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A MODEL OF THE CHARACTERISTICS OF HAND GRIP MUSCLE FORCE BASED ON ELITE FEMALE HANDBALL PLAYERS OF VARIOUS AGES

MODEL ZNAČILNOSTI MOČI STISKA MIŠIC ROK PRI VRHUNSKIH ROKOMETAŠICAH RAZLIČNIH STAROSTNIH KATEGORIJ

ABSTRACT

The aim of the study was to establish trends in the development of contractile characteristics of hand grip in terms of the maximum and relative force, as a test for upper body strength. The sample consisted of 207 female handball players organised into age categories; 52 senior (age = 24.5 ± 3.3), 51 junior (U18, age = 17.4 ± 0.7), 45 youth (U16, age = 15.5 ± 0.9), and 49 young players (U14, age = 13.4 ± 0.5). There is a statistically significant difference of absolute and relative maximal hand grip muscle force between all age groups (Wilks's lambda = 0.416, p = 0.000). The results showed that the values of the maximum right hand grip force ranged from 430.7 N to 297.7 N and from 405.5 N to 268.6 N for left hand for senior to young players, respectively (Table 1). Also, according to the results it was determined that trend of change in observed contractile characteristics according to the age groups are 44.7N and 43.6N for absolute, and 0.462 and 0.463 $N \cdot BW^{-1}$ for relative values of maximal hand grip force for the right and the left hand, respectively.

Keywords: Handball Training, Females, Muscle Force

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IZVLEČEK

Cilj študije je bil modeliranje razvojnih trendov v kontraktilnih karakteristikah največje sile upogibalke mišic prstov na podlagi podatkov iz testiranja stika pesti. Vzorec je sestavljalo 207 rokometašic, organiziranih v starostne kategorije; 52 članic (starost = 24,5 ± 3,3) mladink (U18, starost = 17,4 ± 0,7), 45 kadetinje (U16, starost = 15,5 ± 0,9) in 49 deklic (U14, starost = 13,4). Obstajajo statistično pomembne razlike v abolutni in relativnih rezultatih v testih stiska pesti med starostnimi skupinami (Wilks's lambda = 0.416, p = 0.000). Rezultati kažejo, da so rangi rezultatov testiranje desne roke od 430.7 N do 297.7 in od 405.5 N do 268.6 za levo roko v zaporedju, od rezultatov članic do rezultatov 14 letnih rokometašic. Tudi trend sprememb v opazovanih rezultatih stiska pesti glede na starostno kategorijo je bil med 44.7N in 43.6 N za absolutne vrednosti in 0.462 in 0.463 $N \cdot BW^{-1}$ za relativne vrednosti maximalne moči stiska zapestja v zaporedju za desno in levo roko.

Ključne besede: rokometni trening, ženske. mišična moč

INTRODUCTION

The hand grip test has been used to evaluate the contractile characteristics of muscles in several research areas, from psychology, through medicine and general population healthcare, to sports science (Bohannon, 2001; Guidetti, Musulin, & Baldari, 2002; Dopsaj et al., 2007; Leyk, Ridder, Wunderlich, Ruther, & Sievert, 2007; Wind, Takken, Helders, & Engelbert, 2010; Aadahl, Beyer, Linneberg, Thuesen, & Jørgensen, 2011; Koley, Singh, & Kaur, 2011; Koley, Jha, & Sing, 2012; Ivanović & Dopsaj, 2012; Taghread, 2013; Eliöz, 2015; Zaric, Dopsaj, & Marković, 2018, Dopsaj et al., 2018). To date the majority of studies have analysed muscle force alongside other physical abilities and related it to anthropometric variables, often to height, hand dimensions, BMI etc. (Massy-Westropp, Gill, Taylor, Bohannon, & Hill, 2011). Some previous surveys evaluated various physical and social factors with respect to the relationship between the players (Wind, Takken, Helders, & Engelbert, 2010; Koley et al., 2011; Dopsaj et al. 2011), age, sex or fitness level (Bohannon, 2001; Hager-Ros & Rosbald, 2002; Dopsaj et al., 2009; Ivanović et al., 2009; Aadahl et al. 2011) or to the type of sport (Dopsaj et al. 2009; Ivanović et al., 2009; Carrasco et al., 2010; Koley et al., 2011, 2012; Matthys et al., 2011; Taghread, 2013; Zaric et al., 2018, Dopsaj et al., 2018). It was established that hand grip force variables in children and adolescents could be used to track biological development and evaluate total muscle or physical potential (Bohannon, 2001; Kadir et al., 2005; Wind et al., 2010; Zaric at al., 2018; Dopsaj et al., 2018).

