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# RELIABILITY AND VALIDITY OF BASIC KINEMATICS AND MECHANICAL CHARACTERISTICS OF PULLING FORCE IN SWIMMERS MEASURED BY THE METHOD OF TETHERED SWIMMING WITH MAXIMUM INTENSITY OF 60 SECONDS

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**Abstract**. *The subject of this paper is to define a reliability of the test for the estimation of basic kinematics and mechanical characteristics of pulling force in swimmers measured by the method of tethered swimming with maximum intensity of 60 seconds. The sample was composed of 10 categorized senior age swimmers. All swimmers were specialists in sprint and middle distance crawl techniques (50, 100, 200 and 400m).Testing was administered by tensiometric probe with the hardware-software logistics support by test-retest method. Kinematics characteristics were given in two variables (AVG STROKE 60 TS Time – average stroke duration and AVG HZ 60 TS – realized stroke frequency) while pulling force characteristics were given in five variables (AVG F max 60 TS – average of maximum pulling force (peaks) of individual strokes, AVG F min 60 TS – average of minimal pulling force of the individual strokes, AVG F 60 TS – average of pulling force of the individual strokes, AVG Imp F 60 TS – average of impulses of pulling force of the individual strokes and AVG RFD 60 TS – average rate of force development of the pulling force in individual strokes. On the basis of the obtained results we can conclude that the given estimation method is generally valid on the level of Crombach's alpha = 0.8694, is generally reliable on the level of Spearman-Brown's rtt = 0.9722 (97.22%) and is generally factor valid on the*

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*level of 0.929 to 0.938 (92.8 to 93.8%) so it can be recommended for further use in sports practice. In respect to the observed partial indicators i.e. individual variables it was found out that the variables AVG RFD 60 TS , AVG Stroke 60 TS Time, AVG HZ 60 TS, AVG F max 60 TS, AFG F min 60 TS and AVG F 60 TS are statistically significant and valid in the range of 0.777 to 0.979 and reliable in the range of 0.782 to 0.979 respectively. The variable AVG Imp 60 TS in this research was not either sufficiently valid - 0.518 or reliable – 0.641. Since the general level of validity and reliability is very high and statistically significant we can assume that the insufficient level of partial validity and reliability of - AVG Imp F 60 TS variable is rather a consequence of relatively small sample (10 subjects) than the real measuring characteristics of the given variable.*

**Key words**: *tethered swimming, freestyle, reliability, validity, pulling force, anaerobic work*

## 1. INTRODUCTION

Measuring and evaluation of propulsive force characteristics realized by a swimmer is very difficult due to aquatic ambient of realization. Up to now researchers have developed numerous methods for the given evaluation, some of them indirect such as 3D or 2D biomechanical analyses (Schleihauf et al., 1983), and some direct ones such as the use of piezo gloves (Takagi, & Wilson, 1999), semi-tethered (Wirtz et al., 1999), tethered in still water (Yeater et al., 1981; Keskinen, 1993; Sidney et al., 1996; Hooper et al,. 1998; Dopsaj et al., 2001; Taylor et al., 2001) or in swimming flume pools (Vorontsov et al., 1982). Also considering hydrodynamics some methods measure given characteristics of force in genuine conditions of free or semi – tethered swimming (Vorontsov et al., 1982; Wirtz et al., 1999; Maglischo, 2003) while others take swimming as far as hydrodynamics is considered in less real conditions i.e. during fully tethered swimming (Yeater et al., 1981; Keskinen et al., 1995; Sidney et al., 1996; Hooper et al., 1998; Dopsaj, 2000; Taylor et al., 2001; Dopsaj et al., 2001). Each used method has its advantages and disadvantages (situational, i.e. competition adequate or inadequate conditions for measuring, bigger or smaller evaluation error), but in any case from the scientific and methodological point of view, or testing aspect it has to be result valid.

Modern testing of high-performance sportsmen requires tests to be not only reliable, objective, valid and technology-friendly but situational-specific as well (Wilson, & Murphy, 1996; Hopkins et al., 2001). Specific means by their structure in relation to load and motor task to copy or describe fully situational conditions of efforts and strains exerted during competition (Зациорски, 1982; Müller et al., 2000).

