Research Article

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Metrological characteristics of different early isometric rate of force development characteristics of leg extensors

Abstract

Aim: The aim of this research was to establish the reliability and factorial validity of different early isometric rate of force development (RFD) characteristics of leg extensors in well trained and healthy Serbian males.

Method: Sample consisted of 55 participants. In order to assess characteristics of the RFD isometric leg extensors force, tensiometric probe and standardized "leg press" test were used. The measurement range was defined by seven variables regarding the level of isometric RFD as a voluntary neuromuscular contractile function of leg extensors in each participant at 100 and 180ms level in the first early phase of the contraction (<200 ms), at 250 ms level, as a Stretch-Shorten Cycle time period and at 50% of realized maximal force, as a S-gradient value in the second early phase of the contraction (>200 ms).

Results: The results showed a high statistical significance of p<0.001 in terms of representativeness, generalizability and reliability for all the characteristics observed (Spearman-Brown r -0.693 to 0.954) for the particular test.

Conclusion: As for the methodological aspect of testing, the factor analysis demonstrated the necessity of conducting at least three trials, choosing the best result between the two last trials.

Keywords: Isometric force-time curve, reliability, validity, leg extensors

Volume 1 Issue 3 - 2017

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Received: May 16, 2017 | **Published:** August 16, 2017

Abbreviations: F-t curve, force-time curve; RFD-t curve, rate of force development-time curve; RFD, rate of force development; F_{100ms},the level of achieved force at 100ms; F_{180ms}, The Level of Achieved Force at 180ms; F_{250ms}, the level of achieved force at 250ms; $RFD_{50\%}$, S gradient; RFD_{100ms}, rate of force development measured at 100ms; RFD_{180ms}, rate of force development measured at 180ms; RFD_{250ms}, rate of force development measured at 250ms; RFD_{max}, the indicator of achieved maximal level of rate of force development; $tRFD_{max}$, time necessary to reach maximal level of rate of force development.

Introduction

Adequate training of the leg extensors is extremely important, especially in sports where lower extremity contractile muscle characteristics (muscle force or strength) have a significant influence on executing the different technical-tactical demands.[1–4] Assessing contractile characteristics of a certain muscle group is essential for different purposes such as diagnosing fitness level, monitoring training adaptations or identifying talent. There is a large number of papers aimed to examine correlation between exerted force obtained using some of the methods for measuring maximal isometric force and tests for evaluation most common speed, agility and jumping performances in different sports.[5–10] Therefore, it is necessary to determine the force of leg extensors accurately and objectively, as well as to express fitness levels numerically as a means for measuring. With reliable, valid and calibrated measuring instruments and procedures, the measuring of properties can be accomplished effectively. Generally, the overall purpose of measurement or assessment procedures is to provide valid information for decision-making. Reliable information from testing provides an accurate indicator of an individual`s performance and enables the coach to make appropriate decisions in any later training process. In order to make well-informed decisions, measuring instruments need to be used for their theoretical purpose.[11–12] The measured data for muscle contractile characteristics should have compatible results in repeated trials. Results from measurements should be compatible with the object of those measurements[11] and respective measurements should have appropriate metric characteristics.[2,4,13] Therefore, information on isometric F-t curve characteristics of the certain muscle group is the basic muscle contractile information on athlete's ability which is gathered with intention to control the athlete's physical preparation.[14] Measuring the isometric leg extensors force, we will be able to obtain force-time curve record[2,4,15–19] which will differ based on one's ability. Based on analysis of the isometric force-time curve record, as a physical manifestation, the characteristic outgoing values of the system will be obtained. In this way we will be able directly describe the level of isometric RFD as a voluntary neuromuscular contractile function of leg extensors in each examinee at 100 and 180 ms level in the first early phase of the contraction (<200ms), at 250ms level, as a Stretch-Shorten Cycle time period, at 50% of realized maximal force, as a S-gradient value and at 100% of exerted maximal force in the second early phase of the contraction (>200ms). While performing fast movements of the extremities, it's impossible to achieve absolute values of maximal force at the level of full contractile potential of the engaged muscle. In competitive conditions, top level athletes commonly realize movement in the maximal 300 ms time interval.[1,15,16,20,21] Therefore, all the aspects of directed and specific fitness level should be focused on explosiveness increase (RFD), in the specific time interval in which the movement is realized, i.e. in the early phase of muscle contraction.[18,19] Many researchers[14,22] claim that the diagnostics of physical fitness and athlete selection with regards to contractile abilities, based on basic parameters, specifically, the level of maximal force development (F_{max}) or basic level of explosive force (RFD_{Fmax}), do not provide sufficiently valid data which can be used to monitor the training process regarding specific characteristics of explosiveness in time intervals of 100,180 and 250ms which are responsible for the realization of specific technical-tactical demands in sport. Those data are relevant only for monitoring the effects of training process from the aspect of general/basic indicators of contractile characteristics development. However, the metrological aspect of characteristics of isometric neuromuscular function of leg extensors in the specific time interval in which the movement is realized has not yet to be explained. Therefore, in order to collect information that correlates with what we observe and to control and analyze the physical fitness of athletes relevant to achieving the best results in numerous sports, it is necessary to examine the Metrologic characteristics of different parameters of the early force exerted by leg extensors in various individuals with different levels of training. A lack of literature on this subject methodologically hinders further elaboration of the aforementioned phenomenon. Therefore, we attempted to address this gap related to the measuring isometric muscle force.

