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Original research article

BODY STRUCTURE PROFILES OF R. OF SERBIA'S SENIOR HANDBALLERS FROM DIFFERENT COMPETITIVE LEVELS AS MEASURED BY THE MULTICHANNEL BIOELECTRIC IMPEDANCE METHOD

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Abstract. *The goal of this study was to define body composition characteristics and differences between Serbian male handballers measured by the multiple bioimpedance method. The sample of subjects consisted of 94 male senior handballers from three different competition levels, distributed as follows: the Serbian male national team = 19; the Serbian Super National League = 43; and the Serbian First National League = 32. Twenty-two (22) variables were measured in this research, structured as follows: eight (8) basic and fourteen (14) derived or index variables, with six (6) of the latter being dependent on body voluminosity, seven (7) dependent on body longitudinality, and one (1) was an index variable. For all the results, descriptive statistical characteristics were calculated and multivariate and univariate analysis of variance (MANOVA and ANOVA) were used to establish both general and partial potential inter-group differences, by applying Wilks's Lambda criterion. The results of the MANOVA showed, in general, statistically significant differences in the examined body composition variables between samples of handballers at Wilks's Lambda Value 0.370, F = 2.048, p = 0.001. Established differences explained 39.2% of the general variability (Partial Eta2 =0.392) with the observed statistical power of the data of 100% (Observed Power = 1.000). The statistically significant variables that predominantly defined body composition differences, were: BH, BM, Proteins, Skeletal Muscle Mass, Minerals, Total Body Water, Free Fat Mass and Muscle Mass Index (p = 0.000). The findings of this study show a statistically varied body composition of handballers of different competitive success; in other words, the most successful players, or players in the ranks of the Serbian national team, morphologically differ from players in lower competitive ranks. Also, the findings show that the multiple*

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bioimpedance method is valid in defining the mentioned body composition differences for handball players of different competitive success, and therefore it can be used, both in general and in particular, in practice and in the science of handball. In respect to the partitioning of the initial variables, the findings have shown that this partitioning for defining the differences between the observed samples is somewhat more sensitive than the one in respect to the bodily height, i.e., longitudinality.

Key words: *handball, body composition, males, bioimpedance.*

INTRODUCTION

Handball falls in the category of sport games, and is in its essence a very dynamic game, with lots of fast but short sprints, many ball leading and passing situations, with abrupt direction and course changes, and with many and varied contacts with opponent players, together with performing different types of jumps (Michalisk, Aagaard, & Madsen, 2012; Vukosavljavić, Kocić, Berić, & Stojić, 2015). One previous research established that physical demands were different from one playing position to another, with wing players (WP) demonstrating a more intensive activity in playing pattern (10.9 ± 5.7 % high-intensity running out of totally covered distance) than backcourt players (BP, 6.2 ± 3.2 %) and pivots (PV, 8.5 ± 4.3 %), respectively. According to the data published by Michalisk and co-authors (Michalisk et al., 2012), during a male handball game, the total distance of 3627 ± 568 m is covered per match, the total effective playing time (TPT) is 53:51 ± 5:52 min, while full-time players cover even 3945 ± 538 m. The mean game running speed is 6.40 ± 1.01 km · h^{-1}, where high-intensity running constitutes only 1.7 ± 0.9 % of TPT per match, corresponding to 7.9 ± 4.9 % of the totally covered distance.

In one specific handball match, an average of 1482.4 ± 312.6 activity changes per player were observed, with 53.2 ± 14.1 high intensity runs; also, it was established that the statistical significance of the amount of high-intensity running was lower ($p < 0.05$) in the second half of the game (130.4 ± 38.4 m) than in the first half (155.3 ± 47.6 m), corresponding to a decrease of 16.2 % due to the fatigue effect in the game.

Also, it was found that handballers had 36.9 ± 13.1 high-intense technical playing actions per match, with a mean total effective playing time of 53.85 ± 5.87 minutes. In offense, each player performed 6.0 ± 5.2 fast breaks, received 34.5 ± 21.3 tackles in total, while in defense there were 3.7 ± 3.5 blockings, 3.9 ± 3.0 claspings, and 5.8 ± 3.6 hard tackles. Wing players (84.5 ± 5.8 kg, 184.9 ± 5.7 cm) were lighter and smaller ($p < 0.001$) than backcourt players (94.7 ± 7.1 kg, 191.9 ± 5.4 cm) and pivots (99.4 ± 6.2 kg, 194.8 ± 3.6 cm). The general conclusion is that modern elite male team handball is characterized by a high number of short-term, high-intensity intermittent technical playing actions. Physical demands differ depending on the playing position, with wing players performing more of fast breaks and less of physical confrontations with opponent players than is the case with backcourt players and pivots (Michalsik et al., 2012; Michalsik, Madsen, & Aagaard, 2015).

