FACTA UNIVERSITATIS
Series: **Physical Education and Sport**, Vol. 19, No 2, 2021, pp. 163 - 173
https://doi.org/10.22190/FUPES210627016A

MOTOR ABILITIES AS PREDICTORS IN ARTISTIC SWIMMING: A CROSS-SECTIONAL STUDY

UDC 797.217.012.1

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Abstract. *The aim of this research was to examine the association between motor abilities and achievement in artistic swimmers at the national competition level. Thirty-five junior synchro swimmers (age 16 to 18 years old, height 165.49±3.57cm, and weight of 53±4.23kg) took part in the research. Motor ability evaluation comprised eleven tests for overall and two tests for specific motor abilities. The data analysis was done in SPSS 20.0. The results show a statistically significant association between the predictor system and the criteria (p=.00). The technical execution score was correlated with several physical fitness variables. A multiple regression analysis revealed that push-ups, balance with open eyes, and T2 accounted for a large part (.69%) of the variance in the final score. The results of this research are practically applicable in more qualitative preparation of synchro swimmers and achieving maximal results.*

Key words: *Physical Preparation, Competition Success, Sport-Specific Abilities*

INTRODUCTION

Successful performance in artistic swimming depends on the swimmers' ability to execute a synchronized routine of elaborate moves in water accompanied to music (Rodriguez-Zamora et al., 2014). To achieve this goal, artistic swimmers must train for aerobic and anaerobic fitness, strength, power, endurance, flexibility, performance skills, and artistic expression (Mountjoy, 1999). Similar to gymnastics and figure skating, artistic swimming implies a complex judging system that evaluates many components of skills, synchronization, and artistic impression. Among the many factors that may influence performance, morphological characteristics and physical fitness are the crucial ones (Robinson & Ferraro, 2004; Sundgot-Borgen & Garthe, 2011; Dodigović & Sindik,

Received June 27, 2021 / Accepted July 09, 2021
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2015). Therefore, one should pay attention to the morphological status and motor abilities of artistic swimmers from the very beginning of the training process (Payn & Sharp, 2014; Dodigović & Sindik, 2015; Stanković et al., 2015). Special attention should be given to the training process and other external factors that impact the results of artistic swimmers. In order to define the model characteristics of artistic swimmers, it is necessary to establish physiological, biochemical, biophysical and all other mechanisms that determine individual differences in swimmers' motor abilities and then determine how much we can rely on the influence of these potentials.

Artistic swimming, despite its apparent ease, is a rather demanding sport, and besides serious physical preparation, swimmers must be endurable, strong, flexible, and graceful and perfectly master breath control skills (Alentejano et al., 2010; Homma, 2010; Tošić et al., 2010; Gabrilo et al., 2011; Tošić, 2011; Khosravi et al., 2013; Robertson et al., 2014). Artistic swimmers' movements include rotations around different body axes and are associated with their need to perfectly orientate themselves underwater and to achieve a high level of motor abilities (Dimitrova, 1998; Stanković, Milanović, & Marković, 2015). The performance of various techniques and formation elements includes a combination of highly complex motor actions and skills. Therefore, it is obligatory to determine motor skills and knowledge necessary for the successful performance of figures in artistic swimming. Since motor abilities affect both functional abilities and morphological characteristics, it is compulsory to develop them to the maximum. In artistic swimming, we have always strived to discover all the factors that influence and contribute to achieving better results. Motor abilities play a significant part in the results of synchronized swimming. However, their level has not been determined yet, because the result also depends on other dimensions (morphological characteristics, functional abilities, and psychological factors). Several studies in synchronous swimming relate to basic motor skills. Many authors have studied flexibility in artistic swimming, as one of the more dominant motor abilities (Yamamura et al., 1999; Perić and Spasić, 2010; Tošić, 2011). Most studies (Karpeev, 2008; Perić, 2011) suggest that motor coordination is constantly present in training from the very beginning, since a large number of repetitions occurs when practicing a particular technique. Therefore, coordination should not be specially developed because it is already contained in the primary selection of synchronous swimmers. Research related to strength training suggests that strength also causes positive changes in speed and aerobic capacity due to a more efficient movement economy in water (Hoff et al., 2002; Osteras et al., 2002). Specific motor skills represent an under-explored field in synchronized swimming. Previous studies rarely investigated the association between the competition score and physical fitness variables related to competitive achievement in artistic swimming (Perić, Zenić, Mandić, Sekulić, & Sajber, 2012). In a study conducted by Perić et al. (2012), the authors stated that sport-specific fitness tests are more convenient and applicable than standard fitness tests. Athletes are regularly interested in exercise testing that is directly related to their performance, thus we included two sport-specific tests in physical fitness testing. The results showed that both tests are reliable as diagnostic tools in the analysis of sport-specific explosive strength, and they have high applicability (Perić et al., 2012). The present study aimed at examining the correlation between selected physical fitness variables and the competition score in junior synchronized swimmers' national level in Serbia.

