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Карактеристике телесне структуре врхунских спортиста Републике Србије мерене методом мултисегменталне биоелектричне импеданце

Basic body structure characteristics of the elite Serbian athletes measured by the method of multisegmental bioelectrical impedance

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BMI, percent of body fat, percent of skeletal muscle mass, gender dimorphism, morphology

Abstract

The aim of this study has been to define an initial descriptive model of the basic body structure characteristics of the elite athletes who are engaged in a system of elite sports competition in the Republic of Serbia. The subject samples consisted of 556 (422 males and 134 females) Serbian athletes from 25 different sports (19 Olympic sports). Body composition measuring was done by multisegment bioelectrical impedance method (BIA), using a professional measurement equipment – In Body 720. The results of the study showed that the average BH, BM, and BMI mean value of the Serbian male elite athletes was 185.74±9.12 cm, 85.84±12.96 kg, and 24.78±2.57 kg·m^{-2}, while for female elite athletes was 175.01±10.22 cm, 67.80±9.71 kg, and 22.09±2.28 kg·m^{-2}. Male athletes had 17.73% of the protein and 51.06% of the skeletal muscle and 11.01% of body fat in the body. Female athletes had 15.93% of protein and 44.98% of skeletal muscle mass and 19.54% percent of body fat in the body.

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Кључне речи:
БМИ, проценат телесних масти, проценат мишићне масе, полни диморфизам, морфологија

Сажетак

Циљ овог истраживања био је дефинисање иницијалног дескриптивног модела карактеристика структуре тела код врхунских спортиста Републике Србије. Узорак се састојао од 556 спортиста (442 мушкарца и 134 жена) који су се такмичили у 25 различитих спортова (19 олимпијских). Мерење структуре тела реализовано је применом методе мултиканалне сегменталне биоелектричне импеданце (BIA), коришћењем професионалног мерног инструмента – In Body 720. На основу резултата се може тврдити да су просечна телесна висина, телесна маса и индекс телесне масе код мушкараца на нивоу од 185,74±9,12 cm, 85,84±12,96 kg и 24,78±2,57 kg•m^{-2}, док су код жена на нивоу од 175,01±10,22 cm, 67,80±9,71 kg и 22,09±2,28 kg•m^{-2}. Просечна вредност процента протеина, мишићне и масне масе у телу код спортиста износила је 17,73%, 51,06% и 11,0%, док је код спортисткиња била 15,93%, 44,98% и 19,54%, респективно.

Introduction

Body composition characteristics are one of the most important factors in sports performance [1]. Although total body composition characteristics are important for most athletes, an athlete's body structure is generally of great concern in sports sciences [2]. Assessment of body composition provides additional information beyond the basic measures of body height and body mass to both, the coaches and athletes [3]. A body composition characteristic implies all main elements of matter a human body is made of. At a macro level, the human body is composed of four large measurable segments of elements as well as: water, fat component i.e. adipose tissue, mineral components, and protein i.e. muscle as a contractile component [4]. Body structure characteristics, with motor abilities, are mostly determined by individual characteristics of endogenous and exogenous factors and it is a very important subject of research in sports sciences [5, 6, 7, 8]. Inadequate body structure status can have a negative influence on certain motor abilities [9], or may indicate eating disorder problems [10].

Systematic measuring and longitudinal monitoring of body composition status should be applied during all athletes' career or particular training periods for the purpose to monitor growth/development of athletes, but also for optimization of desirable relationships of different body components [11, 12, 13, 14]. Monitoring changes in body composition in a population of athletes is very important for a scientific and practical reasons, but also for the control of the current status of selected population of athletes as a particular part of the general population.

Basically, the status of body structure can be determined by applying direct and indirect methods of measuring [4, 15, 16]. Bioelectrical impedance analysis is a fast and non-invasive method for evaluation of body structure in field and clinical conditions [8, 17]. Bioelectrical impedance measures body structure by applying a flow of low, safe amount of electric current (800 μamp) through a human body. The obtained results represent a measure of impedance or resistance of electric current as it travels through the water that is found in muscle and fat [18].