One of important aspects when selecting athletes, and furthermore making the ultimate choice of a particular branch of sport and of an individual's playing position, is morphology, or in other words, the features of an individual's body composition. These are of extreme importance for achieving top results in sport in general, therefore also in handball in particular.

Through the training process of several years, it is necessary to achieve a player's specialization for his specific playing position. The physical and morphological features of players must be exceptionally accentuated, and it is through training and competing processes that the final selection is made, in terms of positioning players according to the requirements of a specific playing position an individual athlete is predisposed for. This is exactly the reason why it is necessary to define models of body composition of top players, for the purpose of further technological upgrade of the selection process.

Also, we witness today that handball play is much more powerful and with very many “hard” duels in the defense phase. The game certainly has acceleration in the offense phase, with characteristically high player mobility, i.e., with lots of position switches. This opens up the possibility of rethinking and renewing the model of playerselection, and potentially creating the model of a “universal” player, one who will be able to satisfy the requirements of any and every position.

Despite the considerable global presence of handball sport, the availability of scientific data on body composition measured by multichannel bioimpedance is limited. The goals of our present study, therefore, were: (i) to determine, using multiple bioimpedance methods, the body composition characteristics of male handballers who compete at different competition levels; (ii) to identify possible distinctions in explored body composition variables in these players; (iii) and, to detect the best discriminative and the most sensitive body composition variables that may be used as the future best representatives for controlling the efficiency of training and eating habits, and that properly meet the needs of senior male handball sport.

METHODS

This study is classified as a natural experiment. Body composition is measured using the qualitative approach in collecting data through laboratory measurements. Analytical and statistical methods were used for basic noetics. Functional and comparative analysis were used as analytical methods because of the need to establish relations and differences between the variables of the studied area.

Subjects sample

This particular research examined a sample of 94 senior top-level male handball players (the Serbian male national team = 19; Serbian Super National League = 43; and the Serbian First National League = 32). The term “top-level athlete”, as taken from a previously published paper (Dopsaj & Djordjevic-Nikic, 2016), has the following meaning: 1) a person who is a member of a national selection in a particular sport; 2) a person who competes in international or national competition levels of a particular sport.

Average basic characteristics of the sample were: Overall sample = Age - 23.8±4.8 yrs., Min–Max=17.5–36.6, Training experience - 11.5±4.8 yrs., Min–Max=3.5–23.0 yrs; Serbian male national team = Age - 28.0±4.2 yrs., Min–Max=19.8–35.1, Training experience - 15.5±4.1 yrs., Min–Max=5.5–23.0 yrs; Serbian Super National League = Age - 22.1±4.7 yrs., Min–Max=17.3–36.4, Training experience - 11.8±4.7 yrs., Min–Max=5.0–21.0 yrs; Serbian First National League = Age - 23.4±3.7 yrs., Min–Max=17.0–31.0, Training experience - 8.9±3.6 yrs., Min–Max=3.0–15.0 yrs.

The research was conducted according to the recommendations of the Declaration of Helsinki guidelines for physicians, for biomedical research involving human subjects (WMA, 1996) and with the permission of the Ethics Committee of the Faculty of Sport and Physical Education, University of Belgrade. Each participant was informed about the goals of this research, and each one personally agreed to participate.

Measurement

Body composition measurements were taken according to procedures described in previously published papers (Demura, Sato, & Kitabayashi , 2004; Kasum & Dopsaj, 2012; Dopsaj, Todorov, Vuković, & Radovanović 2013; Dopsaj & Vuković, 2015; Dopsaj et al., 2015; Dopsaj & Djordjević-Nikić, 2016), using multi-segmental bioelectrical impedance analysis (BIA) with In Body 720 (InBody720, 2005) Tetrapolar 8-Point Tactile Electrode System (Biospace, Co., Ltd.). Professional personnel did all measurements, from June 2011 to June 2015, in the Methodological Testing Laboratory – the Faculty of Sports and Physical Education, University of Belgrade.

Variables

This study contained twenty-two (22) variables, grouped as follows: eight basic (8) and fourteen (14) derived or index variables, six of which (6) were body voluminosity dependent, seven (7) were body longitudinality dependent, and one (1) was an index variable.

