FACTA UNIVERSITATIS
Series: **Physical Education and Sport** Vol. 13, N° 1, 2015, pp. 89 - 96

Original research article

THE RELATIONS BETWEEN POWER AND FORCE VARIABLES REALIZED DURING THE SQUAT JUMP WITH START PERFORMANCE IN NATIONAL LEVEL MALE SPRINT SWIMMERS

UDC 797.012

Marko Đurović[1], Igor Beretić[2], Jovana Zrnzević[1], Tomislav Okičić[1], Bojan Jorgić[1], Milan Milanov[1]

[1]Faculty of Sport and Physical Education, University of Niš, Serbia
[2]Faculty of Sport and Physical Education, University of Novi Sad, Serbia

Abstract. *The primary purpose of this study was to determine the relation between muscle contractile potential of the leg extensor muscles and starting performance, and to determine whether the level of average power, peak power, maximal force, relative power, average relative power, relative force, jump height and jump velocity measured with the Squat Jump without the arm swing (SJ) are related to the efficiency of start performance (t10m). Twenty-seven male competitive swimmers performed one trial of the SJ test and two swimming start trials corresponding to a 10m distance. The results of Pearson's correlation showed a statistically significant relation between start efficiency (t10m) and the variables of average power (r = -0.403, p = 0.037), peak power (r = - 0.391, p = 0.044), maximal force (r = -0.420, p = 0.029), relative power (r = - 0.547, p = 0.027), average relative power (r = -0.588, p = 0.023), relative force (r = -0.644, p = 0,007). However, jump height and jump velocity did not show a statistically significant correlation. Regression equation for t10m prediction was defined by the following variables: maximal force (F_{max}) and relative force (F_{rel}). The best model to predict starting time on the 10m included consideration of two variables, SJ maximal force and SJ relative force (R = 0.640, R^2 adjusted = 0.410). Additionally, the results of this study suggest that swimmers, with higher maximal force values and higher relative force values of leg extensors, should be able to be faster on the 10m-mark than swimmers with lower maximal and relative values.*

Key words: *swimming start, muscle potential, vertical jump.*

Received June 21, 2014 / Accepted December 19, 2014
Corresponding author: Marko Đurović
Faculty of Sport and Physical Education, University of Niš, St. Čarnojevića 10a, 18000 Niš, Serbia
Phone: +381 18 510900 • E-mail: djura86@yahoo.com

INTRODUCTION

Each event at a swimming competition begins with a swimming start. It means that all swimmers at the beginning of the race assume the same position. A swimming event consists of the following elements: the swimming start, turns, swimming distance and finish. The influence of each of these phases is important for the final result, depending on the length of the event (Barbosa, Fernandes, Morouco & Vilas-Boas, 2008; Cossor & Mason, 2001; West et al., 2011). The swimmer with the fastest start has two advantages: one is the psychological advantage of being ahead of the competition, and another one is swimming in smooth water, which allows better efficiency of the swimming stroke (Lewis, 1980). In a sprint event there are different technical characteristics which determine the differences between more and less successful swimmers such as: the stroke length, stroke index, start dive length and start dive velocity (Đurović, Beretić, Dopsaj, Pešić & Okičić, 2012). A fast reaction time, significant jumping power, a high take-off velocity and a decrease in drag force during the entry are necessary in order to provide efficient starting performance (Schnabel & Kuchler, 1998). Starting time up to 10 m is a direct indicator of the starting speed (Blanksby, Nicholson & Elliott, 2002) because the speed up to 10 m it is not affected by the speed of the underwater kick, but only by the influence of the achieved starting velocity.

The relationship between starting performance and land tests using a different kind of method with lower body land tests were examined in several studies (Benjanuvatra Edmunds & Blanksby, 2007; West et al., 2011; Breed & Young, 2003). It was shown that strong positive correlations exist between the peak forces measured during the land tests and the peak forces measured on both main and wedge plates of the starting block, advising that land tests can be used as an alternative to pool-based tests for peak force (Arellano, Llana, Tella, Morales & Mercade, 2005). The optimal level of muscle power is required in each sport, so swimming is no exception (Newton, Jones, Kraemer & Wardle, 2002). Swimming sets up some specific requirements in terms of swimmers power. These requirements are conditioned by the character and duration of dynamic effort in the process of competitive activity (Madić, Okičić, Rašović & Okičić, 2011). According to Vila-Boas et al. (2003) the swimming start contains two phases: the first one lasts from the starting signal to take off of the rear leg from block platform and second phase from the "rear leg take off" until the last contact of the front leg with the block platform. Undeniably, the lower body extensors muscles can be of great influence on efficient start performance. Several studies have previously attempted to examine the relationship between strength and power characteristics of lower body muscles with starting performance (Lee, Huang, Wang & Lin, 2001; Breed & Young, 2003; Arellano et al., 2005; Cronin & Hansen, 2005; Mason et al., 2007; West et al., 2011; Beretić, Durović, Okičić & Dopsaj, 2013) using a variety of methods. Furthermore, start time was significantly correlated with the variables of leg extensors maximum voluntary isometric force, leg extensors relative muscle voluntary isometric force, leg extensors specific rate of force development, and leg extensors relative value of specific rate of force development (Beretić et al. 2013).

