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Original research article

CHARACTERISTICS OF THE BILATERAL ISOMETRIC FORCE-TIME AND RFD-TIME CURVE OF LEG EXTENSORS IN HIGH TRAINED SERBIAN MALE FENCERS*

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Abstract. *The primary aim of the study was to define the characteristics of the Force – time (F-t) and Rate of Force Development – time (RFD-t) curve of bilateral voluntary isometric muscle force of leg extensors in Serbian male fencers competing at the national and international level. The secondary aim of the study was to define the differences between the participants based on their competitive level. The sample consisted of twelve Serbian male fencers, who were divided into two different groups according to their competitive level (national N=8 and international level N=4). In order to assess the characteristics of the F-t isometric leg extensor force, tensiometric probes and the standardized seated leg press test were used. The measurement range was defined by 9 variables for the contractile characteristics of the leg extensor isometric muscle force – 1) the maximal force level – $F_{maxLEGEXTISO}$, 2) the time necessary to reach maximal force – $tF_{max\ LEGEXTISO}$ 3) the indicator of the basic (general) level of rate of force development – $RFD_{FmaxLEGEXTISO}$, 4) the indicator of the specific level of rate of force development – $RFD_{50\%LEGEXTISO}$, three indicators for evaluating the special level of explosive force development, i.e. leg extensor explosiveness, 5) measured at 250ms – $RFD_{250msLEGEXTISO}$, 6) measured at 180ms – $RFD_{180msLEGEXTISO}$, 7) measured at 100ms – $RFD_{100msLEGEXTISO}$, 8) the indicator of achieved maximal level of Rate of Force Development – RFD_{max}, and 9) the time necessary to reach maximal level of Rate of Force Development – $tRFD_{max.}$ The results of the multivariate statistical method (MANOVA) and analysis of variance (ANOVA) showed that there was no statistical significant difference between the observed variables among groups of national and international Serbian fencers. In the future, studies will observe female fencing athletes, different age groups, and also establish the relation among F-t and RFD-t variables with the competition performance of fencers.*

Key words: *Isometric muscle force, rate of force development, leg extensors, fencing.*

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INTRODUCTION

Successful performance in modern fencing requires a high level of technical, tactical and physical preparation from each fencer. Besides, a very important role in the modern fencing is played by time and space dimensions, as well as the structure of the competitive activity of each fencer (Barth & Beck, 2007).

Psychological and motor requirements in the fencing bout include frequent changes of direction in the frontal plane, numerous lounges and explosive attacks such as fleches (Milić, 2013). Such characteristics require adequate preparation and high performance in terms of sport technique, tactics and both basic and specific physical preparation (Milišić, 2007). Within the system for observing the development of physical abilities, the level of contractile characteristics (muscle force and strength), in addition to functional abilities, is the main objective of the training process (Zatsiorsky & Kreamer, 2006; Radovanović & Ignjatović, 2009). The characteristics of muscle force and lower extremity strength characteristics have a significant influence on executing competitive performance i.e. different technical-tactical demands in many sports (Aagaard, Simonsen, Andersen, Magnusson, & Poulsen, 2002; Rajić, Dopsaj, Pablos, & Abella, 2008; Dopsaj, 2010; Ivanović, 2010; Čoh, 2010; Ivanović, Dopsaj, Ćopić, & Nešić, 2011), as well as in fencing (Tsolakis & Tsiganos, 2008; Bottoms, Sinclair, Gabrysz, Szmatlan-Gabrysz, & Price, 2011).

A certain time is necessary to develop muscle force for a given motion. In the case of isometric force, it is approximately between 0.3-0.4 s and it usually takes longer than 0.4 s to reach peak force. As sport performance improves, the time of motion tends to shorten. The better the athlete's qualifications are, the greater the role of RFD in the achievement of a high level of performance is (Zatsiorsky & Kreamer, 2006). However, the results of previous studies show that time needed to perform a lounge were similar among elite and non-elite fencers (Tsolakis & Tsiganos, 2008), which indicates an equivalent neurophysiological form of the characteristics of the F-t and RFD-t curve compared with the main technical element in fencing (Zatsiorsky & Kreamer, 2006; Aagaard et al., 2002; Andersen, Andersen, Zebis, & Aagaard, 2010).

