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METRIC CHARACTERISTICS OF THE MOTOR TEST USED TO ESTIMATE THE FORCE OF THE ARMS AND SHOULDERS

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Abstract. *The aim of this paper is to point out to the deficiencies and inconsistencies of the test for estimating muscle force. The sample of participants consisted of over 1000 fourth-grade elementary school boys and school girls and 300 high school sophomores. In this paper the focus of our interest is one of the tests which is a part of the Eurofit battery test. In fact, it is a test named "Endurance in pull-ups" which estimates the force of the arms and shoulders. Analyses of the obtained results indicate that the test does not have the required sensitivity, to discriminate the global pattern weakly. High coefficient values of the skewness variation value with a characteristic of extremely positive curvature, indicate that the motor task is rather difficult for most ten-year-olds. An analysis of the way in which the test is carried out indicates this test is just a standard one (performing on the same, predetermined protocol), but not standardized (the same one in the units of work). The measured physical value is not expressed in newtons (N), which are provided by the international system of physical value and its units. The paper proposes a way in which the test should be modified in order to have the necessary metric characteristics. The interpretation of the results and then the conclusions in kinesiology research, would scientifically be valid only in such a way.*

Key words: *Eurofit battery tests, endurance in pull-ups, force, metric characteristics.*

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INTRODUCTION

The instruments of educational research should collect more precise data on the pedagogical phenomena as far as it is necessary for the measuring instrument to have appropriate metric characteristics. Latent dimensionality in the motor area can be estimated only by actual effects of different manifestations of kinesiology. However, this methodological approach is accompanied by numerous problems. A large number of studies point to the bad metric characteristic of the motor tests which are used for estimation in motor space.

Physical properties of force and strength are one of the most common topics of discussions. Numerous discussions have considered how to differentiate this segment of motor space and which methods and instruments are to be used to estimate these structures.

The research of Matić (1976), Višnjić & Marković (2006) indicates a significant influence of motivation, particularly the surroundings, and competitive factors which could affect the accuracy of measurement. The work of Madić (2006) shows that personality traits are a disrupting factor in estimating motor abilities, as in the case in the tests of static and repetitive power, carried out on a sample of preschool children.

The research of Bala & Krneta (2006) suggests that the results of performing some motor tests never show the same level of relevant skills with equal validity and reliability, so it is necessary to do the same task several times repeatedly, as long as it reduces the possibility of error.

The research of Šekeljić (2010) indicates the bad discrimination of tests for estimating the repetitive power of body.

Many researchers have been attracted by the relations that occur between body mass, force and power. Krsmanović (1982) finds a significant correlation between the test scores (the long jump and the high jump in the pull-up) for estimating the explosive power of the lower extremity stretching or static force of the arms and shoulders and the variables for estimating body volume and mass.

Matić (2006) determined the impact of the system of anthropometric variables with the motor tests for estimating explosive (the long jump) and repetitive strength (body lifting). Using the canonical correlation analysis, Kovač & Đorđić (1998) found that schoolchildren with larger body mass and less subcutaneous fatty tissue on their backs have extremely higher body power and endurance. Kukolj (2006) found similar results a few years later. Specifically, a positive relationship between body mass and the results on the tests for estimating force and power, and a negative correlation between subcutaneous fatty tissue and muscle force. Rodić (2004) was faced with the same conclusions finding a positive effect of body mass on explosiveness and a negative impact on force. With a sample of children aged 8-9, Suhomel (2005) stated significantly higher values of body mass, the body mass index and especially subcutaneous adipose tissue in the participants with low motor ability. Turek (2006) noted that in the whole period of junior high school age the basic somatic indicators gain the character of determinative factors crucially influencing the level of actual movement ability.

Pertinent relations between force and power and body mass and the speed of muscle shortening were determined (Perić, 2003). As the muscle shortens more quickly, the developed muscular force is smaller. In isometric muscle tensions, when there is no change in the muscle length along with sufficient external impedance, the highest value of muscle force can be achieved. Studies (Baker, Wilson, G., & Carlyon, 1994; Enoka 1994;

Jarić & Kukolj, 1996) show that the size of force produced by a muscle under laboratory conditions primarily depends on the size of its physiological cross-section, thus in the attained force (unlike power) per cm^2 there are no significant differences between the sexes, not depending on the state of fitness or type of sport activity the participant is involved in.

