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 180 ms 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

Abbreviations: F-t curve, force-time curve; RFD-t curve, rate of force development-time curve; RFD, rate of force development; F\textsubscript{100ms}, the level of achieved force at 100ms; F\textsubscript{180ms}, The Level of Achieved Force at 180ms; F\textsubscript{250ms}, the level of achieved force at 250ms; RFD\textsubscript{S}, S gradient; RFD\textsubscript{250ms}, Rate of force development measured at 100ms; RFD\textsubscript{180ms}, rate of force development measured at 180ms; RFD\textsubscript{250ms}, rate of force development measured at 250ms; RFD\textsubscript{max}, the indicator of achieved maximal level of rate of force development; tRFD\textsubscript{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. 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. 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. 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 and respective measurements should have appropriate metric characteristics. Therefore, information on isometric F-t curve characteristics of the certain muscle group is gathered with intention to control the athlete’s physical preparation. Measuring the isometric leg extensors force, we will be able to obtain force-time curve record 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. 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. Many researchers 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 ($F_{\text{max}}$) or basic level of explosive force ($RFD_{50\%}$), 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 250 ms 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 metrological 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 (<200 ms) and late early (up to 50% $F_{\text{max}}$) 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±6.52 cm, BM=81.44±9.60 kg, BMI=24.38±2.19, AGE=22.93±3.81 years. All tests were conducted in the laboratory for assessing the basic motoric status in Serbian Institute for Sport and Medicine, Belgrade. Subjects were instructed to exert their maximal force as quickly as possible. In order to minimize the number of attempts, with one minute of rest between attempts. 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.

**Procedures**

Maximal isometric muscle force characteristics were measured using a leg press dynamometer (Serbian Institute for Sport and 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.

**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. 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 (HF). 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).
maximal level of rate of force development (F-ratio ANOVA, \( F=0.268, p=0.849 \)), ANOVA results showed that the mean values of the variables observed did differ between measurements (F-ratio ANOVA, \( F=0.3.676, p=0.014 \) for RFD\(_{100ms}\)) 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

| RFD characteristic | Test 1 | Test 2 | Test 3 | Test 4 | F-Ratio | P-Value |
|--------------------|--------|--------|--------|--------|---------|---------|
| RFD\(_{max}\) (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 |
| t\(_{RFD}\) (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 |
| RFD\(_{50\%}\) (N·s\(^{-1}\)) | Mean±SD | 11605.4±1611.9 | 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 |
| RFD\(_{100ms}\) (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 | 3533.8-21430.7 | 4286.2-20402.9 | 5732.0-20675.8 | 6007.6-21486.8 |
| RFD\(_{180ms}\) (N·s\(^{-1}\)) | Mean±SD | 11328.1±4456.5 | 12464.0±4160.6 | 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 | 6007.6-21486.8 |
| RFD\(_{250ms}\) (N·s\(^{-1}\)) | Mean±SD | 10156.4±3843.5 | 11193.5±3397.0 | 11491.8±3297.7 | 11695.7±3333.4 | 3.676 | 0.014 |
| 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; 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; 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.

**Figure 2** RFD-t relation.

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Table 2 shows results of correlation and structural equation modeling analysis (Average Inter-Item correlation, Kaiser-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 \( \text{RFD}_{250\text{ms}} \) and 0.970 for \( \text{RFD}_{250\text{ms}} \). The representability rate (KMO-MSA) ranged between 0.612 for \( \text{RFD}_{250\text{ms}} \) and 0.848 for \( \text{RFD}_{100\text{ms}} \), the generalizability rate (Cronbach alpha) in male examinees ranged between 0.664 for t\( \text{RFD}_{250\text{ms}} \) and 0.970 for \( \text{RFD}_{250\text{ms}} \), while the reliability rate (Spearman-Brown rr) ranged between 0.693 for \( \text{RFD}_{\text{max}} \) and 0.954 for \( \text{RFD}_{250\text{ms}} \) (Table 2).

