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ANTHROPOMETRIC CHARACTERISTICS AND FUNCTIONAL CAPACITY OF ELITE ROWERS AND HANDBALL PLAYERS

ANTROPOMETRIJSKE KARAKTERISTIKE I FUNKCIONALNE SPOSOBNOSTI VRHUNSKIH VESLAČA I RUKOMETAŠA

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Summary

Introduction. Anthropometric and anaerobic profile of elite athletes are fundamental for the assessment of their respective performance. The present study was designed to evaluate the anthropometric parameters, body composition and anaerobic characteristics of elite male handball players and rowers, and to compare them in relation to specific sport demands. **Material and Methods**. The study group consisted of 41 elite national level athletes: 20 handball players (aged 23.7±3.72) and 21 rowers (aged 19.7±2.84). Anthropometric characteristics (body mass, body height, skinfold thickness, body circumferences), and body fat mass were evaluated, and Wingate anaerobic test for anaerobic power assessment was applied. **Results.** The significant differences were noted in chest, upper arm, waist and hip circumferences, and supraspinal and calf skinfolds between the two investigated groups. Rowers showed higher values of fat body mass (13.2±3.76 vs. 10.7±3.76%), but lower body mass index (22.0±1,92 vs. 25.7±2.31 kg/m^2) compared to handball players. When analyzing the Wingate test parameters, significantly higher values of absolute anaerobic power (786±127 vs. 691±140 W), absolute explosive power in the handball players compared to the rowers were recorded (118±26.3 vs. 105±27.8 W/s), while rowers achieved higher relative anaerobic capacity (192±31.2 vs. 177±20.8 J/kg). **Conclusion**. Specific body composition and anthropometrical assessment as a part of morphological analysis should complement physiological profile of elite athletes. The analysis of the anaerobic performance shows that the handball players have greater alactic anaerobic and explosive power component, compared to the rowers in whom the anaerobic endurance and specific training have the greatest effect on the consumption of dominant metabolic substrate during the race.

Key words: Anthropometry; Athletes; Anaerobic Threshold; Body Composition; Athletic Performance; Exercise Test; Body Fat Distribution; Muscle Strength

Sažetak

Uvod. Analiza antropometrijskog i anaerobnog profila vrhunskih sportista je od fundamentalnog značaja za procenu njihovih funkcionalnih sposobnosti. Cilj ovog istraživanja bio je evaluacija antropometrijskih parametara, telesne kompozicije i anaerobnih sposobnosti kod vrhunskih rukometaša i veslača i njihovo poređenje u zavisnosti od specifičnih zahteva sporta. **Materijal i metode.** Istraživanje je sprovedeno u grupi od 41 vrhunskog sportiste: 20 rukometaša starosti 23,7 ± 3,72 godina i 21 veslača starosti 19,7 ± 2,84 godina. Svim ispitanicima su izmereni antropometrijski parametri (telesna masa, telesna visina, debljine kožnih nabora i telesni dijametri), a masna masa procenjena je metodom bioelektrične impedancije. Za analizu anaerobnih sposobnosti ispitanika primenjen je Vingejt (*Wingate)* anaerobni test kojim se dobijaju sledeći parametri: anaerobna snaga, eksplozivna snaga i anaerobni kapacitet. **Rezultati.** Statistički značajne razlike zabeležene su u vrednostima obima nadlaktice, struka i kukova i grudi, kao i u vrednostima supraspinalnog i kožnog nabora potkolenice. Kod veslača su utvrđene više vrednosti masne mase tela (13,2 ± 3,76 vs. 10,7 ± 3,76%), ali niži indeks telesne mase (22 ± 1,92 vs. 25,7 ± 2,31 kg/m^2) u poređenju sa rukometašima. Poredeći rezultate Vingejt testa, statistički značajno veće vrednosti apsolutne anaerobne snage (786 ± 127 vs. 691 ± 140 W) i apsolutne eksplozivne snage zabeležene su kod rukometaša (118 ± 26,3 vs. 105 ± 27,8 W/s), dok su veslači ostvarili veće vrednosti relativnog anaerobnog kapaciteta (192 ± 31,2 vs. 177 ± 20,8 J/kg). **Zaključak**. Specifična analiza telesne kompozicije i antropometrijska analiza dopunjuju fiziološki profil vrhunskih sportista. Analizirajući anaerobne sposobnosti, rukometaši poseduju izraženiju alaktatnu anaerobnu i eksplozivnu snagu u poređenju sa veslačima, kod kojih anaerobna izdržljivost i specifični trening najviše doprinose utrošku dominantnog metaboličkog supstrata tokom trke.