In high-performance swimmers testing methodology fully tethered swimming test has been in use for long (Бойчев, 1974, 69-73; Yeater et al., 1981; Vorontsov et al., 1982). However, in most cases swimmers were tested in time intervals of 5 to 10 s which in their physiological basis give loads realized only in alactic working regime (Gastin, 2001; Heck et al., 2003). In recent studies researchers have tried to define the quality of relation between swimming abilities and pulling force characteristics during fully tethered swimming in longer intervals of 20 to 60 s. (Keskinen, 1995; Dopsaj et al., 2001; Tayler et al., 2001). In that way the applied test was to simulate as much as possible taking into consideration physiological basis of strain and load the conditions pervading during competition (Maglisho, 2003). In tests where working load lasts up to 10s and where there is

dominant creatine phosphate anaerobic alactic energy potential of the body load and thus evaluate alactic power, in the above mentioned tests with loads of 20 to 60s exert dominant is glycolytical anaerobic lactic energy potential of the body and they evaluate primarily lactic capacity (Gastin et al., 2001; Heck et al., 2003; Maglisho, 2003).

Analysis of world swimming records in relation to the structure of swimming disciplines in the official program (Olympic Games, World and European Championships) shows that duration of current competition disciplines is 21.64s to 874.56s (14:34.56) for male swimmers and 24.13 to 952.10s (15:52.10) for female swimmers (50 to 1500m freestyle respectively) (www.fina.org). This indicates that competition load in swimmers taken from the aspect of dominant load of energy systems of body are realized in the range of anaerobic-lactic (glycolitical mechanism), aerobic-anaerobic (mixed) to the aerobic working load (Gastin et al., 2001; Maglisho, 2003). A fact that in more than 50% of disciplines during swimming a dominant load is on glycolytical energy system gives a theoretical basis for the assumption that swimming tests in the intervals where dominant load is on the same energy mechanism have greater situational value than tests with creatine phosphate energy mechanism.

On the basis of available literature (Keskinen et al., 1995; Dopsaj et al., 2001;Taylor et al., 2001) it can be claimed that the researchers have used the given tethered swimming method to test different working abilities in the intervals of 20, 30 and up to 60 seconds. From the methodological aspect tethered swimming method is validated only for the time intervals up to 10 seconds in high-performance swimmers (Keskinen, 1993; Dopsaj, 2000) i.e. for 30 seconds in swimmers aged 12 (Taylor et al., 2001). However, the application of the given method in time intervals longer than 30 seconds i.e. tethered swimming in anaerobic-lactic working regime was neither validated as a measuring instrument nor from the aspects of different kinematics technique parameters or pulling force characteristics (Зациорски, 1982).

Having in mind a principle of necessary test specificity in regard to the object of measuring, its validity as a measuring instrument (Зациорски, 1982; Wilson, & Murphy, 1996; Hopkins et al., 2001), and different pulling force characteristics measurable in tethered swimming (Dopsaj, 2000; Dopsaj et al., 2001) it was felt a need to validate tethered swimming test method in the time interval of the dominant energy regime during swimming in anaerobic-lactic zone, i.e. in glycolitic regime load (Gastin, 2001; Heck et al., 2003).

The subject of this paper is investigation of the reliability of the test of basic kinematics and mechanical characteristics of pulling force in swimmers measured by the method of tethered swimming with maximum intensity of 60seconds. The aim of the paper is to define general metrological characteristics of the given test as well as metrological characteristics of the basic kinematics parameters of the technique and mechanical parameters of the pulling force which can be estimated by use of the test and the measuring instrument. Thus a verification of the given method is to be done and the basic conditions for further research are to be provided in the testing of swimmers and other aquatic sports athletes (water polo and triathlon sports athletes) in specific conditions.

## 2. METHODS

### 2.1. The sample

The sample was comprised of 10 swimmers. Four swimmers were international category level and represented a national team of Serbia and Montenegro while six swimmers were national category level. All the swimmers were specialists in crawl swimming techniques in sprint and middle distances (50, 100, 200 and 400m). Basic descriptive characteristics of swimmers were: age = 23.7 ± 2.8 years; BH = 1.904 ± 0.008 m; BM = 86.53 ± 7.92kg; BMI = 24.17 ±1.41m2; competitive swimming experience = 11.0 ± 3.3 years; season best time on 100m free (long pool) = 56.35 ± 2.41 s.