Athletes (Olympic, elite, national and regional) are mostly young adult people who have the abilities necessary for participating in physical exercise training, and who have currently competed in sports as a varsity player (individual or team at professional, international or regional level) in competitive games and races for reason to reach their potential of excellence in sports performance [19]. Also, athletes belong to the particular population who, because of the increased daily physical effort i.e. sports training, need to have a specific diet, and those two factors are the reason for a specific level of body composition adaptation.

The aim of this study has been to define the initial descriptive model and gender differences, and dimorphism of the basic body structure characteristics of the elite athletes, who are engaged in a system of elite sports competition in the Republic of Serbia, measured by new measurement technology – direct segmental multi-frequency bioelectrical impedance method.

Methodology
Subject Samples

The subject samples consisted of 556 (422 males and 134 females) Serbian athletes (Olympic, elite international and international level competitors) from 25 different sports (19 Olympic sports). According to the male sample 14.22%, 35.31% and 50.47%, as well as female sample 23.13%, 14.18%, and 50.69% belonged to the individual sports, martial arts sport and sports games, respectively. The meaning of the top-level athlete term is as follows: 1) a person who is a member of the national selection in a particular sport; 2) a person who compete at the international competition level in a particular sport.

The average age of male and female athletes was: 23.1±4.2 (Min–Max=17.5–40.0) and 22.1±3.4 (Min–Max=17.1–33.0) years, with 12.8±4.4 (Min–Max=3.0–26.0) and 11.0±3.9 (Min–Max=3.5–23.0) years of training, respectively. The research was conducted in accordance with the "Declaration of Helsinki for recommendations guiding physicians in biomedical research involving human subjects" [20] and with the permission of the Ethics Committee of the Belgrade University Faculty of Sport and Physical Education. Each subject was well informed about the purpose of the study, and all invited agreed to participate.

Body composition measuring method

Body composition measuring was done by multisegmental bioelectrical impedance analysis (BIA), using a professional measurement equipment – In Body 720 Tetrapolar 8-Point Tactile Electrode System (Biospace, Co., Ltd), using DSM-BIA method (Direct Segmental Multi-frequency bioelectrical impedance Analysis). BIA is a widely used standard method for determining whole body composition and segmental lean mass measurements. InBody [21] body composition analyzer has high test-pretest reliability and accuracy (ICC 0.9995) [18]. Compared with DXA as a golden standard, the interclass correlation coefficient of BIA was between 0.96 and 0.99 in the normal-weight population [17]. For these reasons, this equipment is extensively used in clinics, sports medicine and other health-related fields as a standard body composition assessment.

All measurements were performed in the period May 2013–April 2015, by applying standardized method [8, 14, 15], with respect to the following prerequisites of measuring procedure described previously [8, 22].

Variables

This study contained ten (10) variables, as well as six primary (6) and four (4) derived (index) variables. Primary variables for defining body structure were: BH – body height, expressed in cm; BM – body mass, expressed in kg; Proteins – expressed in kg; SMM – skeletal muscle mass, expressed in kg; BFM, body fat mass – expressed in kg; VFA, visceral fat area – expressed in cm^2. Derived (index) variables for defining body structure were: BMI – body mass index, expressed in kg/m^2; PBF, percent of body fat, calculated as BFM / BM ratio – expressed in %; PPM, percent of protein mass, calculated as Protein / BM ratio – expressed in %; PSMM, percent of skeletal muscle mass, calculated as SMM / BFM ratio – expressed in %.

Gender dimorphism index was calculated for all variables, in order to define the relationship of individual variables among male and female athletes, by applying the following formula: Gender dimorphism index = (value of the given morphological variable of female athletes / value of the given morphological variable of male athletes) • 100. Thus, the percentage ratio of the value of individual body structure variables was obtained with respect to gender [8].