Jarić (2002) finds some relationships between power and muscle force, but they are neglected or misinterpreted in testing. Inappropriate and different methods and tests are used in measurement making it difficult to compare data. During data processing, body mass is not taken into account, thus the score of muscle power is usually wrong.

The aim of this paper is to point out to the deficiencies and inconsistencies of the test for estimating muscle force. Starting from the basic criteria for the classification of scientific research, this paper can be classified as an experimental and theoretical observation in the area of motor abilities. The subject of interest is the "Endurance in pull-ups" test which measures the force of the arms and shoulders. This paper analyzes the data of three independent doctoral dissertations wherein the "Endurance in pull-ups" test is used.

THE METHOD

The sample of participants

The study included more than 1000 fourth-grade elementary schoolboys and schoolgirls and 300 male and female high school sophomore students.

Variables

The muscle force of the arms and shoulders was estimated based on the period of time expressed in seconds for the length of time the participant needs to complete the motor task "Endurance in pull-ups".

Procedures

The muscle force of the arms and shoulders was measured by isometric tension using a standardized test of the Eurofit battery tests called "Endurance in pull-ups".

Instruments: shaft, stopwatch with 1/10 s.

Task: The participant hangs as long as he/she can in the pull-up so the chin is at the level of the shaft bar.

Rating: The time of 1/10 s is measured during which the participant maintains the described position; the stopwatch stops when the chin is lowered below the upper bar edge.

Note: The assistant timing the pull-up stands on the chair so that his face is at the level of the crossbar. All the time he has to encourage the participant to maintain the described position as long as possible. The participant comes back to the initial position with the help of someone.

Statistical data processing

All the data obtained in the research are processed by standard methods of descriptive statistics. In the initial and final measurement, respectively, arithmetic means (X), standard deviation (SD), minimum and maximum values (Min and Max), the coefficient of variation (KV%) and Kolmogorov-Smirnoff test for estimating the frequency distribution were calculated for each variable.

RESULTS WITH DISCUSSION

During the data collection, statistical processing and analysis, some deficiencies were observed at all stages of the research. To make the discussion easier, the observed weaknesses are systematized in several subheadings in this chapter.

The test does not have enough sensitivity

The descriptive results in Table 1. indicate some schoolgirls and schoolboys achieved the measuring result of 0 second on the test. For them the test was too hard, so it could not estimate the isometric force of the arms and shoulders. Out of 164 girls, 20 of them failed to start the test (representing 12,2% of the tested sample). Out of 147 boys, only 9 of them failed to start the test (which is 6,1%). This data refers to the lack of sensitivity of the instrument, because it could not measure any value for a significant number of the participants despite the fact they certainly have some values of muscle force in the arms and shoulders.

Table 1. Categorial review of the results achieved by the participants in the research of Šekeljić (2008). The first line shows the time intervals in seconds (up to 5,5-10 s, 10-20 s, 30-40 s, etc.). The second and third lines show the number of (and percentage %) girls and boys who achieved the results in the above categories.

Time (s)	0		5		10		20		30		40		50		60		60+	
Girls	20	12%	38	23%	42	26%	37	23%	12	7%	2	1%	1	0.6%	2	1%	0	0%
Boys	9	6%	21	14%	19	13%	40	27%	20	14%	12	8%	9	6%	2	1%	5	3%

Which segment of muscular endurance is measured by this test?

Endurance exists as a separate factor in motor space, but it is difficult to determine it uniquely since it is present in some other motor abilities (speed, force or power), and together with them builds composite physical properties such as speed endurance, endurance in power and force, lactate endurance, alactate endurance, aerobic stamina, etc.

Endurance (stamina) is often considered as the ability of a body to keep the given intensity of some activity over a longer period of time. However, we can talk about endurance even with short-term highly intensive loads lasting only a few seconds. Regarding intensity zone, 4 zones are usually defined: (1) the zone of maximum intensity, (2) the zone of submaximal intensity, (3) the zone of high intensity, (4) the zone of moderate intensity. This means that there are a variety of endurance options depending on intensity, and therefore the duration of the activity (Perić, 2003).

