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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

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The aim of this research was to establish the reliability and factorial validity of different isometric basic characteristics of F-t curve related to leg extensors in well trained and healthy Serbian males and females. Sample consisted of 159 examinees. In order to assess characteristics of the F-t isometric leg extensor force, tensiometric probe and standardized "seating leg extension" test were used. The measurement range was defined by 4 variables regarding the contractile characteristics of the leg extensor isometric muscle force – 1) the level of the achieved maximal force – $F_{maxLEGEXTISO}$, 2) the indicator of basic (general) level of rate of force development – $RFD_{BASICLEGEXTISO}$, 3) the time necessary to reach maximal force – $tF_{maxLEGEXTISO}$, 4) basic synergy index. The results showed a high statistical significance of p<0.001 in representability, generalizability and reliability for all the characteristics observed in both genders (Spearman-Brown r – 0.715 to 0.967 for males and 0.713 to 0.941 for females). As for the methodology aspect of testing, the factor analysis demonstrated the necessity of conducting at least three trials, choosing the best result from the two last trials.

Key words: Isometric F-t curve, reliability, validity, leg extensors

1. Introduction

THE RESULTS of numerous researches showed that muscle force and the lower extremity strength have significant influence on executing different technical-tactical demands in many sports – athletics [1], cycling [2], basketball [3], volleyball [4]-[10], handball [11], football [12], skiing [13], weight lifting [14], [15] etc. Because of that, adequate preparation of the leg extensors is highly important especially in sports which involve different jumping techniques, frequent changes of direction in frontal and lateral plane, numerous high and long jumps. Values of developed force in the function of time generated during the isometric (static) muscle contraction, with its own characteristics (F-t curve characteristics) are the fundamental data on contractile ability. Therefore, information on F-t curve characteristics of a certain muscle group is the basic information on the athlete's ability which is gathered with intention to control the athlete's physical preparation [16].

In order to make high-quality decisions, based on data mentioned above, a measuring instrument needs to be used for its theoretical purpose. The measured data of physical characteristics need to have compatible results in the repeated trials, each and every trial needs to be precise, the result of the measurement needs to be compatible with the object of measurement, and respectively measurement needs to have appropriate metric characteristics [17, 18]. Analyzing available literature, especially the researches that examined the validity of different muscle group measurements in isometric regime, it could be concluded that the opinions are divided. Practically, there are no data on the validity result for evaluating F-t curve characteristics regarding the sexual dimorphism. Therefore, in order to collect information that is in correlation with observing, controlling and analyzing the athlete's physical shape, and that is relevant for achieving the highest results in numerous sports, it is necessary to examine metric characteristics of different parameters of the leg extensor isometric force as a first methodological step at the general informative level, considering testing in sports. In order to assess validity of the measuring instrument for evaluating maximal leg extensor isometric force, 99 males and 60 females were examined with the tendency to analyze basic metrological characteristics of the measuring instrument, the measuring procedure and different parameters of isometric muscle force. The second goal was to calculate normative values of the observed leg extensor F-t isometric characteristics for a healthy and well trained population of both genders.

2. Subject & Methods

The subject sample included 159 examinees, 99 well trained and healthy Serbian male (Football N=28, Water polo N=19, Basketball N=41, Control group well trained N=11) and 60 well trained and healthy Serbian female athletes (Track and field N=7, Volleyball N=14, Orienteering N=3, Handball N=24, Table tennis N=3, Control group well trained N=9). The category of trained athletes consisted of examinees that were competing in the First National league in Serbia, while the Control group consisted of examinees that were students at the Faculty for Sport and Physical Education, Belgrade University, who weren't involved in systematic exercise training. The collected basic anthropo-morphological characteristics were as follows: for male examinees BH=190.87±11.19 cm, BM=87.92±12.94 kg, BMI=24.05±1.97, AGE=24.27±7.29 years and for female examinees BH=174.41±9.04 cm, BM=66.22±8.87 kg, BMI=21.76±2.39, AGE=23.19±6.76 years. All tests were conducted in the Laboratory for assessing the basic motoric status in The Republic Institute for Sport, using the same procedure and equipment. The athletes were tested at the beginning of summer season 2007, while the Control group was tested during the academic year 2008/2009. The testing procedure was identical.

