SPECIFIC FORCE-TIME CHARACTERISTICS OF LEG EXTENSORS IN ELITE VOLLEYBALL PLAYERS BOTH GENDER IN SERBIA

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REVIEW ARTICLE

Summary: Adequate preparation of the leg extensors is highly important especially in sports which involve several jumping techniques. Information on force-time characteristics of the certain muscle group is the basic information on athlete ability which are gathered with intention to control the athlete`s physical preparation. The aim of this paper was to determine descriptive and sexual dimorphism of different specific isometric characteristics of force-time model related to leg extensors in elite volleyball Serbian players. Nineteen male (height=199.21±4.94 cm, mass=91.05±6.95 kg, age=22.58±2.97 years) and twenty female (height=184.65±7.00 cm, mass=70.65±6.15 kg, age=22.92±3.73 years) elite volleyball players performed a standardized "isometric leg press" test in order to assess the characteristics of isometric force from their leg extensors. The measurement range was defined by 8 variables according to 4 different dimensions – 1) the level of achieved force, 2) rate of force development, 3) the time necessary for reaching the certain level of force, 4) different index parameters; covering the space of basic, specific and special characteristics of leg extensors muscle force. MANOVA established that there is a significant difference of $p < 0.05$ in all contractile characteristics among observed sub-samples at the level of Wilks´ Lambda 0.098, $F = 25.814$, $p = 0.000$. The present findings demonstrated that the male volleyball players produce higher values than the female players in all contractile characteristics of covering the space of specific and special characteristics of leg extensors muscle force. It is highly likely that these differences cannot be explained only on the basis of sexual differences, but on the basis of overall intensity and volume and/or type of power and strength training during the training process as well, factors which deserves attention in work with athletes. The obtained data can be used as a reverse information on characteristics of a certain leg extensors contractile ability in elite volleyball players in order to follow fitness profile of athletes, to control and optimize training process.

Key words: isometric force, sexual dimorphism, leg press, volleyball

INTRODUCTION

Technical and tactical requirements in volleyball include frequent changes of direction in frontal and lateral plane, numerous high and long jumps, as well as jumps which are characteristic for volleyball (Ziv & Lidor, 2010). Such characteristics require adequate preparation and high performance in terms of sport technique, tactics and both basic and specific physical preparation. Regarding the three extensors groups of knee joints maximal and explosive isometric force, the most important influence on the level of rebound have both characteristics of knee joints extensors force. No matter what kind of jump is being performed during the game, the muscle involvement of leg extensors is 56% (Jarić, 1987). According to many authors (Zatsiorski & Kraemer, 2006; Ivanović et al., 2011; Ivanović et al., 2019; Ivanović et al., 2020), the diagnosis of physical preparation and athletes selection within the contractile abilities, estimated using basic parametres, that is, using the level of maximal force realization (F_{max}) or indicator of explosiveness ($RFDF_{max}$), do not provide valid data for its optimisation. Only values of developed force in the function of time generated during the isometric (static) muscle contraction, with it's own characteristics (Force-time characteristics) are the fundamental data on contractile ability. Therefore, information on the force-time characteristics of a certain muscle group equates to basic information concerning the ability of an athlete, which is gathered with a view to controling his physical preparation (Zatsiorski & Kraemer, 2006; Muminović et al., 2022). Eight variables were observed in this paper, covering the following spaces: 1) force level at 50% of its maximum, at 30% of its maximum; 2) rate of force development – specific and special explosiveness; 3) time parametres – time necessary for reaching the 50% of maximal force, the 30% of maximal force and 4) synergy index – as a criterion of relation between explosive (RFD) and maximal force at the level of 50% and 30% of its maximum.

