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MODELING VARIABILITY OF THE ASSIGNED LEVEL OF FORCE DURING ISOMETRIC CONTRACTIONS OF THE ARMS EXTENSOR MUSCLES IN UNTRAINED MALES

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Abstract. *The research has been carried out in order to measure the variability of the development of muscle force control achieved by the arms extensor muscle within the task requirements. The experiment involved testing the arm extensor muscle by using the isometric Flat Bench Press Test. The sample consisted of 28 subjects who were students of the College of Internal Affairs in Zemun – Belgrade. The subjects had underwent five individual test trials, within which the first trial measured the maximum isometric muscle force (F_{max}izo) and in the other four cases depended on the acquired percentage of F_{max}izo at the levels of 30%, 50%, 70% and 90%. The testing was developed by using a hardware–software system applied in the Special Physical Education Laboratory at the College of Internal Affairs. The variability differences among the observed variables were measured by implementing the ANOVA variance analysis, Kandall's and Wilcoxon's Test. In order to establish the differences among individual variables, the Student's t-test of equal samples was used. The ANOVA results showed a statistically significant difference between the mean values and variability among all of the observed variables at the F = 6.065, p = 0.001 level, in relation to the absolute values and F = 9.956, p = 0.000 and in relation to relative force values. The results of the Student's t-test showed a statistically significant difference among the mean value of errors in the developed force between the level of 30 percent (as the smallest force of the level tested) and all the other levels of 50%, 70% and 90% (as the middle, large and submaximum level of force). Kandall's test showed that the error distribution, that is, the level of force deviation from the force level required by the task, differs from the aspect of absolute and the aspect of relative values (values in percents) at the p = 0.000 level. According to the results, it can be concluded that in regards to the control of muscle force distribution as part of the task, a healthy and untrained male population mostly makes errors in the sense of a low level of force (at*

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the 30 percent level of F_{max}izo), while at the level of 50, 70 and 90 percent of F_{max}izo, the errors are statistically nonsignificant. This means of the ability for fine motoric control, or creating muscle force at the level of 30 percent of $F_{max,}$ for the subjects represented a motor task which they were not able to completely realize, while in the cases where higher levels of force were used, the examinees were more precise with fewer errors.

Key words: *Isometric muscle force, motor control, flat bench press test, level of muscle force control*

1. INTRODUCTION

Many authors were involved in research that included maximum isometric muscle force and its dimensions (Hakkinen & Komi, 1986; McDougall et al., 1991; Pryor et al., 1994; Haff et al., 1997; Muller et al, 2000; Mirkov et al., 2003; Amanović et al., 2005). But, very few researchers were involved in examining specific force parameters and controlling its manifestation (Herzog, 2001; Christou et al., 2002; Linnamao et al., 2002) mostly for the purpose of sports training (Dapsaj et al., 2000; Milošević et al., 2004; Rajić et al., 2004; Amanović et al., 2005.)

The diagnostic level of preparation and selection of athletes in regards to contractile muscle abilities that are to be checked through basic parameters of maximal (F_{max}) or explosive force (RFD F_{max}) does not offer valid data for the function of full control in the training session, and furthermore, not enough data for creating the optimal training session process (Zatsiorsky, 1995; Wilson & Murphy, 1996; Müller et al., 2000; Milošević, 2002). Contemporary technological processes include extensive technological hardware-software systems with high sensitivity tensionmetric, by which it is possible to make note of the force in a time unit frequency of over 100 MHz/s (Dopsaj et al., 2000; Mirkov et al., 2003; Amanović et al., 2004; Milošević et al., 2004). Such speed of data acquisition offers a possibility for the analysis of changes of force in a unit of time in regards to the necessary structure of the mechanical manifestation of the observed muscle contractions. Furthermore, the observation is possible in relation to the time interval (100 ms, 200 ms, 300 ms,..), the desired percentage of maximum force (10%, 20%,30%...of tF_{max}), the desired level of force (30N, 50 N, 150 N, 200 N..), the desired percentage of time from the maximum duration of a contraction (10%, 20%,30%... of F_{max}) etc. It is, therefore, possible to analyze all of the mechanical characteristics of the observed isometric force. This is of great importance, because one of the very important segments of work is collecting information concerning specially defined selection, and a permanent control of training conditions (Zatsiorsky, 1995; Wilson & Murphy, 1996; Müller et al., 2000; Milošević, 2002). The results denoting the athletes' condition obtained through training, and the level to which their physical characteristics have developed are in direct connection to the applied tests, the athletes' training abilities, type of weight, and the condition in which the tests were carried out. In accordance to the more specific tests, in regards to the activities and athletes' burden under the objective conditions (his presence in this particular environment), the information collected during the test period is more valid for the selection, programming force, and the judgment used during the preparation period.

