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Research article

MECHANICAL AND FUNCTIONAL CHARACTERISTICS OF HAND GRIP STRENGTH IN YOUNG FEMALE HANDBALL PLAYERS

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Abstract. *The aim of this research was to define differences in functional and mechanical characteristics of isometric hand grip (HG) strength between young female handball players and the CG comprised of physically active girls with no experience in sport. 70 individuals participated in the research, 36 of whom were the best young female handball players (of cadet and junior categories) while 34 girls comprised the CG. The results obtained show that the young female handball players who took part in the tests achieved* F_{max} *at the levels from 306.4±40.8 to 335.5±47.0 N and* RFD_{max} *at the levels ranging from 1918.1±366.8 to 2174.4±382.1 N/s for the non-dominant and dominant hand. When these results are compared to the ones achieved by the CG it is clear that the young female handball players had a statistically significant higher level of the maximum HG force of both arms as well as the higher level of maximum explosiveness. There was no statistically significant difference between the groups regarding all the indexes of dimorphism (ID) as well as the values of the time needed for achieving the maximum intensity of muscle excitation (*$tRFD_{max}$*). Therefore, it can be concluded that the handball players who underwent the testing procedures showed positive adaptation from the aspect of the mechanical characteristics of hand grip strength, which can most likely be ascribed to the phenomenon of biological adaptation to the training stimuli characteristic for handball. However, the same influence was not detected from the aspect of functional characteristics, more precisely, dimorphism.*

Key words: *Handball, Mechanical Muscle Properties, Hand Grip Test*

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INTRODUCTION

The arms and the hands represent a specialised part of the body responsible for manipulative tasks with different objects. They are able to realise different movements in all three axes with various types of load, with different grip and pinch grip activities, using different intensities (Tyldesley & Grieve, 1996). Proper muscle force production is of crucial importance for any kind of gripping and for this reason the contractile characteristics (functional and mechanical) of hands are one of the most important limiting factors in all upper body motor and manipulative activities (Leyk et al., 2007; Tanner & Gore, 2013).

According to the performance analysis it is well known that handball represents a dominantly high-intensity sports game, with intermittent motor structure and active body contact technical elements of playing (Matthys et al., 2011). As a game in which powerful contacts are very common, handball is a sport which requires high levels of morphological, physical, motor, functional and cognitive positive adaptation, as a consequence of selection and a long-term high intensity training process (Chaouachi et al., 2009; Ingebrigsten & Jeffreys, 2012; Dopsaj, Valdevit, Ilić, Pavlović, & Petronijević, 2017; Tosun, Koç, & Őzen, 2017; Pavlović, Bojić, Stojiljković, Đorđević, & Radovanović, 2018; Petković, Bubanj, Marković, Kocić, & Stanković, 2019; Marković et al., 2019).

One of the most important segments of the long-term development in athletes is devising a long-term system for monitoring and controlling the levels of their readiness, which implies checking the levels of correlation between the crucial motor, physiological and psychological characteristics regarding the sport or the discipline they train (Chaouachi et al., 2009; Matthys et al., 2011). The adequate system of testing with statistical and mathematical procedures used for calculating the most relevant models for optimal monitoring of athletes' performance is one of the crucial segments in the modern technology of creating elite athletes (Tanner & Gore, 2013; Dopsaj et al., 2017; Dopsaj, Valdevit, Vučković, Ivanović, & Bon, 2019[a]).

The main aim of the handball game is to score a goal to the opponent team in accordance with the rules of the game. Among the other important motor skills, such as running, jumping, change of direction etc., ball manipulation is the most important one. Generally, a handball player should be capable of performing different techniques with the ball such as catching, gripping, holding, bouncing, feigning, receiving, passing and finally shooting. In all those techniques, hand and finger manipulation skills with contractile abilities of the responsible muscles have an extremely important role (Tyldesley & Grieve, 1996).