MATERIALS AND METHODS

Participants

The subject sample included 39 examinees devided into 2 different groups on the basis of gender: elite male volleyball players ($Elite_M$, N = 19) and elite female volleyball players ($Elite_F$, N = 20). The collected basic anthropo-morphological characteristics were as follows: BH_F = 184.65 ± 7.00 cm, BM_F = 70.65 ± 6.15 kg, BMI_F = 20.70 ± 0.92, AGE_F = 22.92 ± 3.73 years, $Trainingperiod_F$ = 11.42 ± 3.70 years; BH_M = 199.21 ± 4.94 cm, BM_M = 91.05 ± 6.95 kg, BMI_M = 22.94 ± 1.56, AGE_F = 22.58 ± 2.97 years, $Trainingperiod_M$ = 10.71 ± 2.80 years. All tests were conducted in the Laboratory for assessing the basic motoric status in Serbian Institute of sport and sport medicine, using the same procedure and equipment. In order to conduct unified testing and to obtain the most objective results, all athletes were tested over the same period, at the beginning of the main pre-competitive mezocycle training. All the examinees were suggested not to have hard exercise minimum 48h, nor to eat minimum 2h before testing. Each subject was informed of the potential risks and discomforts associated with the investigation, and measurings were carried out with the willing consent of the examinees in accordance with the ACSM's guidelines for exercise testing and prescription (ACSM's, 2006) and after the permission of Ethical Comitee of the Faculty for sport in Belgrade, Serbia.

Procedures

Maximal isometric force was measured using a leg extension dynamometer (Serbian Institute of sport and sport medicine, Belgrade). Subject were seated on the bench, so that their hip angle was 110°, knee angle 120°, and ankle angle 90°. After the individual 5-minutes warm-up and introducing with the measuring procedure, each examinee had four attempts, with one minute rest between trials. The subjects were instructed to exert their maximal force as fast as possible. In order to assess the contractile characteristics of the leg extensors isometric muscle force (bilateral), standardized equipment was used, i.e. metal device. A foot-platform fixed to the frame by strain-gauge transducers and standardized "isometric leg press" test was used following the earlier described procedures (Ivanović, 2010, 2010a; Ivanović et al., 2010; Ivanović et al., 2011; Ivanović et al., 2019; Ivanović et al., 2020) (Figure 1). Data were collected at 2000 Hz using interface box with an analog to digital card (National Instruments, NI PCI-4461, Austin, TX, USA). All data were recorded and analyzed using specially designed software system (M_S_NI, Nikola Tesla Institute, Serbia, Belgrade).

Thereafter, the data were processed by a PC computer. Maximal isometric force (F_{max}) was defined as the highest values of the force (N) recorded during the bilateral isometric leg extension. The attempt with the highest basic level of rate of force development of leg extensors was chosen for the analysis. In our previous research (Dopsaj & Ivanović, 2011; Ivanović & Dopsaj, 2013), the obtained results showed that the applied measuring procedure and used measuring instruments, i.e. tensiometric device with the following hardware and software system, as well as measuring variables which represented the basic contractile characteristics of the isometric force of leg extensors in the seating position, are statistically very reliable in the function of specialized and sophisticated measuring equipment for testing well and highly trained athletes.

Figure 1. The Measuring Device for Assesing Maximal Leg Extensors Isometric Force

Variables

The measurement range was defined using the 8 variables which can be sistematized in following moduls of the contractile characteristics covering the space of specific (at 50% of its maximum) and special (at 30% of its maximum) characteristics of leg extensors isometric muscle force:

- Modul for evaluating the level of force development
  - Specific characteristic of achived force was defined at the 50% of maximal force – $F_{50\%}$, expressed in N.
  - Special characteristic of achived force was defined at the 30% of maximal – $F_{30\%}$, expressed in N.

- Rate of force development as a modul for evaluating achieved explosiveness
  - The indicator of specific level of rate of force development of leg extensors or the S gradient of the leg extensors force, as a rate of force development achieved at 50% of F_{max} was measured by applying the following procedure (Zatsiorsky & Kraemer, 2006):

$$RFD_{50\%} = \frac{F_{50\%}}{tF_{50\%}}$$

  - The indicator of special level of rate of force development of leg extensors, as a rate of force development achieved at 30% of F_{max} was measured by applying the following procedure:

$$RFD_{30\%} = \frac{F_{30\%}}{tF_{30\%}}$$

- Synergy index – as a modul of relation between explosive (RFD) and achived force
- Specific Synergy Index, as a criterion for evaluating the specific level of rate of force development of leg extensors achieved at 50% of F_{max}, in the range of the S-gradient (Ivanović, 2010; Ivanović et al., 2011):

$$IndSNG_{SPEC} = \frac{RFD_{50\%}}{F_{50\%}}$$

- Special Synergy Index, as a criterion for evaluating the special level of rate of force development of leg extensors achieved at 30% of F_{max} (Ivanović, 2010; Ivanović et al., 2011):

$$IndSNG_{SPECIJ} = \frac{RFD_{30\%}}{F_{30\%}}$$

- Time parametres
- time necessary to reach 50% of maximal force – $tF_{50\%}$ in s,
- time necessary to reach 30% of maximal force – $tF_{30\%}$ in s.