The obtained results in this paper will express (within the healthy untrained population) a natural level of variability of force in relation to tasks which require a certain level of mobility. Such data is very important from the aspect of understanding the subject of motor control development, as part of an ordered set of movements, and can lead to knowledge that will be implemented in the methodology of top athletes' training, especially in regards to the mechanisms of neurousmuscular adaptation during the training for muscle force development (Winter, 1990; Sale, 1992; Muller et. Al., 2000; Milošević et al., 2002).

The aim of the research is to measure variability, as a measure of level control, by viewing the achieved force in accordance with the level of force required by the task in an isometric regime of work, which is done by testing the arms extensor muscle using the flat bench press. The test was chosen as an exercise and as a position that is best for judging the objective contractile ability of the tested muscle group. In such cases, in an indirect way, using mechanisms of output regulation (the exterior components of the rational system effect or mobility task of the command signal are: CNS - the spine - muscle contraction - developed force) and the results in the developed muscle force can be studied by the mechanisms involved in the control of the necessary muscle force level. The offered mechanism is of great importance from the viewpoint of general and specific physical preparation, especially if we bear in mind the application of elementary and also specific training methods. Furthermore, the research results may be very useful in regards to the exercise technique of elite (top) athletes, as well as in the area of physical states, large training components that are displayed at an adequate level of force control, necessary for an efficient performance of professional duties, as can be found in the police, army and etc. (Dopsaj et al., 2002; Amanović, et. al. 2004)

2. METHODS

The research was carried out on a sample of 28 male students (aged 22.1 ±1.5, BN = 1.794 ± 0.058 m, BW = 80.7 ± 7.7 kg) at the College for Internal Affairs in Zemun. All of the participants were in good condition (healthy and physically active) and they freely agreed to participate in the research, developed within the guidelines of the Ethics Code of the College (Statute of the College for Interior Affairs, 1993).

Testing procedures

The arm extensors were tested by using the flat bench press test in isometric conditions (Figure 1). The defined muscle group was chosen for the extremities that are used for manipulating equipment and the implementation of different movement activities (techniques) in different sports, one which belongs to a category of very important muscle groups (Pryor et al., 1994; Zatsiorsky, 1995; Dopsaj et al., 2000; Amanovic et al., 2005).

The experimental procedure required the individuals to engage in 5 different tests in the following order: after the first (five minute) warm-up of each participant, the task for each individual was to develop a maximum isometric muscular force (F_{max}izo) by means of the flat bench press (Figure 1). After that, the subjects were given the result values of the F_{maxIZO} as the primary information on the test results. After a minute's pause each participant made four more attempts to achieve a level of force of 30%, 50%, 70% and 90% of the maximum ($F_{30\%izo}$, $F_{50\%izo}$, $F_{70\%izo}$ and $F_{90\%izo}$). The pauses between each attempt were one minute. In such cases the output of the contractile systems is described with the manipulated ability for fine control used for creating the level of force of 30, 50, 70 and 90% of F_{max}. In order to escape the effects of previous experience, each participant was allowed only one attempt to carry out the task (Schmidt, 1988). The used equipment and the testing procedure has already been evaluated in earlier research work (Pryor et al., 1994; Haff et al., 1997; Dopsaj et al., 2000; Amanović et al., 2004; Milošević et al., 2004; Amanović et al., 2005.)

The test was carried out in the following way: the participant had to lie down on a flat bench and to grab a metal lever with his hands (Figure 1), so that the angle between the upper elbow and lower elbow was 90^o. Pushing up the lever with a joint chain and a tensiometric probe which was attached on the other side to a hook at the end of the construction (Figure 2), the participant, following a signal, carried out the task by extending his hands with as much force as he could, or the force which was required. The results of the test were automatically noted by the usage of a tensiometric probe and a hardware–software system.

Fig. 1. Participant's position while performing the test

Fig. 2. A detail of the construction with a probe

Statistical Analysis

The raw data was further analyzed by applying a descriptive and comparative statistical method. The distribution expansion of the difference in force gives results in relation to the developed and hypothetically calculated values concerning the level of force ($F_{30\%izo}$, $F_{50\%izo}$, $F_{70\%izo}$ and $F_{90\%izo}$) and is presented in absolute (DaN) and in relative values in percents (%). The following are the statistical parameters for measuring the central tendency variability values: arithmetic mean - MEAN, standard deviation - SD, coefficient of variation - cV% maximum - MAX and minimum- MIN variable values.

The distribution correctness of each variable was established by applying the non-parametric Kolmogorov - Smirnov Test. The main difference in the data distribution of all the tests, considered from the aspect of absolute or relative force difference, has been established by the inclusion of Kandall′s W in the tests for several related samples, while the difference between the individual variable pairs has been established by the usage of the Wilcoxon sign rank test.