The basic body composition variables included:
BH – body height, expressed in cm;
BM – body mass, expressed in kg;
Proteins – expressed in kg;
Minerals – expressed in kg;
BFM – body fat mass, expressed in kg;
SMM – skeletal muscle mass, expressed in kg;
TBW – total body water, expressed in L;
FFM – free fat mass, expressed in kg.

The derived variables body voluminosity dependent were:
PP – percentage of protein mass, calculated as Protein / BM ratio, expressed in %;
PM – percentage of mineral mass, calculated as Minerals / BM ratio, expressed in %;
PBF – percentage of body fat mass, calculated as Body fat / BM ratio, expressed in %;
PSMM – percentage of skeletal muscle mass, calculated as SMM / BM ratio – expressed in %;
PTBW – percentage of total body water, calculated as TBW / BM ratio – expressed in %;
PFFM – percentage of free fat mass, calculated as FFM / BM ratio – expressed in %.

The derived variables body longitudinality dependent were:
BMI – body mass index, calculated as BM / BH^2 ratio, expressed in $kg•m^{-2}$;
PMI – protein mass index, calculated as Protein / BH^2 ratio, expressed in $kg•m^{-2}$;
MMI – minerals mass index, calculated as Minerals / BH^2 ratio, expressed in $kg•m^{-2}$;
BFI – body fat mass index, calculated as BF / BH^2 ratio, expressed in $kg•m^{-2}$;
SMMI – skeletal muscle mass index, calculated as SMM / BH^2 ratio, expressed in $kg·m^{-2}$;
TBWI – total body water index, calculated as TBW / BH^2 ratio, expressed in $L•m^{-2}$;
FFMI – free fat mass index, calculated as FFM / BH^2 ratio, expressed in $kg•m^{-2}$.

Index variable was:
PFI – protein fat index, calculated as Protein / Body Fat ratio, expressed in kg.

Basic body variables and TBW, BF, Proteins and Minerals were used to calculate a 4D body composition model, according to the overall sample and subsamples results, and it was presented in absolute (kg and L) and relative (%) values.

Statistics

Descriptive statistical characteristics were calculated (Mean, SD, cV%, Min, Max, 95% confidence interval) for all the results. Normality distribution of the individual variables was tested by applying the Kolmogorov-Smirnov non-parametric test (K-S Z). Multivariate and univariate analysis of variance – MANOVA and ANOVA were used to establish possible general and partial inter-group differences, by applying Wilks's Lambda method. The difference between individual variables was defined by the Bonferroni p test criterion. Inter- and intra- variable differences were determined on the probability level of 95%, that is, a p-value of 0.05 (Hair, Anderson, Tatham, & Black, 1998). SPSS Statistics 17.0 software was used for all statistical procedures (SPSS, 2007).

RESULTS

Basic descriptive statistics of all calculated variables is given in Table 1. Table 2 shows basic descriptive statistics for subsample groups.

Table 1 Overall sample: Basic descriptive statistics of the variables (N=94)

Variables	Mean	SD	cV%	Min	Max	95% Confidence Interval		Kolmogorov-Smirnov test	
						Lower bound	Upper bound	KSZ	Asymp. Sig. p
BH	187.39	7.07	3.77	170.70	203.10	185.82	189.45	0.561	0.912
BM	87.92	10.48	11.91	66.20	114.90	85.36	91.34	0.642	0.804
BMI	25.01	2.39	9.55	19.99	31.95	24.70	25.71	0.649	0.793
Protein	15.30	1.71	11.15	11.90	18.80	14.42	15.81	0.466	0.982
Minerals	5.24	0.63	11.95	3.92	6.54	5.02	5.43	0.546	0.927
BF	11.06	4.92	44.51	2.50	28.50	10.38	12.46	1.046	0.224
SMM	44.15	5.14	11.64	33.90	54.60	43.85	45.68	0.724	0.671
TBW	56.39	6.29	11.15	43.70	69.70	56.05	58.29	0.647	0.817
FFM	76.93	8.61	11.19	59.72	95.04	73.93	79.23	1.170	0.130
PP	17.44	0.98	5.61	13	19.12	17.20	17.60	0.606	0.856
PM	5.96	0.30	5.08	4.67	6.53	5.79	6.02	0.621	0.836
PBF	12.37	4.86	39.28	3.25	32.31	11.56	13.59	0.696	0.717
PSMM	50.32	2.87	5.71	38.44	55.14	49.61	50.79	1.178	0.246
PTBW	64.30	3.62	5.63	49.55	71.13	63.38	64.90	0.944	0.319
PFFM	87.70	4.85	5.53	67.71	96.61	83.05	88.41	0.837	0.345
PMI	4.35	0.33	7.58	3.73	5.47	4.30	4.44	0.756	0.618
MMI	1.49	0.12	7.73	1.26	1.83	1.43	1.52	0.776	0.584
BFI	3.17	1.47	46.46	0.67	9.70	2.93	3.55	0.971	0.303
SMMI	12.55	1.00	7.99	10.62	15.90	12.21	12.82	0.798	0.543
TBWI	16.02	1.18	7.37	13.83	19.71	15.68	16.36	0.660	0.503
FFMI	21.86	1.62	7.41	18.84	27.01	20.87	22.28	1.149	0.189
PFI	1.689	0.864	51.16	0.418	5.880	1.459	1.821	1.388	0.042