The Hand grip test (HG) is the golden standard test for measuring mechanical muscle characteristics, as follows: achieved maximal muscle force (F_{max}), achieved rate of force development (RFD) as a measure of muscle explosiveness, and different time and index parameters (Sahaly, Vandewalle, Driss, & Monod, 2001; Demura et al., 2003; Leyk et al., 2007; Gallup, White, & Gallup Jr, 2007; Dopsaj et al., 2019[b]). There is strong evidence in the scientific literature that HG is highly reliable when it comes to estimating physical abilities as well as genetic, biological and behavioural potentials of a person. It has also been proven that it represents a simple marker of general body power and strength in children, adolescents, young people and adults regardless of gender (Bohannon, 2001; Frederiksen et al., 2002; Wind, Takken, Helders, & Engelbert, 2010; Atkinson et al., 2012; Sayer & Kirkwood, 2015; Marković, Dopsaj, Koropanovski, Ćopić, & Trajkov, 2018[a]; Dopsaj et al., 2019[b]).

The aim of this research was to define the differences in functional and mechanical characteristics of HG strength between young female handball players, and the control group comprised physically active girls with no experience in sport. The practical value of this study lies in obtaining scientific information on the sensitivity of the method of testing and the test used, but also in defining the most valid mechanical and functional variables for the purpose of improving the testing system of top young female handball players.

METHODS

In this study the method used was laboratory testing, while the applied research design was a Cross-Sectional study with a direct measurement protocol. The study was applied according to the standards for research methods in sport (Thomas, Silverman, & Nelson, 2015).

Sample

70 individuals participated in the research, 36 of whom were the best young female handball players (of cadet and junior categories) who participated in training camps during the 2018 season and 34 girls of the same age without any experience in sport comprising the control group. The basic anthropomorphological characteristics of the players were: Age=16.6±1.1 yrs, BH=173.2±5.8 cm, BM=69.7±7.9 kg, BMI=23.20± 1.93 $kg{\cdot}m^{-2}$, PBF=22.58±4.46% and PSMM=43.39±2.53%, and of the control group members: Age=16. 3±1.7 yrs, BH=169.5±8.3 cm, BM=61.0±9.6 kg, BMI=21.11±2.11 $kg{\cdot}m^{-2}$, PBF=23.08±4.75% and PSMM=42.25±2.72 $kg{\cdot}m^{-2}$.

Testing

For the evaluation of the isometric hand grip (HG), a protocol with standardized procedures and equipment (All4gym d.o.o., Serbia) was used, i.e. a sliding device with a fixed tensiometric strain gauge (Marković et al., 2018[a]; Zarić, Dopsaj, & Marković, 2018; Marković, Dopsaj, Koprivica, & Kasum, 2018[b]; Dopsaj, Prebeg, & Kos, 2018; Dopsaj et al., 2019[b]). It was established earlier that the used equipment has a high level of measurement reliability whereby ICC ranges from 0.938 to 0.977 for F_{max}, and from 0.903 to 0.971 for RFD_{max} variables (Marković et al., 2018[a]). The participants were sitting upright in the middle of the chair during the test. The arm of the tested hand was in a natural stretched position, alongside and placed in an abduction position 5 to 10 cm away from the body. The arm of the non-tested hand was resting alongside the body and the participants were not allowed to move during the test.

Prior to the experimental trials of the HG test, each participant was given a detailed test explanation and they performed a pre-trial measurement, for the purpose of becoming familiar with the procedure, alternating hands at sub-maximal intensity, with a pre-test rest period of two minutes. According to the procedure, the power grip was used, where the participants were asked to make the strongest and fastest possible grip trial holding the grip approximately 2 seconds. The HG test of the dominant and non-dominant hand was conducted twice (randomly) with a one-minute interval between different hand trials (Zarić et al., 2018; Dopsaj et al., 2019[b]). All the tests were performed in the Research laboratory

(MIL) at the Faculty of Sport and Physical Education (FSPE) University of Belgrade from 2017 to 2018 by the same investigator.