Statistical analyses

Basic descriptive statistical parameters were calculated for all results in order to define basic measures of central tendency and level of data's dispersion (Mean, SD, cV%, Min, Max, 95% confidence interval). Distribution of individual variables was tested by applying Kolmogorov-Smirnov non-parametric test (K-S Z). After that, using multivariate analysis of variance – MANOVA the difference between genders was calculated by applying Wilks' lambda model. The difference between individual variables was determined by applying Bonferroni test criteria. The level of difference of measurements was determined on the probability level of 95%, that is, a p-value of 0.05 [23]. Software SPSS Statistics 17.0 was used for all statistical procedures.

Results

Results of MANOVA generally showed the existence of statistically significant difference between variables in the function of gender at the level of Wilks' Lambda Value = 0.181, F = 110.87, p = 0.000. Also, the results showed that with established differences, 81.9% of common variances of groups (Partial Eta^2 = 0.819) were explained, while results of analyses had 100% level of the observed power.

Table 1 and 2 present results of descriptive analysis and the basic distribution of information of all studied variables for male and female athletes, respectively. Table 3 presents ANOVA results with gender differences between subjects effects. Table 4 displays ANOVA results used to determine the existence of statistically significant difference between variables (original and index) in the function of gender on a partial level. The results are statistical evidence that

Table 1. Descriptive statistics of body composition variables of male athletes

Males	Mean	SD	cV%	Min	Max	95% Confidence Interval bound		K-S Z	P value
						Lower	Upper		
BH (cm)	185.74	9.12	4.91	161.00	212.60	185.16	187.13	0.62	0.837
BM (kg)	85.84	12.96	15.10	58.10	149.10	85.24	87.80	1.34	0.055
BMI ($kg·m^{-2}$)	24.78	2.57	10.37	18.21	37.76	24.62	25.14	1.51	0.021
Proteins (kg)	15.17	2.10	13.84	10.10	23.50	15.11	15.52	1.17	0.127
SMM (kg)	44.22	6.41	14.50	29.00	69.00	43.60	44.83	1.37	0.047
BFM (kg)	9.64	4.80	49.79	2.30	38.90	9.10	10.10	2.25	0.000
VFA (cm^2)	56.08	24.51	43.71	5.00	172.20	53.84	58.66	1.87	0.002
PBF (%)	11.01	4.27	38.78	2.93	32.31	10.40	11.32	1.28	0.077
PPM (%)	17.73	0.89	5.02	13.37	20.00	17.66	17.85	1.17	0.132
PSMM (%)	51.06	2.62	5.13	38.44	56.79	50.95	51.49	1.09	0.184

Table 2. Descriptive statistics of body composition variables of female athletes

Females	Mean	SD	cV%	Min	Max	95% Confidence Interval bound		K-S Z	P value
						Lower	Upper		
BH (cm)	175.01	10.22	5.84	145.30	196.60	173.50	176.97	0.54	0.931
BM (kg)	67.80	9.71	14.32	45.70	100.40	65.49	70.00	0.08	0.507
BMI ($kg·m^{-2}$)	22.09	2.28	10.32	18.33	36.00	21.56	22.47	1.45	0.029
Proteins (kg)	10.74	1.44	13.41	7.40	13.70	10.42	11.14	0.72	0.683
SMM (kg)	30.43	4.40	14.46	20.00	39.00	29.44	31.61	0.68	0.743
BFM (kg)	13.42	5.38	40.09	4.50	46.60	12.32	14.08	1.68	0.007
VFA (cm^2)	41.27	20.05	48.58	9.00	155.10	36.11	44.59	1.22	0.102
PBF (%)	19.54	6.73	34.44	7.46	46.41	18.46	20.06	1.06	0.215
PPM (%)	15.93	1.12	7.03	10.66	18.41	15.78	16.13	0.98	0.289
PSMM (%)	44.98	3.29	7.31	30.08	52.40	44.67	45.63	0.82	0.509

morphological structure of male and female athletes has statistically significant differences on all used body structure variables at p = 0.000.