Table 2 Results of MANOVA (General – all variables, and according to the methodology of partialisation – Basic Body Composition, Voluminosity dependent and Longitudinality + Index dependent)

	Effect	Multivariate Tests[d]						
		Value	F	Hypothesis df	Error df	sig.	artial Eta^2	Observed Power[b]
Comp_Level	Wilks's Lambda – All Variables	0.370	2.048[a]	44.0	40.0	.001	.392	1.000
	Wilks's Lambda – Basic Body Composition Variables	0.469	4.240[a]	18.0	66.0	.000	.315	1.000
	Wilks's Lambda – Voluminosity dependent variables	0.635	3.652[a]	12.0	72.0	.000	.203	.998
	Wilks's Lambda – Longitudinality dependent variables	0.623	2.807[a]	16.0	68.0	.000	.211	.996

a. Exact statistic; b. Computed using alpha = .05; c. The statistic is an upper bound on F that yields a lower bound on the significance level; d. Design: Intercept + Comp_Level

Table 3 Basic descriptive statistics of handball players according to the subsample for the explored body composition variables

	SRB National Team (N=19)	Super National League (N=43)	I National League (N=32)	Tests of Between-Subjects Effects (ANOVA)			
Variables	Mean ± SD	Mean ± SD	Mean ± SD	value	ig. p	Partial Eta^2	Observed Power
BH	193.40 ± 5.72	187.95 ± 5.79*	183.05 ± 6.59$^{†††,\#}$	17.72	0.000	0.280	1.000
BM	97.72 ± 9.10	87.04 ± 9.20***	83.30 ± 9.20†††	15.09	0.000	0.249	0.999
BMI	26.14 ± 2.45	24.63 ± 2.30	24.85 ± 2.33	2.88	0.061	0.060	0.551
Protein	16.94 ± 1.30	15.42 ± 1.47***	14.16 ± 1.35$^{†††,\#\#}$	23.92	0.000	0.345	1.000
Minerals	5.83 ± 0.51	5.28 ± 0.55***	4.83 ± 0.48$^{†††,\#\#\#}$	22.34	0.000	0.329	1.000
BF	12.51 ± 4.64	9.65 ± 4.02	12.10 ± 5.02	3.49	0.035	0.071	0.638
SMM	49.07 ± 3.92	44.52 ± 4.43***	40.71 ± 4.06$^{†††,\#\#\#}$	23.81	0.000	0.344	1.000
TBW	62.46 ± 4.86	56.79 ± 5.40***	52.26 ± 5.02$^{†††,\#\#\#}$	23.43	0.000	0.340	1.000
FFM	85.23 ± 6.64	74.75 ± 14.19**	69.77 ± 11.85†††	9.57	0.000	0.174	0.978
PP	17.38 ± 0.79	17.76 ± 0.82	17.06 ± 1.14$^{\#\#}$	5.12	0.008	0.101	0.811
PM	5.97 ± 0.24	6.07 ±0.27	5.82 ± 0.33$^{\#\#\#}$	7.43	0.001	0.140	0.935
PBF	12.60 ± 3.97	10.91 ± 4.08	14.21 ± 5.71$^{\#\#}$	4.61	0.012	0.092	0.767
PSMM	50.32 ± 2.27	51.24 ± 2.38	49.04 ± 3.34$^{\#\#}$	5.96	0.004	0.116	0.870
PTBW	64.06 ± 2.99	65.38 ± 2.99	62.98 ± 4.31$^{\#\#}$	4.37	0.015	0.088	0.743
PFFM	87.41 ± 3.97	86.04 ± 14.47	83.74 ± 12.51	0.59	0.556	0.013	0.146
PMI	4.53 ± 0.34	4.36 ± 0.32**	4.22 ± 0.28	5.96	0.004	0.116	0.870
MMI	1.56 ± 0.12	1.49 ± 0.11***	1.44 ± 0.09	7.48	0.001	0.141	0.936
BFI	3.35 ± 1.26	2.75 ± 1.19	3.63 ± 1.79$^{\#\#}$	3.68	0.029	0.075	0.663
SMMI	13.13 ± 1.03	12.59 ± 0.98***	12.13 ± 0.84	6.68	0.002	0.128	0.906
TBWI	16.70 ± 1.23	16.06 ± 1.17	15.58 ± 0.98†††	6.04	0.003	0.117	0.874
FFMI	22.79 ± 1.69	21.16 ± 3.81	20.76 ± 3.15	2.45	0.092	0.051	0.481
PFI	1.555 ± 0.622	1.957 ± 1.044	1.408 ± 0.587	4.28	0.017	0.086	0.733