Previously published papers examined the relationship between contractile abilities in relation to different muscle force and power characteristics and start variables (West et al., 2011; Lee et al., 2001; Breed & Young, 2003; Benjanuvatra et al., 2007; Arellano et al., 2005; Beretic et al., 2013). Our study represents a contribution to the previous studies about relations between muscle contractile abilities of the leg extensors and starting performance in dynamic conditions.

Therefore, the primary purpose of this study was to determine the relations between muscle potential of the leg extensor muscles in dynamic conditions with starting performance, and to determine whether the level of average power, peak power, maximal force, relative power, average relative power, relative force, jump height and jump velocity measured with the Squat Jump are related to the efficiency of start performance. We hypothesized that the muscle potential produced during SJ without arm swing is connected to starting performance. The results obtained in this study in practical use can be essential for swimming coaches in order to achieve an accurate, safe and time efficient testing method for predicting starting efficiency.

THE METHOD

The participants

The study involved 27 male competitive swimmers (body height = 182.2±5.7 cm, body mass = 73.5±7.3 kg, age = 20.1±3.4 yrs, FINA score = 546.5±84.1), all members of the swimming clubs “Sveti Nikola” and “Nis2005” from Nis, Serbia. The tested swimmers had experience at national level competitions for at least four years. The swimmers and the parents of swimmers under 18 gave their informed written consent for participation in this study. All of the methods and procedures of this study were approved by both clubs and the Central Serbia Swimming Federation Expert Advising Committee and by the ethical committee of the University of Nis, Faculty of Sport and Physical Education, Serbia, and conformed to the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Procedures

All dry land tests were performed on the same day at the fitness center of the Sports center "Čair" in the city of Nis. The tests for muscle potential were performed in the morning, while the tests for start performance were performed in the afternoon session, at the 50m swimming pool. Before the battery of tests, the participants performed a standardized warm-up for each test. In the warm-up for the SJ test, the athletes preformed 5 minutes of cycling and then completed 2 to 3 sets with 6 – 8 repetitions of light squats, with pauses between sets of 30 seconds. Before the swimming start tests, the participants completed a warm up, based around their competition warm up, which consisted of an easy swim, some sprint and dive drills to ensure the athletes were ready to perform at their maximal effort. Swimmers were instructed not to be involved in strenuous exercise for at least 48 hours before the testing and consume their normal pre-training diet before the testing.

Muscle contractile potential testing

The testing of muscle contractile potential was measured with the Myotest performance measuring system, Switzerland (Myotest SA, Sion, Switzerland). The Myotest instrument demonstrated a high reliability in testing strength and power, demonstrated by Comstock et al. (2011).

The evaluation of leg extensors was performed following the manual Myotest procedure for the SJ. The procedure is as follows: the Myotest instrument is placed on the belt and set to measure 5 attempts of the jumps. The participants start the test in the standing position, with hands on their hips, facing straight ahead, bend their knees to 90 degrees and stand still. At the short beep, they jump as high as possible without any countermovement lunge while keeping their hands on their waist. The landing should be as soft and smooth as possible. After landing, they return to the previous position with their knees flexed at 90 degrees and, while standing still, await the next beep before repeating the jump. After the fifth attempt, the double beep signals the end of the test. The results are automatically displayed on the screen after the test.