A. Variables

The isometric basic F-t characteristics of the leg extensors were evaluated using the 4 variables:

- The level of achieved maximal force – $F_{maxLegExtISO}$, expressed in N;

- The indicator of basic (general) level of rate of force development of leg extensors was done by applying the following procedure [8], [19]:

$$RFD_{BASICLegExtISO} = \frac{F_{maxLegExtISO}}{tF_{maxLegExtISO}}, \tag{1}$$

where: $F_{maxLegExtISO}$ represents the maximal value of isometric leg extensor force achieved, while $tF_{maxLegExtISO}$ represents the time in ms necessary to reach it, expressed in $N \cdot s^{-1}$.

- Basic Synergy Index, as a criterion for evaluating the relation between general level of rate of force development of leg extensors and the level of maximal force [6], [8], [19]:

$$IndexSNG_{BASIC} = \frac{RFD_{BASICLegExtISO}}{F_{maxLegExtISO}}, \tag{2}$$

where: $RFD_{BASICLegExtISO}$ represents the value of general level of rate of force development of leg extensors, while $F_{maxLegExtISO}$ represents the value of leg extensor maximal isometric force, expressed in index values.

- Time necessary to reach maximal force – $tF_{maxLegExtISO}$ in ms.

B. Measuring procedure

In order to assess the contractile characteristics of leg extensor isometric muscle force (bilateral), standardized equipment was used, i.e. metal device for measuring leg extensor isometric force, a tensiometric probe and standardized “seating leg extension” test were used following the earlier described procedures [6], [8]. The testing was carried out by the hardware-software system (Nikola Tesla Institute, Belgrade) (Fig.1). The tensiometric probe was connected to the force reader (force indicator) and to the PC (Fig.1).

Fig.1. The measuring device for assessing maximal leg extensor isometric force with the hardware-software system (a), tensiometric device within foot platform (b), force reader connected to the PC (c)

Fig.2. Examinee’s position during measuring procedure

The tests were carried out under isometric conditions of exertion with the knee joint at the angle of 120°, and with the ankle joint at 90° (Fig.2). The examinees made their attempt after the sound signal. Each examinee had four attempts, with one minute rest between trials. The result was automatic, measured by tensiometric sounding device and hardware-software system, recorded in special database with the possibility of F-t curve inscription control.

C. Statistical procedure

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 [20]. 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 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 Cronbach alpha. Reliability was assessed by Spearman-Brown rtt and by factor analysis through communalities extracted on the first characteristic (initial) eigenvalues (H^2) [20]. All statistical operations were carried out in the Microsoft ® Office Excel 2007 and the SPSS for Windows, Release 17.0 (Copyright © SPSS Inc., 1989–2002).

Table 1. Basic Item Descriptive Characteristics according to trials (N=99) in male examinees

The results of descriptive statistics for the male sample (N=99)							
Basic F-t characteristic		Test 1	Test 2	Test 3	Test 4	F-ratio	P-value
$F_{maxLEGExtISO}$ (N)	Mean±SD	3310.8±834.7	3552.0±898.7	3702.8±981.1	3790.9±962.4	5.152	0.002
	cV%	25.21	25.30	26.50	25.39		
	Min-Max	1740.0-5930.0	2060.0-6352.0	1968.0-6924.0	1831.0-6847.0		
$RFD_{BASICLEGExtISO}$ ($N \cdot s^{-1}$)	Mean±SD	5800.1±2779.6	6179.9±2178.6	6244.7±1932.1	6377.4±2082.8	1.181	0.315
	cV%	47.92	35.26	30.94	32.66		
	Min-Max	1746.7-18318.8	2378.3-12168.4	3087.5-12215.7	2601.7-12993.5		
$IndexSNG_{BASIC}$ (index values)	Mean±SD	1.77±0.73	1.79±0.70	1.75±0.62	1.72±0.53	0.207	0.891
	cV%	41.02	39.24	35.57	30.68		
	Min-Max	0.72-4.83	0.78-5.26	0.80-4.90	0.97-3.82		
$tF_{maxLEGExtISO}$ (ms)	Mean±SD	655.4±246.9	630.5±201.2	627.8±184.9	634.1±186.7	0.368	0.775
	cV%	37.67	31.91	29.46	29.44		
	Min-Max	207.0-1392.0	190.0-1282.0	204.0-1252.0	262.0-1033.0		