All the participants voluntarily took part in the study and the research was conducted according to the recommendations of the Declaration of Helsinki guidelines for physicians, for biomedical research involving human subjects (http://www.cirp.org/library/ethics/helsinki/), and with the ethical approval number 484-2 of the Ethics Committee of the FSPE, University of Belgrade.

Variables

Functional and mechanical characteristics of HG muscle force were measured in relation to the following dimensions:

1. the maximal (F_{max}) and relative muscle force (F_{rel});
2. the maximal (RFD_{max}) and relative explosive muscle force (RFD_{rel});
3. the time needed for achieving maximum force (tF_{max}) and maximal explosive ($tRFD_{max}$) muscle force;
4. the index of dimorphism (ID) for all muscle force, explosivity and time variables, as well as a specific index of synergy (SIS).

The variables for maximum and relative muscle force characteristics were:

1. Maximum muscle force for the non-dominant (F_{max}_ND) and dominant (F_{max}_D) HG, expressed in Newtons (N);
2. Relative muscle force for the non-dominant and dominant hand calculated as a summarized value of HG relative force (F_{rel}_SUM), expressed in Newtons per kilogram of body mass (N/kg).

The variables for maximum and relative explosive force characteristics:

1. Maximum explosive muscle force for the non-dominant (RFD_{max}_ND) and dominant (RFD_{max}_D) HG, expressed in Newtons per second (N/s);
2. Relative explosive muscle force for the non-dominant and dominant hand calculated as a summarized value of HG relative explosive force (RFD_{rel}_SUM), expressed in Newton per second per kilogram of body mass ($N/s \cdot kg^{-1}$).

The variables for maximum and explosive muscle force-time parameters:

1. The time needed for maximum muscle force production in the non-dominant (tF_{max}_ND) and dominant (tF_{max}_D) HG, expressed in seconds (s);
2. The time needed for maximum explosive muscle force production in the non-dominant ($tRFD_{max}$_ND) and dominant ($tRFD_{max}$_D) HG, expressed in seconds (s).

The variables for the assessment index of dimorphism (ID) and the specific index of synergy (SIS):

1. The Index of dimorphism for F_{max}, RFD_{max}, tF_{max} calculated as a relation between the mentioned characteristics of the non-dominant and dominant hand, expressed in percents (%);
2. The Specific index of synergy (SIS), calculated as a relation between F_{max} and RFD_{max}, expressed in arbitral units.

In this way, the functional and mechanical characteristics of the HG strength of the participants were described by twelve variables.

Statistical Analysis

First, all the raw data underwent descriptive statistical analyses in order for the basic values of central tendency and dispersion (Mean±SD) to be defined. The multiple and univariate analyses of variance (MANOVA and ANOVA) were used to calculate the differences between the subsamples with the Bonferroni Post Hoc test, as a criterion for the inter-group comparisons. All the differences were determined at the probability level of 95%, with a p-value set at level 0.05 (Hair, Anderson, Tatham, & Black, 1998). All the statistical analyses were carried out using the software package IBM SPSS Win Statistics 19.0.

RESULTS

Table 1 shows the results of the descriptive statistical analysis for all the tested participants and the variables. Table 2 shows the results of the MANOVA and ANOVA as the differences between the variables in the function of the examined groups. The results of the multiple analysis of variance prove that generally when it comes to the HG strength of the non-dominant (HG_ND) and the dominant hand (HG_D), as well as the summative values of the maximum force and maximum explosiveness (rel_SUM), there is a statistically significant difference between the young female handball players and the members of the control group, at a statistically significant level (Wilks′ Lambda Value=0.559, 0.573 and 0.190, p=0.000, 0.000 and 0.003, respectively). The only parameter that shows no statistical difference between the analysed variables is the dimorphism index (ID) (Wilks′ Lambda Value=0.092, p=0.332).