The contractile abilities of knee extensors were represented by: average power (P_{avg}) of three best repetitions in 5 jump attempts, in watts (W); peak power (P_{max}) which provides information on the athlete's ability to generate mechanical energy over time in watts (W), maximal force (F_{max}) in Newtons (N) which provides information on athletes ability to produce the highest possible dynamic force against the system moved during the squat jump, squat jump peak height (H_{max}) given in centimeters (cm) and squat jump peak velocity (V_{max}) in centimeters per second (cm/s) which provides the results for the athlete's effort: the greater the impulse, the higher the velocity. The relative values of lower body muscle contractile potential were: relative power P_{rel} (in W/kg), average relative power P_{avgrel} (in W/kg) and relative force F_{rel} (in N/kg).

Start performance testing

After the warm-up in the swimming pool, the participants performed two swimming starts. There was a 5 min rest between start attempts. The fastest trial (time on a 10m) was analyzed. Normal competitive starting procedures were used for both trials. The participants were instructed to perform a maximal effort dive and maximal swim to the 10 meter mark (t10m). Time at 10m is the time span from the starting signal to the moment when the swimmer touches the touchpads at 10m in seconds (0.01 s). The starting block height from the surface of the water was 0.70m. The starting platform was 0.5m × 0.5m, with a 10º slope. The touchpads (Alge Timing - Austria) were set to the 10m mark, attached on one side to the lane line and on the other side to the swimming pool lateral edge. The kinematic characteristic of start performance was represented as: Time at 10m (t10m).

Statistical analyses

Minimum, maximum, means and standard deviations were calculated for each variable. Pearson's correlation was used to quantify the association between the variables we used in the research (t10m and selected SJ variables). The model of dependency in the observed variables (t10m with the variables of average power, peak power, maximal force, relative power, average relative power, relative force, jump height and jump velocity) was defined using a multiple regression analysis (backward method). All the statistical operations were performed using the SPSS 15.0. software (Chicago, IL, USA) and the level of significance was set at $p \leq 0.05$.

RESULTS

Table 1 shows the results for the descriptive statistics of the studied indicators, and the results of Pearson's correlation are presented in Table 2. The time at 10m (4.24 ± 0.28 s) was significantly inversely related to SJ average power (3415.81 ± 610.22 W) with correlation values of ($r = -0.403$, $p = 0.037$), with SJ peak power (3725.66 ± 667.07 W) with correlation values of ($r = - 0.391$, $p = 0.044$), with SJ maximal force (1777.48 ±

270.46 N) with correlation values (r = - 0.420, p = 0.029), with SJ relative power (50.58 ± 6.82 W/kg) with correlation values of (r = -547, p = 0.027), with SJ average relative power (46.40 ± 6.42 W/kg) with correlation values of (r = -0.588, p = 0.023) and SJ relative force (24.16 ± 2.54 N/kg) with correlation values of (r = -0.644, p = 0.007).

Table 1 Descriptive statistics of the start and bilateral force and power characteristics (n=27).

Variable	Mean	SD	Min	Max
FINA score	564.5	84.1	456	707
Time at 10m (s)	4.24	0.28	3.70	4.83
Squat jump peak power P_{max}(W)	3725.66	667.07	2306.0	5323.00
Squat jump average power P_{avg}(W)	3415.81	610.22	2237.0	4907.00
Squat jump maximal force F_{max}(N)	1777.48	270.46	1306.0	2428.00
Squat jump peak height H_{max} (cm)	33.90	4.42	26.70	41.30
Squat jump peak velocity V_{max}(cm/s)	251.48	26.68	146.00	281.00
Squat jump relative power P_{rel} (W/kg)	50.58	6.82	39.10	67.19
Squat jump average relative power P_{avgrel}(W/kg)	46.40	6.42	34.80	62.81
Squat jump relative force F_{rel} (N/kg)	24.16	2.54	18.80	32.40

Abbreviations: Mean = Arithmetic mean, SD = Standard Deviation,
Min = Minimum value, Max = Maximum value.

Table 2 Pearson's correlation coefficient between the start and bilateral force and power characteristics (n=27).

Variable	t10m (s)	p
Squat jump peak power P_{max}(W)	-0.391	0.044
Squat jump average power P_{avg}(W)	-0.403	0.037
Squat jump maximal force F_{max}(N)	-0.420	0.029
Squat jump peak height H_{max} (cm)	-0.173	0.389
Squat jump peak velocity V_{max}(cm/s)	-0.113	0.575
Squat jump relative power P_{rel} (W/kg)	-0.547	0.027
Squat jump average relative power P_{avgrel}(W/kg)	-0.588	0.023
Squat jump relative force F_{rel} (N/kg)	-0.644	0.007

Abbreviations: t10m = Time at 10m, p = Pearson's correlation coefficient level of significance.