In order to collect information that are in correlation with observing, controlling and analyzing athletes physical shape and that are relevant for achieving highest results in numerous sports, it is necessary to examine metric characteristics of different parameters of the leg extensors isometric rate of force development as a first methodological step at general informative level considering testing in sport. In order to assess validity of measuring instrument for evaluating isometric neuromuscular function of leg extensors in the first early (<200ms) and late early (up to 50%F_{max}) phase of the contraction, 55 males were examined with the tendency to analyze metrological characteristics of the measuring instrument, the measuring procedure and different parameters of isometric muscle force.

Materials and methods

Participants

The subject sample included 55 well trained and healthy Serbian males (Football N=7, Biathlon N=2, Karate N=8, Well-trained N=11, Judo N=8, Swimming N=6, Volleyball N=4, Fencing N=9). The category of trained athletes consisted of participants that were competing in the First National league in Serbia, while the well-trained group consisted of participants that were students at the Faculty for Sport and Physical Education, Belgrade University, who weren‘t involved in systematic exercise training. The basic anthropo-morphological characteristics recorded were as follows: BH=182.64±6.52cm, BM=81.44±9.60kg, BMI=24.38±2.19, AGE=22.93±3.81years. All tests were conducted in the Laboratory for assessing the basic motoric status in Serbian Institute of Sport and Sports Medicine, using the same procedure and equipment. Each subject was informed of the potential risks and discomfort associated with the investigation and measurements were carried out with their willing consent in accordance with Declaration of Helsinki[23] and with the permission of the ethical committee of the Faculty for sport and physical education in Belgrade, Serbia. The athletes were tested at the begining of summer season 2013, while the well trained group was tested during the school year 2013/2014. The testing procedure was identical.

Procedures

Maximal isometric muscle force characteristics were measured using a leg press dynamometer (Serbian Institute for Sport and Sport Medicine, Belgrade). Subjects were seated on a bench, so that their hip angle was at 110°, knee angle 120° and ankle angle 90°. After individuals had warmed up for five minutes and received an introduction to the measuring procedure, each subject made four attempts, with one minute of rest between trials. The subjects were instructed to exert their maximal force as quickly as possible. In order to assess the contractile characteristics of the isometric muscle force of leg extensors (bilateral), standardized equipment was used, i.e. a metal device. A foot-platform fixed to the frame by strain-gauge transducers and a standardized “isometric leg press” test was used following the earlier described procedures.[2,4,18,19] Data was collected at 2000 Hz using interface box with an analog to digital card (National Instruments, Austin, TX, USA). All data was recorded and analyzed using a specially designed software system (M_S_NI, Nikola Tesla Institute, Serbia and Belgrade). Thereafter, data were processed using a PC. The force-time analysis on the absolute scale.[2,4,23] included the rate of force development as an indicator of the specific isometric leg extensors explosive force or the S gradient of the leg extensors force RFD50%, as a rate of force development measured at 50% of F_{max}, the indicator of special level of leg extensors explosive force development at time interval of 250 ms of tF_{max} - RFD_{250ms}, measured at time zone of Strech-Shortening Cycle[14,19,24] and the two indicators of special level of explosive force development, RFD_{100ms} and RFD_{180ms}, measured at 100 and 180 ms of tF_{max}.[19,21] Also, we used RFD_{max} as the indicator of achieved maximal level of rate of force development was observed according to previous published article[1,12,15,16] and expressed in N·s-1; $tRFD_{max}$ was time necessary to reach maximal level of rate of force development was observed according to previous published article[1,12,15,16] expressed in seconds (s).