The differences of the main variability between the used variables, in view of the obtained results, have been confirmed by using the ANOVA. To establish the differences between individual variables, the Student′s t-test for paired samples was used (Perić, 1996; Hair et al., 1998).

3. RESULTS

The results show that the participants whose arm extensor muscles were used in an isometric flat bench press test, were able to reach a maximum force (F_{max}izo) of 202.34 ± 32.91 daN (2023.4 ± 3291 N) with a coefficient of variation (cV%) of 16.26%. The results point out that the tested population is homogeneous, while the muscle group can be treated as a representative group (Peric, 1996; Hair et al., 1998). Table 1 shows the data regarding the basic descriptive statistics of the studied variables.

In relation to the achieved level of force of 30% (Table 1 - $F_{30\%izo}$) the participants achieved a greater force than the task in theory required and made errors in average of 20.74 ± 29.84 daN with cV% results of 143.91%. The results show that the mistake was found in the range from – 40.09 daN (the achieved force was lower than was expected by 400.9 N) up to + 72.03 daN (the achieved force was higher than was expected by 702.3 N). When the results are displayed in relative values (in %) it is obvious that the participants made errors with an average of 35.72 ± 48.99%, while achieving the required force value, and that the cV% mistakes reached 137.17%. The cV% value of 137.17% puts the valid sample into a low homogeneous group, which practically speaking means that the ability to precisely control recognizable muscle force, at the level of 30% of F_{max}, was a motor task which they were not able to realize with precision. The mistakes were made during the course of the tasks and the created level of force had been very great, for all of the participants.

In regards to the valid achieved force at the 50% level (Table 1 – $F_{50\%izo}$) the participants, in their attempts, achieved a greater force than the task required at an average level of 1.67 ± 31.81 daN with cV% results of 1908.25%. The results reveal that the errors in the achieved force during the task were found to be from – 61.91 daN (the achieved force was lower than was expected by 619.1N) up to + 53.14 daN (the achieved force was higher than was expected by 531.4 N). From the relative values (in %), it is obvious that the participants made errors of their F_{max} at an average of 2.83 ± 32.48%, considering the task required a force of up to 50% and the cV% mistakes were 1149.73%. The cV% value of 1149.73% puts the valid sample into a low homogenous group, which practically speaking means that the ability to precisely control recognizable muscle force at the level of 50% F_{max} had been a motor task that they were not able to complete with precision, because the mistakes made and the achieved level of force had been very large for all of the participants (either the force task level was overcome or not achieved).

In relation to the valid achieved force at the level of 70% (Table 1 – $F_{70\%izo}$) the participants, in their attempts, achieved a lower force than the task required at an average level of –3.68 ± 25.85 daN, with cV% results of 701.63%. The results reveal that the mistakes made in the achieved force during the task were found to be from– 63.30 daN (the achieved force was lower than was expected by 633.0 N) up to + 30.28 daN (the achieved force was higher than was expected by 302.8 N). When the results are displayed in relative values (in %) it is obvious that the participants made errors at an average of – 2.49 ± 19.32 % from their $F_{max,}$ considering that the required force was up to 70% and that the technical cV% mistakes were valued at 775.55%. The cV% value of 775.55% puts the valid sample into a low homogeneous group, which practically speaking means that the ability to precisely control recognizable muscle force at the level of 70% F_{max} was a motor task that they were not able to realize with precision. The mistakes they made and the created level of force had been very great for all of the participants.

In regards to the valid achieved force at the 90% level (Table 1 – $F_{90\%izo}$) the participants, in their attempts, achieved a lower force than the task required at an average level of – 6.60 ± 14.80 daN, with cV% results of 224.27%. The results reveal that the mistake made in the achieved force during the task was found to be from – 31.68 daN (the achieved force was higher than was expected by 174.4 N). When the results are displayed in relative values (in %), it is obvious that the participants made errors at an average of – 3.57 ± 8.18% of their F_{max}, considering that the required force was up to 90% and the cV% errors were valued at 229.18%. The cV% value of 229.18% puts the valid sample into a low homogeneous group, which practically speaking means that the ability to precisely control recognizable muscle force at the level of 90% F_{max} was a motor task that they could not realize with precision. The mistakes and the achieved level of force, were very great for all of the participants (though in relation to the other tasks, the group in fact had a lower variation level, that is, a lower level of homogeny compared to $F_{50\%izo}$ and $F_{70\%izo}$).