Table 3 shows the results of factor analysis (Commonalities extracted on initial Eigenvalues First Component)-Component Matrix (HF). The factor analysis showed that the results of the second trial described the highest common variability for following variables: \( \text{RFD}_{250\text{ms}}, \text{RFD}_{100\text{ms}}, \text{RFD}_{50\%}, \) \( \text{RFD}_{180\text{ms}} \), \( \text{RFD}_{100\text{ms}} \), \( \text{RFD}_{250\text{ms}} \), while for \( \text{RFD}_{\text{max}} \), \( \text{tRFD}_{\text{max}} \) this happened 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

| Basic F-T characteristic | Average inter-item correlation | Bartlett’s test of sphericity | KMO-MSA | Cronbach alpha | Spearman-Brown reliability | Reliability analysis anova |
|--------------------------|-------------------------------|-------------------------------|---------|----------------|----------------------------|--------------------------|
| RFD_{max} (N s-1)        | 0.942                         | F=200.898 p=0.000            | 0.843   | 0.942          | 0.93                       | F=17.187 p=0.000         |
| tRFD_{max} (s)           | 0.664                         | F=35.904 p=0.000             | 0.847   | 0.664          | 0.693                      | F=2.979 p=0.000          |
| RFD_{50\%} (N s-1)       | 0.953                         | F=225.084 p=0.000            | 0.84    | 0.953          | 0.936                      | F=21.095 p=0.000         |
| RFD_{100ms} (N s-1)      | 0.927                         | F=160.265 p=0.000            | 0.848   | 0.927          | 0.917                      | F=13.729 p=0.000         |
| RFD_{180ms} (N s-1)      | 0.964                         | F=261.618 p=0.000            | 0.84    | 0.964          | 0.947                      | F=27.563 p=0.000         |
| RFD_{250ms} (N s-1)      | 0.97                          | F=296.043 p=0.000            | 0.833   | 0.97           | 0.954                      | F=33.327 p=0.000         |

### Abbreviations
- \( \text{RFD}_{\text{max}} \): Gradient; \( \text{RFD}_{100\text{ms}} \): Rate of Force Development Measured at 100 ms; \( \text{RFD}_{50\%} \): Rate of Force Development Measured at 50 ms; \( \text{RFD}_{180\text{ms}} \): Rate of Force Development Measured at 180 ms; \( \text{RFD}_{250\text{ms}} \): The Indicator of Achieved Maximal Level of Rate of Force Development; \( t\text{RFD}_{\text{max}} \): Time Necessary to Reach Maximal Level of Rate of Force Development; KMO-MSA, Kaiser-Meyer-Olkin Measure of Sampling Adequacy

### Table 3

| Communalities extracted on initial eigenvalues (First Component) Component Matrix (HF) |
|-----------------------------------------------|
| \text{RFD}_{\text{max}} | t\text{RFD}_{\text{max}} | \text{RFD}_{50\%} | \text{RFD}_{100\text{ms}} | \text{RFD}_{180\text{ms}} | \text{RFD}_{250\text{ms}} |
| 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
- \( \text{RFD}_{\text{max}} \): Gradient; \( \text{RFD}_{100\text{ms}} \): Rate of Force Development Measured at 100 ms; \( \text{RFD}_{50\%} \): Rate of Force Development Measured at 180 ms; \( \text{RFD}_{250\text{ms}} \): The Indicator of Achieved Maximal Level of Rate of Force Development; \( t\text{RFD}_{\text{max}} \): 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 (HF) of the observed characteristics of the isometric contraction in leg extensors (Table 3) were highest in trial 2 for \( \text{RFD}_{50\%} \), 0.961, for \( \text{RFD}_{100\text{ms}} \), 0.924, for \( \text{RFD}_{180\text{ms}} \), 0.970, for \( \text{RFD}_{250\text{ms}} \), 0.978, while for \( \text{RFD}_{\text{max}} \) and \( t\text{RFD}_{\text{max}} \) 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 tRFDmax (meritorious).\textsuperscript{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.\textsuperscript{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 Fmax where the result is the better value taken at the second or third trial.\textsuperscript{2,4,22,27,28} Besides that in previous research,\textsuperscript{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\textsuperscript{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: Fmax, RFD, RFD/Fmax and tFmax 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 Fmax and RFD.\textsuperscript{2,4,22,27,28}

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.\textsuperscript{14,16,30} 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).\textsuperscript{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.\textsuperscript{14} Besides, in our previous manuscript\textsuperscript{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.\textsuperscript{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 (Fmax) 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 variable data’s. Results of this studies show that time for RFD in 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\textsuperscript{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\textsuperscript{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\textsuperscript{14} 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 contractual 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 (meritorious), while it is slightly lower for RFD_D_{net} (meritorious).

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Conflict of interest
There aren’t financial interests or any conflict of interest.

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