Table 3 Shows the results of the multiple regression analysis (backward method) between Time at 10m and the different indicators of muscle power characteristics.

Table 3 Backward method multiple-regression analysis of the associations of time at 10m with the significant predictor variables in competitive male swimmers (n = 27).

Variable	Unstd. Beta	Beta	t	p	R	R^2_{adjust}	Std. Err. Est.	F	P
Squat jump maximal force F_{max}(N)	-0.010	-0.420	-2.316	0.029					
Squat jump relative force F_{rel}(N/kg)	-0.323	-1.296	-4.966	0.001	0.640	0.410	0.1831	9. 630	0.018

Abbreviations: Unstd.Beta = Unstandardized regression coefficient values, Beta = Standardized regression coefficient values, t = Standardized regression coefficient significance tests, p = Standardized regression coefficient level of significance, R= Multiple correlation coefficient, R^2_{adjust} = Adjusted determination coefficient, Std. Err. Est. = Standard error of the estimate, F= Multiple regression analysis significance tests, P = Multiple correlation level of significance.

As shown in Table 3, the best model to predict time on the 10m included consideration of two variables, SJ maximal force and SJ relative force (R = 0.640, R^2 adjusted = 0.410). The obtained model significantly explains the criterion (start time at 10m) with the standard error of the estimated level of ±18.31 ms (F = 9.630, p = 0.018, Table 3). The equation for the predicted time at 10m was obtained using the following:

$$t10 = 29.828 – (F_{max} \cdot 0.010) – (F_{rel} \cdot 0.323)$$

DISCUSSION

The aim of this study was to determine the relationships between muscle contractile potential of the leg extensor muscles with starting performance, and to determine whether the level of average power, peak power, maximal force, relative power, average relative power, relative force, jump height and jump velocity measure with the Squat Jump without an arm swing are related to the efficiency of start performance. Previously published papers examined the relationship between contractile abilities in relation to different muscle force and power characteristics and start variables (Benjanuvatra et al., 2007; Beretić et al., 2013; Breed & Young, 2003; Mason et al., 2007; Miyashita, Takahashi, Troup & Wakayoshi, 1992; West et al., 2011).

The correlation results showed a statistically significant association between the start efficiency (t10m) and the variables of average power (r = -0.403, p = 0.037), peak power (r = - 0.391, p = 0.044), maximal force (r = -0.420, p = 0.029), relative power (r = - 0.547, p = 0.027), average relative power (r = -0.588, p = 0.023), relative force (r = -0.644, p = 0,007). The obtained results showed a significant correlation between peak power of the leg extensor muscles measured on land during the Squat Jump and the start times measured on the 10m (r = -0.403, p = 0.037). Miyashita et al. (1992) found a statistically significant relationship between start time and leg extension peak power (r = -0.675, p = 0.01). In the study of West et al. (2011) the aim was to examine the key force and power predictors of start performance in the 50m freestyle on eleven international level British swimmers. The results of that study were significantly related to lower body peak power (r = - 0.85) and average power values showed significant association with 10m start times (r = -0.403, p = 0.037) also. In the study of West et al. (2011), the authors proved the existence of a significant correlation between start performance and average power of knee extensor muscles (r = -0.624). Mason et al. (2007) found that the characteristic most closely observed in excellent starting ability that is linked to efficient start performance was peak power, average power and maximum horizontal propulsive force.

The results of this study showed that swimmers who are able to produce higher maximal force values and higher relative force values during the squat jump have kinetic energy potential to be faster on the 10m-mark then the swimmers with lower maximal force values and lower relative force values. The reason for these observations can be derived from the fact that the swimmers with a greater ability to generate mechanical energy showed greater potential for faster start performance. The obtained results showed a significant relation between the start efficiency (t10m) and the variable of maximal legs extensor force (r = - 0.420, p = 0.029) and relative force (r = -0.644, p = 0,007). In the study of West et al. (2011), start time in elite swimmers was significantly related to the maximal force of lower body 1RM squat (r = -0.74).