Table 1. The results of the basic descriptive variable data

	30% of F_{max} theoretical (DaN)	F30%$_{IZO}$ realized (DaN)	Absolute difference (DaN)	Relative difference (%)
MEAN	60.70	81.44	20.74	35.72
SD	9.87	30.48	29.84	48.99
cV%	16.26	37.42	143.91	137.17
Min	44.80	22.27	–40.09	–55.35
Max	76.42	148.45	72.03	108.92
	50% of F_{max} theoretical (DaN)	$F_{50\%IZO}$ created (DaN)	Absolute difference (DaN)	Relative difference (%)
MEAN	101.17	102.84	1.67	2.83
SD	16.45	32.53	31.81	32.48
cV%	16.26	31.63	1908.25	1149.73
Min	74.66	34.47	–61.91	–58.53
Max	127.36	166.87	53.14	57.63
	70% of F_{max} theoretical (DaN)	$F_{70\%IZO}$ created (DaN)	Absolute difference (DaN)	Relative difference (%)
MEAN	141.64	137.95	–3.68	–2.49
SD	23.03	33.22	25.85	19.32
cV%	16.26	24.08	701.63	775.55
Min	104.52	55.12	–63.30	–52.63
Max	178.30	181.67	30.28	25.96
	90% of F_{max} theoretical (DaN)	$F_{90\%IZO}$ created (DaN)	Absolute difference (DaN)	Relative difference (%)
MEAN	182.11	175.51	–6.60	–3.57
SD	29.62	31.21	14.80	8.18
cV%	16.26	17.78	224.27	229.18
Min	134.39	121.70	–31.68	–18.66
Max	229.25	238.54	17.44	8.89

Table 2 shows the variance analysis results (ANOVA) between the absolute (given in DaN) and relative (given in % of the difference between the force level in theory, at 30, 50, 70 and 90% of F_{maxIZO} and the obtained i.e. achieved force in the $F_{30\%izo}$, $F_{50\%izo}$, $F_{70\%izo}$ and $F_{90\%izo}$ tests) values of the studied variables. The results show that there was a statistically significant difference between the existing values and the variability between the studied variables ($F_{30\%izo}$, $F_{50\%izo}$, $F_{70\%izo}$ and $F_{90\%izo}$) at the level of F=6.065, p=0.001, in relation to the absolute values and F = 9.956, p = 0.000, in relation to the relative values, respectively.

Table 3 presents the results of the differences between the mean of deviation (the errors) that the participants achieved while performing the task. The results show that a statistically significant difference exists between the means of error in force development and between the level of 30% - $F_{30\%izo}$ (as the smallest level of the force tested) and all the other levels (50%, 70% and 90% - $F_{50\%izo}$, $F_{70\%izo}$ and $F_{90\%izo}$, as the middle, large and submaximum level of force) such as $F_{30\%izo}$ vs $F_{50\%izo}$ p = 0.004; $F_{30\%izo}$ vs $F_{70\%izo}$ p = 0.000; $F_{30\%izo}$ vs $F_{90\%izo}$ p = 0.000. Between the medium and higher level of force, i.e. the achievement at the level of $F_{50\%izo}$, $F_{70\%izo}$ and $F_{90\%izo}$ (middle, high and submaximum levels of force) no statistically significant differences have been established (F_{50izo} vs $F_{70\%\ izo}$ p = 0.206; $F_{50\%izo}$ vs $F_{90\%izo}$ p = 0.148; $F_{70\%izo}$ vs $F_{90\%izo}$ p = 0.550). Identical results have also been established in relation to relative data, that is, error level presented in percents (Table 4).

Table 2. ANOVA results in relation to the absolute and relative value of the variables

Absolute variable values					
Source of Variation	SS	df	MS	F	P value
Between Groups	12688.51	3	4229.51	6.065	0.001
Within Groups	75313.18	108	697.34		
Total	88001.69	111			
Relative variable values					
Source of Variation	SS	df	MS	F	P value
Between Groups	29090.65	3	9696.88	9.956	0.000
Within Groups	105192.5	108	974.01		
Total	134283.1	111			

Table 3. The Student's t- test for paired samples (absolute level of force, in DaN)

	Mean of error	Std. Dv. of error	N	Diff	Std.Dv.	t	df	P
$F_{30\%IZO}$ (DaN) $F_{50\%IZO}$ (DaN)	20.736 1.666	29.841 31.806	28	19.069	32.211	3.132	27	0.004
$F_{30\%IZO}$ (DaN) $F_{70\%IZO}$ (DaN)	20.736 −3.684	29.841 25.849	28	24.420	25.849	4.998	27	0.000
$F_{30\%IZO}$ (DaN) $F_{90\%IZO}$ (DaN)	20.736 −6.598	29.841 14.799	28	27.335	23.749	6.090	27	0.000
$F_{50\%IZO}$ (DaN) $F_{70\%IZO}$ (DaN)	1.666 −3.684	31.806 25.849	28	5.351	21.835	1.296	27	0.205
$F_{50\%IZO}$ (DaN) $F_{90\%IZO}$ (DaN)	1.666 −6.598	31.806 14.799	28	8.265	29.387	1.488	27	0.148
$F_{70\%IZO}$ (DaN) $F_{90\%IZO}$ (DaN)	−3.684 −6.598	25.849 14.799	28	2.914	25.499	0.604	27	0.550