Statistical analysis

All the variables were subjected to descriptive statistical analysis, correlation, factor and structural equation modeling analysis. Each muscle mechanical characteristic obtained during the test trials was represented by one item used in multivariate data analyses.[25] Raw results were processed using the descriptive statistical analysis in order to calculate basic descriptive statistical values (MEAN: Mean Value, SD: Standard Deviation, Min: Minimal Variable Value, Max: Maximum Variable Value, cV%: Variable Coefficient of Variation). General statistical validity of results for the observed variables from the aspect of multivariate analysis as well as inter-item correlation was performed by use of Bartlett’s Test of Sphericity. Reliability of the applied test as a measuring instrument was defined by multivariate method for Structural equation modeling and using the General validity analysis in Krombach’s alpha. Reliability was assessed by Spearman-Brown rtt and by factor analysis through communalities extracted on the first characteristic (initial) eigenvalues (H^2).[25] All 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 1 shows descriptive statistics of muscle force characteristics data according to trials (Mean, SD, cV%, Min, Max) and the results of the $ANOVA_{Single\ factor}$. Except for the time necessary to reach maximal level of rate of force development (F-ratio $ANOVA_{Singlefactor}$ -F=0.268, p=0.849), ANOVA results showed that the mean values of the variables observed did differ between measurements (F-ratio $ANOVA_{Singlefactor}$ -F=0.3.676, p=0.014 for RFD_{100ms} to F=18.640, p=0.000 for RFD_{250ms}) which means that the items of single muscle force characteristics are with different measurement values, which mean that they didn`t belong to the same measuring range (Table 1). The reason could be probably found in the fact that in all muscle force characteristics which didn`t belong to the same measuring range, was measured significantly lower level of explosiveness and the highest variation coefficient in the first trial in comparison with the other three trials (Table 1)(Figure 1)(Figure 2). Notably, (Table 1)(Figure 1)(Figure 2) between these muscle force characteristics there were almost no difference in the last three trials. The variation coefficient (cV%) as the variability rate of the measurement results showed that the results in male examinees varied between 28.50 % for RFD_{250ms} to 41.44 % for RFD_{100ms} (Table 1).

Table 1 Basic Item descriptive characteristics according to trials

The results of descriptive statistics (N=55)