The first aim of the study was to define the characteristics of the Force-time (F-t) and Rate of Force Development-time (RFD-t) curve of bilateral voluntary isometric muscle force of leg extensors in Serbian male fencers which compete at the national and international level of competition. The second aim of the study was to define the differences between the participants according to their competitive level.

METHOD

The sample of participants

Twelve Serbian male fencers, divided into two different groups according to their competitive level (national N=8 and international level N=4), took part in this research and they were tested at The Serbian Institute for Sport in Belgrade. The following basic morphological characteristics of the tested sample is presented in Table 1.

Table 1. The morphological characteristics of the national and international level group.

	Level	N	MEAN	SD	cV%	Min	Max
Body height (m)	Nat.	8	1.84	0.04	2.10	1.80	1.89
	Int.	4	1.85	0.05	2.48	1.80	1.89
Body weight (kg)	Nat.	8	82.8	15.6	18.84	70.0	115.0
	Int.	4	82.0	10.4	12.67	70.0	88.0
BMI ($kg \cdot m^{-2}$)	Nat.	8	24.31	4.15	17.05	20.45	33.63
	Int.	4	23.89	2.02	8.46	21.60	25.44
Age (yrs)	Nat.	8	25.4	5.6	21.88	19.0	33.0
	Int.	4	23.0	5.6	24.21	18.0	29.0

As mentioned above, all of the tests were conducted in a specialized laboratory for assessing the basic motoric status at The Serbian Institute for Sport, using the same standardized procedure and equipment. All of the participants – athletes - were tested in similar training circumstances, in the middle of the in-season (competitive cycle) of 2011/2012. The off-season months of training are from September to December, while in-season competition months run from January to August.

The testing Procedure

In order to assess the contractile characteristics of leg extensor isometric muscle force (bilateral), standardized equipment was used, i.e. a metal device for measuring leg extensor isometric force, and a tensiometric probe as well as the standardized seated leg extension test were used following the earlier described procedures (Ivanović, 2010; Dopsaj & Ivanović, 2011; Ivanović et al., 2011).

The testing was carried out by means of a hardware-software system (Nikola Tesla Institute, Belgrade, Serbia), where the tensiometric probe was connected to the force reader (force indicator) and to the PC computer. The tests were carried out under bilateral isometric conditions of exertion with the knee joint at an angle of 120°, and with the ankle and hip joint at 90°, in accordance with the data found in previously published articles (Dopsaj & Ivanović, 2011; Ivanović et al., 2011).

After the 5 minutes of a standardized warm-up, the participants performed their attempts after the sound signal. Each participant had four attempts, with a one minute rest between the trials. The result was automatic, measured by the tensiometric sounding device and hardware-software system, recorded in a special database with the possibility of F-t curve inscription control. The best trial according to the basic level of explosive force (RFD_{Fmax}) was chosen for further statistical analyses.

It should be noted that in this study, the relative values of the F-t and RFD-t curve were not analyzed because of non-significant differences of morphological characteristics between the groups.

The following seven characteristics of the bilateral isometric F-t curve of the leg extensors were calculated as:

- $F_{maxLEGEXTISO}$, the level of achieved maximal muscle force expressed in N;
- $tF_{max\ LEGEXTISO}$, time necessary to reach maximal force expressed in seconds (s);
- $RFD_{FmaxLEGEXTISO}$, the indicator of the basic (general) level of the rate of force development of leg extensors, expressed in $N \cdot s^{-1}$, was determined by applying the

following procedure (Zatsiorsky & Kraemer, 2006; Dopsaj & Ivanović, 2011; Ivanović et al., 2011);

- $RFD_{50\%LEGEXTISO}$, the indicator of specific isometric leg extensor explosive force or the S gradient of the leg extensor force, as a rate of force development measured at 50% of Fmax, was determined by applying the following procedure (Zatsiorsky & Kraemer, 2006; Dopsaj & Ivanović, 2011; Ivanović et al., 2011);
- $RFD_{250msLEGEXTISO}$, the indicator of the special level of leg extensor explosive force development, measured in the time zone of the Stretch-Shortening Cycle, i.e. at 250 ms of tFmaxLEGEXTISO, was determined by applying the following procedure (Zatsiorsky & Kraemer, 2006; Dopsaj & Ivanović, 2011; Ivanović et al., 2011);
- $RFD_{180msLEGEXTISO}$, the indicator of the special level of explosive force development, measured at 180 ms of tFmaxLEGEXTISO was measured by applying the following procedure (Dopsaj & Ivanović, 2011; Ivanović et al., 2011);
- $RFD_{100msLEGEXTISO}$, the indicator of the special level of explosive force development, measured at 100 ms of tFmaxLEGEXTISO was measured by applying the following procedure (Dopsaj & Ivanović, 2011; Ivanović et al., 2011).