SRB National Team vs. Super National League, * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.000$;
SRB National Team vs. First National League, † $p \leq 0.05$; †† $p \leq 0.01$; ††† $p \leq 0.000$;
Super National League vs. First National League, # $p \leq 0.05$; ## $p \leq 0.01$; ### $p \leq 0.000$.

Results of the MANOVA show the general statistically significant differences (Table 2) between all the studied body composition variables in the samples of handball players:

Wilks's Lambda Value 0.370, F = 2.048, p = 0.001 and Partial Eta^2 =0.392. Also, as the partial MANOVA statistics shows, statistically significant differences are present for Basic body composition variables between the groups (Wilks's Lambda Value 0.469, F = 4.240, p = 0.000 and Partial Eta^2 =0.315), for Voluminosity dependent variables between groups (Wilks's Lambda Value 0.635, F = 3.652, p = 0.000 and Partial Eta^2 =0.203) and for Longitudinality dependent variables between groups (Wilks's Lambda Value 0.623, F = 2.807, p = 0.000 and Partial Eta^2 =0.211). At the general level, established inter-groups differences explained 39.2% of the mutual variability with the observed statistical power of data at 100% (Observed Power = 1.000).

Figures 1a and 1b show the 4D model of body composition in handball subsamples, with the established characteristics.

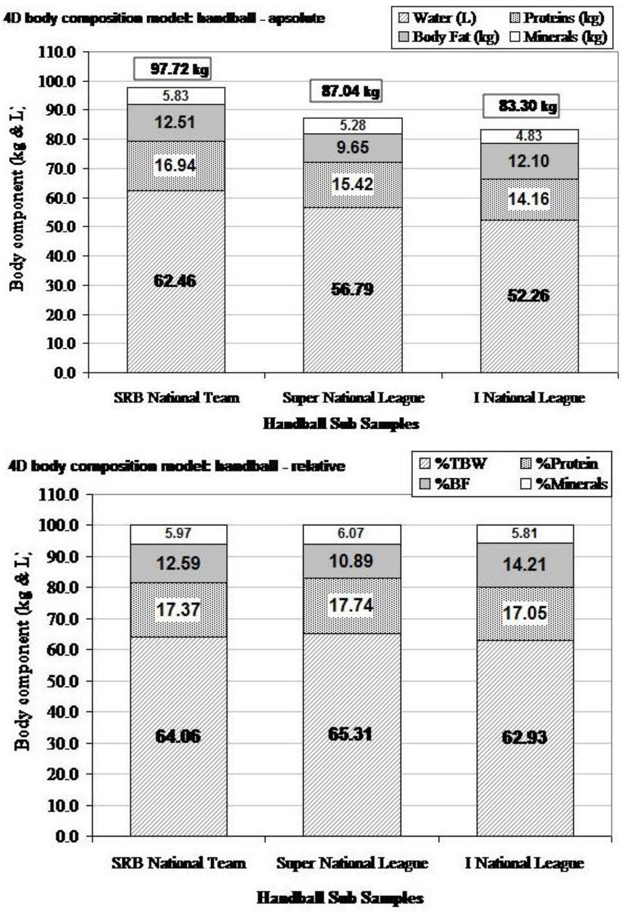

Fig. 1 (a and b). The 4D model of body composition according to the subsamples of handball players (absolute and relative values, respectively).

DISCUSSION

The goal of this cross-section study was to define body structure characteristics and differences, based on the sample of Serbian male handball players, members of teams from different competitive levels.

The results of the MANOVA show the existence of statistically significant differences (Table 2) between explored body composition variables as the function of groups, generally with the level of Wilks's Lambda Value = 0.370, F = 2.048, p = 0.001. Partial Eta^2 explained 39.2% of the body structure differences between groups with a statistical power of data at 100% (Observed Power = 1.000). For various levels of competitive success, and in respect to the senior handball system of Serbia, based on the presented results it may be concluded that it is necessary to make the selection of players with different body characteristics, i.e., different body composition.