Making a career in any sport involves following a programme of training and competition which is intended to ensure that the athlete achieves top sporting results within his or her period of optimal biological development (Ford et al., 2011). Monitoring and control of the athlete's long-term development, as a deterministic system, requires an understanding of developmental trends in all features of the athlete's physiology and psychology which are crucial to performance. In other words, it is necessary to describe the development of each sub-system on which top sport results are dependent, such as morphology, organic systems – energy and contractile components – as well as the development of important general and specific skills, psychological characteristics, etc. (Milišić, 2007).

Describing relevant characteristics and defining mathematical models of their development to facilitate monitoring is an important task for sports science (Zatsiorsky, 1982).

Handball is a high-intensity, intermittent body contact, team sport, involving a large variety of motor skills: running, sprinting, pushing, jumping, hitting, etc. (Matthys et al., 2011; Weber, van Maanen-Coppens, & Wegner, 2018). The variety of motor skills involved in handball, have made it one of the most attractive and popular sports games; cyclical (running) and acyclical (throwing, jumping) motor skills will be interwoven throughout a game (Tosun, Koç, & Özen, 2017). The varied nature of play and training means that handball has a broad influence on the body, facilitating balanced progress towards the realisation of one's anthropological potential as well as improving morphological characteristics and motor functions.

As a game which involves 'powerful contact', mostly 'permitted contact', handball leads to balanced development of all an athlete's motor functions. The very structure of the game means that an athlete must have balanced and developed morphology, strength, endurance and explosive power to be adequately physically prepared (Matthys et al., 2011; Ghobadi, Rajabi, Farzad, Bayati, & Jeffreys, 2013).

A player's ability depends not just on physical preparedness, but also on having the technical skill to execute the specific tasks imposed on him or her by the game situation in a timely and effective manner. As well as being competent in all movement tasks, a player should be capable of catching the ball efficiently in one or both hands, holding the ball in one hand and executing the full range of passes and shots at the goal. Hand function is crucial to these skills, which require precise, coordinated and powerful manipulative movements in the course of catching, passing, leading and holding the ball (Tyldesley & Grieve, 2000; Matthys et al., 2011). In all these ball handling techniques, hand position closely follows the shape of the object held; this reflects the basic functional value of a hand (Tyldesley & Grieve, 2000) and in gripping the ball, the most important role is played by the flexor muscles of fingers and interosseous hand muscles.

The dominant technical element of handball is ball manipulation and the main manipulative organ is the hand; the contractile capabilities of the hand provide a valid index of handball capability, therefore it is important to describe the parameters which determine the functional capability of the hand to inform and monitor the long-term preparation of handball athletes.

The aim of this work was to model developmental trends in contractile characteristics in terms of the maximum force of the flexor muscles of the fingers based on hand grip test data collected in a sample of female handball players recruited from the Republic of Serbia's female handball training system. We hypothesized that it is possible to define a significant model of observable characteristics which will be useful in the design and monitoring of long term physical fitness development in female handball players.

METHODOLOGY

Study design

The research was undertaken as a transverse and cross-sectional design study. Measurements were carried out under laboratory conditions, applying a dynamometric method using tensiometric probe and a standardised procedure for the hand grip test (Ivanović and Dopsaj, 2012; Zarić et al., 2018; Dopsaj et al., 2018). The research was conducted in accordance with the guidelines for physicians carrying out biomedical research involving human subjects set out in the Declaration of Helsinki (http://www.cirp.org/library/ethics/helsinki/) as was approved by the Ethics Committee of the Faculty of Sport and Physical Education, University of Belgrade.