From Table 1 it is obvious that 35% of boys and 25% of girls were not able to perform this motor task for more than 5 seconds. For them, such a task is a load of maximum intensity, and it could be said that in this case the alactate component of anaerobic endurance was estimated. Most of the participants (54% of boys and 56% of girls) accomplished this motor task during 10-30s. For them, this load was within the limits of submaximum intensity when lactic components of anaerobic endurance are significantly involved. For the participants who were able to maintain the position longer than a minute, this load was moderately intense (at least until the end of the test), while performing in predominantly aerobic conditions. It is not difficult to conclude that this test measures the different aspects of endurance in various types of participants, depending on the force they possess.

If these results are compared with the 400m race, the following analysis could be made. Regarding the well-trained athletes who can run this distance in 1min or less, this motor task could be used to estimate anaerobic capacity. In the case of individuals living a predominantly sedentary lifestyle, but who can cross this distance in a few minutes, this test would estimate mostly their aerobic ability.

It is obvious that the different aspects of endurance are measured in participants with different levels of force. Hence, it is not scientifically correct to compare the results not belonging to the same segment of motor space in kinesiology research.

Insufficient discrimination of the test

Based on the results shown in Tables 2 and 3, representing the central and dispersive parameters of the motor variables used to estimate muscle force, and by the analysis of the variation coefficient, great exceptions from the mean values in the test of endurance in the pull-up can be observed. Once more, this confirms our observations that this kind of test is too difficult for many participants of both sexes.

Table 2. Central and dispersion parameters of the test results: standing on one leg on the bench (KL) and standing on one leg eyes closed (flamingo) (FL), girls (F) and boys (M) of the first, second and third experimental group at the initial (i) and final (f) measurement.

Init.	X	Sd	err	Min	Max	KV%	Interv.	pov.	Skew	Kurt	p
E1F	10.9	10.4	1.3	.00	50. 3	95.4	8.2	13.6	1.63	3.67	.999
E2F	7.6	7.1	1.1	.80	27.4	92.8	5.4	9.8	1.5	1.1	.030
E3F	12.1	9.9	1.2	.00	54.7	82.0	9.6	14.6	1.76	4.0	.072
E1M	18.6	16.3	2.2	.00	70.0	87.5	14.1	23.1	1.45	2.05	.322
E2M	12.6	11.4	2.15	1.00	49.0	90.3	8.2	17.0	1.62	2.2	.750
E3M	22.0	18.5	2.6	.00	80.2	84.0	16.8	27.2	1.13	.81	.346
Fin.	X	Sd	err	Min	Max	KV%	interv.	pov.	Skew	Kurt	p
E1F	12.2	11.9	1.5	. 00	58.4	97.0	9.2	15.3	1.76	3.83	.931
E2F	9.8	7.3	1.1	1.0	30.0	75.1	7.5	12.0	1.06	. 773	.028
E3F	9.8	7.1	.88	.00	34.0	72.0	8. 06	11.6	1.44	1.83	.239
E1M	19.8	17.0	2.3	1.0	66.8	85.9	15.1	24.4	1.09	.28	.255
E2M	15.6	13.8	2.6	2.0	53.0	88.3	10.2	20.9	1.32	1.05	.873
E3M	21.4	18.0	2.5	.00	76.2	84.1	16.3	26.5	1.07	.49	.074

Table. 3. Central and dispersion parameters of the test results of the research by Sturza-Milić (2009) realized on the sample of the fourth-grade elementary schoolboys and schoolgirls: Endurance in pull-ups - boys (ZGIBB) and girls (ZGIBG).

variable	min	max	mean	std	kv %	skew.	kur.	kol. smir.
zgibb	0.00	68.0	18.447	15.370	18.35	1.302	.985	2.374
zgibg	0.00	83.0	11.145	10.939	98.11	2.615	9.682	2.908

Namely, high positive values of the skewness in all the groups show that the values are close to an extremely positive asymmetry. In the sample the test is too difficult for a significant number of the participants, thus dominating in the low values. A high value of kurtosis marks a large number of the accumulated results indicating the bad discrimination of the test not adapted to this age group.