Ključne reči: antropometrija; sportisti; anaerobni prag; sastav tela; sportski učinak; vežbe, testovi; distribucija masnog tkiva; mišićna snaga

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Abbreviations

AC – anaerobic capacity
AP – anaerobic power
BMI – body mass index
EP – explosive power
BF (%) – body fat percent

Introduction

Specific physiological and morphological parameters are important components of performance in many sports. It has been confirmed that certain physical characteristics such as body composition (body fat, body mass, muscle mass) and physique (somatotype) can significantly influence sport results [1]. Numerous studies have revealed that optimal body composition in athletes is associated with enhancements in aerobic and anaerobic performance [2, 3] and muscular strength [4–6]. It is generally accepted that lower relative body fat is desirable for successful competition in most sports. The term "morphological optimization" [7] refers to the selection of specific body structure and morphological characteristics needed for particular sport. Anthropometric measurements are of great importance for the assessment of body structure since the large amount of data can be collected with non-invasive methodology and inexpensive equipments [8, 9].

Studies on individuals with different levels of physical activity have confirmed that athletes tend to have different anthropometric parameters and energetic capacities compared to non athletes [10, 11]. In elite sports, different sport disciplines require optimal physiological and morphological attributes needed for top level performance. Optimal anthropometric profile in these disciplines may be considered as an important factor to the athlete's success, together with the technique and experience. Several studies have shown that anthropometric characteristics influence sport performance [12–14] and they should be determined and continuously monitored during the training process [15].

Alongside with morphological measures, it is fundamental to analyze energetic capacities of athlete as well. Although aerobic capacity has been more extensively evaluated in literature, corresponding data for anaerobic performance are still scarce, particularly in elite sports. For instance, handball is physically demanding intermittent sport, with substantial aerobic component, but also with high intensity periods with anaerobic energy release. In addition, competitive rowing is a sport discipline based on highly developed both energetic capacities (aerobic and anaerobic). Since rowing and handball rely on anaerobic metabolism to some level, we wanted to explore if there were differences in specific anaerobic components (alactic and anaerobic endurance) between these athletes. There is a great number of tests that can be used to evaluate anaerobic abilities; among them is the Wingate Test, a valid and highly reproducible tool, which is easy to be administered.

The Wingate test is a 30-second supramaximal pedaling test in which the power output can be computed every 5 s [16]. Besides this, it has a meaningful correlation with anaerobic parameters such as maximum lactate concentration and oxygen deficit [17–20]. These characteristics make this test very suitable for the analysis of anaerobic performance of individuals at different levels of physical activity and sport disciplines [21, 22]. The Wingate test provides basic parameters of anaerobic performance: anaerobic power (AP) is the maximal value one achieves in the first few seconds of the test and represents the phosphocreatine energetic pathway of power development; the mean power is a unit of anaerobic capacity (AC) that includes glycolytic energy release as well; the explosive power (EP) is the speed at which maximal power is achieved and reflects transformation of chemical energy into mechanical work.

The present study was aimed at evaluating the anthropometric parameters, body composition and anaerobic performance of elite male handball players and rowers, and comparing them in relation to specific physiological demands of sport disciplines.

Table 1. Basic anthropometric characteristics of handball players and rowers
Tabela 1. *Osnovne antropometrijske karakteristike rukometaša i veslača*

Subjects/*Ispitanici*	Height (cm) *Visina (cm)*	Body mass (kg) *Telesna masa (kg)*	Age (years) *Starost (god)*	Sport experience (years) *Sportsko iskustvo (god)*
Handball players/*Rukometaši* (n = 20)				
X	189	91.6*	23.7*	9.55*
SD	4.15	8.14	3.72	3.93
MIN	181	79.0	19.0	2.00
MAX	198	112	32.0	20.0
Rowers/*Veslači* (n = 21)				
X	185	79.3	19.7	4.58
SD	3.58	6.13	2.84	2.14
MIN	174	68	16	1.00
MAX	191	90	25	10.0