RFD characteristic		**Test 1**	**Test 2**	**Test 3**	**Test 4**	**F-Ratio**	**P-Value**
RFDmax (N s-1)	Mean±SD	12283.9±4540.0	13539.6±4715.0	13308.6±4538.1	13973.7±4552.4	6.752	0
	cV%	36.96	34.82	34.1	32.58		
	Min-Max	3871.9-22444.3	4543.7-23155.5	5749.9-22957.7	6034.6-25005.1		
tRFDmax (s)	Mean±SD	0.149±0.044	0.143±0.050	0.152±0.049	0.146±0.045	0.268	0.849
	cV%	29.23	35.12	32.65	30.96		
	Min-Max	0.072-0.267	0.049-0.261	0.063-0.250	0.050-0.243		
RFD50% (N s-1)	Mean±SD	11605.4±5161.9	12973.6±4682.0	13047.1±4460.8	13183.8±4250.3	8.006	0
	cV%	44.48	36.09	34.19	32.24		
	Min-Max	2400.2-22654.8	4168.7-21455.6	5749.9-22056.6	5998.4-21973.1		
RFD100ms (N s-1)	Mean±SD	11273.9±5206.5	12698.0±5097.7	12236.0±5070.1	12559.5±4535.1	3.676	0.014
	cV%	46.18	40.15	41.44	36.11		
	Min-Max	3533.8-24770.2	2746.7-21900.8	4121.9-22907.9	4592.9-23561.5		
RFD180ms (N s-1)	Mean±SD	11328.1±4456.5	12464.0±4106.0	12557.7±4013.9	12890.0±3826.6	11.088	0
	cV%	39.34	32.94	31.96	29.69		
	Min-Max	3549.9-21430.7	4286.2-20402.9	5732.0-20675.8	6007.6-21148.6		
RFD250ms (N s-1)	Mean±SD	10156.4±3843.5	11193.5±3397.0	11491.8±3297.7	11695.7±3333.4	18.64	0
	cV%	37.84	30.35	28.7	28.5		
	Min-Max	3331.9-18122.3	3940.2-20303.0	5427.7-19364.5	5615.3-19996.3		

Abbreviations $RFD_{50\%}$, S Gradient; RFD100ms, Rate of Force Development Measured at 100 ms; RFD_{180ms}, Rate of Force Development Measured at 180 ms; RFD_{250ms}, Rate of Force Development Measured at 250 ms; RFD_{max}, The Indicator of Achieved Maximal Level of Rate of Force Development; $tRFD_{max}$, Time Necessary to Reach Maximal Level of Rate of Force Development; Mean±SD, Mean Value and Standard Deviation; cV%, Variable Coefficient of Variation; Min-Max, Minimal And Maximal Variable Value

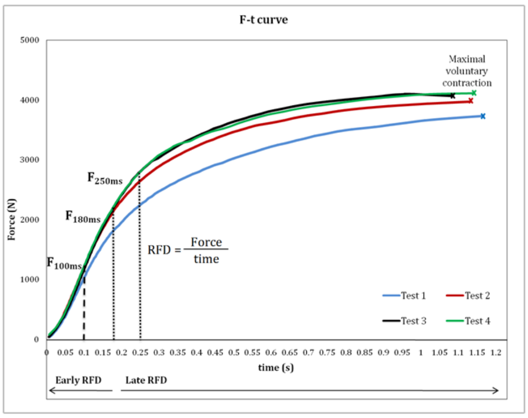

Figure 1 F-t Relation of leg extensors.

F-t Curve, force-time curve; RFD, rate of force development; F_{100ms}, the level of achieved force at 100 ms; F_{180ms}, the level of achieved force at 180 ms; F_{250ms}, the level of achieved force at 250 Ms.

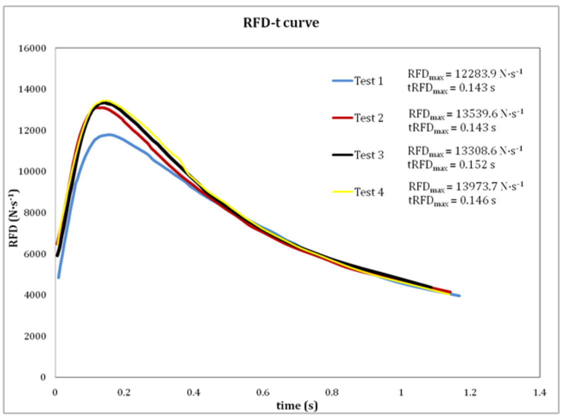

Figure 2 RFD-t relation.