### 2.2. Testing

Testing was performed in the indoor pool of the sports center "Banjica" – Belgrade by means of tensiometric probe and hardware-software support of the Pro-Ing company, Belgrade.(Dopsaj et al., 1999; Dopsaj et al., 2000; Dopsaj et al., 2001). Tethered swimming method was applied with the above mentioned equipment and procedure (Dopsaj, 2000; Dopsaj et al., 2001). After individual warm-up in the pool in the 15min interval all subjects had two trials with tethered swimming crawl technique of medium intensity, the first trial lasting 15s and the second about 60s. In that way all subjects were familiarized with the equipment, measuring procedure and testing conditions. After 15 minutes pause the first test was administered in the following way: a subject starts medium intensity swimming and on whistle sign after 2-3 single strokes follows maximum intensity tethered swimming. Immediately after whistle sign for the single right hand stroke computer assistant initiates probe data activation. On agreement with subjects each 15s a whistle sign is given for the sake of better time orientation during testing. After 60s software program stops data activation automatically and these are then stored in separate data bases. At the same time after 60s a subject is given a sign for test stop. During testing each subject continues the same breathing pattern, i.e. identical to the one used during free swimming. After first testing each subject had an active 10 minutes recovery time with easy continuous 300-400m swimming. After that subjects had the same time for passive recovery. Second testing was administered after a described break at the same procedure.

Thus reliability of basic characteristics of pulling force in swimmers was estimated by use of test – retest method. (Зациорски, 1982).

### 2.3. Variable samples

In this research for the estimation of the reliability of basic kinematics and pulling force characteristics in tethered swimming 7 variables were used (Keskinen et al., 1993; Dopsaj, 2000; Dopsaj et al, 2001):

- kinematics indicators of crawl technique during 60s maximum intensity of fully tethered swimming – (TS60)

1. ${}_{AVG}Stroke^{60}{}_{TSTime}$ -average single stroke time, given in ms,
2. ${}_{AVG}Hz^{60}{}_{TS}$ - realized stroke frequency, given in Hz.

- mechanical characteristics of pulling force by free style during 60s maximum intensity of fully tethered swimming

1. $_{AVG}F_{max}{}^{60}{}_{TS}$ -average of maximum pulling force (peaks) for single strokes, given in N,
2. $_{AVG}F_{min}{}^{60}{}_{TS}$ - average of minimum pulling force for single strokes, given in N,
3. $_{AVG}F^{60}{}_{TS}$ -average of pulling force for single strokes, given in N,
4. $_{AVG}F^{60}{}_{TS}$ -average of pulling force impulse values for single strokes, given in Ns,
5. $_{AVG}RFD^{60}{}_{TS}$ -rate of force development for single strokes, given in N/s.

### 2.4 Statistics

Raw results were processed by use of descriptive statistical analysis in order to calculate basic descriptive statistical values (MEAN - mean value, SD – standard deviation, sX% - standard arithmetic mean error, Min - minimal variable value, Max – maximum variable value, cV% - variable coefficient of variation). For regular distribution of results a Colmogorov-Smirnov test was used (K-S).

A check on the difference between the values of the observed test and retest variables (Test I and II) was done by use of the paired samples Student's test. General statistical validity of results for the observed variables from the aspect of multivariate analysis as well as inter-item correlation was performed by use of Bartlett's Test of Sphericity.

Possible general differences between overall test variability of the Test I and II was defined by use of Multivariate Exploratory Technique and Wilks' Lambda whereas possible general correlation was estimated by use of Canonical correlation – Canonical R.

Reliability of the applied test as a measuring instrument was defined by multivariate method for Structural equation modeling, and by use of General validity analysis in Krombach's alpha, reliability was assessed by Spearman-Brown rtt and by factor analysis through communalities extracted on the first characteristic (initial) eigenvalues (H2) (Hair et al., 1998).

Statistical analysis was performed through software packages SPSS for Windows (release 7.5.1- Standard Version, Copyright © SPSS Inc., 1989-1996) and Statistica 6.0 (Copyright © StatSoft, Inc. 1984-2001).

## 3. RESULTS

Table 1 contains basic descriptive statistics results. Results of the coefficient of variation (cV%) as a measure of descriptive homogeneity of raw results are ranging from 4.08% for $_{AVG}Hz^{60}{}_{TS}$ to 35.27% for $_{AVG}F_{min}{}^{60}{}_{TS}$. Results of standard error for the arithmetic mean (sX%) as a measure of descriptive objectivity of the raw results are ranging from 1.29% for $_{AVG}Hz^{60}{}_{TS}$ to 11.15% for $_{AVG}F_{min}{}^{60}{}_{TS}$.

Results of Kolmogorov-Smirnov Z ratio show that the distribution of used variables does not differ from the model of hypothetically normal on the level of p values from 0.230 for $_{AVG}F_{max}{}^{60}{}_{TS}$ to 0.995 for $_{AVG}ImpF^{60}{}_{TS}$ (Table 1). On the basis of the results of descriptive homogeneity and objectivity of raw data and the results of the regularity of all variables distribution we can assert that the results are valid for further statistical processing. Thus the conditions for further use of parametric statistics in successive statistical processing are provided (Hair et al., 1998).