The following two characteristics of the bilateral isometric RFD-t curve of leg extensors were calculated:

- RFD_{max}, the indicator of achieved maximal level of Rate of Force Development was calculated in accordance with the data previously published (Andersen et al., 2010), and expressed in $N \cdot s^{-1}$;
- $tRFD_{max}$, the time necessary to reach maximal level of Rate of Force Development, was observed in accordance with the data previously published (Andersen et al., 2010), expressed in seconds (s).

Statistical analyses

All the obtained results were statistically evaluated by a method of basic descriptive statistics [Mean, Standard Deviation - SD, Coefficient of Deviation – cV %, Absolute and Relative Standard Error of Mean – sX and sX (%), Upper and Lower Confidence Interval at 95 %]. To determine general differences among the variables of the two subsamples determined based on their competition level, the multivariate statistical method (MANOVA) was used. Also, to determine differences among the sets of variables, which were in the function of the competition level, the analysis of variance (ANOVA) was used. Differences among pairs of single variables were determined by Bonferoni criteria. All the statistical operations were carried out by applying the Microsoft ® Office Excel 2007 and the SPSS for Windows, Release 17.0 (Copyright © SPSS Inc., 1989–2002).

RESULTS

Table 2 and Table 3 show results for descriptive statistic of the observing variables of the tested sample.

Table 2. The descriptive statistics of the F-t characteristics.

Leg extensors	Category	N	MEAN	SD	cV (%)	sX	sX (%)	Upper Int. 95%	Lower Int. 95%
$F_{maxLEGEXTISO}$ (N)	Nat.	8	3963.60	777.53	19.62	262.32	6.62	3379.12	4548.07
	Int.	4	4927.22	651.38	13.22	370.91	7.53	4100.65	5753.80
$tF_{max\ LEGEXTISO}$ (s)	Nat.	8	0.9048	0.2677	29.59	0.095	10.50	0.694	1.115
	Int.	4	1.1271	0.2667	23.66	0.134	11.89	0.829	1.425
$RFD_{FmaxLEGEXTISO}$ ($N \cdot s^{-1}$)	Nat.	8	4728.75	1626.73	34.40	576.78	12.20	3443.61	6013.89
	Int.	4	4652.59	1642.13	42.10	815.68	17.53	2835.14	6470.05
$RFD_{50\%\ LEGEXTISO}$ ($N \cdot s^{-1}$)	Nat.	8	13466.96	5026.14	37.32	1520.45	11.29	10079.19	16854.72
	Int.	4	13715.39	1643.79	14.68	2150.24	15.68	8924.36	18506.41
$RFD_{250ms\ LEGEXTISO}$ ($N \cdot s^{-1}$)	Nat.	8	11339.59	2588.95	22.83	871.70	7.69	9397.31	13281.86
	Int.	4	13611.92	2150.25	19.27	1232.77	9.06	10865.13	16358.71
$RFD_{180ms\ LEGEXTISO}$ ($N \cdot s^{-1}$)	Nat.	8	12801.40	4215.71	32.93	1303.94	10.19	9896.04	15706.76
	Int.	4	14392.86	1967.68	16.68	1844.05	12.81	10284.06	18501.65
$RFD_{100ms\ LEGEXTISO}$ ($N \cdot s^{-1}$)	Nat.	8	12114.77	6160.92	50.85	1838.26	15.17	8018.86	16210.67
	Int.	4	13121.23	1243.42	11.55	2599.70	19.81	7328.74	18913.71

* Statistically significant differences at p<0,05.

Table 3. The descriptive statistics of RFD-t characteristics.