Table 2. Basic Item Descriptive Characteristics according to trials (N=65) in female examinees

The results of descriptive statistics for the female sample (N=65)							
Basic F-t characteristic		Test 1	Test 2	Test 3	Test 4	F-ratio	P-value
$F_{maxLEGExtISO}$ (N)	Mean±SD	2057.2±598.9	2348.4±638.4	2515.9±737.5	2619.2±745.6	7.750	0.000
	cV%	29.11	27.19	29.31	28.46		
	Min-Max	958.4-4664.1	1345.1-4718.2	1232.3-5083.2	1433.1-4665.1		
$RFD_{BASICLEGExtISO}$ ($N \cdot s^{-1}$)	Mean±SD	1573.3±853.4	1844.1±888.2	2124.6±999.1	2187.3±1049.5	5.281	0.001
	cV%	54.24	48.16	47.02	47.98		
	Min-Max	451.5-3694.8	586.9-4492.8	533.9-5251.0	638.7-5090.5		
$IndexSNG_{BASIC}$ (index values)	Mean±SD	0.80±0.46	0.80±0.39	0.85±0.37	0.84±0.41	0.312	0.816
	cV%	58.16	48.12	44.93	48.10		
	Min-Max	0.28-1.92	0.36-2.15	0.30-2.51	0.30-2.21		
$tF_{maxLEGExtISO}$ (ms)	Mean±SD	1669.1±822.4	1526.6±673.7	1393.6±608.0	1433.1±641.8	1.880	0.134
	cV%	49.27	44.12	43.63	44.78		
	Min-Max	518.0-3622.5	462.0-3254.0	399.0-3304.0	449.5-3286.5		

3. RESULTS

Table 1 and 2 show descriptive statistics of muscle force characteristics data according to trials (Mean, SD, cV%, Min, Max) and the results of the $ANOVA_{Single\ factor}$ for males and females. Except for the level of achieved maximal force analyzed $F_{maxLEGExtISO}$, ANOVA results showed that the mean values of the variables observed did not differ between measurements (F-ratio $ANOVA_{Singlefactor}$ – F=0.207, p=0.891 for $IndexSNG_{BASIC}$ to F=5.152, p=0.002 for $F_{maxLEGExtISO}$), which means that the items of single muscle force characteristics in males belong to the same measuring range (Table 1). Similarly, except for the level of achieved maximal force analyzed $F_{maxLEGExtISO}$ and $RFD_{BASICLEGExtISO}$, in females, ANOVA results showed that the mean values of the variables observed did not differ between measurements for $IndexSNG_{BASIC}$ and $tF_{maxLEGExtISO}$ (F-ratio $ANOVA_{Singlefactor}$ – F=0.312, p=0.816 for $IndexSNG_{BASIC}$ to F=7.750, p=0.000 for $F_{maxLEGExtISO}$) (Table 2).

The variation coefficient (cV%), as the variability rate of the measurement results, showed that the results in male and female examinees varied between 25.21 to 26.50% and 27.19 to 29.31% for $F_{maxLEGExtISO}$, respectively; between

30.94 to 47.92% and 47.02 to 54.24% for $RFD_{BASICLEGEXTISO}$, respectively; between 30.68 to 41.02% and 44.93 to 58.16% for $IndexSNG_{BASIC}$, respectively and between 29.44 to 37.67% and 43.63 to 49.27% for $tF_{maxLEGEXTISO}$, respectively (Table 1 and 2). This indicates that only for the level of achieved maximal force the variability of the results with respect to the mean value lied within normal values (below 30%) for both genders, while for the other characteristics it varied between 30 and 50% in male and between 30 and 60% in female examinees (Table 1 and 2).