Table 1. Basic descriptive statistics

| Variables | Test | MEAN | SD | sX% | Min | Max | cV% | K-S Z ratio | K-S p value |
|---|---|---|---|---|---|---|---|---|---|
| $_{AVG}Stroke^{60}{}_{TSTime}$ | 1 | 775.47 | 37.02 | 1.51 | 700.28 | 817.23 | 4.77 | 0.479 | 0.976 |
| (ms) | 2 | 771.05 | 37.71 | 1.55 | 706.28 | 817.61 | 4.89 | 0.689 | 0.729 |
| $_{AVG}Hz^{60}{}_{TS}$ | 1 | 76.33 | 3.94 | 1.63 | 72.46 | 84.82 | 5.16 | 0.470 | 0.980 |
| (N/min) | 2 | 76.66 | 3.13 | 1.29 | 72.35 | 81.18 | 4.08 | 0.748 | 0.631 |
| $_{AVG}F_{max}{}^{60}{}_{TS}$ | 1 | 185.51 | 27.28 | 4.65 | 144.95 | 224.91 | 14.71 | 0.452 | 0.987 |
| (N) | 2 | 182.76 | 16.01 | 2.77 | 148.35 | 201.31 | 8.76 | 1.040 | 0.230 |
| $_{AVG}F_{min}{}^{60}{}_{TS}$ | 1 | 26.53 | 7.82 | 9.32 | 17.79 | 37.64 | 29.48 | 0.533 | 0.939 |
| (N) | 2 | 26.86 | 9.47 | 11.15 | 12.32 | 28.46 | 35.27 | 0.469 | 0.980 |
| $_{AVG}F^{60}{}_{TS}$ | 1 | 95.63 | 16.98 | 5.62 | 74.61 | 121.42 | 17.76 | 0.494 | 0.968 |
| (N) | 2 | 97.32 | 13.65 | 4.43 | 78.92 | 117.96 | 14.02 | 0.484 | 0.973 |
| $_{AVG}ImpF^{60}{}_{TS}$ | 1 | 81.61 | 18.90 | 7.32 | 61.57 | 116.52 | 23.16 | 0.551 | 0.921 |
| (Ns) | 2 | 79.40 | 12.93 | 5.15 | 61.46 | 99.87 | 16.28 | 0.411 | 0.995 |
| $_{AVG}RFD^{60}{}_{TS}$ | 1 | 359.09 | 59.54 | 5.24 | 269.28 | 462.33 | 16.58 | 0.485 | 0.973 |
| (N/s) | 2 | 353.67 | 57.90 | 5.17 | 243.29 | 405.25 | 16.37 | 0.803 | 0.540 |

Results of canonic correlation show high degree of correlation in multivariate area defined by all variables in Test I and II on the canonical R level from 0.9789 i.e. 97.89% with the values of Chi test of $\chi^2 = 38.656$ and p values of 0.00098. In respect of general validity of the multivariate area defined by all variables in Test I and II results show its high degree on Crombach's alpha 0.8649. This points to the fact that the overall validity of multivariate variance defined by Test I and II (140 items, i.e. 10 subjects x 7 variables x 2 testing) is generally the same on the level of 86.49% explained variance whereas defined difference of the unexplained variance is only 13.51% (Hair et al., 1998).

In relation to the general reliability of the multivariate area defined by all variables in Test I and II results show its high degree on Spearman-Brown $r_{tt}$ 0.9722. This shows that the overall reliability of the multivariate variance defined in Test I and II (140 items, i.e. 10 subjects x 7 variables x 2 testing) is generally the same on the level of 97.22 explained one whereas defined difference of the unexplained variance is only 2.78% (Hair et al., 1998).

In Table 2 the results of single reliability of used variables are given.

The results of Crombach's alpha as validity measure show that single values of used variables are ranging from 51.8% for $_{AVG}ImpF^{60}{}_{TS}$ to 97.9% for $_{AVG}F^{60}{}_{TS}$ (Table 2). Results of Bartlett's Test of Sphericity show that value $\chi^2$ in all variables is statistically significant on the level of $p < 0.05$, except for $_{AVG}ImpF^{60}{}_{TS}$ where $p_{value} = 0.292$. This shows that there is no statistically significant inter-correlation between Test I and II in given variable.

In Table 3 Paired samples Student's test results are given.

On the basis of Student's test results we can assert that average values of variables do not differ statistically significant between testing because p value is above critical level of 0.05, i.e. it is ranging from 0.498 for $_{AVG}RFD^{60}{}_{TS}$ to 0.992 for $_{AVG}ImpF^{60}{}_{TS}$ (Table 3).