RFD-t Curve, rate of force development-time curve; RFD_{max}, the indicator of achieved maximal level of rate of force development; $tRFD_{max}$, time necessary to reach maximal level of rate of force development

Citation: Milivoj D, Jelena I. Metrological characteristics of different early isometric rate of force development characteristics of leg extensors. *MOJ Sports Med.* 2017;1(3):46–52. DOI: 10.15406/mojsm.2017.01.00013

Table 2 shows results of correlation and structural equation modeling analysis (Average Inter-Item correlation, Keiser-Meyer-Olkin Measure of Sampling Adequacy (KMO-MSA), Bartlett`s test of Sphericity, Cronbach alpha, Equal Length Spearman-Brown reliability and ANOVA of Reliability Analysis). The average inter-item correlation in all variables described mutual correlation within a correlation matrix at a statistically significant level at p<0.001 (Bartlett`s test of Sphericity) and ranged between 0.664 for $tRFD_{max}$ and 0.970 for RFD_{250ms}. The representability rate (KMO-MSA) ranged between 0.612 for $tRFD_{max}$ and 0.848 for RFD_{100ms}, the generalizability rate (Cronbach alpha) in male examinees ranged between 0.664 for $tRFD_{max}$ and 0.970 for RFD_{250ms}, while the reliability rate (Spearman-Brown rtt) ranged between 0.693 for $tRFD_{max}$ and 0.954 for RFD_{250ms} (Table 2).

Table 3 shows the results of factor analysis (Communalities extracted on initial Eigenvalues First Component)-Component Matrix (H^2). The factor analysis showed that the results of the second trial described the highest common variability for following variables: for $RFD_{50\%}$ 0.961, for RFD_{100ms} 0.924, for RFD_{180ms} 0.970, for RFD_{250ms} 0.978, while for RFD_{max} and $tRFD_{max}$ this hapened in third trial-0.955 and 0.807, respectively. (Figure 1)(Figure 2) show the F-t and RFD-t relation of leg extensors for each made trial.

Table 2 The results of correlation and structural equating modeling

Basic F-T characteristic	Average int-item correlation	Bartlett`S test of sphericity	Kmo-msa	Cronbach alpha	Spearman-brown reliability	Reliability analysis anova
RFDmax (N·s-1)	0.942	F=200.898 p=0.000	0.843	0.942	0.93	F=17.187 p=0.000
tRFDmax (s)	0.664	F=35.094 p=0.000	0.612	0.664	0.693	F=2.979 p=0.000
RFD50% (N·s-1)	0.953	F=225.048 p=0.000	0.84	0.953	0.936	F=21.095 p=0.000
RFD100ms (N·s-1)	0.927	F=160.265 p=0.000	0.848	0.927	0.917	F=13.729 p=0.000
RFD180ms (N·s-1)	0.964	F=261.618 p=0.000	0.84	0.964	0.947	F=27.563 p=0.000
RFD250ms (N·s-1)	0.97	F=296.043 p=0.000	0.833	0.97	0.954	F=33.327 p=0.000

Abbreviations $RFD_{50\%}$, S Gradient; RFD_{100ms}, Rate of Force Development Measured at 100 ms; RFD_{180ms}, Rate of Force Development Measured at 180 ms; RFD_{250ms}, Rate of Force Development Measured at 250 ms; RFD_{max}, The Indicator of Achieved Maximal Level of Rate of Force Development; $tRFD_{max}$, Time Necessary to Reach Maximal Level of Rate of Force Development; KMO-MSA, Kaiser-Meyer-Olkin Measure of Sampling Adequacy

Table 3 The factor analysis (Extraction method: Principal component analysis)

Communalities extracted on initial eigenvalues (First Component) Component Matrix (H^2)						
	RFDmax	tRFDmax	RFD50%	RFD100ms	RFD180ms	RFD250ms
Item 1 (Test 1)	0.877	0.699	0.916	0.885	0.931	0.943
Item 2 (Test 2)	0.93	0.684	0.961	0.924	0.97	0.978
Item 3 (Test 3)	0.955	0.807	0.935	0.913	0.953	0.963
Item 4 (Test 4)	0.929	0.624	0.944	0.907	0.952	0.957
Total extraction: Sums of Squared Loadings	3.41	1.997	3.525	3.292	3.622	3.689
% of explained Variance	85.256	49.927	88.126	82.312	90.549	92.215

Abbreviations $RFD_{50\%}$, S Gradient; $RFD100_{ms}$, Rate of Force Development Measured at 100 ms; RFD_{180ms}, Rate of Force Development Measured at 180 ms; RFD_{250ms}, Rate of Force Development Measured at 250 ms; RFD_{max}, The Indicator of Achieved Maximal Level of Rate of Force Development; $tRFD_{max}$, Time Necessary to Reach Maximal Level of Rate of Force Development