METHODS

Participants

Thirty-five female artistic swimmers, age 16 to 18, volunteered to participate in the present study. Based on the results of the final score at the National Competition in the organization of the National Synchro Swimming Association of Serbia, they held a national rank of competition at the moment of research. All the participants were free of injury, trained regularly (5-6 days per week, approximately 3 hours per session), had at least 5 years of experience, and took part in competitions 3-4 times per year according to the national calendar. After a detailed briefing about the experimental procedure and the potential risks involved in the study, all swimmers provided written consent to be part of the study. The study was approved by the Institutional Review Board of the Educons University, and all procedures followed the Declaration of Helsinki.

Procedures

All measurements were made in the morning hours before training and after the warm-up. Physical fitness and technical execution assessments were performed during two separate sessions 2 days apart. The anthropometric measurements were made first, and then physical fitness elements were assessed in the following order: balance, lower and upper body flexibility, muscle endurance, jumping performance, agility. A standardized warm-up (including 5 min jogging interspersed with general and specific movements of moderate-intensity, 10 min of static, and 10 min of dynamic sport-specific stretching) preceded each session.

Measures

Shoulder flexibility

The shoulder circumduction test consisted of the shoulder pass through (with a stick 2.5 cm in diameter and 165 cm in length, with a plastic holder at one end of the stick covering 15 cm of the wooden part, with a centimeter-scale with a zero point, directly to the plastic holder) while maintaining a grip as narrow as possible. The result was recorded in centimeters (cm). The task was performed three times. The forward bend test requires a forward bend of the trunk from a standing position on a bench with the legs extended. The result was recorded in centimeters. The task was performed three times (Radaš & Bobić, 2011).

Hip range of motion – Side split

The estimated total duration of the assignment for one respondent is about 1 minute. The initial position is the “prone position” with hands wide apart. The legs must be fully extended. The participant takes maximum propagation to the resistance of sitting with hands wide apart. When the participants reach the lowest possible position, the examiner measures the height from the axis of the pubis to the ground to 0.1cm. The result is the distance from the axis of the pubis to the ground in cm. The examiner is a female.

Body hyperextension

The bridge test was used to assess body hyperextension. Since the height of an athlete may affect the distance between wrists and heels, the measurement was standardized by subtracting it from the swimmer's height with arms raised (up to the wrist) and then dividing it by the height with arms raised. Donti et al. (2016) reported the ICC for body hyperextension in a sample of swimmers of the same age group, 0.89 ($p<0.01$). All flexibility measurements were taken twice and the best result was taken for further analysis (Donti, Bogdanis, Kritikou, Donti, & Theodorakou, 2016).

Balance

We used two static balance tests (balance on the preferred leg with eyes open and closed), because of the nature of the sport. Artistic swimming involves posture in static positions, so it is obligatory to have a high level of balance ability for the successful performance of technical elements. For both balance tests, testing time was maximum in that position. One examiner tested all the participants. A balance beam for testing balance was used (2 cm wide, 4 cm high, 60 cm long, fixed to a 60x30 cm thick plank in the middle). The goal was to stand with the preferred foot along the board and with hands on hips. The other foot is on the ground. The measurement begins when the participant lifts her leg, which is on the ground, and stops when she lowers the leg, falls off the board, or moves her hands (Radaš & Bobić, 2011).

The eyes-closed test starts when the participant closes her eyes, and the test ends when she falls off the beam, touches the floor or beam with the other leg, opens her eyes, or has visible disturbances of balance. The average result of three measurements is the final result of the balance test.