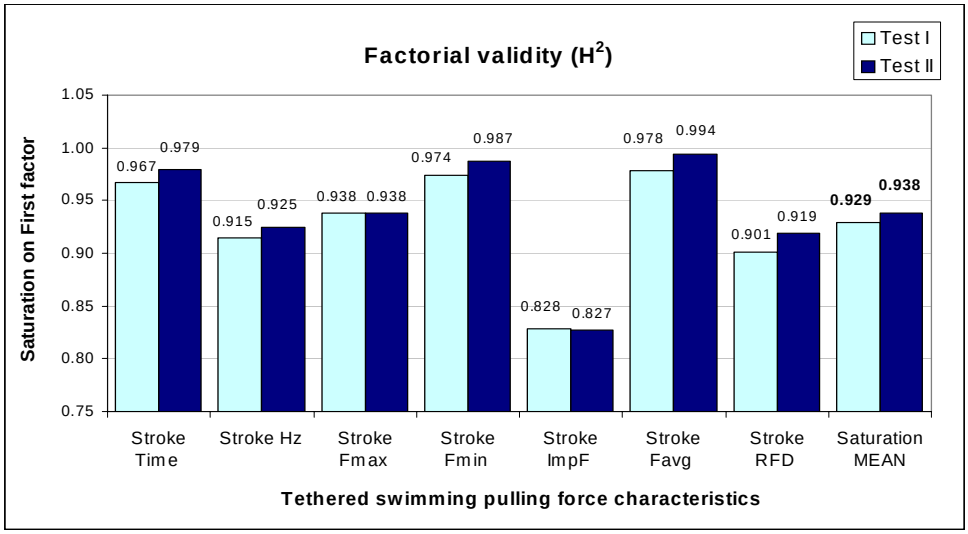
Table 2. Results of single reliability of used variables.

| Variables | Crombach's alpha | Reliability Analysis ANOVA | Spearman-Brown reliability - $r_{tt}$ | Bartlett's Test of Sphericity | Communalities extracted on initial Eigenvalues - $H^2$ |
|---|---|---|---|---|---|
| $_{AVG}Stroke^{60}{}_{TSTime}$ (ms) | 0.955 | $F_{ratio}$=0.349 $p_{value}$=0.569 | 0.955 | $\chi^2$ = 13.589 $p_{value}$=0.000 | 95.735 |
| $_{AVG}Hz^{60}{}_{TS}$ (N/min) | 0.801 | $F_{ratio}$=0.152 $p_{value}$=0.706 | 0.817 | $\chi^2$ = 4.871 $p_{value}$=0.027 | 84.557 |
| $_{AVG}F_{max}{}^{60}{}_{TS}$ (N) | 0.865 | $F_{ratio}$=0.011 $p_{value}$=0.921 | 0.866 | $\chi^2$ = 6.564 $p_{value}$=0.010 | 88.184 |
| $_{AVG}F_{min}{}^{60}{}_{TS}$ (N) | 0.947 | $F_{ratio}$=0.358 $p_{value}$=0.564 | 0.963 | $\chi^2$ = 14.950 $p_{value}$=0.000 | 96.469 |
| $_{AVG}F^{60}{}_{TS}$ (N) | 0.979 | $F_{ratio}$=0.000 $p_{value}$=0.992 | 0.979 | $\chi^2$ = 18.947 $p_{value}$=0.000 | 97.959 |
| $_{AVG}ImpF^{60}{}_{TS}$ (Ns) | 0.518 | $F_{ratio}$=0.000 $p_{value}$=0.995 | 0.541 | $\chi^2$ = 1.112 $p_{value}$=0.292 | 68.558 |
| $_{AVG}RFD^{60}{}_{TS}$ (N/s) | 0.777 | $F_{ratio}$=0.498 $p_{value}$=0.498 | 0.782 | $\chi^2$ = 3.999 $p_{value}$=0.046 | 82.117 |

Table 3. Paired samples Student's test

| Test I/II | $_{AVG}Stroke^{60}{}_{TSTime}$ | $_{AVG}Hz^{60}{}_{TS}$ | $_{AVG}F_{max}{}^{60}{}_{TS}$ | $_{AVG}F_{min}{}^{60}{}_{TS}$ | $_{AVG}F^{60}{}_{TS}$ | $_{AVG}ImpF^{60}{}_{TS}$ | $_{AVG}RFD^{60}{}_{TS}$ |
|---|---|---|---|---|---|---|---|
| t ratio | 0.591 | -0.390 | 0.102 | -0.598 | -0.249 | 0.010 | 0.706 |
| p value | 0.569 | 0.706 | 0.921 | 0.564 | 0.809 | 0.992 | 0.498 |

In Graph 1 factorial validity results are given and are validated through communalities saturation on first factor.