Discussion

The primary findings in this investigation indicate that evaluating an early isometric RFD characteristics, with testing protocols as used in the present investigation, has the potential to provide information that could increase training efficiency.[14] The training system represents a long-term process which involves several permanent cycles. Each cycle has its own general objective and several special objectives as well, which are logically and functionally connected to general objective of the training system - achieving the highest results, irrespective of the age-groups of the athletes.[26] Within the system for observing the development of physical abilities, the level of contractile characteristics, in addition to functional abilities, is the main objective training process.[14] It is necessary to determine figures accurately and objectively, as well as to express fitness levels numerically as a means for measurement.[11,24,26] With reliable, valid and calibrated instruments and procedures, properties can be measured accurately.

The results of this study have the following implications for the assessment of different early RFD characteristics during maximal isometric leg press in trained high level athletes:

a. On a general level, the communality rates (H^2) of the observed characteristics of the isometric contraction in leg extensors (Table 3) were highest in trial 2 for $RFD_{50\%}$ 0.961, for RFD_{100ms} 0.924, for RFD_{180ms} 0.970, for RFD_{250ms} 0.978, while for RFD_{max} and $tRFD_{max}$ this happened in third trial 0.955 and 0.807 respectively;

b. The standardization of the seating leg press test in isometric testing conditions requires three trials where last two trials in all observed neuromuscular characteristics of leg extensors, where the results represent the better values;

c. Generally, the measurement of sample adequacy (KMO-MSA) is highly significant for all observed isometric early RFD characteristics (marvelous), while it is slightly lower for $tRFD_{max}$ (meritorious).[25]

d. Obtained results showed that the applied measuring procedure and the measuring instruments used, i.e. a tensiometric device with the relevant hardware and software system, as well as the measuring variables which represented isometric neuromuscular function of leg extensors in the first early (<200 ms) and second early (>200 ms) phase of the contraction in the seating position, are statistically very reliable in the function of specialized and sophisticated measuring equipment for testing well and highly trained athletes.

Considering literature that has examined the reliability and variability of measuring different muscle groups in an isometric regime, it could be concluded that there is none of this research has mentioned applied methodology and metrology values of different early isometric RFD characteristics of leg extensors with regard to obtaining valid information on given contractile properties. In addition, there are several pieces of research on determining metrological values and identifying the most reliable trials in tests for evaluating the mechanical characteristics of maximal isometric force.[2,4,22,27,28] The results of these investigations strongly support our findings according specialized and sophisticated measuring equipment for testing well and highly trained athletes in isometric regime and suggested that the standardization of the leg extension test in isometric testing conditions requires a minimum of three trials for F_{max}, where the result is the better value taken at the second or third trial.[2,4,27,28] Besides that in previous research,[4] results indicate that athletes from different sport disciplines require a different methodology for measuring the muscle force of leg extensors, especially in disciplines associated with different surfaces. According to results of this research[4] the standardization of the seating leg press test in isometric testing conditions requires two trials in football and basketball and three trials in water polo for the following parameters: F_{max}, RFD, RFD/F_{max} and tF_{max}, where the results represent the better values. However, these tests are focused on general characteristics of muscle force and explosiveness, i.e. on maximal values as well as F_{max} and RFD_{Fmax}.[2,4,27,28]