Table 4. The Student's t-test for paired samples (relative level of force, in %)

	Mean of error	Std. Dv. of error	N	Diff	Std.Dv.	t	Df	p
$F_{30\%IZO}$ (%) $F_{50\%IZO}$ (%)	35.718 2.825	48.994 32.484	28	32.892	41.328	4.211	27	0.000
$F_{30\%IZO}$ (%) $F_{70\%IZO}$ (%)	35.718 –2.491	48.994 19.323	28	38.209	39.346	5.138	27	0.000
$F_{30\%IZO}$ (%) $F_{90\%IZO}$ (%)	35.718 –3.570	48.994 8.182	28	39.288	44.756	4.645	27	0.000
$F_{50\%IZO}$ (%) $F_{70\%IZO}$ (%)	2.825 –2.491	32.484 19.323	28	5.316	22.037	1.276	27	0.212
$F_{50\%IZO}$ (%) $F_{90\%IZO}$ (%)	2.825 –3.570	32.484 8.182	28	6.395	30.280	1.117	27	0.273
$F_{70\%IZO}$ (%) $F_{90\%IZO}$ (%)	–2.491 –3.570	19.323 8.182	28	1.078	18.319	0.311	27	0.757

The results from Table 1 expressed in Figure 1 show that the result distribution span for the higher level of force has a lower value, that is, the span is highest in the task requiring 50% of force. After that, it continually decreases and has the least level in the task requiring 90% of force (the error span is defined as the difference between the Min and Max values of the achieved force variable; in relation to the task requirements for $F_{30\%izo}$ which were 112.12 DaN, for $F_{50\%izo}$ counted 115.05 DaN, for $F_{70\%izo}$ valued 93.58 DaN and for $F_{90\%izo}$ counted 49.12 DaN). Mainly, the same phenomena has been established in regards to relative facts (for $F_{30\%izo}$ valued 164.27% for $F_{50\%izo}$ valued 116.16% for $F_{70\%izo}$ valued 78.59% and for $F_{90\%izo}$ valued 27.55%) (Figure 2).

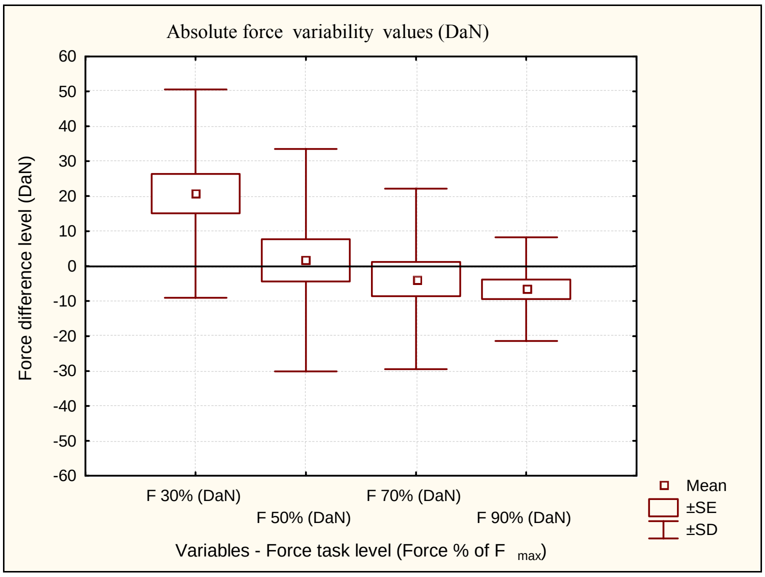

Fig. 1. Distribution range of force results differences (variation) in relation to the tests (in absolute force values)

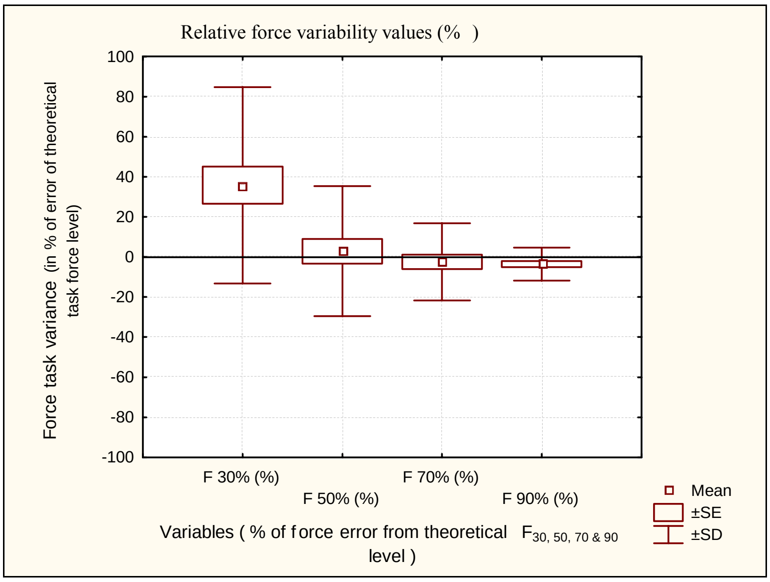

Fig. 2. Distribution range of force results differences (variation) in relation to the tests (in relative values i.e. percents of deviance)