Participants

The sample consisted of 207 participants organised into age categories as follows: 52 senior players (age = 24.5 ± 3.3, body height (BH) = 174.6 ± 6.8cm, Body mass (BM) = 68.8 ± 5.9kg, BMI = 22.57 ± 1.34kg/m^2, training history = 12.2 ± 3.2 years), 51 junior players (U18, age = 17.4 ± 0.7, BH = 172.4 ± 6.6cm, BM = 67.5 ± 8.7kg, BMI = 22.75 ± 2.31kg/m^2, training history = 8.1 ± 1.4 years), 45 cadet players (U16, age = 15.5 ± 0.9, BH = 172.2 ± 6.1cm, BM = 66.3 ± 9.0kg, BMI = 22.96 ± 1.19kg/m^2, training history = 5.1 ± 0.9 years), and 49 young players (U14, age = 13.4 ± 0.5, BH = 168.8 ± 6.5cm, BM = 60.1 ± 8.5kg, BMI = 21.04 ± 2.31kg/m^2, BMI = 22.99 ± 1.20kg/m^2, training history = 3.8 ± 1.4 years). All participants were active handball players who played in national teams or participated in national training camps for talented players between 2012 and 2016. Upon obtaining consent and written approval from their parents and their clubs' management, all the handball players agreed and signed up to participate in this research voluntarily.

Measures

Tests were carried out in the Methodical Research Laboratory of the Faculty for Sport and Physical Education at the University of Belgrade (MIL). Field testing was carried out by the same examiners, using the same procedure during preparations and camps for the selection of national teams from 2012 to 2016, in the Republic of Serbia.

The maximal isometric contractile characteristics of arms were measured using the isometric handgrip test (HG) with standardized equipment, i.e., a sliding device that measures isometric finger flexor force in accordance with the procedure described earlier (Ivanović and Dopsaj, 2012; Zarić et al., 2018; Dopsaj et al., 2018). The standard tensiometric probe (all4gym d.o.o., http://www.all4gym.rs/) with the measurement precision of ± 0.01N was connected to the force reader. A specially designed software-hardware system (Isometrics Lite, ver. 3.1.1, Isometrics SMS All4Gym, Belgrade) was used for data collection and processing. The force–time signal was sampled at 500 Hz and low-pass filtered (10 Hz) using a fourth-order (zero-phase log) Butterworth filter. The onset of the contraction was defined as the point in time when the first derivative of the force–time curve exceeded the baseline by 3% of its maximal value. The maximal force was assessed through the maximum of the achieved muscle force level (F_{max}) (Knezevic, Mirkov, Kadija, Nedeljkovic, Jaric, 2014).

All testing was performed between 09:00 a.m. and 11:00 a.m. after a standard warm-up period of at least 10 minutes. After the warm-up each subject performed two trial hand grips with each hand, alternating between hands, in order to familiarise herself with the procedure. After a rest of 3 to 5 minutes measurements were taken following the procedure described above (Ivanović and Dopsaj, 2012; Zarić et al., 2018; Dopsaj et al., 2018). Each subject was tested while sitting upright, gripping with power grip the measuring device with the hand tested while the arm was extended in the natural posture alongside the body in an abduction position of approximately 5 degrees. There were two alternate measurements, using the left and the right hands (the players chose the hand to begin the test with) with a 1-min of the rest between trials. All test trial results for all tested variables were recorded in the database, and the best result for each variable was used for data processing. The players were instructed by the examiner to grip the dynamometric construction with maximal force as fast as possible.

Variables

The contractile properties of hand grip muscle force were measured using five variables: the absolute and relative values for maximum muscle force for left and right hand and an index of functional dimorphism which were calculated as follows.

Absolute muscle force:

- Maximal muscle force for the right hand grip ($F_{maxR_}$HG), expressed in Newtons (N);
- Maximal muscle force for the left hand grip ($F_{maxL_}$HG), expressed in Newtons (N);

Relative muscle force (i.e. maximal muscle force per unit body mass):

- Relative muscle force for the right hand grip ($F_{relR_}$HG), expressed in Newtons per kg of Body Mass (N/kg BM);
- Relative muscle force for the left hand grip ($F_{relL_}$HG), expressed in Newtons per kg of Body Mass (N/kg BM);

Functional dimorphism was defined as the ratio of the maximum muscle force achieved in the non-dominant and dominant hand:

- Index of functional dimorphism of maximum hand grip muscle force, non-dominant to dominant hand (F_{max}Nd/Do).