Practically, there are no data on the validity result for evaluating F-t curve characteristics regarding the isometric neuromuscular function of leg extensors in the first early (< 200 ms) and second early (> 200 ms) phase of the contraction. It is very important because based from results of the previous studies on the specificity of moving structure in competitive conditions and on defining time parameters for realizing the most characteristic motor tasks of movement techniques, the following typical time intervals can be isolated: 250 ms as the time necessary to perform the stretch-shortening cycle, 180 ms as the characteristic ground contact time during running in sub maximal exertion regime, frequent changes of movement direction and vertical rebounds and 100 ms as ground contact time during running in absolute maximal intensity.[14,16,20] Elite athletes need 50 to 250 ms to perform fast moves, while in order to develop absolute muscle force in most muscle groups, they need more time (300 ms for the elbow flexors and knee extensors).[15,21] Therefore, every increase of RFD in the specific time interval is highly significant because it provides high-level intensity of force development in the first early phase of muscle contraction (first 100-200ms), i.e. consequently efficient and faster motoric performance. As the performance increases, the phenomenon of the intensification of the sports competition (game or race performance) can be observed, which consequently increases the movement speed, that is, decreases the time needed to perform the elements of technique, the role of specific characteristics of maximal and explosive force.[14] Besides, in our previous manuscript[10] the relationships between the jumping performance and the leg strength variables were mainly significant (r = 0.23-0.68) and similar in 2 groups. Those results showed that leg strength variables (i.e., the ability to rapidly exert high muscle forces) should be taken into account when designing various training and testing procedures that target the performance of jumping and possibly other rapid and explosive movements. Specifically regarding the strength measures, it seems that RFD could be a potentially better predictor of jumping performance than the maximum force.

In order to make high-quality decisions, based on data mentioned above, measuring instrument could to be used for its theoretical purpose. The measured data of different RFD characteristics have compatible results in the repeated trials, each and every trial are precise, the result of the measurement are compatible with the object of measurement, respectively measurement have appropriate metric characteristics.[9,22,29] Based on previous studies and showed results, it is recommended that tests for assessing neuromuscular function of leg extensors, especially in the first early phase of muscle contraction (first 100-200ms), should be in line with the concept of specificity. In order to diagnose the training level of well trained athletes and to provide absolute and valid data in the function of observing, controlling and optimizing the training process, among the basic indicators of the maximal force (F_{max}) development level, it is recommended to use specific and special characteristics of force-time characteristics of leg extensor in time intervals of 250, 180 and 100 ms, 50 % of maximal force and RFD_{max} variable data's. Results of this studies show that time for RFD_{max} appearance interval for investigated sample and isometric seating leg press test was between 143 and 152 ms, with 44 to 50 ms of standard deviation values (Table 1).

Besides that, in according to results of studies Maffiuletti and associates[30] as compared to pure maximal voluntary contraction (MVC) strength, RFD seems to be

1. Better related to most performances of both sport-specific and functional daily tasks,
2. More sensitive to detect acute and chronic changes in neuromuscular function.
3. Potentially governed by different physiological mechanisms.

Authors[30] concluded that the ability to properly quantify and interpret RFD obtained during voluntary isometric contractions is therefore extremely important not only for researchers in the field of human and exercise physiology, but also for practitioners in the fields of physical training and rehabilitation. According to results of previous and present studies[2,4] additional research in the area of metrological values of different isometric RFD characteristics of leg extensors in the case of trained subjects with different levels of fitness, with different ages and training history according to gender is necessary for consummate standardization of isometric leg press testing conditions.

Conclusion

The obtained results showed that the applied measuring procedure and used measuring instruments, i.e. tensiometric probe device with the hardware and software system, as well as measuring variables which represented isometric neuromuscular function of leg extensors in the first early (< 200 ms) and second early (>200 ms) phase of the contraction in seating position, are highly statistically reliable (Sperman-Brown r was 0.693 to 0.954) and can be reliable in the function of specialized and sophisticated measuring equipment for testing well and highly trained athletes. The results yielded highly acceptable rates for the indicators of sensitivity, reliability and validity at the significant level of $p<0.001$. On general level, in all observed early RFD characteristics the factor analysis demonstrated the highest reliability of measured contractile characteristics - 82.312% to 92.215% of the explained total variance in the population of the tested males. The standardization of the seating leg extension test in isometric testing conditions requires minimum three trials, where the results is the better value taken at the second or third trial. The measure of sample adequacy (KMO-MSA) is highly significant for all observed early RFD characteristics (marvelous), while it is slightly lower for $tRFD_{max}$ (meritorious).[25,31]

Acknowledgements

The paper was realized as part of project III47015 sponsored by Ministry of science and technological development in the Republic of Serbia.

Conflict of interest

There aren't financial interests or any conflict of interest.

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