Table 5 shows the Kandall's test results for the observed variables and the composed distribution. The results reflect that the error distribution, that is, the achieved deviation (variation) of value assigned to the level of force required by the task, differs in relation to the achieved level of force. That has also been confirmed from the absolute value aspect (values in DaN), Kandall's W = 0.311, $\chi^2 = 26.143$, and in the relative values (values in %) Kandall's W = 0.235, $\chi^2 = 19.757$, on the level of p = 0.000, respectively.

Table 5. Kandall′s W Test Results (Coefficient of Concordance)

	Absolute values F (N)	Relative values F (%)
Sample (N)	28	28
Kandall's W	0.311	0.235
Chi – Square	26.143	19.757
Df	3	3
p value	0.000	0.000

The data distribution difference results between the variable pairs revealed the existence of statistically significant errors (deviations) which were achieved by the participants in regards to the level of achieved force between $F_{30\%izo}$ (as the smallest measured level) and all the other levels ($F_{50\%izo}$, $F_{70\%izo}$ and $F_{90\%izo}$ as the middle, large and submaximum levels of force) such as $F_{30\%izo}$ vs $F_{90\%\ izo}$ p = 0.000). Between the achieved error $F_{50\%izo}$, $F_{70\%\ IZO}$ and $F_{90\%izo}$ (as the middle, large and submaximum level of force) a statistically significant difference has not been confirmed ($F_{50\%izo}$, vs $F_{70\%izo}$ p = 0.122; $F_{50\%izo}$ vs $F_{90\%izo}$ p = 0.127; F_{70izo} vs $F_{90\%izo}$ p = 0.295). Identical results have been confirmed and in regards to the relative values (in %), which are shown in Table 6.

Table 6. Results of Wilcoxon′s signed ranks test

	$F_{30\%izo}$ vs $F_{50\%izo}$	$F_{30\%izo}$ vs $F_{70\%izo}$	$F_{30\%izo}$ vs $F_{90\%izo}$	$F_{50\%izo}$ vs $F_{70\%izo}$	$F_{50\%izo}$ vs $F_{90\%izo}$	$F_{70\%izo}$ vs $F_{90\%izo}$
Z (absolute values)	2.755	3.826	4.053	1.548	1.526	1.047
Asymp. Sig. (p)	0.006	0.000	0.000	0.122	0.127	0.295
Z (relative values)	3.507	3.780	3.643	1.344	1.025	0.751
Asymp. Sig. (p)	0.000	0.000	0.000	0.179	0.305	0.452

4. Discussion

In summary, the results of this empirical study suggest that the methodology and its system and measurements allow the measurement and comparison of the observed control parameters of the level of muscle force required by the task. As the mechanism of neuro-adaptation and the controlled achievement of the necessary level of force is, in a way, not clear enough, this empirical study represents an attempt at a better understanding of the offered mechanisms, during different mobility programs, within training and competitions.

This work studies the arm extensor muscle in regards to the control of variability of force, according to the requirements of the task, during isometric contractions achieved by the implementation of the flat bench press test, by means of the level of achieved force ($F_{30\%izo}$, $F_{50\%izo}$, $F_{70\%izo}$, and $F_{90\%izo}$) and in relation to the achieved percentage. It suggests that the control necessary to achieve the required level was achieved in the following way: in creating the task level of $F_{30\%izo,}$ a higher level of force than the theoretical one has been achieved.

In practice, that means that the ability of fine motor control, that is, controlled muscle force achievement, at the level of 30% of F_{max} for participants, was a motor task which they could not successfully realize. It may be concluded that the control system, the CNS, engaged in the achievement of force control made an important error, which had low achievement force values as a result of inadequate mobility experience from the aspect of the coordinated contractile tested muscle group characteristics, or the coefficient level of inter-muscular control of the created force on a low level of force achievement. This study only treats the variability of the exterior force. Although the activities of the mobility units in recent experiments (Moritani & Muro 1987; Sale, 1992; Guyton & Hall, 1999; Linnamo et al., 2002; Milošević et al., 2004; Jones et al., 2004), emphasized the variability of force during isometric contractions from the low and slow ones up to the higher and faster ones, muscles within each muscle unit make contractions at the same time (Zatsiorsky, 1995; Guyton & Hall, 1999). Motor units may be included as part of asynchronic (successive) and synchronic (consecutive) different impulse numbers. In each muscle, they differ according to the reflection level and the level of force that can be achieved. Considering these categories, motor units can be grouped into four characteristic groups, starting from the group of a low excitation level and the lowest level of force up to the group of a high excitation level and the greatest level of force (Jones et al., 2004; Milošević et al., 2004; Winter, 1990). The motor units of one group have a reflection level after which they start to produce force, and a level after which they do not react by making a higher level of force, no matter how many impulses they receive. So, each group is limited by the level of force that is possible, no matter how many impulses they receive.