Figure 1 present gender dimorphism of all variables of body structure composition of the elite Serbian male and female athletes, while Table 4 show BMI and PBF structure according to WHO and ACE normative standards for examined sample of athletes.

Table 3. ANOVA results – tests of between-subjects effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta²	Observed Power
Gender	BH	10699.3	1	10699.3	115.76	0.000	0.193	1.00
	BM	31700.4	1	31700.4	201.88	0.000	0.294	1.00
	Proteins	1849.4	1	1849.4	466.63	0.000	0.490	1.00
	BFM	1165.6	1	1165.6	49.12	0.000	0.092	1.00
	SMM	16864.3	1	16864.3	467.83	0.000	0.491	1.00
	VFA	22721.9	1	22721.9	41.03	0.000	0.078	1.00
	BMI	737.9	1	737.9	116.35	0.000	0.193	1.00
	PBF	6342.6	1	6342.6	318.71	0.000	0.397	1.00
	PPM	288.9	1	288.9	340.92	0.000	0.413	1.00
	PSMM	3318.3	1	3318.3	467.28	0.000	0.491	1.00

Table 4. BMI and PBF structure according to WHO and ACE normative standards for examined sample of male and female Serbian athletes

Male (N = 422)			Female (N = 134)		
BMI (kg•m⁻²)	**N**	**%**	**BMI (kg•m⁻²)**	**N**	**%**
> 30.00	15	3.55	> 30.00	1	0.75
25.00–29.99	167	39.57	25.00–29.99	9	6.72
18.50–24.99	239	56.64	18.50–24.99	123	91.79
18.49 <	1	0.24	18.49 <	1	0.75
PBF (%)	**N**	**%**	**PBF (%)**	**N**	**%**
> 25.00	4	0.95	> 32.00	2	1.49
18.00–24.99	21	4.98	25.00–31.99	16	11.94
14.00–17.99	55	13.03	21.00–24.99	25	18.66
6.00–13.99	296	70.14	14.00–20.99	78	58.21
2.00–5.99	46	10.90	10.00–13.99	8	5.97
1.99 <	0	0.00	9.99 <	5	3.73

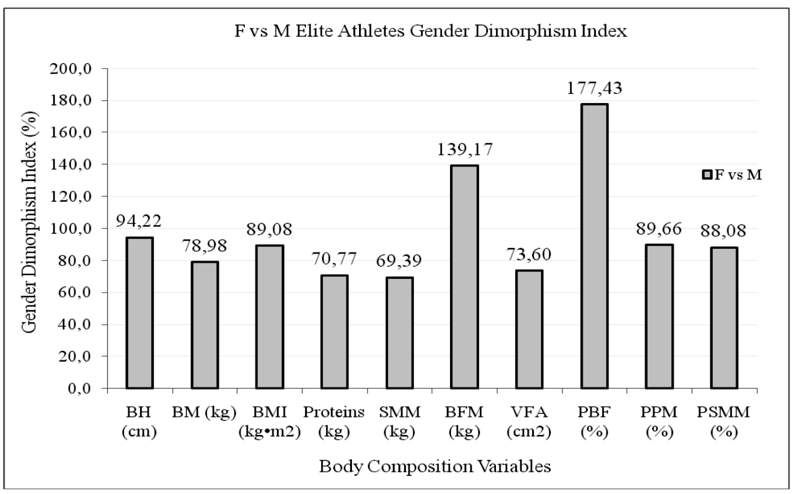

Figure 1. Gender dimorphism indexes of the body structure variables of the elite Serbian athletes

Discussion

This cross-section study examined the basic morphological and body structure characteristics on the sample of Serbian elite athletes of both genders. The present study was aimed to create an initial generic model of body composition characteristics of elite Serbian athletes using the method of multichannel bioelectrical impedance.