Graph 1. Saturation of single items for pulling force characteristics on first factor (given in %)

General results of factorial analysis have shown that KMO –MSA (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) as a measure of multivariate homogeneity of results is 0.415 and 0.432 and it is statistically significant on the level of $\chi^2$ = 85.61 and 57.81 and p value = 0.000 for Test I and II respectively. Single factor has given 82.16 and 78.16% of total variance explained.

Results of partial factorial validity i.e. factorial validity defined in respect to the single variables have shown that average saturation of observed pulling force characteristics for Test I is 0.929 (92.9%) and for Test II is- 0.938 (93.8%). The biggest saturation was obtained in ${}_{AVG}F^{60}{}_{TS}$ ranging from 0.978 and 0.994, while the smallest was obtained in ${}_{AVG}ImpF^{60}{}_{TS}$ ranging from 0.828 and 0.827, for Test I and II, respectively (Graph 1).

## 4. DISCUSSION

In comparison to kinematics indicators the average single stroke of the tested sample during tethered swimming with maximum intensity for 60 seconds is 775.47 ms for Test I and 771.05 ms for Test II. The average value for stroke frequency is 76.77 to 77.12 for single strokes in a minute. In relation to elite free swimming swimmers with maximum intensity at 100 m distance (analog duration and energy load in the given test), it can be noticed that average value for single stroke duration is about 550 ms, while frequency for single strokes is ranging from 100 to 112 Hz/min (Maglischo, 2003, 98, 701). During tethered swimming with maximum intensity of 60 seconds subjects have manifested by 37.76% smaller single stroke frequency while single stroke duration was by 40.59% longer in comparison to the same indicators defined in elite free style swimmers with maximum intensity in 100 m. In comparison to the same method of testing but in duration of 10 seconds the data show that average values of single stroke duration are ranging from 626.38 to 654.92 ms with the frequency stroke of 98.67 to 99.68 Hz/min (Dopsaj, 2000). Results of this study show that the subjects have on average and during testing manifested single strokes by 20.70% longer time and by 28.89% smaller frequency in relation to the same method of testing but with duration of 10 seconds.

As for the mechanical characteristics of pulling force realized by free style during tethered swimming for the tested sample an average of peaks for maximum pulling force ${}_{AVG}F_{max}{}^{60}{}_{TS}$ ranges from 182.76 to 185.51 N, average of minimum pulling force ${}_{AVG}F_{min}{}^{60}{}_{TS}$ ranges from 26.53 do 26.86 N, pulling force average is ${}_{AVG}F^{60}{}_{TS}$ from 95.63 to 97.32 N, average of pulling force impulse is - ${}_{AVG}ImpF^{60}{}_{TS}$ - from 79.40 to 81.61 Ns, and average of rate force development is ${}_{AVG}RFD^{60}{}_{TS}$ - from 353.67 to 359.09 N/s for Test I and II respectively. In relation to the given testing for 60 seconds data show that obtained values for variables ${}_{AVG}F_{max}{}^{60}{}_{TS}$, ${}_{AVG}F_{min}{}^{60}{}_{TS}$, ${}_{AVG}ImpF^{60}{}_{TS}$ and ${}_{AVG}RFD^{60}{}_{TS}$ - for 39.30%, 82.90%, 9.31% and 86.63% are smaller than the values obtained for the same pulling force mechanical characteristics realized by swimmers in tethered swimming with maximum intensity but in 10 seconds, respectively (Dopsaj, 2000).

In relation to non-aquatic tests used to estimate maximum and explosive force (RFD) of the muscle contraction ability it was defined that the test-retest correlation is 0.96 and 0.84, respectively (Wilson & Murphy, 1996). In comparison to isometric multi-joint tests defining mechanical characteristics of muscle force a high degree of reliability was found in Crombach's alpha from 0.991 for $F_{max}$ to 0.872 for $I_{mp}F$ (Dopsaj et al., 2000). The general level of inter-item reliability of five mechanical characteristics of muscle force

such as maximum force ($F_{max}$), time to reach $F_{max}$ ($tF_{max}$), speed of motor units inclusion ($C_{max}$), force impuls($I_{mp}F$) and rate of force development i.e. explosive force (RFD) measured on five different muscle groups (trunk flexors, finger flexors and shoulder flexors and knee and trunk extensors is statistically significant and is ranging from 0.873 for $F_{max}$ to 0.343 for $tF_{max}$ (Dopsaj et al., 1999). The results of the given studies show that the mentioned mechanical characteristics of muscle contraction abilities in non – aquatic conditions can be measured reliably regardless of one or multi-joint systems or different contraction characteristics in different muscle groups.