Statistical Analysis

During testing all results were entered into a specially prepared Excel database. The first step in the analysis was calculation of basic descriptive statistics: measures of central tendency (mean) and measures of dispersion (standard deviation, SD). Multiple and Univariate analysis of variance (MANOVA and ANOVA) were used to define differences between dependent variables as a function of age group, and the Bonferroni criterion was applied to pairwise comparisons between groups. Trends in variables as a function of age were defined using linear regression and by mathematical modelling method using dependency functions (Hair et al., 1998). Statistical analysis was carried out using the software package Microsoft®Office Excel 2003 (Microsoft Corporation, Redmond, USA) and SPSS Win 17.0 (SPSS Inc., Chicago, Illinois, USA).

RESULTS

Table 1. Descriptive statistics for variables for hand grip muscle force

		Age 20	Age 18	Age 16	Age 14
F_{maxR}	*Mean±SD*	430.7±53.8 ‡, ¥	402.6±53.1 ‡, ¥	354.2±50.9 *, †, ¥	297.7±59.8 *, †, ‡
	Min−Max	340.0−591.8	303.6−590.8	275.8−472.3	194.2−433.5
F_{maxL}	*Mean±SD*	405.5±58.9 ◊, $	349.1±57.2 #	323.8±35.5 #	268.6±56.6 #, ◊, $
	Min−Max	303.8−530.0	213.6−480.0	263.8−390.0	130.4−402.1
F_{relR}	*Mean±SD*	6.29±0.87 ‡	6.04±0.99 ‡	5.37±0.83 *, †	4.97±0.81 *, †
	Min−Max	4.61−9.58	4.02−9.59	4.02−7.20	3.25−7.09
F_{relL}	*Mean±SD*	5.93±0.98 ◊, ‡, ¥	5.23±0.97 #	4.93±0.75 #	4.50±0.87 #, ◊
	Min−Max	4.05−8.29	3.26−7.17	3.25−6.19	2.32−7.52
F_{max}Nd/Do	*Mean±SD*	0.878±0.096	0.848±0.085	0.881±0.089	0.864±0.103
	Min−Max	0.702−1.024	0.663−1.026	0.695−1.025	0.613−1.054

*, p < 0.000 – Age 20 vs. Age 16; Age 20 vs. Age 14;
#, p < 0.000 – Age 20 vs. Age 18; Age 20 vs. Age 16; Age 20 vs. Age 14;
†, p < 0.001 – Age 18 vs. Age 16; Age 18 vs. Age 14;
◊, p < 0.001 – Age 18 vs. Age 20; Age 18 vs. Age 14;
‡, p < 0.001 – Age 16 vs. Age 20; Age 16 vs. Age 18; Age 16 vs. Age 14;
$, p < 0.001 – Age 16 vs. Age 20; Age 16 vs. Age 14;

Table 1 gives basic descriptive statistics for hand grip muscle force. The results of MANOVA showed statistically significant differences between groups according to the hand grip contractile properties, at Wilks's lambda = 0.416, p = 0.000. The results of ANOVA, as a between groups effects showed existence of statistically significant differences for $F_{maxR_}$HG (F=55.73, p = 0.000), $F_{maxL_}$HG (F=53.40, p = 0.000), $F_{relR_}$HG (F=22.27, p = 0.000) nad $F_{relL_}$HG (F=21.45, p = 0.000).

Only at the functional dimorphism variable were no differences found (F_{max}Nd/Do, F=1.14, p = 0.335).

Figure 1 shows the trend in maximal muscle force for both hand grips as a function of age group, where all trends was statically significant ($F_{maxR_}$HG, ANOVA of regression F=162.8, R^2 = 0.9795, p=0.000, SEE = 0.85 N; $F_{maxL_}$HG, ANOVA of regression F=157.5, R^2 = 0.9808, SEE = 0.86 N). Figure 2 shows the trend in relative muscle force for both hand grips as a function of age group, where also all trends was statically significant ($F_{relR_}$HG, ANOVA of regression F=65.2, R^2 = 0.9716, p=0.000, SEE = 1.01 N; $F_{relL_}$HG, ANOVA of regression F=63.5, R^2 = 0.9733, SEE = 1.01 N). Figures 3 and 4 show development trends in maximal and relative muscle force as a function of age group expressed as a standardised values.