Leg extensors	Category	N	MEAN	SD	cV (%)	sX	sX (%)	Upper Int.95 %	Lower Int. 95 %
RFD_{max} ($N \cdot s^{-1}$)	Nat.	8	13687.90	5159.99	37.70	1560.98	11.40	10209.82	17165.98
	Int.	4	14760.63	1688.57	13.97	2207.56	14.96	9841.88	19679.37
$tRFD_{max}$ (s)	Nat.	8	0.1749	0.06043	34.54	0.018	10.29	0.135	0.215
	Int.	4	0.1471	0.01221	10.16	0.026	17.68	0.090	0.204

According to general differences, the MANOVA indicates that there is no significant differences between all the variables which represented the F-t curve characteristics (Wilks' Lambda Value 0.172; F=2.753, p=0.172; Observed Power = 0.343) and all the variables of the RFD-t curve characteristics (Wilks' Lambda Value 0.894; F=0.533, p=0.604; Observed Power = 0.133).

The same results were found according to partial differences, where the ANOVA indicates that there were no statistical differences at the partial level i.e. differences between single variables. Only one variable showed the potential to have a statistically significant level – $F_{maxLEGEXTISO}$ (F=4.498, p=0.060), however, due to the small sample there was no statistical difference, despite of high level of the F value indicator (Table 4).

In the following table, the results of between-participant effects tests are presented.

Table 4. The test of between-participant effects results.

Tests of Between-Subjects Effects								
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
Groups	$F_{maxLEGEXTISO}$	2476193.62	1	2476193.62	4.498	0.060	0.310	0.483
	$tF_{max\ LEGEXTISO}$	0.13	1	0.13	1.845	0.204	0.156	0.233
	$RFD_{FmaxLEGEXTISO}$	15464.88	1	15464.88	0.006	0.941	0.001	0.051
	$RFD_{50\%LEGEXTISO}$	164573.32	1	164573.32	0.009	0.927	0.001	0.051
	$RFD_{250msLEGEXTISO}$	1.377E7	1	1.377E7	2.265	0.163	0.185	0.276
	$RFD_{180msLEGEXTISO}$	6753975.40	1	6753975.40	0.497	0.497	0.047	0.098
	$RFD_{100msLEGEXTISO}$	2701232.44	1	2701232.44	0.100	0.758	0.010	0.059
	RFD_{max}	3068665.62	1	3068665.62	0.157	0.700	0.015	0.065
	$tRFD_{max}$	0.01	1	0.01	0.793	0.394	0.073	0.127

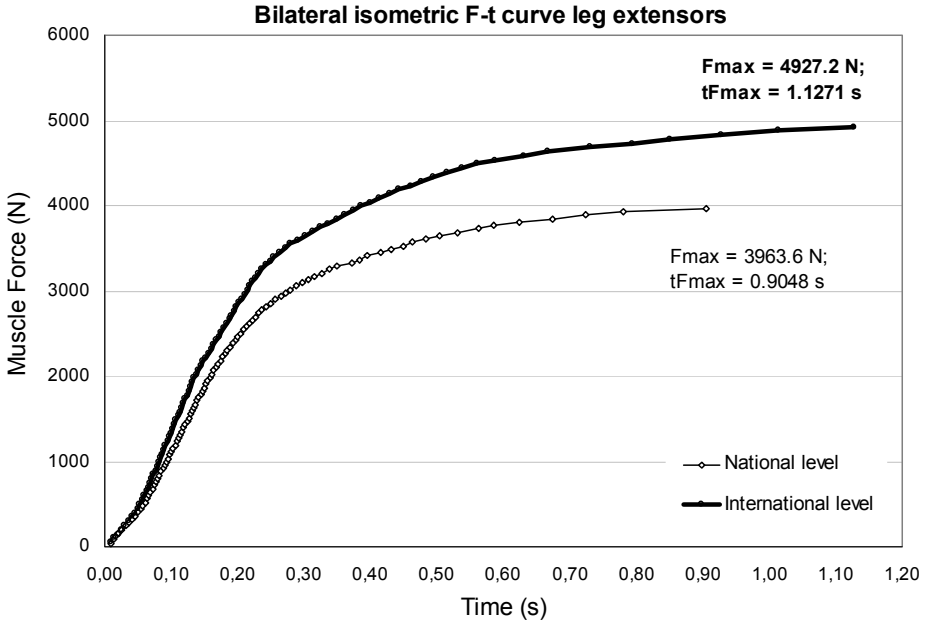

Fig. 1. The relation of the F-t curve among Serbian fencers of the national and international level.