Table 3 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 0.465 for $IndexSNG_{BASIC}$ and 0.923 for $F_{maxLEGEXTISO}$ in male and between 0.488 for $IndexSNG_{BASIC}$ and 0.869 for $F_{maxLEGEXTISO}$ in female examinees. The representability rate (KMO-MSA) ranged between 0.745 for $IndexSNG_{BASIC}$ and 0.818 for $F_{maxLEGEXTISO}$ in male and between 0.663 for $IndexSNG_{BASIC}$ and 0.777 for $F_{maxLEGEXTISO}$ in female examinees, the generalizability rate (Cronbach alpha) in male examinees ranged between 0.776 for $IndexSNG_{BASIC}$ and 0.980 for $F_{maxLEGEXTISO}$ and female between 0.788 for $IndexSNG_{BASIC}$ and 0.962 for $F_{maxLEGEXTISO}$, while the reliability rate (Spearman-Brown rtt) in males ranged between 0.715 for $IndexSNG_{BASIC}$ and 0.967 for $F_{maxLEGEXTISO}$ and between 0.713 for $IndexSNG_{BASIC}$ and 0.941for $F_{maxLEGEXTISO}$ in females (Table 3).

Table 3. The results of Correlation and Structural Equation Modeling

Basic F-t characteristic		Average Int-Item correlation	Bartlett`s Test of Sphericity	KMO-MSA	Cronbach alpha	Spearman-Brown reliability	Reliability Analysis ANOVA
MALE	$F_{maxLEGEXTISO}$ (N)	0.923	F=726.753 p=0.000	0.818	0.980	0.967	F=65.072 p=0.000
	$RFD_{BASICLEGEXTISO}$ ($N\cdot s^{-1}$)	0.555	F=152.556 p=0.000	0.791	0.833	0.796	F=2.518 p=0. 058
	$IndexSNG_{BASIC}$ (index values)	0.465	F=105.730 p=0.000	0.745	0.776	0.715	F=0.379 p=0.769
	$tF_{maxLEGEXTISO}$ (s)	0.545	F=149.326 p=0.000	0.765	0.828	0.766	F=0.776 p=0. 508
FEMALE	$F_{maxLEGEXTISO}$ (N)	0.869	F=375.846 p=0.000	0.777	0.962	0.941	F=57.236 p=0.000
	$RFD_{BASICLEGEXTISO}$ ($N\cdot s^{-1}$)	0.571	F=106.111 p=0.000	0.696	0.838	0.765	F=12.097 p=0.000
	$IndexSNG_{BASIC}$ (index values)	0.488	F=80.807 p=0.000	0.663	0.788	0.713	F=0.602 p=0.614
	$tF_{maxLEGEXTISO}$ (s)	0.522	F=90.180 p=0.000	0.709	0.807	0.753	F=3.850 p=0.011

Table 4. The Factor Analysis (Extraction Method: Principal Component Analysis)

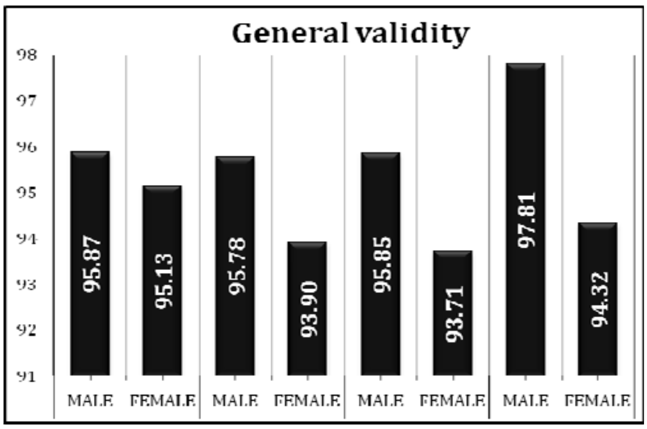
Communalities extracted on initial Eigenvalues (First Component) Component Matrix (H^2)					
		$F_{maxLEGEXTISO}$	$RFD_{BASICLEGEXTISO}$	$IndexSNG_{BASIC}$	$tF_{maxLEGEXTISO}$
MALE	Item 1 (Test 1)	0.942	0.724	0.702	0.726
	Item 2 (Test 2)	**0.985**	**0.873**	**0.827**	**0.845**
	Item 3 (Test 3)	**0.986**	0.815	0.771	0.836
	Item 4 (Test 4)	0.971	0.851	0.793	0.839
	Total extraction: Sums of Squared Loadings	3.772	2.675	2.400	2.644
	% of explained Variance	94.291	66.873	60.001	66.101
FEMALE	Item 1 (Test 1)	0.886	0.807	0.785	0.797
	Item 2 (Test 2)	**0.979**	**0.883**	**0.878**	**0.881**
	Item 3 (Test 3)	**0.979**	0.821	0.781	0.845
	Item 4 (Test 4)	0.954	0.783	0.693	0.676
	Total extraction: Sums of Squared Loadings	3.613	2.718	2.477	2.583
	% of explained Variance	90.321	67.939	61.918	64.570