Table 1 Results of the descriptive statistics of the tested participants

	Sample	Handball		Control	
	Variables	ND	D	ND	D
Mechanical Characteristics	F_{max}	306.4±40.8	335.5±47.0	250.3±43.5	269.7±48.4
	RFD_{max}	1918.1±366.8	2174.8±382.1	1696.3±398.6	1868.0±415.6
	tF_{max}	0.774±0.330	0.698±0.230	0.539±0.215	0.554±0.215
	$tRFD_{max}$	0.131±0.019	0.128±0.018	0.127±0.016	0.123±0.019
	SIS	6.241±0.738	6.483±0.658	6.734±0.806	6.909±0.762
	F_{rel}_SUM	9.268±1.181		8.602±1.280	
	RFD_{rel}_SUM	58.919±8.628		58.587±10.323	
Functional Characteristics	ID_F_{max}	0.920±0.104		0.934±0.102	
	ID_RFD_{max}	0.889±0.134		0.910±0.109	
	ID_tF_{max}	1.179±0.462		1.042±0.383	
	ID_$tRFD_{max}$	0.968±0.118		0.980±0.115	
	ID_SIS	1.024±0.118		1.035±0.110	

Table 2 MANOVA and ANOVA results

		Multivariate Tests[c]						
Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta^2	Observed Power
HG_ND	Wilks' Lambda	.559	10.108	5.00	64.00	.000	.441	1.000
HG_D	Wilks' Lambda	.573	9.534	5.00	64.00	.000	.427	1.000
ID	Wilks' Lambda	.092	1.174	5.00	64.00	.332	.084	.390
rel_SUM	Wilks' Lambda	.190	6.266	2.00	66.00	.003	.160	.882
		Tests of Between-Subjects Effects						
		Type III Sum^2	df	Mean Square	F	Sig.	Partial Eta^2	Observed Power
HG_ND	F_{max}_ND	54949.2	1	54949.2	30.94	.000	.313	1.000
	RFD_{max}_ND	859975.7	1	859975.7	5.88	.018	.080	.666
	tF_{max}_ND	.97	1	.97	12.35	.001	.154	.934
	SIS_ND	4.24	1	4.24	7.21	.009	.096	.754
	$tRFD_{max}$_ND	.00	1	.00	.80	.375	.012	.142
HG_D	F_{max}_D	75693.8	1	75693.8	33.27	.000	.328	1.000
	RFD_{max}_D	1645626.1	1	1645626.1	10.35	.002	.132	.887
	tF_{max}_D	.32	1	.32	6.40	.014	.086	.703
	SIS_D	3.17	1	3.17	6.29	.015	.085	.696
	$tRFD_{max}$_D	.00	1	.00	2.75	.102	.039	.373
HG_SU	F_{rel}_SUM	7.63	1	7.63	5.05	.028	.070	.601
M	RFD_{rel}_SUM	1.90	1	1.90	.02	.885	.000	.052

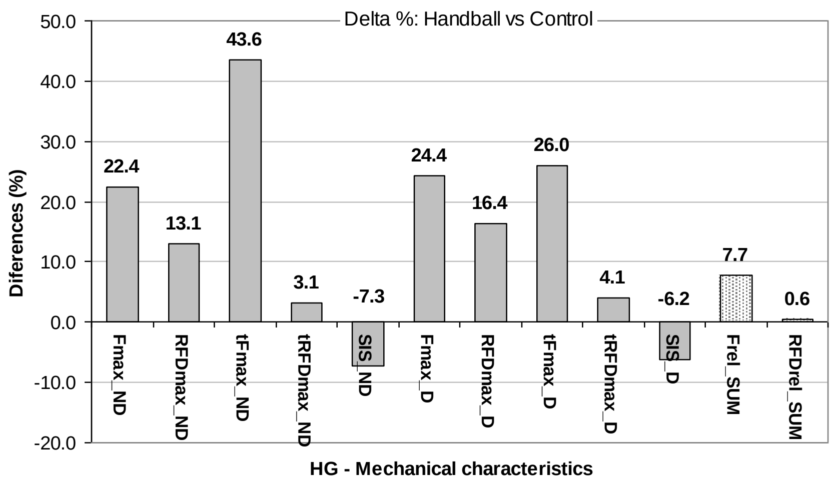

Fig. 1 Differences among the variables of the mechanical characteristics of the examined sub-specimens HG expressed as a percentage