The excitation level of each group moves from 5 to 20Hz, after that from 20 to 30 Hz, from 30 to 65 Hz and at lastly from 65 to 100 Hz in a second (Sale, 1992; Guyton & Hall, 1999; Milošević, 2002). Having in mind the reflection level, we see that they can achieve an average level of force moving from 1 to 105 daN. The created level of force is higher if a larger number of motor units of different characteristics are engaged in each muscle, and the created force is higher, in a time unit. Research done on the results of top (elite) athletes (Milosevic, 2002), showed that the average level of produced force differs between groups of motor units of one athlete, but also differs within one group among different athletes. An increase in the force of different motor unit groups increases the created muscle force. The largest force increase in a second is found in the interval of 18% up to 32% of the maximum created level of force F_{maxIZO} (Zatsiorsky, 1995; Milošević, 2002).

In the present experiment, the increase of isometric force at the level of 30% of F_{max}, arises, mostly, from recruiting a higher number of small motor units from the necessary ones (Milošević, 2002; Christou et al., 2002). As a result of it, possible differences in the created level of force in relation to the achieved percentage of F_{maxIZO} may be bound to differences in the stimulation of motor units. We suppose that this is a matter of control adaptiveness (Hakkinen & Komi, 1986; Guyton & Hall, 1999; Christou et al., 2002). For example, if the movement is not elaborated correctly, the brain makes a correction and in the next attempt sends a correct signal. This means that the changed force level brings about, according to a formula, changes to motor unit engagement, with the abilities of the CNS to anticipate in making its choice of a correct formula for motor unit engagement, for the required level of force. The sensor-motor neuron connection plays an important role in motor unit connections, which can considerably modify the number and speed of the engaged motor units, as well as the frequency of those centrally planned (Sale, 1992). This should be a matter for investigation in the near future, using the suggested methodology and EMG surface.

As in the cases of the $F_{30\%izo}$ level, the $F_{50\%izo}$ level created a stronger force level (50% of F_{max}). But, compared to the 30%, this achievement encompassed a number of participants who achieved a lower force than the theoretical one, as well as those who created a greater force than the theoretical one. The average error is, therefore, low but the normal variation is high. A similar result was achieved by Milošević et al. (2004) while researching the control of force created in the functioning of the muscle contraction intensity, where a number of participants overcame the set force level, so the error percentage was low, and yet the variability was high. Also, similar results were found in a study of the control of force created during the functioning of different muscle groups (Milosevic et al., 2004). The tested muscle groups developed greater forces than the required task level of 50%, in the range from 2% (leg extensors muscles) up to 14% (right hand grip). We may conclude that the ability of precise and controlled muscle force creation at the level of 50% of F_{max} was, for the tested population, such a motoric task that the group created was not very homogenized, because the errors of all of the individuals were quite different and recognizable.

In achieving the level of 70% and 90%, the participants created a lower force (failed) than the assigned one, which means that even this control of muscle contraction intensity at a higher level of force (70% and 90% of F_{max}) was a difficult motor task, as the errors, on the whole were very high. But the result distribution range, within the higher level of force, has a lower value in relation to the other levels of controlled force development.

That really means that the participants who had values higher ($F_{70\%izo}$ and $F_{90\%izo}$) than the assigned force, made fewer errors, and were nearer to the theoretically assigned level of force (70% and 90% of F_{max}). Milošević et al. (2004), affirmed a similar result in the research on the control of force created by muscle contraction intensity, and they concluded that the force created by the muscle contraction intensity developed a lower force than the assigned level, in cases of 70% and 90% of F_{max}, in a range from 1.2% (right hand grip) up to 6.3 % (leg extensors).

The experimental study results recognized a variation between the assigned level of force (% of Fmax) and the achieved level of force of physically healthy people as part of an untrained male population. Furthermore, the acquired results revealed that the control models for the force created by muscle contraction (30%, 50%, 70% and 90% of F_{max}) and the created level of force ($F_{30\%izo}$, $F_{50\% izo}$, $F_{70\%izo}$ and $F_{90\%izo}$) differ, along with the existence of variability difference (errors) between the level of $F_{30\%izo}$ (low level of force) and the rest of the tested assigned levels of force ($F_{50\%izo}$, $F_{70\%izo}$ and $F_{90\%izoO,}$ that is, medium, high and submaximum). At a force of lower level, our participants created a level of force lower than the assigned one, while in the cases of a greater level of force, the participants were more precise, and made fewer errors.