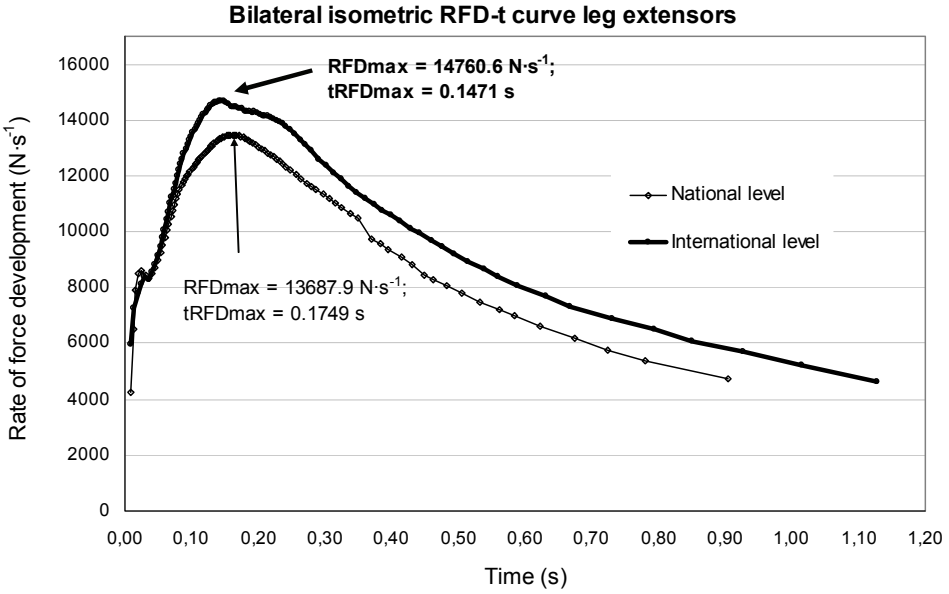

Fig. 2. The relation of the RFD-t curve among Serbian fencers of the national and international level.

DISCUSSION

The main purpose of the present study was to define the characteristics of the Force-time (F-t) and Rate of Force Development-time (RFD-t) curve of the bilateral voluntary isometric muscle force of leg extensors in Serbian male fencers which were competing at the national and international level. Further, one of the main goals of the present study was to define general descriptive values of measured variables for the best Serbian fencers, because there is a lack of that kind of data in the available national and international literature.

First of all, the results shown that the present anthropometric data, according to body height, are very similar to the published information (Harmenberg, Ceci, Barvestad, Hjerpe, & Nystrom, 1991) whereby World class epee fencers were approximately 184cm in height, but were not so similar in terms of body mass: BM=77 kg according to approximately 82.0 kg for Serbian epee fencers. Also, the Body Mass Index (BMI) found in the present study was higher (BMI=23.89-24.31 $kg \cdot m^2$, Table 1) than the previously reported one for seven British international fencers – BMI = 21.0-22.4 $kg \cdot m^2$ (Koutedakis, Ridgeon, Sharp, & Borehamt, 1993).

Based on the obtained Force-time (F-t) and Rate of Force Development-time (RFD-t) curve results, the mean value of achieved maximal muscle force of bilateral leg extensors for Serbian fencers of the national level is 3963.60±777.53 N, while Serbian fencers of the international level had a mean value of 4927.22 ±651.38 N. The coefficient of variation (cV%), as the variability rate of the measurement results showed that the results of the national and international participants varied between 13.22 to 19.62%, for $F_{maxLEGEXTISO}$, which is considered a homogeneous group (Perić, 1996). However, the results of the ANOVA indicate that there were no statistical differences between the two groups re-

garding $F_{maxLEGEXTISO}$, although the p value was very close to becoming statistically significant (P = 0.060, Table 4). Anyway, it is possible to compare those results with the obtained model $F_{maxLEGEXTISO}$ results from previous research (Dopsaj & Ivanović, 2011). Thus, Serbian fencers at the international level can be classified as excellent (mark 6), while Serbian fencers at the national level can be classified as average (mark 4). Also, after comparing the mean values of $F_{maxLEGEXTISO}$ of Serbian fencers of the national and international level, with the mean value of $F_{maxLEGEXTISO}$ of well-trained male athletes from a previous study (Dopsaj & Ivanović, 2011), it is notable that Serbian fencers of the national and international level have higher results by 4.56% and 29.97%, respectively, than athletes of the national level in different sports.

