AN ANALYSIS OF THE RELIABILITY AND FACTORAL VALIDITY OF SELECTED MUSCLE FORCE MECHANICAL CHARACTERISTICS DURING ISOMETRIC MULTI-JOINT TEST

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We applied the "Dead Lift" test in isometric conditions to establish the reliability and factoral validity of pre-selected muscle force mechanical characteristics on a sample of 23 young males. The muscle force mechanical characteristics (hip extensors, trunk extensors and shoulder elevators as a multi-joint system) were represented by maximum voluntary force (F_{max}), time needed to reach F_{max} (tF_{max}), rate of force development (RFD), force impulse (ImpF) and maximum value of muscle involvement velocity (C_{max}). The results yielded highly acceptable rates for the indicators of sensitivity (cV%), reliability and validity at the significant level of $p < 0.001$. The standardization of the multi-joint test in isometric testing conditions requires three trials for C_{max} and F_{max}, where the result is the better value taken at the second or third trial, and three to five trials for RFD, ImpF and tF_{max}, with the best values taken as the result.

KEY WORDS: muscle force mechanical characteristics, isometric test, young male

INTRODUCTION: The muscle system is so structurally and functionally complex that measurements of some of its characteristics are influenced by a variety of factors such as equipment, experience, training and health status, motivation, testing condition, etc. (MacDougal, Wenger, & Green, 1991). The aim of research was to establish the reliability and factoral validity for the essential muscle force mechanical characteristics, tested during maximal voluntary contraction (MVC) by a multi-joint test in isometric conditions of contraction.

METHODS: Samples: The subjects of the research were 23 healthy male Police Academy students. They were randomly chosen from the student population. The mean age, height and mass (± SD) were 22.1±1.2 years, 1.813±0.031 m and 78.26±5.15 kg, respectively.
Testing procedure. After the 5min standard and specific warm-up exercises, the subjects performed five MVC trials of "Dead Lift", with a 3-5 min rest between trials. Figure 1 shows the muscle force testing procedure and body position. The test was performed under isometric conditions using the equipment developed at the Department of Special Physical Education and a hardware-software system connected to a tensiometrics dynamometer (Program Inžinjering, Belgrade). The muscle force mechanical characteristics (hip extensors, trunk extensors, and shoulder elevators as a multi-joint system) were represented by maximum voluntary force (F_{max}), time needed to reach F_{max} (tF_{max}), rate of force development (RFD), force impulse (ImpF) and maximum value of muscle involvement velocity (C_{max}) (Blagojević et al., 1997). Each subject was familiar with the equipment since its use is regular in checking physical fitness of students during their studies (twice per school year).
Statistics. An SPSS 7.5 for WIN (SPSS Inc.) statistical package was used to perform the statistical procedures. 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 (Hair, Anderson, Tatham, & Black, 1995).

RESULTS: Table 1 shows descriptive statistics of muscle force characteristics data according to trials (Mean, SD, cV, Min, Max, Skewness and Kurtosis). 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, ANOVA of Reliability Analysis), while Table 3 shows the results of factor analysis (Communalities extracted on initial Eigenvalues - H^2).

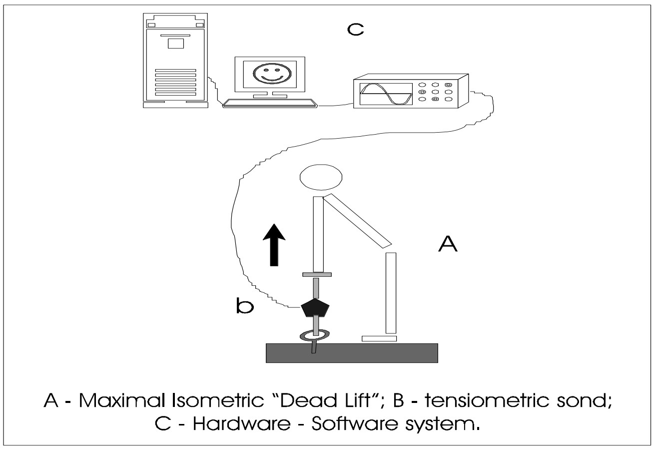

Figure 1 - Muscle force testing procedure and position.