Table 4 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 $RFD_{BASICLEGEXTISO}$ 0.873, for $IndexSNG_{BASIC}$ 0.827, for $tF_{maxLEGEXTISO}$ 0.845, while for $F_{maxLEGEXTISO}$ this happened in third trial – 0.986 but the second was similar, 0.985. In female examinees the second trial described the highest common variability for all the observed variables: for $RFD_{BASICLEGEXTISO}$ 0.883, for $IndexSNG_{BASIC}$ 0.878, for $tF_{maxLEGEXTISO}$ 0.881, for $F_{maxLEGEXTISO}$ 0.979.

Based on the obtained values of measured contractile leg extensor characteristics for the total sample, applying metrological procedure for defining standards in sport [21], we were able to evaluate standards which we used to rank examinees into seven categories in regard to the level of different ability: superior – 7, excellent – 6, good – 5, average – 4, satisfying – 3, not satisfying – 2, bad – 1. In order to define standards for the measured characteristics of leg extensor muscle force, we used data of measuring trial that showed the highest mutual variability. It was the second trial (Table 4) in both male and female examinees. Standard values are shown in Table 5.

Table 5. Standard values for evaluating the development status of contractile characteristics in leg extensors

Standard values for evaluating the development status of contractile characteristics in leg extensors									
MALE									
Characteristics / Values		$F_{maxLEGEXTISO}$		$tF_{maxLEGEXTISO}$		$RFD_{BASICLEGEXTISO}$		$IndexSNG_{BASIC}$	
Superior	7	5349.4		228.2		10537.5		3.1983	
Excellent	6	4450.7	5349.3	429.4	228.1	8358.8	10537.4	2.4952	3.1982
Good	5	4001.5	4450.6	530.0	429.3	7269.4	8358.7	2.1437	2.4951
Average	4	3102.8	4001.4	731.1	529.9	5090.7	7269.3	1.4406	2.1436
Satisfying	3	2653.4	3102.7	831.7	731.0	4001.6	5090.6	1.0890	1.4405
Not satisfying	2	1754.7	2653.3	1032.9	831.6	1822.5	4001.2	0.3859	1.0889
Bad	1		1754.6		1032.8		1822.4		0.3858
FEMALE									
Characteristics / Values		$F_{maxLEGEXTISO}$		$tF_{maxLEGEXTISO}$		$RFD_{BASICLEGEXTISO}$		$IndexSNG_{BASIC}$	
Superior	7	3625.3		179.5		3620.5		1.5793	
Excellent	6	2986.9	3625.2	853.2	179.4	2732.4	3620.4	1.1921	1.5792
Good	5	2667.7	2986.8	1190	853.1	2288.3	2732.3	0.9985	1.1920
Average	4	2029.2	2667.6	1863.6	1189.9	1400.2	2288.2	0.6113	0.9984
Satisfying	3	1710.0	2029.1	2200.4	1863.5	956.0	1400.1	0.4176	0.6112
Not satisfying	2	1071.6	1709.9	2874.2	2200.3	67.9	955.9	0.0304	0.4175
Bad	1		1071.5		2874.1		67.8		0.0303



Graph 1. Variance with respect to trials, explained as total and for each individual factor

General validity of the test was very high in each and every test, 95.78% for test 2 to 97.81% for test 4 of valid variance (as a factorial analysis variance explanation), which means that test (seating position) and measuring instrument with applied measuring procedure was highly reliable in measuring variables (Graph 1).