*p<0.05

Table 2. Body fat mass, skinfold thickness and girds of handball players and rowers
Tabela 2. *Masna masa tela, debljina kožnih nabora i telesni obimi rukometaša i veslača*

	Handball players/*Rukometaši*	Rowers/*Veslači*
	$\overline{X} \pm SD$	$\overline{X} \pm SD$
BF (%)	10.7 ± 3.76	13.2±3.28
BMI (kg/m^2)	25.7 ± 2.31	22.0 ± 1.92
Skinfold thickness (mm)/*Debljina kožnih nabora (mm)*		
Chest/*Grudni*	8.51 ± 2.4.09	6.89± 63.37
Subscapular/*Supskapularni*	13.1 ± 3.95	11.2± 5.29
Midaxillary/*Srednji aksilarni*	10.5* ± 4.92	7.81± 3.35
Biceps/*Biceps*	5.13 ± 1.76	5.66 ± 2.39
Triceps/*Triceps*	10.2 ± 3.52	9.70 ± 3.61
Abdominal/*Abdominalni*	15.9 ± 5.29	14.8 ± 7.55
Suprailiac/*Suprailijačni*	10.8± 5.31	9.63 ± 4.31
Supraspinal/*Supraspinalni*	8.64 ± 4.37	11.8*± 6.32
Front thigh/*Natkolenica*	16.0± 3.43	16.4 ±7.06
Medial calf/*Potkolenica*	9.78 ± 3.97	12.8* ± 5.65
Circumferences (cm)/*Obimi (cm)*		
Forearm/*Podlaktica*	28.9 ± 1.60	27.2 ±1.51
Upper arm relaxed/*Nadlaktica opuštena*	31.7* ± 2.16	28.7 ± 2.42
Upper arm flexed/ *Nadlaktica savijena*	35.9* ± 2.57	31.8± 2.61
Chest/*Grudi*	101* ± 5.48	93.2± 4.90
Waist/*Struk*	84.6* ± 5.10	76.4 ± 3.98
Hips/*Kukovi*	102* ± 4.16	96.4 ± 4.76
Mid-thigh/*Natkolenica*	58.1± 2.68	55.1 ± 3.61
Calf/*Potkolenica*	40.3 ± 2.54	37.6 ± 2.71

*p < 0,05, BMI - indeks telesne mase; BF% - procenat telesne masti

Material and Methods

The study group consisted of 41 elite national level athletes: 20 handball players (aged 23.7±3.72) and 21 rowers (aged 19.7±2.84). We performed anthropometric measurements (body mass, body height, skinfold thicknesses, body circumferences), body composition analysis, and the Wingate anaerobic test for anaerobic power assessment. The nutritional level was defined according to the body mass index values (BMI), obtained by dividing a person's weight in kilograms by the square of the person's height in meters.

The anthropometric data included 3 types of measurements: basic (body height, body mass, BMI), body circumferences (chest, flexed and relaxed upper arm, forearm, waist, hip, mid-thigh, calf) and skinfold thickness (chest, subscapular, midaxillary, biceps, triceps, abdominal, suprailiac, supraspinal, front thigh, medial calf) on the right side of the body according to the standard methods proposed by the International Society for the Advancement of Kinanthropometry [23].

The body height was measured by Harpenden anthropometer (Holtain Ltd, Croswell, UK), with the precision of 0.1 cm. The body fat mass (FAT%) and total body mass were measured by Tanita bioimpedance analyzer TBF-310 (Tanita Corporation, Tokyo, Japan). The skinfold thicknesses were measured by means of Harpenden caliper (Holtain Ltd, Croswell, UK) with the precision of 0.2 mm. All skinfold thicknesses were measured three times and the final value was the average between the three measurements.

All participants performed the Wingate Anaerobic Test in its standard version in duration of 30s on the air brake cycle with calibrated resistance [19]. All subjects underwent a 5-minute to 10-minute intermittent warm-up prior to the test. Standard measures of anaerobic abilities were recorded: the peak power, or AP is the highest power output observed during the first few seconds of test, it indicates the energy generating capacity of the immediate energy system; AC reflects the local endurance of involved muscles; and EP reflects the explosive component of muscle contraction. All parameters were recorded by means of the software installed in PC, which was directly connected with the ergometer machine and then analyzed in absolute and relative values. After the Wingate test, the individuals performed a period of active recuperation on the cycle ergometer in duration of 2 to 3 minutes.