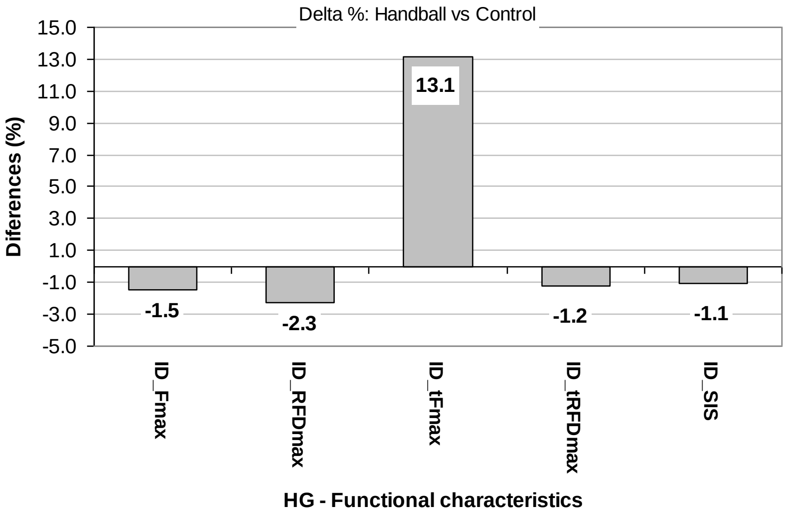

Fig. 2 Differences among the variables of the mechanical characteristics of the examined sub-specimens HG expressed as a percentage

Both figures 1 and 2 show the differences in mechanical and functional characteristics between the examined sub-specimens expressed as a percentage. The pairwise comparison results show that the levels of the statistically significant differences in the non-dominant hand vary from the highest in the F_{max}_ND ($F=30.94$, $p=0.000$, Partial $\eta^2= 0.313$, 22.4% difference) values to the lowest ones in the RFD_{max}_D ($F=5.88$, $p=0.018$, Partial $\eta^2= 0.080$, 13.1% difference), with only one variable, $tRFD_{max}$_ND, showing no difference between the sub-specimens (Table 2 and Figure 1). When it comes to the dominant hand, the levels of the statistically significant differences vary form the highest values, again, in the F_{max}_D ($F=33.27$, $p=0.000$, Partial $\eta^2= 0.328$, 24.4% difference) to the lowest values in the SIS_D ($F=6.29$, $p=0.015$, Partial $\eta^2= 0.085$, -6.2% difference), with the same variable showing no statistically significant difference between the two sub-specimens, $tRFD_{max}$_D, (Table 2 and Figure 1).

DISCUSSION

The results obtained show that the handball players who underwent the testing process achieved F_{max} at the levels from 306.4±40.8 to 335.5±47.0 N and RFD_{max} at the levels from 1918.1±366.8 to2174.4±382.1 N/s for the non-dominant and the dominant hand (Table 1). When compared to the control group, the young female handball players achieved a statistically significant higher level of the maximum HG force for both the non-dominant ($F=30.94$, $p=0.000$) and the dominant ($F=33.27$, $p=0.000$) hand, as well as a higher level of maximum explosiveness ($F=5.88$, $p=0.018$ and $F=10.35$, $p=0.002$, respectively) (Table 2). The achieved level of F_{max} is by 23.4% and the achieved level of RFD_{max} is by 14.8% higher than the control group levels, on average. It is also evident that the variable F_{max} had a span of influence between 31.3% and 32.8%, whereas the RFD_{max} had a span of influence between 8.0% and 13.2% on the difference between the studied groups, respectively (Table 2). The previously discussed results point to the influence that the maximum HG level has on the difference between the studied young female handball players and the members of the control group, which is 3.02 times higher than the influence of the maximum explosiveness. The results also show that the influence of the F_{max} and RFD_{max} on the differences between the young female handball players and the members of the control group in the dominant hand variable is 14.6% higher than in the non-dominant hand variable. This difference can probably be ascribed to the cumulative influence that the handball training sessions had on the girls, as opposed to the members of the control group who did not have any sport or organized physical activity.