4. DISCUSSION

Mean value of the observed contractile characteristics found earlier for well-trained young males corresponds excellently with the present data ($RFD_{BASICLEGEXTISO}$ = 5672.39 $N \cdot s^{-1}$, $IndexSNG_{BASIC}$ = 1.5217 [7]; for elite volleyball players corresponds well $F_{maxLEGEXTISO}$ = 4080.47 N, $RFD_{BASICLEGEXTISO}$ = 8409.12 $N \cdot s^{-1}$, $IndexSNG_{BASIC}$ = 2.0838, $tF_{maxLEGEXTISO}$ = 0.529 s [8] and for untrained males corresponds good $F_{maxLEGEXTISO}$ = 3024.63 N,

$RFD_{BASICLegExtISO}$ = 3072.49 $N \cdot s^{-1}$, $IndexSNG_{BASIC}$ = 0.9877, $tF_{maxLegExtISO}$ = 1.218 s [6]. Similarly, mean value of the observed contractile characteristics found earlier for well-trained young females corresponds excellently with the present data ($F_{maxLegExtISO}$ = 2109.92±484.35 N, $RFD_{BASICLegExtISO}$ = 1628.23 $N \cdot s^{-1}$, $IndexSNG_{BASIC}$ = 0.7820, $tF_{maxLegExtISO}$ = 1.951±0.518 s [7]; for elite volleyball players corresponds well $F_{maxLegExtISO}$ = 2631.76±692.57 N, $RFD_{BASICLegExtISO}$ = 2481.47 $N \cdot s^{-1}$, $IndexSNG_{BASIC}$ = 1.0292, $tF_{maxLegExtISO}$ = 1.275±0.649 s [8] and for untrained females corresponds good $F_{maxLegExtISO}$ = 2005.79±420.52 N, $RFD_{BASICLegExtISO}$ = 1628.23 $N \cdot s^{-1}$, $IndexSNG_{BASIC}$ = 0.5538, $tF_{maxLegExtISO}$ = 1.584±0.769 s [6]. The indicators of variability, i.e. sensitivity (cV%) show that the results are reliable for almost all variables and they are beyond the acceptable range of about 40% of mean. Vitasalo and associates [22] established that the cV% of RFD (in single joint muscles) is four times higher than the cV% of F_{max}, while simultaneous isometric test on both legs had cV% for RFD approximately three times higher than cV% for F_{max} [25] and multi-joint isometric test had cV% for RFD approximately two times higher than cV% for F_{max} [26]. Present data suggest that with the isometric leg test in seating position the cV% of $RFD_{BASICLegExtISO}$ is between 1.17 to 1.9 times higher than cV% of $F_{maxLegExtISO}$ in male (Table 1) and between 1.79 to 2.08 times in female examinees (Table 2), so it is proposed that greater discrepancies between the results and the mean value are due to the method chosen to test these muscle characteristics.

In regard to gender differences, the results are similar to those in previous researches [3], [6]–[8], [25], [26]. The most noticeable feature among the examined characteristics in this research is that the difference between the observed variables, regarding the gender, decreases during the measurement trials. The minimal difference is in the fourth trial (Table 1 and 2).

The results of the structural equation modeling showed statistically significant reliability of the test at p<0.000 for all the characteristics observed (Table 3). In males the test described 71.5 to 77.6% of the variability of $IndexSNG_{BASIC}$ area, 76.6 to 82.8% of the variability of $tF_{maxLegExtISO}$ area, 79.6 to 83.3% of the variability of $RFD_{BASICLegExtISO}$ area and 96.7 to 98.0% of the variability of knee extensor $F_{maxLegExtISO}$ area, while in females 71.3 to 78.8% of the variability of $IndexSNG_{BASIC}$ area, 75.3 to 80.7% of the variability of $tF_{maxLegExtISO}$ area, 76.5 to 83.8% of the variability of $RFD_{BASICLegExtISO}$ area and 94.1 to 96.2% of the variability of knee extensor $F_{maxLegExtISO}$ area (Spearman-Brown rtt and Cronbach Alpha, respectively – Table 3).