Statistical Analysis

All the obtained results were statistically evaluated by the method of descriptive statistics, the multivariate statistical procedure General Linear Model – multivariate procedure and post-hoc test (Bonferroni's test) (Hair et al., 1998). All statistical operations were carried out by applying the Microsoft ® Office Excel 2003 and the SPSS for Windows, Release 17.0 (Copyright © SPSS Inc., 1989–2002).

RESULTS

The results of the descriptive statistic for the total sample in terms of gender of the examinees are presented in Table 1. The coefficient of variation of the observed variables in male examinees ranged from 16.32% for the variable $F_{50\%}$ to 45.76% for the variable $RFD_{30\%}$. In female subsample the coefficient of variation ranged from 26.32% for the variable $F_{50\%}$ to 98.88% for the variable $tF_{30\%}$. The average values of the observed leg extensors isometric force characteristics for the subsample elite female volleyball players ranged from 1315.9±346.3 N for $F_{50\%}$ to 789.5 ± 207.8 N for $F_{30\%}$. At the level of explosiveness from 13903.7 ± 9074.1 N^{-s} for $RFD_{50\%}$ to 13086.9±9095.2 N^{-s} for $RFD_{30\%}$. At the level of relation between explosiveness and the maximal force development from 10.736±6.180 for $IndSNG_{SPEC}$ to 17.032 ± 10.944 for $IndSNG_{SPECIJ}$ (index values) (Table 1). Average values of the observed characteristics of the leg extensors isometric force in male volleyball players were measured at the level of 2040.2±333.0 N for $F_{50\%}$ to 1224.1 ± 199.8 N for $F_{30\%}$. At the level of explosiveness from 22130.8±9759.6 N-s for $RFD_{50\%}$ to 23441.0 ± 10726.5 N^{-s} for $RFD_{30\%}$. At the level of time parameters from 0.103±0.032 s for $tF_{50\%}$ to 0.059 ± 0.022 s for $tF_{30\%}$. At the level of relation between explosive and maximal force development from 10.723±3.769 for $IndSNG_{SPEC}$ to 18.858 ± 7.114 for $IndSNG_{SPECIJ}$ (index values) (Table 1).

Table 1. Descriptive Statistics for the Total Subsample in Terms of Gender

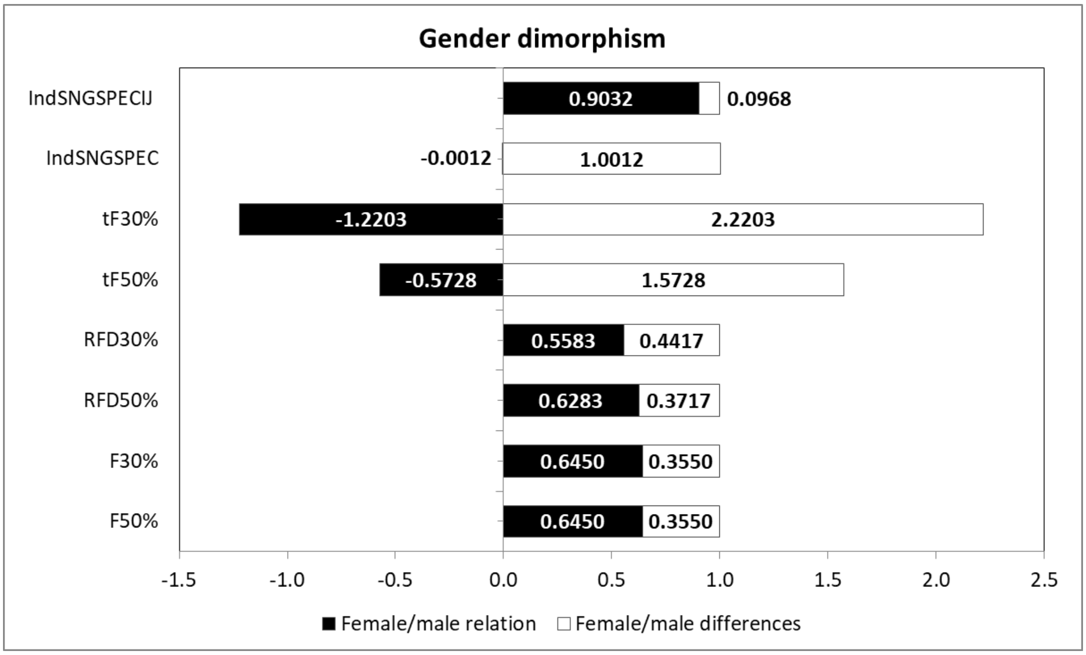
Force-time characteristics	Female (N=20)			Male (N=19)		
	Mean±SD	cV%	Min-Max	Mean±SD	cV%	Min-Max
$F_{50\%}$ (N)	1315.9±346.3	26.32	910.1-1955.1	2040.2±333.0	16.32	1131.0-2661.0
$F_{30\%}$ (N)	789.5±207.8	26.32	546.1-1173.1	1224.1±199.8	16.32	678.6-1596.6
$RFD_{50\%}$ (N^{-S})	13903.7±9074.1	65.26	2402.3-30882.6	22130.8±9759.6	44.10	9142.5-56388.0
$RFD_{30\%}$ (N^{-S})	13086.9±9095.2	69.50	1559.4-28223.8	23441.0±10726.5	45.76	8923.1-48990.0
$tF_{50\%}$ (s)	0.162±0.134	82.89	0.055-0.412	0.103±0.032	36.50	0.043-0.203
$tF_{30\%}$ (s)	0.131±0.129	98.88	0.028-0.377	0.059±0.022	32.34	0.028-0.113
$IndSNG_{SPEC}$ (index)	10.736±6.180	57.57	2.426-18.182	10.723±3.769	35.15	4.931-23.485
$IndSNG_{SPECIJ}$ (index)	17.032±10.944	64.26	2.656-35.398	18.858±7.114	37.73	8.889-35.740