In relation to aquatic testing applying tethered swimming high reliability given in the correlation coefficient of r = 0.993 was found in stroke frequency (Keskinen, 1993, 32). During tethered swimming with maximum intensity for 10 seconds it was defined that variable validity (the same variables were used as in this study) was ranging from 0.591 to 0.957 and the reliability was ranging from 0.632 to 0.971 for single stroke rate and stroke frequency respectively. Mentioned results have shown that estimation of average maximum pulling force, rate of force development (pulling force explosiveness), average of force impulse and single stroke frequency are statistically reliable while an insufficient level of reliability was found in the average minimum pulling force and single stroke time (Dopsaj, 2000).

Comparing age groups competitive swimmers aged 11.8±0.3 and using the tethered swimming test with maximum intensity for 30 seconds it was found that the measuring average puling force was reliable whereas measuring the average maximum pulling force peaks was not sufficiently reliable (Taylor et al., 2001).

Discussing the results of this study it was mentioned that Crombach's alpha results as validity measures for single variables are arranging from 51.8% for ${}_{AVG}ImpF^{60}{}_{TS}$ to 97.9% for ${}_{AVG}F^{60}{}_{TS}$ (Table 2). As 0.60 is considered lower threshold level estimating metric values of some measuring instrument (validity, reliability, discrimination, objectivity) given Crombach's alpha results show that in ${}_{AVG}ImpF^{60}{}_{TS}$ there was no significant validity in relation to the applied measuring Test-Retest (Hair et al., 1988, 88). Since general measure of Crombach's alpha is very high (0.8649) i.e higher than 0.800 and has a meritorious value we can assume that miserable level of validity in force impulse estimation is more a consequence of small sample than bad measure features of the given measuring category (Hair et al., 1988, 99-100).

On the basis of general factorial validity results it can be concluded that all athletes in the tested sample in both tests have mainly realized tethered swimming in the same way from kinematics aspect of swimming technique and characteristics of realized pulling force as well. Yet obtained results show that in relation to partial characteristics subjects have found the biggest problem to be identical realization of force impulse during tethered swimming. In other words some subjects were not able during tethered swimming for 60 seconds to realize identical motor structure of movements patherns defined by the quantity of manifested force in time function (ImpF = F x t).

Possible explanation why the enough levels of validity and reliability of variable ${}_{AVG}ImpF^{60}{}_{TS}$ are not obtained to such results can be offered in the following facts. It is known that level of manifested pulling force is in reverse proportional linear dependence to the swimming speed. Realized pulling force during tethered swimming with maximum intensity is 2.41 times bigger than the one realized during free swimming with sub maximum or maximum speed (Vorontsov et al., 1982). Since in tethered swimming it was necessary to use single strokes to realize force 2.41 times bigger than the one realized in

free swimming with simultaneous use of single strokes in changed space-time conditions (duration and length of strokes in relation to free swimming) it is evident that some swimmers in the sample were not capable of fast motor adaptation (in sense of motor learning) so that in repeated test they did not manage during tethered swimming in the same structural way and with the realized strokes for 60 seconds to have the same quantity of movement, i.e. to realize the same pulling drive.

## 5. CONCLUSION

The obtained results enable the authors to draw conclusions that the given method of estimation of kinematics indicators and mechanical characteristics of the pulling force in adult competitive swimmers measured by tethered swimming with the maximum intensity for 60 seconds is generally valid on Crombach's alpha level = 0.8649 (86.49%), as well as that it is generally reliable on the level of Spearman-Brown's $r_{tt}$ = 0.9722 (97.22%), and generally factorial valid on the level of 0.929 to 0.938 (92.8 do 93.8%). Therefore it can be recommended for further use in sports practice.

Referring to partial indicators, i.e. single variables it was found that the following variables ${}_{AVG}RFD^{60}{}_{TS}$, ${}_{AVG}Stroke^{60}{}_{TSTime}$, ${}_{AVG}Hz^{60}{}_{TS}$, ${}_{AVG}F_{max}{}^{60}{}_{TS}$, ${}_{AVG}F_{min}{}^{60}{}_{TS}$ i ${}_{AVG}F^{60}{}_{TS}$ are statistically valid in the range of 0.777 to 0.979, and reliable in the range of 0.782 to 0.979 respectively (Table 2). For variable ${}_{AVG}ImpF^{60}{}_{TS}$ in this study there was no sufficient level of either validity 0.518, nor reliability 0.541 (Table 2.) Since the general level of validity and reliability is very high and statistically significant we might assume that the insufficient level of partial validity and reliability for variable ${}_{AVG}ImpF^{60}{}_{TS}$ is more the consequence of a relatively small sample (10 subjects) than the real measuring characteristics of the given variable.