In respect to the basic body and morphology characteristics, such as BH, BM and BMI, the results show that handball players of the Serbian national team are statistically significantly taller and heavier than the players of the Super National League and the First Serbian League with p = 0.000, but no statistically significant difference has been found in respect to the overall indicator of body tissue, i.e., body volume compared to BMI (Table 3). National selection players are taller than those from the Super and First leagues by 5.4 (2.9%) and 10.3 cm (5.7%), and also heavier by 10.7 (12.3%) and 14.4 kg (17.3%), respectively.

In general terms, and in respect to the anthropometric characteristics of 409 elite handball players who participated in the World Championship of 2013 (Ghobadi, Rajabi, Farzad, Bayati, & Jeffreys, 2013), with an average TV of 190.10±6.82 cm, average TM of 92.37±9.80 and average BMI of 25.53±2.09 kg·m^{-2}, the national team players are taller, heavier and burlier, i.e., their body volume is bigger. However, when the mentioned results of the 2013 championship players are analyzed in the context of placement (teams ranking from 1st to 4th place, 5th to 8th place, 9th to 13th place, and so forth), it is obvious that the players from the Serbian national team fall into the category within the first four positions of the mentioned Championship based on their body height (TV 193.22±7.75 cm), but in terms of their TM and BMI (TM 95.74±10.92 and BMI 25.59±2.05 kg·m^{-2}), their TM is higher by 2.07%, and their BMI is higher by 2.18%. In other words, the national team players are of the same height as those from the top four ranked teams, but have more body tissue, i.e., their body volume is larger.

When observing the results in relation to the continental aspect (players grouped by continent – Europe, Africa, Asia, America and Oceania), the national team players are on average taller than elite European players by 1.03 cm or 0.54% (236 European players = 192.37±6.69 cm), being, however, on average heavier by 3.03 kg (3.20%) and with a higher BMI by 0.60 kg·m^{-2} (2.34%).

In terms of the national standards for top Serbian athletes, the national team of handball players of Serbia fall in the category of taller than average athletes (the average height of the elite Serbian athletes ranges from 181.2 cm to 190.3 cm), while the players competing in the Super and First National leagues fall into the category of averagely tall Serbian athletes (Dopsaj & Djordjevic-Nikic, 2016).

The situation is identical for TM and BMI; compared to the national standards of top Serbian athletes, national team handball players fall into the category of above average body mass and BMI (the range of average TM and BMI of top Serbian athletes is from 79.4 to

92.3 kg and 23.50 do 26.07 kg·m^{-2}), while players competing in the Super and First national leagues belong in the category of top athletes within the given average values (Dopsaj & Djordjevic-Nikic, 2016).

Such results are indicative for drawing a conclusion about the existing need to play top quality handball at the national team level, i.e., the top quality at an international level in terms of anthropomorphic features of players, who need to have above average body height, and a proportionally larger body mass with respect to height, and therefore also the body mass index value. In other words, tall and proportionally burly players are the necessity that characterizes top competitive handball of modern times. In respect to various national competitive levels of handball, for the overall national sport standard, averagely tall and proportionally burly players are typical for the given level of the game of handball.

In respect to the basic body structure characteristics, such as: Proteins, Minerals, BF, SMM, TBW and FFM, the results show that statistically significant differences exist between all of the examined groups of handball players, in all the variables (p = 0.01, Table 3) except the variable BF. Thus, it should be pointed out that the ANOVA determined the existence of an overall difference in variability within groups (Table 3, F=3.49, p=0.035, Partial Eta^2=0.071), but this difference has not been confirmed between pairs of mean BF values (SRB national team vs. Super National League – t=2.859, p = 0.099; SRB national team vs. First National League – t=0.429, p = 1.000; Super National League vs. First National League – t=2.457, p = 0.092). In other words, the studied Serbian handball players divided by levels of competitive success, in respect to their basic body structure variables, have shown a statistically significant difference in the quantity in mass of Proteins, Minerals, Skeletal Muscles, total quantity of body water and lean body mass, but did not differ in total fat quantity (BF, Table 3).

Compared to the previously mentioned variables, the greatest carriers of inter-group differences were the following body structure variables: Proteins, SMM and TBW (Table 2, Partial Eta^2 = 0.345, 0.344 and 0.340, respectively). The highest values of given variables were established in the Serbian national team players (16.94 kg, 49.07 kg and 62.46 L), followed by the players of Super National League (15.42 kg, 44.52 kg and 56.79 L), and players of the First National League (14.16 kg, 40.71 kg and 52.26 L, respectively).