Multivariate statistical analysis established general statistically significant difference in all tested characteristics at the level of Wilks` Lambda 0.098, F = 25.814, p = .000, among the observed subsamples. Partial statistically significant difference was established in following variables: $F_{30\%}$ F = 44.251, p = .000; in $RFD_{30\%}$ F = 10.610, p = .002; in $tF_{30\%}$ F = 5.536, p = .024; in $RFD_{50\%}$ F = 7.442, p = .010; $F_{50\%}$ F = 44.251, p = .000. In variables $tF_{50\%}$, $IndSNG_{SPECIJ}$ statistically significant difference was not established (Table 2). Table 2 represents absolute and relative differences of the observed force-time characteristics in the elite volleyball players in terms of gender.

Table 2. Partial Differences of the Observed F-t Characteristics in Elite Volleyball Players

Force-time characteristics	Absolute differences	Relative differences %	Significant
$F_{50\%}$ (N)	724.4*	55.05	0.000
$F_{30\%}$ (N)	434.5*	55.05	0.000
$RFD_{50\%}$ (N^{-s})	8227.1*	59.17	0.010
$RFD_{30\%}$ (N^{-s})	10354.1*	79.12	0.002
$tF_{50\%}$ (s)	-0.059	-36.42	0.066
$tF_{30\%}$ (s)	-0.072*	-54.96	0.024
$IndSNG_{SPEC}$ (index)	-0.013	-0.12	0.994
$IndSNG_{SPECIJ}$ (index)	1.826	10.72	0.543

The results showed that male examinees have higher average values of the observed characteristics in following variables: in variable $F_{50\%}$ difference was at the absolute level of 724.4 N, that is, at the relative level of 55.05%; in variable $F_{30\%}$ difference was at the absolute level of 434.5 N, that is, at the relative level of 55.05%; in variable $RFD_{50\%}$ difference was at the absolute level of 8227.1 N^{-s}, that is, at the relative level of 59.17%; in variable $RFD_{30\%}$ difference was at the absolute level of 10354.1 N^{-s}, that is, at the relative level of 79.12%; in $IndSNG_{SPECIJ}$ the absolute value at the index level was 1.826, that is, at the relative level of 10.72%, respectively. The results showed that female examinees have higher average values of the observed characteristics in following variables: $IndSNG_{SPEC}$, the difference in index values was 0.013, 0.12%; in $tF_{50\%}$ difference was 0.059 s, 36.42%; in $tF_{30\%}$ the difference was 0.072 s, 54.96%.