The results of this study can provide encouraging support for the efficiency of muscle contractile potential under squat jump procedure to predict the time on the 10m-mark in male competitive swimmers. The major advantage of this finding can be found in its practical application, offering a statistically accurate, safe and time-efficient testing method for predicting starting efficiency (R^2_{adjust} = 0.410, Std. Err. Est = 18.31 ms, F = 9.630, P = 0.018, Table 3). Equation for t10m prediction is defined by variables that measure the maximal force and relative force during SJ movement. Thus by means of the testing model applied in this paper, by inserting value of F_{max} and F_{rel} in the obtained equation, coaches can calculate the time required by a particular swimmer to cover a distance of 10m after starting with a prediction accuracy range of ± 18.31ms. Any possible differences, realized as time underestimation (slower than predicted), overestimation (faster than predicted), or proper time, indicate lower or higher start technique efficiency (Beretić et al., 2013). All of this can help coaches predict efficient start performance depending on the swimmer’s measured muscle contractile abilities of leg extensors muscles. The results obtained in this study can be essential in practical use for swimming in order to achieve an accurate, safe and time-efficient testing method for predicting starting efficiency.

CONCLUSION

The results of this study have shown that muscle potential characteristics obtained by performing the vertical jump tests measured on land do relate to swimming start performance and can be used by swimmers and coaches to predict starting efficiency. The contractile ability indicators of the leg extensors muscles included in the study (P_{avg}, P_{max}, F_{max}, P_{rel}, P_{avgrel} and F_{rel}) showed a significant correlation with swimming start times on the 10m i.e. swimmers with higher maximal force values and higher relative force values of the leg extensors muscles should be able to be faster on the 10m-mark than swimmers with lower maximal and relative force values. The findings of this study can be used for a safe, exact and time-efficient testing method in order to predict starting efficiency. All of this can help coaches predict an efficient start performance, depending on the swimmer’s measured muscle abilities, and also can give directions for the development of an efficient start performance technique.

REFERENCES

Arellano, R., Llana, S., Tella, V., Morales, E., & Mercade, J. (2005) A comparison CMJ, simulated and swimming grab-start force recordings and their relationship with start performance. In Wang, D., *Proceedings of XXIII International Symposium on Biomechanics in Sports*, (pp. 923-926) Beijing: The China Institute of Sport Science.

Barbosa, T.M., Fernandes, R.J., Morouco, P., & Vilas-Boas, J.P. (2008). Predicting the intra-cyclic variation of the velocity of the centre of mass from segmental velocities in butterfly stroke: a pilot study. *Journal of sports science & medicine*, *7*(2), 201-9.

Benjanuvatra, N., Edmunds, K., & Blanksby, B. (2007). Jumping ability and swimming grab-start performance in elite and recreational swimmers. *International Journal of Aquatic Research and Education*, *1*, 231-241.

Beretić, I., Durović, M., Okičić, T., & Dopsaj, M. (2013). Relations between lower body isometric muscle force characteristics and start performance in elite male sprint swimmers. *Journal of sports science & medicine*, *12*(4), 639-45.

Blanksby, B., Nicholson, L., & Elliott, B. (2002). Biomechanical analysis of the grab, track and handle swimming starts: an intervention study. *Sports biomechanics / International Society of Biomechanics in Sports*, 1, 11-24.

Breed, R. V. P., & Young, W. B. (2003). The effect of a resistance training programme on the grab, track and swing starts in swimming. *Journal of sports sciences*, 21, 213-220.

Comstock, B. A., Solomon-Hill, G., Flanagan, S. D., Earp, J. E., Luk, H.-Y., Dobbins, K. A., Dunn-Lewis, C., et al. (2011). Validity of the Myotest® in measuring force and power production in the squat and bench press. *Journal of strength and conditioning research*, *25*(8), 2293-2297.

Cossor, J., & Mason, B. (2001) Swimstart performance at the Sydney 2000 Olimpic In: Blackwell, J.R., Sanders, R.H (Eds.), *Proceedings of the XIX International Symposium on Biomechanics in Sports*, (pp. 70-74). San Francisco: University of San Francisco.

Cronin, J. B., & Hansen, K. T. (2005). Strength and power predictors of sports speed. *Journal of strength and conditioning research*, 19, 349-357.

Đurović, M., Beretić, I., Dopsaj, M., Pešić, M., & Okičić, T. (2012). A comparison of kinematic variables between European elite, national elite and regional elite male 100m freestyle swimmers. *Facta Universitatis, Series Physical Education and Sport, 10* (4), 339 – 346.

Lee, C., Huang, C., Wang, L., & Lin, D. (2001). Comparison of the dynamics of the swimming grab start, squat jump and countermovement jump of the lower extremity. In: Blackwell, J R., Sanders, R.H. (Eds.), *19 International Symposium on Biomechanics in Sports 2001*, (pp. 143-146). University of San Francisco.