In previously published studies, it was shown that the HG levels of F_{max} and RFD_{max} in female judokas of the same age were from 240.8±64.7 to 241.8±47.6 N and from 1651.3±717.2 to 1633.0±554.3 N/s, for the left and the right hand, respectively (Marković et al., 2018[b]), while in female basketball players of the same age the given characteristics were at the following levels: from 286.2±41.7 to 302.0±48.7 N and from 2032.2±394.4 to 2182.2 ±458.0 N/s, for the left and the right hand, respectively (Zarić et al., 2018).

If these results are compared to the standard values of F_{max} and RFD_{max} for the young female population, which were determined to vary from 255.0±51.1 to 272.1±56.0 N and from 1624±354 to 1728±441 N/s for the non-dominant and the dominant hand respectively (Dopsaj et al., 2019[b]), it can be claimed that the level of the maximum HG force in handball players aged 16.6 is higher by 21.7%, and that the level of the maximum explosiveness during maximum HG is also higher by 22% than the results of the same variables in healthy girls aged 24.5.

The results obtained for F_{max} and RFD_{max} lead to the general conclusion that female handball players aged 16.6 have maximum HG force levels higher by 20-25%, and maximum HG explosiveness level higher by 15-20% than the same variables in the general population of adult girls (Dopsaj et al., 2019[b]). When compared to the results achieved by other female representatives of some different sport disciplines (judo and basketball), the differences vary from 10 to 30% for F_{max}, and from 0 to 25% for RFD_{max} (Markovic et al., 2018[b]; Zaric et al., 2018). When compared to the standards defined for female handball players aged 16, it can be concluded that the measured levels of F_{max} and RFD_{max} are in accordance with them (Dopsaj et al., 2019[a]). These facts only add up to the external validity of the current research.

If the numerical values of the F_{max} and RFD_{max} of the studied handball players are standardized in a point score by applying the mathematical model defined for the population of girls, it can be claimed that their F_{max} is at the development level of 68.29 points, whereas their RFD_{max} is at the development level of 67.02 points. In general, the sum of the HG contractile development is at the level of 68.98 points, which is higher than the average values for these particular mechanical characteristics (Dopsaj et al., 2019[a]).

The results of the time parameters show that there is no statistically significant difference, irrespective of the hand dominance, in the time needed for achieving the maximum intensity of the muscle excitation ($tRFD_{max}$) involved in the HG (flexor digitorum superficialis) between the female handball players and the members of the control group (Table 2). It can also be claimed that the aforementioned time variable is completely in accordance with the previously published results for the population of young females (Dopsaj et al., 2019[a]). However, when it comes to the time needed for achieving the maximum HG force (tF_{max}), it was determined that the female handball players needed statistically significant more time than the members of the control group did, irrespective of hand dominance (34.8% more time, Figure 1; tF_{max} HG_ND, F=7.21, p=0.001, D = 6.40, p=0.014, Table 2). The reasons why the members of the control group who had never had training sessions needed statistically significant less time to achieve maximum HG force might lie in the following phenomenon: a certain degree of acute or chronic fatigue of the hand muscles responsible for the activity caused by everyday training sessions, including ball manipulation.