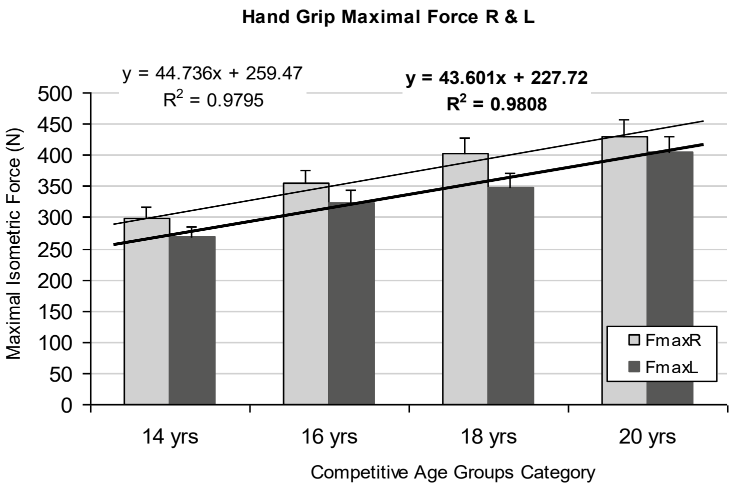

Figure 1. The trend in maximal force for both hands grip as a function of age group