The analysis of the standard deviations (Std) values indicates a greater dispersion of the results than were mathematically expectated. The variation coefficient of these motor variables ranges up to 97%, leading to the conclusion that the test does not have a satisfying discrimination and homogeneity. The values of the Kolmogorov-Smirnoff test indicate that the value distribution often varies from the normal distribution as in the case of the second experimental (E2Ž) group of the girls at the initial (p=0,30) and final measurement (p=0,28). Thus, the test results in the statistical analysis must be considered with an increased level of risk, while in some cases such data must even be discarded.

Slightly more moderate results in terms of the descriptive parameters of the central and dispersion tendency can be found in the research results of Marković (2009), carried out on a sample of first and second year high school students. In this study, large ranges are observed – a high coefficient of variation (KV-98%), and the Endurance in pull-ups test has the greatest deviation from the mean values reflected in the standard deviation of 275,12.

The test is deeply influenced by motivation

It often happens that the results of this test are worse at the final measuring than they are in the initial one. Sometimes, with no reason some participants refuse to participate in the test without explanation. Marković (2009) explains it as a lack of motivation which, in his opinion, determines the duration of the motor task in this test. During the measurement we observed that a large number of the participants felt severe pain in the m. biceps brachi after the test. The pain lasted for days getting stronger in flexion and extension of the elbow joint. To avoid the unpleasant pain in the following test (final), they consciously give up much earlier.

Measurement units are not adequate to the measuring quantities

The test results are not presented by appropriate measurement units. In this test, the force of the arms and shoulders are estimated, while the results are expressed in seconds (s). The second is a measurement unit for time, but in the international system measurement unit for force is newton (N). Therefore, it is reasonable to ask why the measurement units in kinesiology research are not consistent with the measured quantities as recommended by international standards.

The test standardization

Because of the way the motor task is performed and the method used to estimate the endurance of the flexor muscle of the elbow joint, it can be said this is just a standard test (performed in the same way, exactly determined by protocol), but not standardized (the same in the units of work). The test is standardized if external (mechanical) work for all the participants is the same, as is not the case in this test. External work, according to the basic law of mechanics, largely depends on body mass. Therefore, for the participants of different body masses the performed mechanical work is different.

According to Newton's second law, force equals mass times acceleration ($F = m \cdot a$). In the international system of measurement units, the unit of force is newton. Newton is defined as the amount of force required to accelerate the mass of one kilo by one meter per second squared ($1N = kgm/s^2$). But newton is also the unit of weight. The Earth attracts all the bodies towards its center, through gravity. Therefore, all the bodies press the surface they lean on. If a man wants to keep the high position on the shaft, as in our case, he must engage some muscle force. The total pressure of the body on the horizontal surface on which it stands or the steering of the gravity force acts on the body while hanging is called body weight. On the surface of the Earth the result of the gravity force effect on the body is constant and it is $9{,}81m/s^2$, often amounting to $10m/s^2$. Body weight (Q) is proportional to body mass and gravity force ($Q = m \cdot g$), thus the body of 1kg mass has the weight of about 10N. During free fall the body mass accelerates under the effect of gravity. Therefore, if in the unit for force ($F = m \cdot a$) instead of acceleration "a" we put the value of gravitational acceleration "g", the value obtained for force F is called weight.

Hence, the body weight (Q) would be equal to the mass (m) multiplied by gravity force (g). If the body does not move, the active force equals to inertial, with the same course but the opposite direction, so the sum of these two forces is zero. Therefore it can be said that the body produces the active force sufficient for the body to resist acceleration gained under the action of gravity (inertial) force. In our example, the body acts with muscle force (expressed in newtons) for maintaining a high position in the pull-up (it prevents the body from falling on the ground), with the force necessary to annul the effect of gravity on the body. Since the mass and weight are of a proportional size, it is clear that the force for keeping the position high on the shaft must be greater if the body mass is larger.