However, the mean value of the time necessary to reach maximal force ($tF_{max\ LEGEXTISO}$) expressed in seconds, for national participants is 0.9048±0.2677 s, while the mean value for international participants is 1.1271±0.2667 s. The coefficient of variation (cV%), for $tF_{max\ LEGEXTISO}$, showed that the results of national and international participants varied between 23.66 to 29.59%. Also, it is possible to compare those results with the results obtained from previous research, (Dopsaj & Ivanović, 2011). According to this study, Serbian fencers of the national level can be classified as not satisfactory (mark 2), while Serbian fencers of the international level can be classified as bad (mark 1).

After a comparison of the mean value of $tF_{maxLEGEXTISO}$ of Serbian fencers of the national and international level, with a mean value of $tF_{maxLEGEXTISO}$ of well-trained athletes from a previous study (Dopsaj & Ivanović, 2011), it is notable that Serbian fencers of the national and international level have lower results by 44.31% and 79.74%, respectively, than well-trained athletes involved in different sports.

Based on the obtained results, the mean value of the indicator of basic (general) level of the Rate of Force Development of leg extensors, $RFD_{FmaxLEGEXTISO}$, for Serbian fencers of the national level is 4728.75±1626.73 N•s-1, and a mean value for Serbian fencers of the international level is 4652.59±1642.13 N•s-1. The coefficient of variation (cV %), for $RFD_{FmaxLEGEXTISO}$, showed that the results of the national and international participants varied between 34.40 to 42.10%, respectively. It is possible to compare those values with the results obtained from previous research (Dopsaj & Ivanović, 2011). According to it, Serbian fencers of the international level and Serbian fencers of the national level can be classified as satisfactory (mark 3). After a comparison of the mean value of $RFD_{FmaxLEGEXTISO}$ of Serbian fencers of the national and international level, with the mean value of $RFD_{FmaxLEGEXTISO}$ of well-trained athletes from a previous study (Dopsaj & Ivanović, 2011), it is notable that Serbian fencers of the national and international level have lower results by 25.85% and 27.05%, respectively, than well-trained athletes involved in different sports.

The mean value of the S gradient ($RFD_{50\%\ LEGEXTISO}$) of the bilateral leg extensor force for the Serbian national level is 13466.96±5026.14 N•s-1, while the mean value for Serbian international fencers is 13715.39±1643.79 N•s-1. The coefficient of variation (cV%), for $RFD_{50\%\ LEGEXTISO}$, showed that the results for the national and international participants varied between 14.68 to 37.32%.

After a comparison of the descriptive values of the S gradient with the descriptive values from previous research (Ivanović et al., 2011), it is notable that Serbian fencers of the national level have lower results by 0.50% and Serbian fencers of the international level have higher results by 1.35% than athletes of the national level involved in different sports.

The mean value of $RFD_{250ms\ LEGEXTISO}$ of the bilateral leg extensor force for Serbian fencers of the national level is 11339.59±2588.95N•s-1, while the mean value for Serbian

international fencers is 13611.92±2150.25N•s-1. The coefficient of variation (cV%), for $RFD_{250ms\ LEGEXTISO}$, showed that the results for national and international participants varied between 19.27 to 22.83%.

After a comparison of $RFD_{250ms\ LEGEXTISO}$ descriptive values with the descriptive values from previous research (Ivanović et al., 2011), it was determined that Serbian fencers of the national level have lower results by 6.10% and Serbian fencers of the international level have higher result by 12.71% than athletes of the national level involved in different sports. The mean value of $RFD_{180ms\ LEGEXTISO}$ of the bilateral leg extensor force for Serbian fencers of the national level is 12801.40±4215.71 N•s-1, while the mean value for Serbian international fencers is 14392.86±1967.68 N•s-1. The coefficient of variation (cV%), for $RFD_{180ms\ LEGEXTISO}$, showed that the results of the national and international participants varied between 16.68 to 32.93%.