The average BH, BM, and BMI mean value of male elite athletes was 185.74±9.12 cm, 85.84±12.96 kg and 24.78±2.57 kg•m^{-2} (Table 1). According to previously published data, tested samples of male athletes are taller for 2.16 cm (1.18%), have a higher body mass for 2.96 kg (3.57%), and have higher BMI for 0.24 kg•m^{-2} (0.98%), than Belgrade students population, respectively [8]. Considering BH, BM and BMI the average values of Serbian female elite athletes was 175.01±10.22 cm, 67.80±9.71 kg and 22.09±2.28 kg•m^{-2} (Table 2). Comparing it to criteria of non-athletes data our data showed on the sample of female athletes that they are taller for 7.56 cm (4.51%), they are heavier for 6.78 kg (11.1%), and they have higher BMI for 0.38 kg•m^{-2} (1.75%), than Belgrade female students population [8]. Also, comparing same variables with Belgrade communal police female members data's by average ages of 29.7 ± 6.2 yrs. we can conclude that athletes are taller for 8.11 cm (4.86%), they are heavier for 4.19 kg (6.59%), but they have lower BMI value for 0.88 kg•m^{-2} (3.83%) [25].

Male athletes had 15.17 kg of proteins and 44.22 kg of skeletal muscles, which was 17.73% of the protein and 51.06% of the skeletal muscle in the body (Table 1). Previously published study showed that randomly selected healthy adult of 157 Serbian males with an average age of 30.81±9.73 years, weight 86.17±14.95 kg, height 182.35±7.09 cm and BMI 25.88±3.99 kg•m^{-2} had in a total 14.11 kg of proteins, 40.59 kg of SMM, 47.59% of muscles and 16.5% of proteins in the body [7]. Based on the results of this study we can conclude that athletes have the highest level of protein for 7.51%, SMM for 8.94%, PSMM for 7.29 and PPM for 7.46% than non-athletes adult population. The almost same differences in body protein content are between male Serbian athletes and physically active young adult population – 6.08% [8].

Female athletes had 10.74 kg and 30.43 kg of proteins and skeletal muscles. Regarding relative value, it was 15.93% of protein and 44.98% of skeletal muscle mass in the body (Table 2). We can conclude that the Serbian female athletes have 1.62 kg or 17.76% more proteins than Belgrade female student's population [8]. Almost identical data was found comparing our results to female Belgrade communal police members because they have 1.61 kg or 17.63% less protein than Serbian female athletes [25].

Regarding the different fat component, results showed that male athletes had 9.64 kg of fat mass, 56.08 cm^2 of visceral fat area (as an abdominal and internal organs fat), and 11.01% of total body fat (Table 1). The female athletes had 13.42 kg of fat mass, 41.27 cm^2 of the visceral fat area and 19.54% of total body fat (Table 2).

Comparing to previously published results male athletes have 1.42 kg or 12.84% less body fat, 2.48 cm^2 or 4.23% less visceral fat area and 1.90 or 14.72% less percent of total body fat than physically active Serbian University male students [8].

Comparing to healthy female students, results showed that female athletes have 1.40 kg (9.45%) less body fat, 1.68 cm^2 (3.91%) less visceral fat area and 4.26 (17.90%) less percent of total body fat [8]. According to the body structure characteristics at female members of the communal police in Belgrade of average ages 29.7 ± 6.2 yrs. we can conclude that their results were: 17.10 kg of total body fat, 26.24% of total body fat and 57.07 cm^2 of the visceral fat area [25]. Based on results of comparison between Serbian athletes and female communal police it can be conclude that athletes have lower level of total body fat mass for 3.68 kg (21.52%), lower level of PBF for 6.70 (25.53%), and lower level of VFA for 15.80 cm^2 (25.53%) of internal abdomen fat.