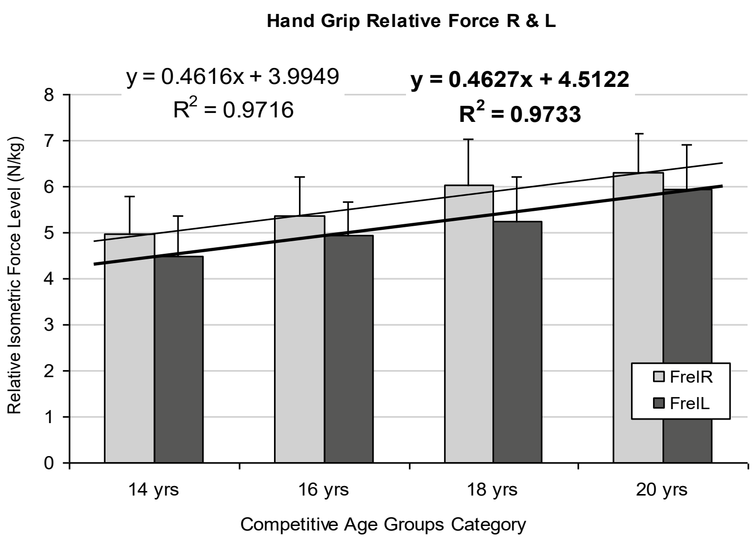

Figure 2. Trend in relative hands grip muscle force as a function of age group

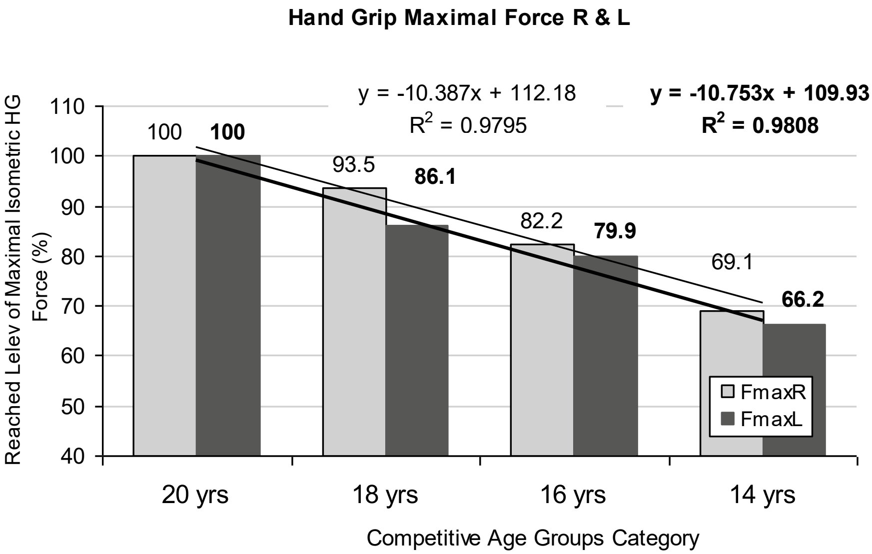

Figure 3. Trend in maximal muscle force of hand grip as a percentage of developmental potential across age groups

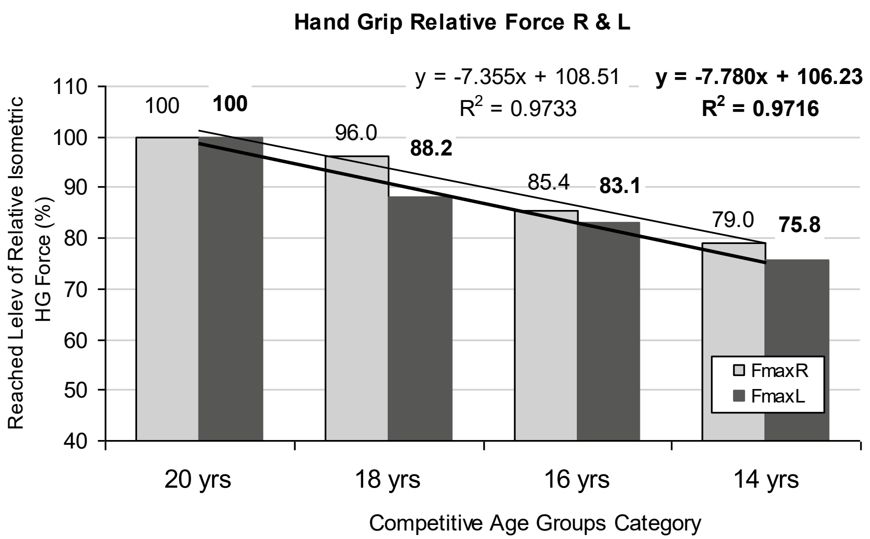

Figure 4. Trend in relative muscle force of hand grip as a percentage of developmental potential across age groups

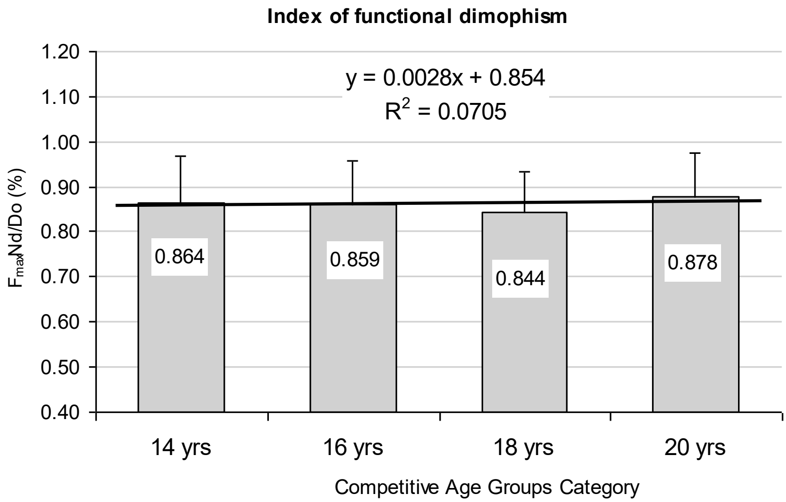

Figure 5. Trend in functional dimorphism with respect to hand grip maximal muscle force as a function of age group

If the absolute (maximal) and relative muscle force of hand grips in seniors are assumed to represent peak development (100%) then players in age group U18 (i.e. players at the penultimate training and developmental stage) achieve 93.5 percent and 86.1 percent of their potential in terms of absolute muscle force with their right and left hands, respectively, and 96.0 and 88.2 percent in terms of relative muscle force; similarly players in age group U16 (i.e., players from the medium training and developmental stage) achieve 82.2 and 79.9 percent of their potential in terms of absolute muscle force, and 85.4 and 83.1 percent of their potential in terms of relative muscle and players in age group U14 (i.e. players from the initial training and developmental stage) achieve 69.1 and 66.2 percent of their potential in terms of absolute muscle force and 79.0 and 75.8 percent of their potential in terms of relative muscle force.