After a comparison of $RFD_{180ms\ LEGEXTISO}$ descriptive values with descriptive values from previous research (Ivanović et al., 2011), it was determined that Serbian fencers of the national level have lower results by 1.37% and Serbian fencers of the international level have higher results by 10.89% than athletes of the national level involved in different sports.

The mean value of $RFD_{100ms\ LEGEXTISO}$ of the bilateral leg extensor force for Serbian fencers of the national level is 12114.77±6160.92 N•s-1, while the mean value for Serbian international fencers is 13121.23±1243.42 N•s-1. The coefficient of variation (cV%), for $RFD_{100ms\ LEGEXTISO}$, showed that the results for national and international participants varied between 11.55 and 50.85%.

After a comparison of the $RFD_{100ms\ LEGEXTISO}$ descriptive values with descriptive values from previous research (Ivanović et al., 2011), it was determined that Serbian fencers of the national level have lower results by 1.11% and Serbian fencers of the international level have higher results by 7.10% than athletes of the national level involved in different sports.

The obtained results probably indicate the specific development adaptation of bilateral $F_{maxLEGEXTISO}$ and bilateral $RFD_{250ms\ LEGEXTISO}$, $RFD_{180ms\ LEGEXTISO}$, $RFD_{100ms\ LEGEXTISO}$, during the training process of Serbian fencers.

On the other hand, it is obvious that quality adaptation of bilateral $RFD_{FmaxLEGEXTISO}$ was not sufficient, because Serbian fencers need 44.31 to 79.74% more time to reach maximum level of $RFD_{FmaxLEGEXTISO}$, compared to well-trained male athletes (Dopsaj & Ivanović, 2011).

The fact is that the measured contractile characteristics of two groups of fencers did not confirm the existence of a statistically significant difference, which shows that they probably trained on the same way. This indirectly implies that the difference between Serbian fencers of the international level and Serbian fencers of the national level is based on other characteristics relevant for success, including: technique, tactics, psychology, etc.

In terms of the characteristics of the RFD-t curve, the available literature does not contain any information which indicates that the results from this study, for a given sample and test procedure, have an initial descriptive scientific value.

The mean value of RFD_{max} of the bilateral leg extensor force for Serbian fencers of the national level is 13687.90±5159.99 N•s-1, while the mean value for Serbian international fencers is 14760.63±1688.57 N•s-1. The coefficient of variation (cV%), for RFD_{max}, showed that the results for national and international participants varied between 13.97 and 37.70%. Also, the obtained results, for $RFD_{max,}$ show that international participants have higher results by 7.37% than national participants.

The mean value of time necessary to reach RFD_{max} ($tRFD_{max}$) expressed in seconds, for national participants is 0.1749±0.06043s, while the mean value for international participants is 0.1471±0.01221 s. The coefficient of variation (cV%), for $tRFD_{max}$, showed that the results for national and international participants varied between 10.16 and 34.54%. The obtained results, for $tRFD_{max,}$ show that the international participants have higher results by 15.90% than national participants.

CONCLUSION

The most important results of the present study are summarized as follows:

According to general and partial differences there are no statistically significant differences between the studied variables between the groups of national and international Serbian fencers.

Descriptive values for the studied variables for Serbian fencers of the national level are: $F_{maxLEGEXTISO}$ (3963.60±777.53 N), $tF_{max\ LEGEXTISO}$ (0.9048±0.2677 s), $RFD_{FmaxLEGEXTISO}$ (4728.75±1626.73 N•s-1), $RFD_{50\%\ LEGEXTISO}$ (13466.96±5026.14 N•s-1), $RFD_{250ms\ LEGEXTISO}$ (11339.59±2588.95N•s-1), $RFD_{180ms\ LEGEXTISO}$ (12801.40±4215.71 N•s-1), $RFD_{100ms\ LEGEXTISO}$ (12114.77±6160.92 N•s-1), RFD_{max} (13687.90±5159.99 N•s-1), $tRFD_{max}$ (0.1749±0.06043 s).