The observed results are strongly in line with those previously published, with defined World Championship final ranking of teams and the respective anthropometrics measures (Ghobadi et al., 2013), as well as BH (r = -0.398, p=0.001) and BM (r = -0.253, p=0.001). Also, according to the research results of Michalsik and co-authors, their findings showed that body anthropometry seemed to have an important influence on playing performance because it is highly related to playing positions. This study suggests that male elite team handball players, along with body anthropometry and body structure, should also implement more position-specific training regimens, while also focusing on anaerobic training and strength training (Michalsik et al., 2015). It was established in preceding studies, that the strength and the working capability level achieved in the anaerobic regimen of strain, are directly connected to the body mass of proteins and skeletal muscles (Perez-Gomez et al., 2008), while the quantity of body water is in proportion to the mass of skeletal muscles (Lukaski, 1996). Also, one previously published manuscript (Gorostiaga, Granados, Ibanez, & Izquierdo, 2005) suggests that more muscular and powerful players are at an advantage in handball. The differences observed in free fatty mass between elite professionals and amateur handball players, may partly explain the observed differences between groups in respect to absolute maximal strength and muscle power. In the elite group, higher efficiency in handball throwing velocity is associated with both upper and lower extremity power output capabilities, while this relationship may be different in the amateur group.

Regarding the derived variables dependent on body voluminosity, as well as percentages of protein (PP), minerals (PM), body fat (PBF), skeletal muscle mass (PSMM), total body water (PTBW) and free fatty mass (PFFM), the results have shown statistically significant differences between groups for all variables, except for PFFM (Table 3, F=0.59, p=0.556, Partial Eta^2=0.013).

In respect to previously mentioned variables, the greatest carriers of inter-group differences were the following: PM (p=0.001, Partial Eta^2=0.140), PSMM (p=0.004, Partial Eta^2=0.116) and PP (p=0.008, Partial Eta^2=0.101). The highest values of the variables were established for the Serbian national team (5.97%, 50.32% and 17.38%), followed by players of the Super National League (6.07%, 51.24% and 17.76%), and finally by players of the First National League (5.82%, 49.04% and 17.06%, respectively). It is necessary to emphasize in this place that no statistically significant difference has been established between the samples from the SRB National Team and the Super National League in respect to the mentioned variables, but that the differences were found only between the samples of the Super National League and the First National League.

Compared to the players from the first two samples, that is, from the samples of the most active players in terms of competitiveness (the SRB National Team and Super National League), it was established that there are no differences in the percentage of body proteins, minerals, fat, skeletal muscles and water between them. At the same time, based on descriptive results it may be concluded that higher, i.e. better values of PP, PM, PBF, PSMM and PTBW variables were measured in players from the Super National League, than in players from the SRB national team, which is certainly a surprising finding. A general conclusion may be that from the national level of competitive success in male handball it is necessary to reach the appropriate parameters of body structure partitioned according to body mass, and that the finally achieved competitive level depends on other factors in sport, such as: basic and specific physical fitness level, technical and tactical skills, psychological factors, as well as competitive efficiency (Gorostiaga et al., 2005; Bojić, Kocić, & Stajić, 2015; Ilić, 2015; Michalsik et al., 2015; Pavlović, Bojić, Radovanović, & Valdevit, 2015; Vukosavljević et al., 2015).

When the obtained results are compared with the overall standards for top Serbian athletes, it may be claimed that PBF values for the first two subsamples are within the standard, that is, within the expected average (standard PBF for Serbian athletes = from 8.88 to 13.15%), the same being established also for PP and PSMM (standard PP and PSMM for Serbian athletes = from 17.29 to 18.18% and from 49.75 to 52.37%, respectively). The only PBF values below average were determined for the handballers from the First National League (below-average PBF value for Serbian athletes = 13.16 to 17.42%), and they also had below-average values for PP and PSMM (below-average PP and PSMM values for Serbian athletes = from 16.40 to 17.28% and from 47.13 to 49.74%, respectively) (Dopsaj & Djordjevic-Nikic, 2016).

Regarding the derived variables dependent on body longitudinality and one index variable, as well as: protein mass index (PMI), mineral mass index (MMI), body fat index (BFI), skeletal muscle mass index (SMMI), total body water index (TBWI), free fat mass index (FFMI) and protein-fat index (PFI), the results have shown a statistically significant difference between all the variables, except for FFMI (F=2.45, p=0.092, Partial Eta^2=0.051, Table 3). According to the MANOVA results, longitudinality dependent variables have shown a slightly higher level of variance explanation as compared to the voluminosity dependent (21.1% vs. 20.3%, Table 2). The greatest carriers of inter-groups differences were the following variables: MMI (p=0.001, Partial Eta^2=0.141), SMMI (p=0.002, Partial Eta^2=0.128), TBWI (p=0.003, Partial Eta^2=0.117) and PMI (p=0.004, Partial Eta^2=0.116).