DISCUSSION: Mean value of F_{max}, tF_{max} and C_{max} found earlier for well-trained young males corresponds well with the present data (F_{max} 190.6±25.85 DaN; tF_{max} 1525.1±479.9 ms; C_{max} 6.394±2.906 - Blagojević, Milošević, Dopsaj, & Arlov, (1997)). The indicators of variability, i.e. sensitivity (cV%) show that the results are reliable for F_{max} and tF_{max}, while for RFD, ImpF and C_{max} they are beyond the acceptable range of 30% of MEAN. Viitasalo, Saukkonen & Komi (1980) established that the cV% of RFD (in single-joint muscles) is four times greater than the cV% of F_{max}. Present data suggest that with a multi-joint isometric test the cV% of RFD is two times greater than cV% of F_{max}, 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. Thus, Pryor, Wilson, & Murphy (1994) confirmed that because of relatively "uncomfortable feelings during an isometric activity some subjects may not apply maximum efforts as instructed" for each trial. The values of skewness and kurtosis fall within regular result distribution pattern in all measurements, except of C_{max} at Tests 1, 2 and 5 with kurtosis, where there was positive data distribution asymmetry (a great number of items with low values). Results of $ANOVA_{Single\ factor}$ show no difference between Inter-Item mean values, which means that the items of single muscle force characteristics belong to the same measuring area (Table 1).

The average inter-item correlation values (Table 2) ranged from 0.596 for ImpF to 0.961 for F_{max} and they all described mutual correlation within a correlation matrix at a statistically significant level at $p < 0.001$ (Bartlett's Test of Sphericity). The measure of sample adequacy (KMO-MSA) is highly significant for F_{max} (marvelous), RFD, ImpF, C_{max} (meritorious), while it is slightly less so for tF_{max} (middling) (Hair, Anderson, Tatham, & Black, 1995, p. 374). The reliability indicators (Cronbach alpha, as a measure of reliability for a set of two or more construct indicators and Spearman-Brown reliability) are excellent for F_{max}, C_{max} and RFD (0.991-0.992, 0.923-0.931, 0.893-0.926, respectively) and very good for tF_{max} and ImpF (0.878-0.891, 0.872-0.880, respectively). Other researchers also established a high level of reliability of RFD, r = 0.84 and 0.82, respectively (Viitasalo, Saukkonen, & Komi, 1980; Pryor, Wilson, & Murphy, 1994). Generally, in the view of reliability of the items observed, tF_{max} had lower level than the others, which had already been proved (Viitasalo, & Komi, 1978).

Validity analysis results (Factor Analysis) showed that two to three trials were enough to obtain reliable data for C_{max} and F_{max}. However, to do so for RFD, ImpF and tF_{max} it took three to five trials (Table 3).

CONCLUSION: The results yielded highly acceptable rates for the indicators of sensitivity (cV%), reliability and validity at the significant level of $p < 0.001$. The standardization of the multi-joint test in isometric testing conditions requires three trials for C_{max} and F_{max}, where the result is the better value taken at the second or third trial, and three to five trials for RFD, ImpF and tF_{max}, with the best values taken as the result.