Descriptive values for the studied variables for Serbian fencers of the international level are: $F_{maxLEGEXTISO}$ (4927.22 ±651.38 N), $tF_{max\ LEGEXTISO}$ (1.1271±0.2667 s), $RFD_{FmaxLEGEXTISO}$ (4652.59±1642.13 N•s-1), $RFD_{50\%\ LEGEXTISO}$ (13715.39±1643.79 N•s-1), $RFD_{250ms\ LEGEXTISO}$ (13611.92±2150.25N•s-1), $RFD_{180ms\ LEGEXTISO}$ (14392.86±1967.68 N•s-1), $RFD_{100ms\ LEGEXTISO}$ (13121.23±1243.42 N•s-1), RFD_{max} (14760.63±1688.57 N•s-1), $tRFD_{max}$ (0.1471±0.01221 s).

After a comparison between Serbian fencers and well-trained male national athletes involved in different sports, it was determined that Serbian international fencers had higher results in the following variables: $F_{maxLEGEXTISO}$ (by 29.97%), $RFD_{50\%\ LEGEXTISO}$ (by 1.35%), $RFD_{250ms\ LEGEXTISO}$ (by 12.71%), $RFD_{180ms\ LEGEXTISO}$ (by 10.89%) and $RFD_{100ms\ LEGEXTISO}$ (by 7.10%). But, on the other hand, Serbian international fencers had lower results in the two following variables: $tF_{max\ LEGEXTISO}$ (by 79.74%) and $RFD_{FmaxLEGEXTISO}$ (by 27.05%).

Future studies will focus on female fencing athletes, different age groups, and also establish a relation between F-t and RFD-t variables with the competitive performance of fencers.

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ODLIKE BILATERALNE IZOMETRIJSKE KRIVE ODNOSA IZMEĐU SILE I VREMENA I RFD I VREMENA MIŠIĆA EKSTENZORA KOD VRHUNSKIH SRPSKIH MAČEVAOCA

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Primarni cilj istraživanja je definisanje izometrijskih F-t i RFD-t karakteristika krive ekstenzora nogu srpskih mačevalaca koji su se takmičili na nacionalnom i internacionalnom nivou takmičenja. Sekundarni cilj istraživanja je definisanje razlika između ispitanika u zavisnosti od njihovog takmičarskog nivoa. Uzorak je sačinjavalo dvanaest mačevalaca muškog pola, podeljenih u dve različite grupe u zavisnosti od takmičarskog nivoa (nacionalni N=8 i internacionalni N=4). U cilju procene izometrijskih F-t karakteristika ekstenzora nogu, korišćena je standardizovana oprema, tenziometrijska sonda i standardizovan test, potisak nogama u sedećoj poziciji. Merni opseg je definisan na osnovu 9 varijabli u odnosu na kontraktilne karakteristike izometrijske sile ekstenzora nogu – 1) nivo ostvarene maksimalne sile – $F_{maxLEGEXTISO}$, 2) vreme neophodno za dostizanje maksimalne sile – $tF_{max\ LEGEXTISO}$, 3) opšti pokazatelj razvijenosti eksplozivne sile – $RFD_{FmaxLEGEXTISO}$, 4) specifični pokazatelj razvijenosti eksplozivne sile – $RFD_{50\%LEGEXTISO}$, tri indikatora za procenu specijalnog nivoa razvijenosti eksplozivne sile tj. eksplozivnosti opružača nogu 5) izmeren na 250ms – $RFD_{250msLEGEXTISO}$, 6) izmeren na 180ms – $RFD_{180msLEGEXTISO}$, 7) izmeren na 100ms – $RFD_{100msLEGEXTISO}$, 8) indikator ostvarenog nivoa maksimalne eksplozivne sile – RFD_{max}, i 9) vreme neophodno za dostizanje maksimalne eksplozivne sile. Rezultati multivarijantne statističke metode (MANOVA) i analize varijanse (ANOVA) su pokazali da nema statistički značajnih razlika između ispitivanih varijabli obe grupe srpskih mačevalaca nacionalnog i internacionalnog nivoa. Preporuka je da se u budućim istraživanjima testiraju i ženski takmičari, zatim različite uzrasne grupe, kao i da se uspostavi relacija ispitivanih F-t i RFD-t varijabli sa mačevalačkim takmičarskim dostignućima.

Ključne reči: *izometrijska mišićna sila, eksplozivnost, opružači nogu, mačevanje.*