The highest values of the mentioned variables were found for the Serbian national team players (1.56, 13.13, 16.70 and 4.53), followed by the Super National League (1.49, 12.59, 16.06 and 4.36), and finally the First National League (1.44 kg•m^{-2}, 12.13 kg•m^{-2}, 15.58 L•m^{-2} and 4.22 kg•m^{-2}, respectively). It is necessary to emphasize here that most of the inter-groups differences were established between the samples of the SRB National Team and Super National League.

CONCLUSION

The biggest differences in body composition of the elite handballers of various competitive levels (national selection, super and the first national leagues) that are selected and trained applying the current working technology of the Serbian handball sport were found for contractile structure (SMM and Proteins), total amount of body water and minerals, and in BH and BM. In other words, the players of the national team are statistically significantly taller, burlier and with more proteins and muscle structure, but with the same amount of body fat, in comparison to the players of lower competitive ranks.

Also, when examining structural body differences between handballers from the national team and those from the Super National League, the obtained results point to the conclusion that, from the standpoint of scientific methodology, it is more justifiable to use variables partitioned by body height, i.e., partitioning for longitudinality, than partitioning for body mass, i.e., by the criterion of voluminosity. The results have also shown that the method of multichannel bioelectric impedance is valid and sensitive for defining the differences in body composition of senior handballers competing in different ranks by the success criterion. Speaking in general, all of the obtained descriptive indicators may serve as basis for defining standards in terms of control, and even selection in terms of developing a system of body composition control of handballers from various competitive levels.

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TELESNA STRUKTURA RUKOMETAŠA REPUBLIKE SRBIJE SA RAZLITIČIH NIVOA TAKMIČENJA MERENA METODOM BIOELEKTRIČNE IMPENDANCE

Cilj ovog istraživanja bio je da se definišu odlike telesne kompozicije i razlike između srpskih rukometaša, merene metodom bioelektrične impendance. Uzorak ispitanika činilo je 94 rukometaša seniorske grupe koji se takmiče na različitim nivoima takmičenja, a koji su bili podeljeni na sledeći način: srpska muška rukometna reprezentacija = 19; srpska super nacionalna liga = 43; i srpska prva nacionalna liga = 32. Ukupno, 22 varijable merene su u ovom istraživanju, podeljene na sledeći način: (8) osnovnih i (14) indeks varijabli, od kojih (6) zavise od voluminoznosti tela, (7) od longitudinalnosti tela, a (1) je indeks varijabla. Deskriptivni statistički parametri su izračunati, kao i MANOVA i ANOVA koje su odredile i opšte i delimične međugrupne razlike, primenom Wilks's Lambda kriterijuma. Rezultati MANOVA pokazali su da postoje statistički značajne razlike između *analiziranih varijabli telesne kompozicije između uzorka rukometaša, za vrednost Wilks's Lambda Value 0.370, F = 2.048, p = 0.001. Utvrđene razlike objašnjavaju 39.2% opšte varijabilnosti (Partial Eta2 =0.392) pri Observed Power = 1.000. Statistički značajne varijable koje u najvećoj meri definišu telesnu kompoziciju su: BH, BM, Proteini, Skeletni mišići, Minerali, Ukupna količina vode u telu, Telesna masa bez masnih naslaga i Indeks mišićne mase (p = 0.000). Rezultati ovog istraživanja ukazuju na statistički raznovrsnu telesnu kompoziciju rukometaša koji postižu različite nivoe uspeha; drugim rečima, najuspešniji igrači, ili igrači srpskog nacionalnog tima se u morfološkom smislu razlikuju od rukometaša nižih rangova takmičenja. Takođe, rezultati ukazuju na to da metoda bioelektrične impendance je validan metod za određivanje razlika u telesnoj kompozicij na primeru rukometaša, pa se samim tim može primenjivati u daljim istraživanjima u oblasti rukometa. Što se tiče podele inicijalnih varijabli, rezultati su pokazali da se ova podela radi definisanja razlika između posmatranih uzorka može smatrati delikatnijom od one koja zavisi od visine tela, odnosno longitudinalnosti.*

Ključne reči: *rukomet, telesna kompozicija, muškarci, bioelektrična impendanca.*