With respects to the BMI structure, results showed in the category of obese was 3.55%

and 0.75%, and at the underweight category was 0.24 and 0.75% of the investigated sample for the males and females, respectively (Table 4). Prevalence of normal BMI was 56.64 and 91.79%, and for overweight was 39.57 and 6.72% for males and females, respectively to (Table 4).

But, according to the PBF standards, there were only 0.95 and 1.49% of obese and 10.90 and 5.97% males and females athletes with essential body fat level, respectively (Table 4). We have to notice that, even, 3.73% of female athletes had a percent of body fat lower than essential body fat level (below than 10.0%).

Generally, according to gender dimorphism, the highest level of differences was found in group of contractile mass variables as well as: SMM – F = 467.63, p = 0.000, PSMM – F = 467.28, p = 0.000, Proteins – F = 466.64, p = 0.000, and PPM – F = 340.92, p = 0.000, with Partial Eta^2 value, as a proportion of variance associated to main effects differences at level of 0.491, 0.491, 0.490 and 0.413, respectively (Table 3, Figure 1).

The second level dimorphism variable group responsible for statistically significant gender differences was found in a group of basic body shape variables as well as: BM – F = 201.88, p = 0.000, BMI – F = 116.35, p = 0.000, and BH – F = 115.76, p = 0.000, with Partial Eta^2 value at level of 0.294, 0.193 and 0.193, respectively (Table 3, Figure 1).

The third level dimorphism variable group responsible for statistically significant gender differences was found in a group of non-contractile mass i.e. body fat variables as well as: PBF – F = 318.71, p = 0.000, BFM – F = 49.12, p = 0.000, and VFA – F = 41.03, p = 0.000, with Partial Eta^2 value at level of 0.397, 0.092 and 0.078, respectively (Table 3, Figure 1).

Males and females elite athletes included in our sample were significantly different in body size and body structure (Table 3) with males being taller, heavier, with a higher level of contractile mass component and lower level of body fat component than females on average (Figure 1). Our data confirm and are very similar with previous studies showing a distinct male-female body size dimorphism [8, 12]. The gender dimorphism index (Figure 1) for the primary variables ranged from 69.39 to 139.17, whereas the range of derived variables (Figure 1) was significantly higher (between 88.08 and 177.43).

Generally, gender dimorphism is most expressed for the relative total body fat content i.e. PBF at al level of 177.43, which means that female athletes have 77.43% more fat content in body than males (Figure 1). Very similar results were found among physically active Belgrade students (184.31%), which indicate the fact about similarities in body fat composition between young adult males and females in total body fat percent regardless they are athletes or physically active persons.

When we consider Protein dimorphic index we can confirm the value of 70.77% (Figure 1). The meaning of the previous result is that female athletes have 29.23% protein less that male. At the same time, for the Belgrade University physically active population the same index was 64.55%, or 9.64% higher (female students have 35.45% protein less than male students). We can assume that the Protein dimorphic index differences between athletes and physically active University students, probably result in greater muscle hypertrophy as a consequence of the strength training muscle grow effect, especially in female athletes [1, 13, 16].

Conclusion

In the present study, we have analyzed and defined the initial descriptive model of body structure characteristics of elite Serbian athletes according to the gender measured by the method of multi-channel segmental bioelectrical impedance. Also, the results are analyzed with respect to gender dimorphism.

The average BH, BM, and BMI mean value of Serbian male elite athletes was 185.74±9.12 cm, 85.84±12.96 kg, and 24.78±2.57 kg•m^{-2}, while for female elite athletes was 175.01±10.22 cm, 67.80±9.71 kg, and 22.09±2.28 kg•m^{-2}. Male athletes had 15.17 kg of proteins and 44.22 kg of skeletal muscles, which was 17.73% of the protein and 51.06% of the skeletal muscle in the body, while female athletes had 10.74 kg and 30.43 kg of proteins and skeletal muscles, or regarding to relative value it was 15.93% of protein and 44.98% of skeletal muscle mass in the body. Regarding the different fat component, results showed that male athletes had 9.64 kg of fat mass, 56.08 cm^2 of the visceral fat area, and 11.01% of body fat. The female athletes had 13.42 kg of fat mass, 41.27 cm^2 of the visceral fat area and 19.54% of body fat.