Lewis, S. (1980). Comparison of five swimming starting techniques. *Swimming Technique*, 16, 124-128.

Madić, D., Okičić, T., Rašović D., & Okičić, S. (2011). Snaga u plivanju. *Sport Mont*, (25-27/VIII), 359-365.

Mason, B., Alcock, A., & Fowlie, J. (2007). A Kinetic analysis and recommendations for elite swimmers performing the sprint start. In: Menzel, H.J, Chagas, M.H. (Eds.), *Proceedings of XXV International Symposium on Biomechanics and Sport*, (pp- 192-195). Ouro Preto: Brazil. 192-195.

Miyashita, M., Takahashi, S., Troup, J.P., & Wakayoshi, K. (1992). Leg extension power of elite swimmers. In: *Biomechanics and medicine in Swimming VI*. Eds: MacLaren, D., Reily, T., Less, A. London: E & FN Spon. 295-301.

Newton, R., Jones, J., Kraemer, W.J., & Wardle, H. (2002). Strength and power training of Australian Olympic swimmers. *Strength & Conditioning Journal*, *24* (3), 7-15.

Schnabel, U., & Kuchler, J. (1998). Analysis of the starting phase in competitive swimming. In H.J. Ruehle, M.M., Vieten, M.M. (Eds.), *Proceedings of XVI International Symposium of Biomechanics in Sports*, 247-250.

Vilas-Boas, J. P., Cruz, J., Sousa, F., Conceicao, F., Fernandes, R. & Carvalho, J. (2003). Biomechanical analysis of ventral swimming starts: Comparison of the Grab Start with Two Track-Start Techniques. In Chatard, J. P. Saint-Etienne (Ed.). *Proceeding of the IX International Symposium on Biomechanics and Medicine in Swimming*. France: Universite de Saint-Etienne. 249-253.

West, D. J., Owen, N. J., Cunningham, D. J., Cook, C. J., & Kilduff, L. P. (2011). Strength and power predictors of swimming starts in international sprint swimmers. *Journal of Strength and Conditioning Research*, 25(4), 950-955

POVEZANOST VARIJABLI SILE I SNAGE PROIZVEDENE TOKOM VERTIKALNOG SKOKA IZ POLUČUČNJA SA PARAMETRIMA STARTNOG SKOKA U PLIVANJU KOD NACIONALNIH SPRINTERA

Cilj ovog istraživanja bio je da se utvrdi povezanost mišićnog potencijala donjih ekstremiteta sa parametrima startnog skoka u plivanju, i da se odredi da li nivo prosečne snage, maksimalne snage, maksimalne sile, visine skoka i brzine skoka merenih pomoću vertikalnog skoka iz polučučnja (SJ) utiče na efikasno izvođenje startnog skoka u plivanju (t10m). Dvadeset sedam muških plivača nacionalnog ranga, svi članovi plivačkog kluba "Sveti Nikola" i "Niš2005" iz Niša, Srbije (visina = 182.2 ± 5.7 cm, težina = 73,5 ± 7,3 kg, starost = 20.1 ± 3.4 godina) izvršili su jedan pokušaj SJ testa i dva izvođenja startnog skoka sa preplivavanjem deonice do 10m maksimalnim intenzitetom. Rezultati Pirsonove korelacije su pokazali statistički značajnu povezanost između efikasnosti starta (t10m) i varijabli prosečne snage (r = -0,403, p = 0,037), maksimalne snage (r = - 0.391, p = 0.044) i maksimalne sile (r = - 0,420, p = 0,029). Međutim, visina skoka i brzina skoka nisu pokazali statistički značajnu korelaciju. Jednačina regresije za predviđanje vremena na 10m definisana je sledećim varijablama: prosečnom snagom (P_{avg}), maksimalnom snagom (P_{max}), maksimalnom silom (F_{max}), maksimalnom visinom skoka (H_{max}) kao i maksimalnom brzinom skoka (V_{max}). Najbolji model predikcije vremena plivanja do 10m uključuje razmatranje samo jedne varijable, a to je maksimalna sila prilikom SJ (R = 0,420, R2 = 0,177 prilagođen). Pored toga, rezultati ove studije ukazuju na to da plivači, sa većim maksimalnim i prosečnim vrednostima snage, trebalo bi da budu efikasniji na startu od plivača sa nižim vrednostima ovih varijabli.

Ključne reči: *startni skok u plivanju, mišićni potencijal, vertikalni skok.*