Graph 1. Gender Dimorphism of the Observed Characteristics of Leg Extensors Isometric Force in Elite Volleyball Players

The gender dimorphism is at the level from -1.2203 for variable $tF_{30\%}$ to 0.4417 for variable $RFD_{30\%}$. At the level of achieved force, the dimorphism differences were 0.3550 at the absolute level. At the level of explosiveness, the dimorphism differences were at the level from 0.3717 for RFD50% to 0.3717 for $RFD_{50\%}$. At the level of time parameters from -1.2203 for tF30% to -0.5728 for $tF_{50\%}$. At the level of relation between explosive and maximal force development from 0.0968 for $IndSNG_{SPECIJ}$ to -0.0012 for $IndSNG_{SPEC}$ (index value) (Graph 1).

DISCUSSION

In terms of gender, the results of all examined indicators for evaluating leg extensors isometric force, except the variable IndexSNGSPEC, showed higher values in male examinees. The highest differences were measured in general indicator of leg extensors explosiveness RFD30% (79.12%), while the lower differences were measured in IndSNGSPECIJ (10.72%) (Table 2). The results of absolute contractile characteristics of the leg extensors isometric force in female examinees showed 62.09% of deficit in regard to average values in male examinees. In relative (index) values, as a criterion for evaluating relation between explosive and maximal force development, the average values are even lower – 5.30%.

In previous researches, gender dimorphism was mainly monitored at the level of maximum isometric force. Average percentage difference values of the maximal force in the terms of gender, in available literature, were at the level of approximately 30% for the benefit of male examinees (Komi & Karlson, 1978; Hakkinen, 1991; Demura et al., 2003; Dopsaj et al., 2009; Schmitz & Shulz, 2010). In order to establish differences of maximal leg extensors isometric force in terms of gender, Komi & Karlsson (1978) established that the average values of maximal leg extensors isometric force in female examinees were at the level of 80.3% of the measured average values in male (171.9 ± 30.0 kp vs 214.2 ± 54.5 kp), while the average values of time necessary to reach 70% of maximal force in female examinees were at the level of 198.9% of measured values in male examinees (to achieve the same level of force, female examinees needed 2 times more time, 748.1 ± 344.2 ms vs 376.3 ± 255.7 ms). Similar results were established in order to define sexual dimorphism of different muscle groups in elite basketball players (Hakkinen, 1991). The coefficient of sexual dimorphism for leg extensors maximal isometric force was at the level of 0.6955, for maximal trunk flexion force was at the level of 0.5240 and for the maximal trunk extension force was at the level of 0.5860. It was also established that male examinees needed less time to achieve the same level of maximal force, especially in higher values of force level (to achieve force of 2000 N female examinees needed 331 ± 19 ms and male 93 ± 24 ms). In order to define sexual dimorphism of maximal hand grip force, established coefficient was at the approximately same level as maximal force in different muscle groups, for the right hand 0.5922 and for the left hand 0.5829 (Dopsaj et al., 2009). The importance of evaluating the rate of force development lies in fact that the time necessary to reach the specific force level is sometimes very significant in the terms of gender. Observing the results of the mentioned researches, the differences in the variable time necessary to reach certain force level were higher than differences in the variable maximal force regarding the gender. It can be concluded that, in terms of gender, the differences of achieved explosive force in certain time intervals are higher than the differences of achieved maximal force. In elite volleyball players tested in our research, differences of time parameters for estimating leg extensors isometric force on the different level of achieved force were in range from 54.96% for variable time necessary to reach 30% of maximal force to 36.42% for time necessary to reach 50% of maximal force (Table 2).

Obtained differences of sexual dimorphism in measured indicators for evaluating leg extensors explosiveness are higher than the differences of sexual dimorphism in measured values of leg extensors maximal isometric force. Measured average differences of indicators of leg extensors maximal isometric force are at the level of 55.05%, while in variable explosiveness are at the level of 69.15%.

It should be emphasized that in variables IndSNGSPEC, IndSNGSPECIJ and tF50% the statistically significant differences were not established in regard to gender (Table 2). Although the measured average values in RFD30% and RFD50% in volleyball players were much higher than the average values in female volleyball players, in variables IndSNGSPEC, IndSNGSPECIJ as a criterion for evaluating the relation between the level of development of explosive and maximal force at 30% and 50% of Fmax in time intervals that are typical for volleyball and for realization of the volleyball elements, no sexual dimorphism was established.