Data Analysis: The data were analyzed by means of the t-student test. The level of significance adopted was $p < 0.05$.

Table 3. Anaerobic characteristics of handball players and rowers
Tabela 3. *Anaerobne karakteristike rukometaša i veslača*

Subjects *Ispitanici*	Parameter *Parametar*	Anaerobic power (W) *Anaerobna snaga (W)*	Relative anaerobic power (W/kg)/*Relativna anaerobna snaga (W/kg)*	Explosive power (W/s) *Eksplozivna snaga (W/kg/s)*	Relative explosive power (W/kg/s)/*Relativna eksplozivna snaga (W/kg/s)*	Anaerobic capacity (J) *Anaerobni kapacitet* (J)	Relative anaerobic capacity (J/kg)/*Relativni anaerobni kapacitet (J/kg)*
Handball players *Rukometaši*	X	786*	8.52	118*	1.28	16259	177
	SD	127	1.14	26.3	0.25	2092	20.8
	min	610	6.46	77.8	0.78	11860	124
	max	1061	11.4	175	1.84	20420	220
Rowers *Veslači*	X	691	8.69	105	1.32	15211	192*
	SD	140	1.53	27.8	0.31	2778	31.2
	min	389	5.72	42.5	0.57	8900	131
	max	958	12.2	162	1.96	20310	264

*p<0.05

Results

Table 1 shows the basic anthropometric characteristics and sport experience of handball players and rowers. The handball players were taller and significantly heavier than the rowers, with longer sport experience.

Table 2 gives body fat level, body mass index, skinfold thickness and body circumferences of handball players and rowers.

The significant differences were noted in the chest, forearm, waist and hip circumferences between the two groups. In general the rowers were found to possess more deposition of subcutaneous fat in the lower regions of body (supraspinal and calf skinfold), while the value of midaxillary skinfold was higher in the handball players. Other anthropometric variables did not show any significant differences.

The values of Wingate test parameters in investigated groups are shown in **Table 3.**

The analysis of the Wingate test parameters of athletes engaged in different sport types (handball players and rowers) has revealed significantly higher values of absolute anaerobic power and absolute explosive power in the handball players representing sports with more anaerobic characteristics compared to the rowers, who had higher values of anaerobic capacity.

Discussion

Physiological features are of great importance for achievements in elite sports. Specific sport disciplines require different body parameters and body structure for maximal performance. It has been found that the athletes with optimal body fat level have higher performance parameters, while the excess of body fat reduces physical abilities [24]. Body composition studies have found a high, negative relationship between performance in various activities, BMI and body fat mass [25]. When comparing anthropometric and body composition profiles of handball players and rowers, significant differences were found in the values of BMI, body fat mass, body circumferences and skinfold thickness. According to our results, handball players are taller, heavier with higher BMI and all circumferences compared to rowers. Rowers in general are found to possess more deposition of subcutaneous fat in the lower body regions compared to handball players, whereas significantly higher values of upper arm, chest, waist and hip circumferences were found in handball players. These results also indicate greater lean body mass in handball players. Measurement of circumferences may be considered as a field anthropometric tool to evaluate representation of muscle mass, when other methods are not available [26] since there are a few limitations and inaccuracies associated [27].

When comparing anthropometric characteristics to recent data on handball players, we found similar values of average height to those reported from the World Cup held in 2013 where average weight of most successful teams from 24 countries amounted to 92.37 kg, and average height was 190.10 cm [28]. The analysis of previous data on anthropometry of handball players (World Cup 2007) has suggested that there is morphological evolution in this sport, presented as an increase in certain body dimensions (body height, body weight) [28]. Optimal body structure is needed for specific demands of this type of sports, with developed lean body mass and the least possible percentage of body fat. This is in accordance with our results, which show that handball players are tall, lean people with 10.7% of fat body mass.