Table 1 Basic Item Descriptive Charateristics according to trials (N = 23)

		Test 1	Test 2	Test 3	Test 4	Test 5	*F-ratio* Anova: Single Factor	*P-value*
F_{max} (DaN)	Mean	188.76	188.17	190.71	191.90	188.68	0.072	0.991
	SD	26.10	27.55	28.16	30.52	30.02		
	cV (%)	13.83	14.64	14.77	15.91	15.91		
	Min	141.86	140.61	144.34	140.61	136.88		
	Max	258.82	262.56	267.53	279.98	276.24		
	Skew	0.39	0.65	0.66	0.74	0.94		
	Kurt	1.22	1.42	1.28	2.06	2.16		
tF_{max} (ms)	Mean	1746.8	1776.6	1772.2	1793.2	1793.5	0.034	0.998
	SD	491.4	479.7	484.8	504.1	543.0		
	cV (%)	28.13	27.00	27.35	28.11	30.27		
	Min	790.0	776.9	968.9	897.2	794.3		
	Max	2626.6	2773.6	3079.5	2960.0	2705.1		
	Skew	0.12	-0.06	0.81	0.32	0.07		
	Kurt	-0.54	-0.28	1.31	0.25	-0.70		
RFD (DaN/s)	Mean	118.32	115.44	113.98	115.97	117.76	0.042	0.997
	SD	43.79	42.43	30.39	40.03	48.85		
	cV (%)	37.01	36.76	26.66	34.51	41.48		
	Min	57.80	66.64	63.44	58.66	55.80		
	Max	244.13	225.83	199.25	226.08	258.49		
	Skew	1.29	1.22	0.93	1.16	1.46		
	Kurt	2.00	1.01	1.85	1.57	2.29		
ImpF (DaNs)	Mean	265.44	264.96	268.04	255.29	264.49	0.066	0.992
	SD	87.65	84.17	90.21	101.19	89.99		
	cV (%)	33.02	31.77	33.65	39.64	34.02		
	Min	116.76	105.72	138.26	100.72	116.74		
	Max	437.35	433.01	507.91	486.33	426.19		
	Skew	0.38	0.29	0.71	0.39	0.01		
	Kurt	-0.58	-0.29	0.78	-0.06	-0.61		
C_{max}	Mean	7.99	6.48	7.19	7.37	6.15	0.433	0.784
	SD	5.84	6.03	4.58	5.78	4.13		
	cV (%)	73.15	93.20	63.75	78.40	67.15		
	Min	2.05	1.63	1.89	1.93	2.21		
	Max	27.00	28.99	17.38	23.66	20.21		
	Skew	1.81	2.73	0.84	1.50	2.00		
	Kurt	3.98	8.72	-0.14	1.84	5.25		

Table 2 The Results of Correlation And Structural Equation Modeling

	Average Int-Item correl.	Bartlett's Test of Sphericity	KMO - MSA	Cronbach alpha	Spearman-Brown reliability- r_{tt}	Reliability Analysis $_{ANOVA}$
F_{max} (DaN)	0.961	F=227.72 p=0.000	0.918	0.991	0.992	F=1.590 p=0.184
TF_{max} (ms)	0.621	F=67.76 p=0.000	0.781	0.878	0.891	F=0.082 p=0.988
RFD (DaN/s)	0.715	F=101.32 p=0.000	0.808	0.893	0.926	F=0.111 p=0.979
ImpF (DaNs)	0.596	F=56.83 p=0.000	0.823	0.872	0.880	F=0.156 p=0.960
C_{max}	0.731	F=81.75 p=0.000	0.856	0.923	0.931	F=1.469 p=0.218

Table 3 The Factor Analysis (Extraction Method: Principal Component Analysis)

	Communalities extracted on initial Eigenvalues (First Component) - Component Matrix (H^2)				
	F_{max}	tF_{max}	RFD	ImpF	C_{max}
Item 1 (Test 1)	0.973	0.727	0.761	0.749	0.902
Item 2 (Test 2)	0.984	0.662	0.632	0.719	0.909
Item 3 (Test 3)	0.991	0.864	0.912	0.921	0.800
Item 4 (Test 4)	0.979	0.912	0.965	0.776	0.882
Item 5 (Test 5)	0.989	0.916	0.952	0.902	0.911
Total Extraction: Sums of Squared Loadings	4.834	3.385	3.650	3.341	3.889
% of Explained Variance	96.687	67.694	73.001	66.834	77.774

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