Figure 5 shows the change in functional dimorphism with respect to maximal muscle force (F_{max}Nd/Do) as a function of age. Functional dimorphism was similar in all age groups (Table 2), i.e. the trend was almost horizontal, increasing by only 0.28% across the age range in our sample.

DISCUSSION

Optimal functioning of the hand in daily activities requires a preserved range of motion in all joints of the upper limbs, muscle strength and a fully functional grip. Maximal hand grip force is correlated with variables representing the morphological structure of the body, the balance between the types of muscle fibres, characteristics of the skeleton and bone tissue, fitness status and can be an acceptable indicator of total body muscle force potential for the purpose of sports selection (Bohannon, 2001; Wind et al., 2010; Koley et al., 2011; Dopsaj et al., 2018).

Hand muscles, particularly hand grip muscles, are very important in hand function and play a role in all manipulative activities performed using the arms, thus having a significant role in everyday activities and more specific professional activities (Tyldsley & Grieve, 1996; Leyk et al., 2007; Wind et al., 2010; Taghread, 2013), including sport activities (Guidetti et al., 2002; Kadir et al., 2005; Dopsaj et al., 2009; Carrasco et al., 2010; Zarić et al., 2018), particularly handball (Metthys et al., 2011; Ivanović and Dopsaj, 2012; Ingebrigtsen & Jeffreys, 2012).

An earlier survey showed that the mean (± SD) muscle force exerted by 20-year-old female athletes with their hand grip was 383N ± 60 and 345N ± 56 for the dominant and non-dominant hand respectively, whilst functional dimorphism was 0.903 ± 0.080. In a sample of elite female handball players the corresponding values for hand grip were 406N ± 63 and 357N ± 53 and 0.883 ± 0.090 for functional dimorphism (Ivanović and Dopsaj, 2012). In students who were not involved in sport and had a moderate level of physical activity, maximal hand grip force was 315N ± 36 and 287N ± 35 for the right and left hand respectively, whilst functional dimorphism was 0.913 (Kljajić et al., 2012). Danish researchers reported very similar results in a sample of women ranging from 19 to 20 years of age (mean maximal force for the dominant hand grip = 32.4kg ± 5.1; Aadahl et al., 2011). The above results of the analysed studies confirm the external validity of our findings, since they all agree as for the reference numerical values of each of them for maximal hand grip force in a sample of women of a similar age.

If we consider the maximal hand grip muscle force in young, physically active women as a reference (Dopsaj et al., 2007), our results indicate that our handball respondents aged 20 years have achieved 85 percent, at the age of 18 they have achieved 60 to 70 percent, at 16 years between 35 and 40 percent whilst at age 14 years they have achieved 5 percent of the reference value. Obviously, female handball players of the aged 18 and 20 years have a much higher than average maximal muscle force in both hand grips, whereas in age groups U16 and U14 maximal hand grip muscle force is below the mean for adult women. However, handball players have greater hand grip functional dimorphism than the general population. In general, the data for our index of functional dimorphism confirmed that maximal muscle force ability in the non-dominant hand is between 84.8% and 88.1% of the dominant hand, which, as per defined normative indicates functional asymmetry. Generally, in our sample, functional dimorphism in all age groups was between 25 and 30% of the mean value for healthy, young, physically active women (Ivanović & Dopsaj, 2012).

Although handball training involves developing the technical skills of both hands, most of the effects occur in the initial phases of training. Our findings on functional asymmetry show that baseline contractile ability (F_{max}) lags behind in the non-dominant hand and this may be viewed as a consequence of insufficient training with this particular hand. To address this asymmetrical development it would be necessary to implement a training program aimed at ensuring equal development of the two extremities - both in terms of technical skill and development of strength or power - from the time an athlete first takes up the sport of handball in order to avoid disruption to the natural level of functional dimorphism.