Upper-body muscular endurance

Muscular endurance of the arms and chest muscles was measured using the 1 min push-ups test. The participant was in a prone position on her toes and hands. The hands were placed shoulder-width apart with the fingers pointing forward. The elbows were held in full extension and the feet were placed 10 cm apart. The swimmers were instructed to keep the body in a straight position and bend their elbows until the chin touched the mat and then fully extended their arms again. The maximum number of push-ups performed consecutively in one minute was used for further analysis. Donti et al. (2016) reported ICC for the 1 min push-ups test was 0.91 ($p<0.01$). For muscular endurance, the participant performed as many repetitions as possible using maximum speed throughout the test. The test was stopped if two consecutive repetitions were unsuccessful or if the participant was unable to continue. An unsuccessful repetition was regarded as one that deviated from the standard procedure. The maximum number of push-ups was documented to evaluate muscular endurance (Augustsson et al., 2009).

Muscular endurance of the abdominal muscles

Testing of the muscular endurance of the abdominal muscles included sit-ups. The swimmers lay face up on a mat with their knees bent at 90° and crossed their arms over their chest with their hands on their shoulders at all times. From this position, they raised the upper torso until their elbows touched their knees and then lowered their upper torso until their shoulder blades touched the floor. The examiner assisted by anchoring the swimmer's feet on the ground. The maximum number of correctly executed repetitions was recorded (Radaš & Bobić, 2011; Donti et al., 2016).

Isometric Back Extension Endurance Test

Endurance was evaluated by timing (holding time measured in seconds) how long the participant could hold the upper part of the body horizontal, while lying prone, with no support beyond the upper border of the iliac crest. The hands were kept behind the neck and the thighs and ankles were fixed to the table by 2 wide straps. The participants were instructed to hold the position as long as they could. Coefficients of inter-tester reproducibility for holding time ranged from 0.66 to 0.89 in earlier studies (Augustsson et al., 2009).

Jumping performance – The Standing Long Jump

The athlete stands behind a line marked on the ground with feet slightly apart. A two-foot take-off and landing are used, with the swinging of the arms and bending of the knees to provide forward drive. The participant attempts to jump as far as possible, landing on both feet without falling backward. A better result from two attempts is evaluated, with an accuracy of one centimeter. The test-retest reliability in previous studies varies from 0.91-0.96 (Manske & Reiman, 2013).

Speed and Agility – The Sport-specific motor test
("Sprint freestyle" 25m + diving 25m with barracuda and boost at 12.5m (T1))

In the starting position, the swimmer holds the pool wall with one hand and the other hand in the forward position on the water surface, while the feet are placed on the pool wall. At the sign, the swimmer responds with a somber reflection, followed by a short glide through the water. Towards the end of the slide (when the slowing begins), the swimmer works with her feet and hands using the trail technique. In this swimming technique, the legs alternate downward strokes. On impact, the movement begins with the leg bent and returns with the leg extended. In the trail case, arms alternate with the curves in such a way that they are bent at the elbow, while one hand pushes the water backward, while the other returns through the air to the "upset" position. Because swimmers swim at full speed ("sprint"), they do only 4 to 5 breaths on a 25m section. After 25m, swimmers touch the wall of the pool, take a breath, dive, and push away from the wall with a sultry reflection. After pushing, the swimmer glides through the water and dives with free technique (underwater breaststroke technique), up to half of the specified length of diving. At 12.5m, swimmers turn to the "back pike" position (hull and legs close a 45 ° angle, and the feet are perpendicular to the surface of the water with their feet), to prepare for the "Barracuda" water jump. After the boost, once they breathed in, the swimmers dive and continue their free-diving dive to the pool wall (to the starting point of measurement). The shorter the runtime, the better the result. Propulsive techniques and postures of the body in motion are such that they allow swimmers to move as fast as possible at all times. This is a problem, and there are no performance errors that cause a swimmer to repeat the test. The test was designed with the idea that swimmers, after high-intensity work, have apnea work, in this case diving, which will be interrupted by asynchronous elements. To break this section, 2 elements of explosive power were used in this test. In one element, swimmers do not breathe and in the other, they take one breath. Similar situations occur during the execution of figures (Perić, 2011).