Results of BMI structure showed that for the males and females in the category of obese was 3.55% and 0.75%, and at the underweight category was 0.24 and 0.75% of the tested athlete's sample, respectively. Prevalence of normal BMI was 56.64 and 91.79% and for overweight was 39.57 and 6.72% for males and females, respectively.

But, according to the PBF standards, there were only 0.95 and 1.49% of obese and 10.90 and 5.97% males and female athletes with essential body fat level, respectively. We have to notice that, even 3.73% of female athletes were with the percent of body fat lower than essential body fat level (below than 10.0%).

A clear gender dimorphism is manifested in all variables, i.e. males and females elite athletes included in our sample were significantly different in body size and body structure. The males were taller (for 10.73 cm or 6.13%), heavier (BM for 21.0% and BMI for 10.92%), with higher level of protein and muscle contractile mass component (4.43 kg or 41.25% and 13.79 or 45.32%, respectively) and with lower level of body fat mass (-3.78 kg or -28.17%) than females on average.

Compared with the healthy non-athlete physically active youth adult population, based on the results of this study, we can conclude that explored sample of athletes are taller (males = for 2.16 cm or 1.18%; females = for 7.65 cm or 4.51%), heavier (males = for 2.96 cm or 3.57%; females = for 6.78 kg or 11.11%) and with bigger BMI value (males = for 0.24 $kg\bullet m^{-2}$ or 0.98%; females = for 0.38 $kg\bullet m^{-2}$ or 1.75%) than general youth adult population. Also, athletes have a higher level of protein mass (males = 0.87 kg or 6.08%; females = 1.62 kg or 17.76%) and a lower level of fat mass (males = - 1.42 kg or - 12.84%; females = - 1.40 kg or -9.45.76%) in the body.

Generally, it can be concluded that elite Serbian athletes are taller, heavier and larger than general non-sport population.

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References

1. Garrido-Chamorro, R. P., Sirvent-Belando, J. E., Gonzales-Lorenzo, M., Mertin-Carratala, M. L., Roche, E. (2009). Correlation between body mass index and body composition in elite athletes. *Journal of Sports Medicine and Physical Fitness*, 49: 278-284.
2. Lorenz, D., Reiman, M., Lehecka, B. (2013). What performance characteristics determine elite versus non-elite athletes in the same sport? *Sports Health*, 5(6): 542-547.
3. Larry Kenney, W., Wilmore, J., Costill, D. (2012). *Physiology of sport and exercise* (Fifth Ed.). Champaign, IL: Human Kinetics.
4. Heymsfield, S. B., Lohman, T. G., Wang, Z., Going, S. B. (2005). *Human Body Composition* (Sec. Ed.). Champaign, IL: Human Kinetics.
5. Scanlan, A., Dascombe, B. (2011). The anthropometric and performance characteristics of high-performance junior life savers. *Serbian Journal of Sports Sciences*, 5(1-4): 61-66.
6. Dimitrijević, R., Vuković, M., Ćopić, N., Dopsaj, M. (2012). Strukturni pokazatelji komponenti masnog tkiva kod studentkinja Kriminalističko-policijske akademija. *Bezbednost*, 54(3): 62-85.
7. Rakić, S., Marković, M., Dopsaj, M., Mlađan, D., Subošić, D. (2013). The initial model of men's muscle structure indicators defined by the method of multichannel bioelectrical impedance. *Facta Universitatis Series: Physical Education and Sport*, 11(1): 23-33.
8. Dopsaj, M., Ilic, V., Djordjevic-Nikic, M., Vukovic, M., Eminovic, F., Macura, M., Ilic, D. (2015). Descriptive model and gender dimorphism of the body structure of physically active students of Belgrade University: a pilot study. *Anthropologist*, 19(1): 239-248.
9. Copic, N., Dopsaj, M., Ivanovic, J., Nesic, G., Jaric, S. (2014). Body composition and muscle strength predictors of jumping performance: differences between elite female volleyball competitors and nontrained individuals. *Journal of Strength and Conditioning Research*, 28(10): 2709-2716.