In various sport disciplines, certain time is necessary to develop certain muscle force level. To perform quick, explosive moves – 50 to 250 ms and it takes longer to reach absolute muscle force in different muscle groups (300 ms in elbow flexors and knee extensors). Therefore, in certain sport disciplines high level of explosive force during the initial (early) phase of muscle contraction can be significant for performing explosive moves. Large number of physiological factors can influence on the RFD force development: the type of muscle fiber and myosin heavy chain (MHC) composition (Harridge et al., 1996), muscle cross sectional area (Miller et al., 1993), Fmax, visco-elastic properties of the muscle–tendon complex4 and neural drive to the muscle (Aagaard et al., 2002).

Sexual dimorphism in muscle cross section area (leg extensors – 25% less than in women), in muscle structure, muscle architecture, ratio of fibers length and surface of physiological cross section (surface of the fibers type II, 7700 to 4040 μm2), the difference in the speed of the nervous activation of the muscle, the difference in skeletal muscle mass (33.0 to 21.0 kg, 38.4 to 30.6%) and statistically significant correlation of the muscle force and cross section muscle area of the leg extensors are the factors that influence on the lower level of muscle force in female subsample in regard to male subsample (Miller et al., 1993; Aagaard et al., 2002). However, large number of authors (Komi & Karlsson, 1978; Hakkinen, 1991; Dopsaj et al., 2009; Janssen et al., 2000) suggested that the differences obtained in measured values of maximal isometric force of different muscle groups and in other physical abilities – maximal force, endurance etc., cannot be explained only on the basis of sexual differences, but on the basis of overall intensity and volume and/or type of power and strength training during the training process as well, factors which deserves attention in work with athletes. Authors concluded that the obtained differences in measured values of muscle force and in cross section area of leg extensors muscles between tested trained and untrained population can be explained with differences in muscle tissue and maximal nervous activation of muscles during the specific training, i.e., adaptation to specific training (Komi & Karlsson, 1978; Hakkinen, 1991; Aagaard et al., 2002; Andersen & Aagaard; 2006; Andersen et al., 2010).

Based on the results of various researches, the increase in explosive muscle strength (contractile RFD and impulse) after heavy-resistance strength training is obvious. The average value of RFD under the influence of heavy-resistance strength training21 is increased for 23–26% in early phase (0–50 ms) and in the late phase of muscle contraction (100–200 ms) for 17–20%. Relative value of RFD (RFD/Fmax) is increased for 15% under the influence of training and corresponding to the very initial phase of muscle contraction as it involves a time interval of 30 ms relative to the onset of contraction (34 ms before the training, 28.5 ms after the training). According to Aagaardu et al., (2002), this change in relative RFD properties indicates that qualitative changes may have occurred in training, i.e., potentially involving alterations in motoneuron recruitment and firing frequency, increased incidence of discharge doublets, and changes in MHC isoform composition and sarcoplasmic reticulum Ca2+ kinetics. The large number of researches on the influence of high-intensity resistance training on contractile rate of force development (RFD) in early (<100 ms) and late phases (>200 ms) of rising muscle force showed that this type of training is not the best choice if the goal is to increase the production of explosive movements (Andersen et al., 2010). In intent to test the influence of quality and quantity muscle adaptation, as a response to high intensity resistance training on contractile characteristics of the rate of force development (RFD) in early (<100 ms) and late phases (>200 ms), Andersen et al. (2010) conclude that in different time intervals of RFD respond different to high intensity resistance training during differential influences of quality and quantity muscle adaptation in early and later phases of the RFD. The results showed that RFD is higher in the later phase of muscle force generation under the influence of high intensity resistance training, while in the early phase no changes were seen. Relative value RFD (RFD/Fmax) in early phase is lower. Quantitative, muscle fiber cross-sectional area and Fmax increased whereas, qualitatively, the relative proportion of type IIX muscle fibers decreased. Multiple regression analysis showed that while increased Fmax positively influenced both early and late RFD, decreased-type IIX negatively influenced early RFD only.

