 kcal. In the most recent paper about time-motion analysis[33], during nine games of the 2007 men's World Cup, mean total distance covered by players was 2058 m for goalkeepers, 2786 m for pivots, 2839 m for backs, and 3710 m for wing players. Analyzing movement categories, the total distance covered consisted of 34.3% walking, 44.7% of slow running, 17.9% fast running and 3.0% sprinting.

Handball rules allow substitutions of players at any moment during the match. This makes possible to retain high playing intensity during whole match, because players can be given rest periods whenever needed[35]. Well-developed tactics, containing skillful use of substitutions in combination with above mentioned 34.3% of walking breaks and 44.7% of slow running activity will allow enough time for players to recover regardless the value of maximal oxygen uptake. All of this will result in high intensity game that does not necessarily require high VO_2 max. Gorostiaga et al.[10], support this opinion by stating that handball players do not need high aerobic capacity in order to excel in handball and more importantly, that endurance capacity does not represent a limitation factor for further high performance in handball. Ziv and Lidor[22] also showed that endurance capacity per se is most likely not the limiting factor in handball performance. Rules and dynamic of nowadays handball game require reconsideration of factors that may be limiting in top-level handball. Moreover, no study has been performed on measuring oxygen consumption during handball games and consequently up to date there is no information about real functional demands at the top-level of performance.

Presumably, handball is a team game, inappropriate functional abilities and measured VO_2 max, can be corrected or covered with team strategy. Despite the mentioned widespread opinion about the general importance of aerobic capacity, concept of VO_2 max importance in sport was very strongly challenged years ago by Noakes[16–18]. Some of the reasons why VO_2 max is a relatively poor predictor of performance is because athletes differ in their rate of oxygen consumption at any sub-maximal running speed and at running speed they reach during the maximal treadmill test[20]. On the other side, earlier studies showed that the type of training performed, depending on sport discipline, may mediate and influence physiological parameters achieved during exhausting test[36]. Factors that determine the peak treadmill running velocity are still not exactly determined, but according to Noakes et al.[37] are not likely to be related to maximum rates of muscle oxygen consumption. This fact is related to sport-specificity of the exercises used in tests and must be taken into account when analyzing the abilities of acyclic, intermittent sports like handball.

Moreover, VO_2 max value achieved on maximal treadmill test is far from, sport-specific repeated short sprint ability, which is important for nowadays handball. Analyzing the importance of VO_2 max in game performance, the study by Delamarche et al.[19], reported that players with highest VO_2 max values were not necessary the most active during the game. On the other side, a number of studies reported that handball demands predominately the motor capacities that depend on the anaerobic metabolism[19,21]. Predominance of anaerobic metabolism with high intensity intermittent play, classify handball players closer to sprinters than to endurance athletes[21], and based on that, predefined level of anaerobic and not aerobic potential, should be one of the criterions in selection of candidates for competitive handball[20].

Conclusion

In conclusion, on a contrary to expectations and predictions, top-level teams assembled of players that recorded low values of VO_2 max and owned extremely high levels of body fat tissue for elite handball players, achieved outstanding competitive success. This study have some limitations, reflected throughout the sample of only four individuals on the goalkeeper and pivot positions which are not a representative for morphological/functional profiling of a particular position. Since this research operates with cases from different parts of the world this kind of success cannot be analyzed and described as a coincidence. Therefore, certain suggestions, although open for more research, put new

light on miss understandings among importance of functional and morphological characteristics and nowadays handball success. Quick substitutions and low intensive activity combined produce an effect where player's recovery is not as VO_2 max dependent as previously believed. Well-developed team strategy consisting of team and individual tactics through appropriately called time-outs also contributes VO_2 max independency. Linking previously stated good competitive performances in modern top-level handball might be more reliant on optimal tactical preparation than on the functional abilities of an individual athlete.

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UTJECAJ SASTAVA TIJELA I VO_2 MAX NA USPJEH U NATJECANJIMA NAJVIŠE RAZINE RUKOMETAŠA

SAŽETAK

Svrha istraživanja bila je utvrditi morfološke i funkcionalne karakteristike 32 srpska nacionalna U20 rukometaša (dob 20,43±1,16y, trening iskustvo 8,12±1,89y) prije Europskog prvenstva u Švicarskoj (2006), kao i utvrditi njihov utjecaj na kvalitetu nastupa i postizanje vrhunskih rezultata. Rezultati pokazuju da se krilni igrači razlikuju od ostalih igrača u morfološkim karakteristikama. Vrijednosti za razinu tjelesne mase, BMI-a, mišićne mase i mase masnog tkiva bile su značajno niže u odnosu na druge igračke pozicije. Izuzetno niske vrijednosti maksimalnog primitka kisika (VO_2 max) izmjerene su kod svih igrača (u rasponu od 2,68 do 4,66 $l \times min^{-1}$). Pivoti su imali najveću razinu VO_2 Max u apsolutnim vrijednostima (3,76 $l \times min^{-1}$), a krilni igrači u relativnom smislu (40,83 $ml \times kg^{-1} \times min^{-1}$). Rukomet karakterizira visoki intenzitet igranja s prekidima igre, nakon čega slijedi niz hodajućih pauza uz brze zamjene. To omogućuje da se zadrži visok intenzitet igranja tijekom cijele utakmice, jer igrači mogu dobiti razdoblja odmora kad god je potrebno. To dovodi do visokog intenziteta igre koje nužno ne zahtijevaju visoku razinu VO_2 Max. Uspjeh u natjecanjima u modernom vrhunskom rukometu bi se više mogao oslanjati na optimalnu taktičku pripremu nego na sastav tijela i razinu VO_2 Max pojedinog sportaša.