When someone with a mass of 50kg maintains the position high in the pull-up, it means the force of 500N has to be engaged each second. However, to keep in the position in the period of 10s the force of 5000Ns (newtonsecond) is required. If we compare two participants with different masses (50 and 100kg) to maintain the position for 10s, it can be calculated that the first one needs a force of 5000Ns ($50kg \cdot 9{,}81m/s^2 \cdot 10s$), and the second one needs 10000Ns ($100kg \cdot 9{,}81m/s^2 \cdot 10s$). This example points to the conclusion that the participants with different body masses need different muscle forces to fulfill the same motor task.

Recommendation for a new method of testing

Analyzing the conditions under which the test is carried out, based on the research results and on the knowledge of the basic laws of physics, it is possible to modify the current test and standardize it, thereby obtaining better information on muscle force. A new method of testing could be carried out as follows:

- To perform the motor task on the lat machine while sitting. Using the weights on the lat machine, it would be possible to make accurate load dosing in accordance with the individual abilities of each participant,
- To express the values by SI system in the units provided (N) and newton-second (Ns),
- To express the parameters of endurance in force as the relative values in newton-seconds per kg of the body mass (Ns-kg).

The study limitations

The limitations of this study come from the partly experimental character, while the conclusions are drawn by logical insight in the relations between the data and the laws of classical physics. Therefore, the conclusions based on the descriptive-causal method are needed to verify experimentally with the appropriate number of participants of different profiles, ages, with different physical characteristics, abilities and level of training, as well as in relation to the presence of certain motor disorders.

The obtained results can be used for further research in the field of anthropometry, sports, medical rehabilitation, special education and rehabilitation, professional training and professional retraining.

CONCLUSION

Reviewing the results of the studies carried out on a sample of 10-year-old boys and girls, it can be seen that the test for estimating static force of the arms and shoulders – high position in the pull-up:

- is unreliable and heavy,
- is under extreme influence of motivation,
- does not have sufficient sensitivity, thus the measured ability could not be estimated for some of the participants on the basis of the test,
- does not have satisfying discrimination and homogeneity, thus the results often deviate from the normal distribution and they are not reliable in further statistical analysis,
- is not standardized,
- the values of the test are not in agreement with the measurement units recommended by the International System of Measurement Units.

There is, in this paper, a recommendation on how the test should be performed, so that they could fulfill the accurate estimation of the muscular force of the arms and shoulders.

The significance of this study is reflected in the fact that the current test, as a part of the Eurofit battery for estimating motor abilities, does not have the required metric characteristics and cannot collect accurate data. Thus validity of the research results is questionable. Also, this paper offers new solutions that would enable obtaining better information in the motor space.

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METRIJSKE KARAKTERISTIKE MOTORIČKOG TESTA ZA PROCENU SILE RUKU I RAMENOG POJASA

Goran Šekeljić, Milovan Stamatović, Živorad Marković, Jovan Marković

Cilj rada je da se ukaže na nedostatke i nedoslednosti testa za procenu snage mišića. Uzorak ispitanika sačinjavalo je preko 1000 učenika i učenica četvrtih razreda osnovne škole i 300 učenika II razreda srednje škole.Predmet našeg interesovanja u ovom radu jeste jedan od testova koji su deo Eurofit baterije testova. Naime, radi se o testu Izdržaj u zgibu kojim se procenjuje sila ruku i ramenog pojasa. Analize dobijenih rezultata ukazuju da test ne poseduje potrebnu osetljivost, da slabo diskriminiše globalni uzorak. Visoke vrednosti koeficijenta varijacije vrednosti skjunisa sa karakteristikom izrazito pozitivne zakrivljenosti, ukazuje da je motorički zadatak težak za većinu desetogodišnjaka. Analiza načina na koji se test realizuje ukazuje da je ovaj test samo standardan (izvodi se na isti, protokolom tačno utvrđen način), ali ne i standardizovan (isti u jedinicama rada). Merena fizička veličina se ne izražava u mernim jedinicama njutnima (N) koje su predviđene međunarodnim sisitemom fizičkih veličina i njihovih jedinica. U radu se preporučuje način na koji bi test trebalo modifikovati, kako bi imao neophodne metrijske karakteristike. Tek u tom slučaju bi se interpretacija rezultata, a samim tim i zaključci u kineziološkim istraživanjima, učinili naučno valjanim.

Ključne reči: *eurofit baterija testova, izdržaj u zgibu, sila, metrijske karakteristike.*