Studying literature that examined reliability and variability of measurement in different muscle groups in isometric regime, we can conclude that the opinions on this subject are different. Different results can partially come from the equipment, from differences in applied methodology or from different reliability due to different muscle group testing. Wilson and Murphy [27] obtained smaller correlation coefficients in RFD (r=0.84) than in F_{max} (r=0.96), while certain researchers [28] obtained higher correlation coefficients in RFD (0.83 to 0.94) than in F_{max} (0.64 to 0.91). Presumably, those differences came as a result of differences among muscle groups. Certain researchers, on the other hand, consider the frequency of data recording as a factor for reliability. The structure of test battery and the number of repetitions during the measuring should be taken into consideration as well [23], [28].

Some other factors can affect reliability of the obtained results. Certain authors [29] believe that, in cases where the variable F_{max} and RFD are measured, it is necessary to carry out two measurements with different commands (hard, respectively hard and fast), and in case of time limitation, the hardest and the fastest [28]. According to Sahaly and associates [29] the obtained differences in isometric explosive leg extensor force at the value of almost 5000 $N \cdot s^{-1}$ in regard to different command are significant (9739 $N \cdot s^{-1}$ measured force on command hard and fast and 14189 $N \cdot s^{-1}$ on command fast). On the other hand, measuring maximal isometric force, large number of the researchers obtained variability coefficient in the range of 0.85 to 0.99 [22], [23], [27] which is considered to be almost perfect reliability [30]. Very high reliability of isometric F_{max} measured on knee extensors of a single leg by test-retest method was also found in the research of Vitasalo and associates [22] at r=0.98, i.e. 98%; of isometric voluntary knee extensor muscle force from standing position by trial method was found in Dopsaj and associates [23] between 96.7 to 96.9% for F_{max}, 73.2 to 77.7% for RFD and 77.5 to 79.1% for tF_{max}; performed five trials of MVC Dead lift [24] between 99.1 to 99.2 for F_{max}, 89.3 to 92.6% for RFD and 87.8 to 89.1% for tF_{max}. Based on results of numerous researches, it was established that the measuring reliability level for different muscle groups in isometric regime is in the range of 0.939 to 0.980 [23], [24], [26], [31]. In Mirkov's research [32] reliability was established for the majority of isometric tests of hand flexors, ICC coefficient was measured in the range of 0.6 to 0.8, and even though 6 weeks passed between the pre- and post-tests, the reliability of RFD and F_{max} was satisfying.

5. Conclusions

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, the factor analysis demonstrated the highest reliability of the F-t curve measured contractile characteristics – 95.87% to 97.81% of the explained total variance in the population of the tested males, and 94.86% to 96.40% in the population of tested females. The standardization of the seating leg extension test in isometric testing conditions requires a minimum of three trials for $F_{maxLegExtISO}$, where the result is the better value taken at the second or third trial.

The measure of sample adequacy in both genders (KMO-MSA) is highly significant for $F_{maxLegExtISO}$ (marvelous), $RFD_{BASICLegExtISO}$ (meritorious) while it is slightly lower for $IndexSNG_{BASIC}$ and $tF_{maxLegExtISO}$ (middling), which indicates that the obtained results for the measured sample can be accepted as a population valid [20].

The obtained results show that the applied measuring procedure and used measuring instruments, i.e. tensiometric probe device with the following hardware and software system, as well as measuring variables which represented the basic contractile characteristics of leg extensor isometric force in seating position, are highly statistically reliable (Sperman-Brown r was 0.715 to 0.967 for males and 0.713 to 0.941 for females) and can be reliable in the function of specialized and sophisticated measuring equipment for testing well and highly trained athletes.

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