Arguments for encouraging symmetrical development of all aspects of contractile abilities in both arms rest on the need for both general and specific arm strength and power for the technical and the tactical skills of defensive handball play. The benefit of this training is that coaches can use players in all positions throughout a game, providing potential for an equally high quality of technical and tactical solutions on both sides.

We found that the trend change constant in absolute muscular force (a measure of trainability) with regard to age groups was 44.74N for the right hand and 43.60N for the left; the corresponding values for relative muscular force were 0.462 N/kg TM and 0.463 N/kg TM (Figure 1 and 2). In percentage terms the trend change constants were 10.38% and 10.75% with regard to age groups for absolute muscle force, and 7.36% and 7.78 % for relative muscle force, respectively (Figure 3 and 4).

Based on the results of the study and the established trend change constant models, it can be concluded that absolute hand grip muscular force changes more with age than relative muscular force; the constant of change for relative muscular force was 27.63% and 29.09% lower than that for absolute muscular force for the right and left hand, respectively (Figure 3 and 4). This implies that the dominant mechanism for increasing hand grip muscle force in players in the age range we tested was related to the increase in body mass i.e. a physiological, developmental mechanism, whereas training had a relatively smaller effect. It has been established that maximum hand grip force directly correlates with all other main muscle groups in various trained population, the strongest grip is found in athletes who make the most use of methods for development of maximum force or power, that is, who practice gym workouts in large volume and intensity (Dopsaj et al., 2009). Our data on older players (ages 18 and 20) indicate that their training had not involved appropriate use of methods for the development of relative force.

Since no surveys can be directly compared with the data presented herein, our models provide useful tools for future research. Hand grip firmness is important for all handball players, regardless of differences in body dimensions and physical predispositions or the player's position or age, as it is an important factor in ball control (Chaouachi et al., 2009; Scarbalius, 2003; Matthys et al., 2011; Ghobadi et al., 2013). A strong hand grip facilitates all types of ball manipulation: catching, holding and throwing (both passing and shooting). It is important to highlight this because there has been a significant increase in the number of goals scored per game in the major national leagues in Europe, goals per match have increased by an average of 5, or about 10% from 2002-2003 through 2008-2009 (Meletakos & Bayios, 2010). It can be said that successful Handball teams in the modern era could have benefit from improved ball manipulation through increased hand grip strength.

Our results can be used to help identify talent and improve player selection in handball, and to improve training programs, taking into account the developmental phase of the players.

Also, we would like to emphasize the certain limitations of this study, such as the lack of data considering phase of handball training and its possible cumulative impact on fitness status of players during the hand grip testing process. Namely, the characteristics of the training that the players had in their clubs, and before coming to the training camps with national teams was not controlled. Therefore, it is possible that the players were tested at different stages of training preparation, which possibly had some effect on the quantitative level of results obtained in this study.

CONCLUSION

To play proficiently a player must, not only be able to move well, but also be capable of catching the ball effectively with one or both hands, holding the ball in one hand and performing a variety of passes or shots at goal. Hand function has a crucial role in these skills as it is needed for the precise, coordinated and powerful manipulative movements required for catching, passing, leading and holding the ball. The goal of our work was to model developmental changes in the contractile characteristics of the maximal muscle force in the flexor muscles of the fingers based on hand grip test data from a sample of female handball players recruited from the training system for female players in the Republic of Serbia.

This research has found that generally, there is a statistically significant difference of absolute and relative maximal hand grip muscle force with regard to the age group, i.e. the 2-year training cycle period.

According to the results it was determined the following trend of change in the contractile characteristics of female handball players according to the age groups are 44.7N and 43.6N for absolute, and 0.462 and 0.463 $N \cdot BW^{-1}$ for relative values of maximal hand grip force for the right and the left hand, respectively.

RECOMMENDATIONS

These results contribute to scientific knowledge on the physical abilities of female handball players and can be used to verify the level of development of systems when identifying and selecting players, which can lead to improvement of the efficiency of training models for handball players at every stage of their physical development.

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