Although there is no statistically significant difference in the measured characteristics of the non-dominant and the dominant hand, i.e. the dimorphism index (ID) between the female handball players and the members of the control group, the established quantitative values are important for both sports science and practice (Table 1). The results show that the values of the dimorphism index in the female handball players are at the level of 0.920, and in the control group members at the level of 0.934, which implies that the level of the maximum force development of the non-dominant hand in the female handball players is at 92.0% of the dominant hand development, whereas the same difference in the control group members is at 93.4%. In other words, the bilateral deficit in the female handball players is at 8.0% and in the control group members at 6.6%. This deficit is higher in the RFD_{max} variable and reached the level of 11.1% and 9% for the female handball players and the control group members, respectively (Table 1). These results are completely in accordance with the previously defined standards of the functional dimorphism values set for top players, where the average asymmetry values of F_{max}ID are within the range from 0.8980 to 0.9287, which includes the results of the female handball players, and the symmetry values range from 0.9288 to 0.9594, which includes the results of the control group members (Ivanović & Dopsaj, 2012).

For the measured values of the ID time parameters (Table 1, ID_tF_{max} – Female handball players = 1.179 vs Control group = 1.042; ID_$tRFD_{max}$ – Female handball players=0.968 vs Control group=0.980), as well as for the specific synergy index (ID_SIS – Female handball players=1.024 vs Control group=1.035) there is no available data for comparison in the published literature, so they represent, from the standpoint of sport science, initial quantitative values.

CONCLUSIONS

The results obtained in this research show that the mechanical characteristics of the hand muscles, i.e. flexor digitorum superficialis of female handball players aged 16.6 on average (cadet-junior age) are more developed at a statistically significant level when compared to those of the members of the control group, young but physically inactive girls. It was established that in the studied female handball players the level of the maximum force ranged from 306.4±40.8 to 335.5±47.0 N and that the level of the maximum explosiveness ranged from - 1918.1±366.8 to 2174.8±382.1 N/s for the non-dominant and dominant hands, respectively. When compared to the general model of the given contractile properties, the levels of development of the measured HG characteristics were at 68.98 points, which is higher than the average values for the population of young girls. It was also shown that the tested time parameters of F_{max} and RFD_{max}, excitation, as well as the values of the dimorphism index, were within the standard values, and that they were not very different from the values determined for the control group members. All the results prove that there is a positive adaptation from the aspect of the mechanical characteristics of the HG force, which is, most likely, the direct consequence of the biological adaptation to training stimuli specific to handball. However, the same influence was not established in the functional characteristics, that is, the tested dimorphism.

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MEHANIČKE I FUNKCIONALNE KARAKTERISTIKE SNAGE STISKA ŠAKE MLADIH RUKOMETAŠICA

Cilj ovog istraživanja bio je da se utvrde razlike u funkcionalnim i mehaničkim karakteristikama izometrijske snage stiska šake (SŠ) između mladih rukometašica i kontrolne grupe (KG) koju čine fizički aktivne devojke bez iskustva u sportu. U istraživanju je učestvovalo 70 ispitanika, od kojih je 36 najboljih mladih rukometašica (kadetske i juniorske kategorije), a 34 KG devojke. Dobijeni rezultati pokazuju da su mlade rukometašice koje su učestvovale u testovima postigle Fmax na nivoima od 306.4±40,8 do 335.5±47.0 N i RFDmax na nivoima od 1918.1±366.8 do 2174.4±382.1 N/s za nedominantnu i dominantnu šaku. Kada se ovi rezultati uporede sa rezultatima KG, jasno je da su mlade rukometašice imale statistički značajno viši nivo maksimalne snage SŠ obe šake, kao i viši nivo maksimalne eksplozivnosti. Nije bilo statistički značajne razlike između grupa u pogledu svih indeksa dimorfizma (ID), kao i u pogledu vremena potrebnog za postizanje maksimalnog intenziteta mišićne ekscitacije (tRFDmax). Na osnovu toga se može zaključiti da su rukometašice koje su prošle proces testiranja pokazale pozitivnu adaptaciju sa aspekta mehaničkih karakteristika snage stiska šake, što se najverovatnije može pripisati fenomenu biološke adaptacije na trenažne stimuluse karakteristične za rukomet. Nije međutim zapažen isti uticaj sa aspekta funkcionalnih karakteristika, tačnije dimorfizma.

Ključne reči: *rukomet, mehanička mišićna svojstva, test stiska šake*