5. Conclusion

The present findings support deviation existence or the variability of the control of force created by the muscle contraction intensity in relation to the isometric contractions of the arm extensors' level of force. The members of the tested sample of healthy untrained male individuals made mistakes at the level of $F_{30\% izo}$ as the smallest measured level of force (20.74 ± 29.84 DaN absolutely, and 35.2 ± 48.99% relatively) and $F_{50\%izo}$ as the middle level of measured force (1.67 ± 31.81 DaN absolutely, and 2.83 ± 32.48 relatively) creating a greater force, at the level of $F_{70\%izo}$, as the greater level of measured force (- 3.68 ± 25.85 DaN, absolutely and – 2.49 ± 19.32% relatively), and $F_{90\%izo}$, as the submaximum level of measured force (-6.60 ± 14.80 DaN, absolutely, and – 3.57 ± 8.18% relatively). The participants made errors by creating a lesser force than the required one. That supports the findings that the ability of fine motor control at the level 30% of F_{max}, the participants in the motor task were not able to realize successfully, while in the cases of a greater level of force, the participants were more precise, and made fewer errors.

The research results are important from the standpoint of sports training, and mostly for understanding neuro-motor adaptation during muscle force training.

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VARIJABILITET KONTROLE ISPOLJAVANJA ZADATOG NIVOA SILE MIŠIĆA OPRUŽAČA RUKU U IZOMETRIJSKOM REŽIMU RADA KOD NETRENIRANIH OSOBA MUŠKOG POLA

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Istraživanje je obavljeno sa ciljem da se proceni varijabilitet kontrole realizacije ostvarenog nivoa mišićne sile kod mišića opružača ruku u funkciji zadatkom zadatog. Eksperimentom je bilo obuhvaćeno testiranje mišića opružača ruku primenom testa ravni bendž-pres u izometrijskim uslovima naprezanja, a realizovano je nad uzorkom sastavljenom od 28 ispitanika, studenata Više škole unutrašnjih poslova u Zemunu – Beograd. Ispitanici su tokom eksperimentalnog testiranja ostvarili po 5 pojedinačna testovna pokušaja, pri čemu je pri prvom pokušaju merena maksimalna mišićnu sila (F_{maxIZO}) a u preostala četiri ostvarena sila u odnosu na zadati procenat od maksimalne sile F_{max} na nivou od 30%, 50%, 70% i 90%. Testiranje je izvršeno pomoću hardversko-softverskog sistema koji se koristi u Dijagnostičko prognostičkoj laboratoriji (DPL) za Specijalno fizičko obrazovanje u Višoj školi unutrašnjih poslova u Beogradu. Razlika varijabiliteta između posmatranih varijabli utvrđena je primenom analize varijanse – ANOVA, Kendalovog i Vilkoksonovog testa. Za utvrđivanje postojanja razlike između pojedinačnih varijabli korišćen je Studentov t test za parne uzorke. Rezultati ANOVE su pokazali da postoji statistički značajna razlika između srednjih vrednosti i varijablliteta kod posmatranih varijabli na nivou $F = 6.065$, $p = 0.001$, u odnosu na apsolutne vrednosti, i $F = 9.956$, $p = 0.000$, u odnosu na relativne vrednosti sile. Razultati Studentovog t-testa pokazali su da postoje statistički značajne razlike između srednje vrednosti grešaka ostvarene sile između nivoa od 30% (kao najnižeg testiranog nivoa sile) i svih ostalih nivoa (50%, 70% i 90%, kao srednjeg, velikog i submaksimalnog nivoa sile). Kendalov test pokazuju da se distribucije grešaka, tj. postignutih odstupanja nivoa sile od zadate vrednosti, razlikuju i sa aspekta apsolutnih i sa aspekta relativnih vrednosti (vrednosti izražene u %) na nivou $p = 0.000$. Generalno posmatrano, na osnovu rezultata se može zaključiti da u odnosu na kontrolu ispoljavanja mišićne sile u funkciji zadate zdrava i ne trenirana populacija muškaraca najviše greši u odnosu na mali nivo sile (nivo od 30% od F_{maxIZO}), dok su na nivoima od 50, 70 i 90% od F_{maxIZO} greške statistički značajno manje. To praktično znači da je sposobnost fine motorne kontrole tj. kontrolisanog ispoljavanja mišićne sile na nivou od 30% od F_{max} za ispitanike predstavljalo motorički zadatak koji oni nisu mogli uspešno, odnosno precizno da realizuju, dok su kod većih nivoa sile ispitanici bili precizniji tj. manje su grešili.

Ključne reči: *izometriska mišićna sila, motorna kontrola, ravni bendž-pres, kontrola ispoljavanja mišićne sile.*