Rowing is the kind of sports which requires both endurance and strength, where body size and structure are performance related factors [29]. Studies of morphological parameters and physical abilities in adult rowers emphasize the importance of anthropometric measurements for rowing performance [30, 31]. Previous and recent research studies on the anthropometric profile [32–35] have shown that elite rowers generally have the same characteristics as our study group. Previous studies presented a typical rower as a tall, lean and heavy athlete with developed energetic capacity. Our results are similar to more recent studies showing shorter and lighter athletes compared to the data from 2008 Olympics [36]. Despite these morphological differences, athletes showed high performance in relation to body dimensions [36]. This is probably the result of excellent technical skills, genetics factors, and specific rowing training (the large volume of aerobic training together with anaerobic type of training) leading to anaerobic endurance and metabolic efficiency [14].

Body structure assessment is of great importance for general and athletic population, but there are no adequate reference values for elite athletes [37–39], especially in certain parameters such is BMI. An interesting finding of this study is BMI value of handball players (25.7±2.31 kg/m^2), which is similar to the values recorded in athletes from World Cup in 2013 (25.53±2.09 kg/m^2), indicating the importance of body fat mass measurements. The BMI considers only height and weight of an individual, but the body composition aspects are not evaluated in this assessment [40]. The BMI depends not only on the fat content in the human body, but also on the muscles and bone mass, as well as on the water content. A high value of the BMI can be measured in athletes with greater skeletal muscles mass because training in many sports disciplines leads to an increase of muscle mass and the whole body mass as well as in body mass index [41]. A high BMI value is observed in weight lifters, body builders, rowers, professional football and handball players, etc. Results of previous research [42, 43] have shown that an increase in BMI is not necessarily an indicator of excess fat in athletes, but more likely of increased muscle mass. According to the results of present research the BMI has low level of validity when assessing body composition in athletes since it does not discriminate muscle from fat mass and could lead to misinterpretation of higher values in handball players as overweight. These findings highlight the importance of body composition assessment in athletes.

The evaluation of anaerobic profiles of the study groups has revealed differences in all Wingate parameters, with significant higher values in absolute AP and absolute EP in handball players. These higher values are expected since handball is sport characterized by short high-intensity periods, where anaerobic abilities are very relevant to maximal performance [44, 45]. Another study done on professional handball players showed higher absolute maximum power and a relative maximum power compared to our investigated athletes [22]. It is possible that the discrepancies encountered in the two studies are due to differences in anthropometric characteristics (active muscle mass) and different age range of athletes.

In our investigation, handball players are taller and heavier than rowers, with longer sport experience. These anthropometrical differences could partly explain the results of Wingate Anaerobic Test, where higher values of AP and explosive power were recorded in the handball players than in the rowers. In other words, the handball players showed more alactic AP and greater AC in relation to the rowers, in whom significantly higher values were recorded in the relative AC indicating the importance of power endurance in this sport. Rowing is considered mostly aerobic sport, but at the beginning and in the finish of the race, anaerobic component also plays an important role. Secher [46] has found that the initial spurt at start of rowing race is crucial for maximal performance and probably highly depends on AP and capacity of athlete. Previous studies have also revealed that competitive rowing is sport with highly developed both (aerobic and anaerobic) energetic capacities [14, 29]. Lower values of peak and explosive power of rowers compared to handball players could be explained by the repetitive nature of rowing, where in contrast to explosive movements such as jumping present in handball, rowers are not specifically trained to produce such AP outputs. The present results are in line with other studies, suggesting that AP and specific anthropometric characteristics are important training objectives to optimize rowing performance [14]. Data from previous studies suggest that efficiency of anaerobic processes evaluated by the Wingate test could be a predictor of rowing performance [14, 32, 47]. These findings are consistent with previous studies that have confirmed that anaerobic and morphometric characteristics of rowers are the result of the large volume of aerobic training undertaken, together with weight training, leading to specific body structure and physiological profile.

Conclusion

Specific body composition and morphometric parameters could be considered as an important factor contributing to the athlete's respective performance in addition to the technique and sport experience. Based on our Wingate test results, it can be concluded that handball players have greater alactic anaerobic power compared to rowers in whom, most likely, the anaerobic endurance and specific training contribute to the determination of the predominant metabolic substrate during the race.

These physiological attributes may be used for talent identification and to develop more specific assessment methods in elite sports. Furthermore, it may assist the trainers or sport scientists in developing a training program that targets and improves all of the essential attributes to the levels required for success.

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