The results of our previous research (Ivanović, 2010), showed significant higher values of the tested basic and specific characteristics of leg extensors explosiveness in elite female volleyball players, in regard to unspecific and untrained population. Values of standardized differences between the observed variables of different trained population were between 10731.65 N-s, that is, 338.32% (unspecific trained female athletes) for variable RFD50%LEGEXTISO and 0.2472 (index value), that is, 31.61% (untrained group) of deficit for variable IndexSNG in regard to elite female volleyball players. The existence of interaction between sport discipline and leg extensors force production in regard to unspecific trained and untrained population isn`t surprising, especially in athletes, for whom the adaptation is the most intensive at the force level (Ivanović, 2009; Ivanović et al., 2019; Schiltz et al., 2009). The participation of leg extensors in sports characterized by great variety of jumps is highly significant. Different training methods and significance of leg extensors in female volleyball players improves explosiveness – relation of RFD and maximal force on the different levels of leg extensors force manifestation in female elite volleyball players in regard to unspecific trained population. Defining basic and specific characteristics of leg extensors explosive force in well trained female volleyball players, competed in the Second Serbian Division, tested in standing position, Rajić et al., (2008) obtained average values of Synergy Index of basic explosive force and maximal isometric force of leg extensors

IndexSNG = 0.7598. Comparing the results from that and our research, the difference values are at the level of 35.45% or 0.2694 of deficit in female elite volleyball players. The results have also shown that the values of leg extensors explosive force at the levels of 100 ms, 180 ms, 250 ms, as well at the level of 50% of maximal force significantly surpassed the obtained values of basic explosiveness (approximately four times higher). The results in our research confirmed these results – the values of specific isometric leg extensors force are higher than the obtained values of basic explosive force by 5.59 times.

CONCLUSION

This work defines the differences of basic and specific characteristics of leg extensors isometric force-time characteristics in elite Serbian volleyball players in the function of gender. Multivariate statistical analysis established general statistically significant differences between the observed subsamples in regard to gender at the level of Wilks` Lambda 0.098, F = 25.814, P = .000 for the benefit of male examinees. Regarding the observed contractile characteristics, dimorphism was at the level of 0.3550 in parameter achieved force, at the level of 0.4417 in RFD30% to 0.3717 in RFD50%, in parameter time necessary to reach certain force level, dimorphism was at the level of -1.2203 in tF30% to -0.5728 in tF50%, while in Synergy Index was at the level of 0.0968 for IndSNGSPECIJ to -0.0012 for IndSNGSPEC. In tF50%, IndSNGSPEC, IndSNGSPECIJ no statistically significant difference was established. Generally speaking, it is highly likely that these differences may be explained not only by the sexual differences in factors such as cross-sectional area, muscle fiber characteristics, differences in skeletal muscle mass and the distribution of muscle mass in upper limbs, but by common anatomical differences as well and on the basis of overall intensity and volume and/or type of power and strength training during the training process, factors which deserves attention in work with athletes.

REFERENCES

Aagaard, P., Simonsen, E. B., Andersen, J. L., Magnusson, P., & Poulsen, P. D. (2002). Increased rate of force development and neural drive of human skeletal muscle following resistance training. *Journal of Applied Physiology, 93*, 1318–1326.

American College of Sports Medicine (2006). *ACSM's Guidelines for Exercise Testing and Prescription* (7th Ed.). USA: Lippincott Williams & Wilkins.

Andersen, L. L., & Aagaard, P. (2006). Influence of maximal muscle strength and intrinsic muscle contractile properties on contractile rate of force development. *European Journal of Applied Physiology, 96*, 46–52.

Andersen, L. L., Andersen, J. L., Zebis, M. K., & Aagaard, P. (2010). Early and late rate of force development: differential adaptive responses to resistance training? *Scandinavian Journal of Medicine & Science in Sports, 20*(1),162–169.

Demura, S., Yamaji, S., Nagasawa, Y., Sato, S., Minami, M., & Yoshimura, Y. (2003). Reliability and gender differences of static explosive grip parameters based on force – time curves. *Journal of Sports Medicine and Physical Fitness, 43*, 38–35.

Dopsaj, M., Ivanović, J., Blagojević, M., & Vučković, G. (2009). Descriptive, functional and sexual dimorphism of exsplosive isometric hand grip force in healthy university students in Serbia. *FACTA UNIVERSITATIS Series: Physical Education and Sport, 7*(2), 125−139.

Dopsaj, M., & Ivanović, J. (2011). The Analysis of the Reliability and Factorial Validity in the Basic Characteristics of Isometric F-t curve of the Leg Extensors in Well Trained Serbian Males and Females. *Measurement Science Review, 11*(5), 165-172.