10. Bar, R. J., Cassin, S. E., Dionne, M. M. (2015). Eating disorder prevention initiatives for athletes: A review. *European Journal of Sports Sciences*, 27: 1-11.
11. Ruff, C. B. (2000). Body mass prediction from skeletal frame size in elite athletes. *American Journal of Physical Anthropology*, 113: 507-517.
12. Wardle, J., Haase, A. M., Steptoe, A. (2006). Body image and weight control in young adults: international comparisons in university students from 22 countries. *International Journal of Obesity*, 30: 644-651.
13. Carbuhn, A. F., Fernandez, T. E., Bragg, A. F., Green, J. S., Crouse, S. F. (2010). Sport and training influence bone and body composition in women collegiate athletes. *Journal of Strength and Conditioning Research*, 24(7): 1710-1717.
14. Kasum, G., Dopsaj, M. (2012). A descriptive profile of body structure of top Greco-roman style wrestlers defined with the method of multichannel bioelectric impedance. *SportLogia*, 8(2): 123-131.
15. Röthlingshöfer, L., Ulbrich, M., Hahne, S., Leonhardt, S. (2011). Monitoring change of body fluid during physical exercise using bioimpedance spectroscopy and finite element simulations. *Journal of Electrical Bioimpedance*, 2: 79-85.
16. Koley, S., Jha, S., Sandhu, J. S. (2012). Study of back strength and its association with selected anthropometrical and physical fitness variables in inter-university hockey players. *Anthropologist*, 14(4): 359-363.
17. Ling, C. H., de Craen, A. J., Slagboom, P. E., Gunn, D. A., Stokkel, M. P., Westendorp, R. G., Maier, A. B. (2011). The accuracy of direct segmental multi-frequency bioimpedance analysis in the assessment of total body and segmental body composition in middle-aged adult population. *Clinical Nutrition*, 30(5): 610-615.
18. Gibson, A. L., Holmes, J. C., Desautels, R. L., Edmonds, L. B., Nuudi, L. (2008). The ability of new octapolar bioimpedance spectroscopy analyzers to predict 4-component–model percentage body fat in Hispanic, black, and white adults. *American Journal of Clinical Nutrition*, 87(2): 332-338.
19. Swann, C., Moran, A., Piggott, D. (2015). Defining elite athletes: Issues in the study of expert performance in sports psychology. *Psychology of Sport and Exercise*, 16(1): 3-14.
20. World Medical Organization (1996). Declaration of Helsinki – 1964. *British Medical Journal*, 313 (7070): 1448-1449. On http://www.cirp.org/library/ethics/helsinki/
21. InBody 720 (2005). *The precision body composition analyser Users Manual*. Seoul: 1996-2004 Biospace Co., Ltd. Korea.
22. ACSM –American College of Sports Medicine (2012). *Resource manual for guidelines for exercise testing and prescription 5th ed.* Baltimore: Lippincott Williams and Wilkins.
23. Hair, J. F., Anderson, R. E., Tatham, R. L., Black, W. C. (1998). *Multivariate Data Analysis (5th Edition)*. Upper Saddle River, NJ: Prentice Hall.
24. ACE (2009). Ace lifestyle & weight management consultant manual. *American Council on Exercise: The Ultimate Resource for Fitness Professionals*.
25. Dimitrijević, R., Umičević, D., Dopsaj, M. (2013). Morfološki model ženskih pripadnika Komunalne policije Beograda. *Glasnik Antropološkog društva Srbije*, 48: 97-106.