Considering the methodological domination of Test I results in the first trial or Test II results in the second trial analysis of the difference in mean values in Student's t test has shown that there are no statistically significant differences between the averages of results in all used variables (Table 3) and that there are no differences of general factorial validity between test and retest (Test I and II). The obtained results enable one to suggest that during the testing of swimmers by the application of this method the results in one trial can be taken as valid information but on condition that a subject after a warm-up performs at least two tethered swimming trials with medium intensity for 15 or 60 seconds and that the testing be administered only after a break of about 15 minutes.

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# POUZDANOST I VALIDNOST PROCENE OSNOVNIH KINEMATIČKIH I KARAKTERISTIKA SILE VUČE KOD PLIVAČA PRIMENOM TESTA PLIVANJA U MESTU MAKSIMALNIM INTENZITETOM U TRAJANJU 60 SEKUNDI

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*Predmet ovog rada je ispitivanje pouzdanosti testa za procenu osnovnih kinematičkih i karakteristika sile vuče kod plivača primenom testa plivanja u mestu maksimalnim intenzitetom u trajanju od 60 sekundi. Uzorak je činila grupa od 10 kategorisanih plivača seniorskog uzrasta. Svi plivači su bili specijalisti za kraul tehniku plivanja na sprinterskim i srednjim distancama (50, 100, 200 i 400m). Testiranje je izvršeno pomoću tenziometrijske sonde sa pratećom hardversko-softverskom podrškom metodom test - retest. Kinematičke karakteristike su bile predstavljene sa dve varijable (${}_{AVG}Stroke^{60}{}_{TSTime}$ - prosek trajanja pojedinačnog zaveslaja i ${}_{AVG}Hz^{60}{}_{TS}$ - realizovana frekvencija zaveslaja) dok su karakteristike sile vuče bile predstavljene sa pet varijabli (${}_{AVG}F_{max}{}^{60}{}_{TS}$ - prosek maksimalne sile vuče (pikova) pojedinačnih zaveslaja, ${}_{AVG}F_{min}{}^{60}{}_{TS}$ - prosek minimalne sile vuče pojedinačnih zaveslaja, ${}_{AVG}F^{60}{}_{TS}$ - prosek sile vuče pojedinačnih zaveslaja, ${}_{AVG}ImpF^{60}{}_{TS}$ - prosek impulsa sile vuče pojedinačnih zaveslaja i ${}_{AVG}RFD^{60}{}_{TS}$ - prosek vrednosti gradijenta prirasta sile vuče pojedinačnih zaveslaja. Na osnovu dobijenih rezultata može se zaključiti da je dati metod procene generalno validan na nivou Krombahove alfe = 0.8649 (86.49%), generalno reliabilan na nivou Spirman-Braunovog $r_{tt}$ = 0.9722 (97.22%) i generalno faktorski validan na nivou od 0.929 do 0.938 (92.8 do 93.8%), pa se može predložiti za dalju upotrebu u sportskoj praksi. U odnosu na posmatrane parcijalne pokazatelje tj. pojedinačne varijable utvrđeno je da su varijable ${}_{AVG}RFD^{60}{}_{TS}$, ${}_{AVG}Stroke^{60}{}_{TSTime}$, ${}_{AVG}Hz^{60}{}_{TS}$, ${}_{AVG}F_{max}{}^{60}{}_{TS}$, ${}_{AVG}F_{min}{}^{60}{}_{TS}$ i ${}_{AVG}F^{60}{}_{TS}$ statistički značajno validne u rasponu od 0.777 do 0.979, i pouzdane u rasponu od 0.782 do 0.979, respektivno. Za varijablu ${}_{AVG}ImpF^{60}{}_{TS}$ u ovom istraživanju nije utvrđen dovoljan nivo ni validnosti - 0.518, ni pouzdanosti - 0.541. Kako je generalni nivo validnosti i pouzdanosti veoma visok i statistički značajan, pretpostavljamo da je nedovoljan nivo parcijalne validnosti i pouzdanosti varijable - ${}_{AVG}ImpF^{60}{}_{TS}$ više posledica relativno malog uzorka (10 ispitanika) nego stvarnih mernih karakteristika date varijable.*

**Ključne reči:** *plivanje u mestu, slobodan stil, pouzdanost, validnost, sila vuče, anaerobni rad*