Hair, J., Anderson, R., Tatham, R., & Black, W. (1998). *Multivariate Data Analysis* (Fifth Ed.). New Jersey, USA: Prentice - Hall, Inc.

Hakkinen, K. (1991). Force production characteristics of leg extensor, trunk flexor and extensor muscles in male and female basketball players. *Journal of Sports Medicine and Physical Fitness, 31*, 325−331.

Harridge, S. D., Bottinelli, R., Canepari, M., Pellegrino, M. A., Reggiani, C., Esbjornsson, M., & Saltin, B. (1996). Whole-muscle and single- fibre contractile properties and myosin heavy chain isoforms in humans. *Pflugers Archiv European Journal of Physiology, 432*, 913–920.

Ivanović J. (2010). *Isometric F-t characteristics of leg extensors in top level volleyball players in regard to different trained and untrained persons* (Unpublished MSci thesis). Belgrade: Faculty of Sport and Physical Education. (In Serbian).

Ivanović, J. (2010a). Characteristics of indicators for evaluating leg extensors explosiveness in the elite volleyball players in Serbia of both genders. *Faculty of sport and physical education Yearbook, 16*, 159−185.

Ivanović, J., Dopsaj, M., Nešić, G., & Stanković, R. (2010). Sexual dimorphism in different indicators for evaluating isometric leg extensors explosive force. *Physical Culture, Journal of sport Science & Physical Education, 64*(1), 46−62.

Ivanović, J., Dopsaj, M., & Nešić, G. (2011). Factor structure differences of indicators for evaluating isometric leg extensors explosive force in female volleyball athletes and different trained female population. *British Journal of Sports Medicine, 45*, 542.

Ivanović, J., & Dopsaj, M. (2013). Reliability of force-time curve characteristics during maximal isometric leg press in differently trained high-level athletes. *Measurement, 46* (7), 2146–2154.

Ivanović, J., Dopsaj, M., Jakovljević, S., & Karalejić, M. (2019). Relationship between isometric neuromuscular function of the leg extensors with performance tests in basketball. *Russian open medical journal, 8*, e0101.

Ivanović, J., Dopsaj, M., & Gajević, A. (2020). Early and Late Rate of Force Development of the Leg Extensors According to Playing Position in Basketball. In: K. Dupuis (Ed.), Essential Topics in Basketball (pp. 85-111). New York, USA: NOVA Publishers.

Janssen, I., Heymsfield, S. B., Wang, Z., & Ross, R. (2000). Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. *Journal of Applied Physiology, 89*, 81−88.

Jarić, S. (1987). Biomechanical studies of maximal counter movement jump and their implication in practice. *Physical Culture, 41*(1), 30−37.

Komi, P. V., & Karlsson, J. (1978). Skeletal muscle fibre types, enzime activities and physical performance in young males and females. *Acta Physiologica Scandinavica, 103*(2), 210−219.

Miller, A. E. J., MacDougall, J. D., Tarnopolsky, M. A., & Sale, D. G. (1993). Gender differences in strength and muscle fiber characteristics. *European Journal of Applied Physiology, 66*, 254–262.

Muminović, J., Pržulj, R., & Jovanović, R. (2022). Uticaj visokointezivnog intervalnog treninga kod učenika. *Sport i Zdravlje, 17*(1), 31-42.

Rajić, B., Dopsaj, M., & Abela, C. P. (2008). Basic and specific parameters of the explosive force of leg extensors in high trained serbian female volleyball players: characteristics of the isometric force- time curve model. *Serbian Journal of Sports Sciences, 2*(4), 131–139.

Schiltz, M., Lehance, C., Maquet, D., Bury, T., Crielaard, J. M., & Croisier, J. L. (2009). Explosive Strength Imbalances in Professional Basketball Players. *Journal of Athletic Training, 44*(1), 39–47.

Schmitz, R. J., & Shultz, S. J. (2010). Contribution of knee flexor and extensor strength on sex-specific energy absorption and torsional joint stiffness during drop jumping. *Journal of Athletic Training, 45*(5), 445-452.

Zatsiorsky, V. M., & Kraemer, W. J. (2006). *Science and practice of strength training* (Sec. Ed.). Champaign, IL: Human Kinetics.

Ziv, G., & Lidor, R. (2010). Vertical jump in female and male volleyball players: a review of observational and experimental studies. *Scandinavian Journal of Medicine and Science in Sports, 20*(4), 556–567.

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