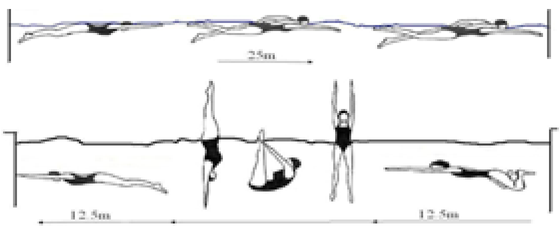

Fig. 1 "Sprint freestyle" 25m + diving 25m with barracuda and boost at 12.5m (T1)

Endurance – The Sport-specific motor test ("Flutter kick" 25m + diving 25m (T2))

Test T2 is performed in such a way that the swimmer crosses 25m using the propulsion technique “leg bike” and then dives 25m freestyle. The “foot bike” is an integral part of arriving at the panel of judges during the figure competition. It is one of the basic propulsive techniques in synchronization and has been included in newly constructed tests. The body is upright in the water with the characteristic position of the legs and arms whose alternating circular motion allows movement while the shoulders and head are above the surface of the water. In this position, the swimmer can move in various directions (forward, lateral and backward, and even diagonally). The lateral movement is the one that is performed most quickly and is therefore assigned in this test. The height of the shoulders above the surface of the water is determined by the swimmer’s intensity. The higher the shoulders are above the water, the more intense arm and leg work is required to maintain it. Therefore, it was determined that when performing the test, only the upper part of the shoulder should be above the water surface to have an optimal speed-to-height ratio. The initial position of the body is similar to that of movement, except that the intensity of work is much lower, and the arms are stretched out so that the swimmer once held to the pool wall. At the sign, the swimmer detaches herself from the wall and moves with intense work, moving to her dominant side. After 25m of this technique, the swimmer touches the pool wall by hand, dives, pushes away from the wall with a sulfurous reflection, and dives 25m with a free technique (underwater breaststroke technique). The technique of underwater chest curling is performed in such a way that the arms curl while the arms are bent at the same time. While extended, the arms pull water backward in a semi-circular motion, all the way to the hip line. When the bandage ends, the palms in front of the chest and face are drawn as briefly as possible until re-arming. The legs push the water backward in a semi-circle. Thus, the feet are open to the outside and are attracted to the lower legs. The knees extend, but do not extend beyond the feet. At the end of the impact, the legs are assembled and are extended. When preparing the legs for impact, the lower legs bend so that they can strike. This way the “extended” curtain allows for a slight glide through the water. The depth at which the dive is arbitrary is in the lower half of the depth of the basin (usually closer to the bottom of the basin). With such diving techniques, swimmers control the depth well, can change their body position quickly, and do not have enough space for any errors that would affect the test time. Underwater thoracic swimmer techniques go faster than a given section (faster dives) and are less tired than diving with the “trail leg” technique. The test measurement time stops when the swimmer, after the dive section, touches the edge of the pool with a hand (Perić, 2011).

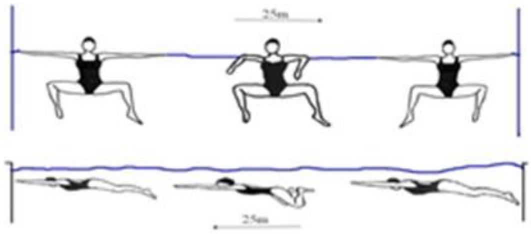

Fig. 2 "Flutter kick" 25m + diving 25m (T2)

The criterion variable is the final result (RANG) of the National Artistic Swimming Championship according to FINA rules (2013-2017).

Statistical analysis

Data processing was performed in the program SPSS 20.0. and reported as means and standard deviations (SD). Pearson's correlation coefficient (r) was used to detect associations among variables and the final score. A multiple regression analysis was used to investigate which physical fitness variables contributed most significantly to the technical execution score. Statistical significance was at $p<.05$. All analyses were performed using SPSS (version 20.0, SPSS Inc., Chicago, IL, USA).

RESULTS

The results of descriptive statistics and Pearson correlation analysis are shown in Table 1. The results of a correlation analysis showed big correlations between rank at the competition and ten of the 13 variables.

Table 1 Descriptive Statistics and Pearson correlations

Variables	Minimum	Maximum	Mean	SD	Rang
Side split	-44.00	22.00	-3.66	16.84	-.408*
Shoulder flexibility	15.00	98.00	54.24	19.04	-.327
Sit and reach	7.00	29.00	17.69	5.49	.484**
Long distance jump	141.00	192.00	164.83	11.76	-.163
Bridge	11.00	61.00	38.57	14.32	-.303
Endurance abs	3.00	50.00	13.00	8.77	.416*
Endurance back	78.00	206.00	126.40	32.37	.366*
Balance eyes open	3.00	27.67	12.91	5.79	.619**
Balance eyes closed	7.67	60.00	36.33	16.31	.528**
Push-ups	6.00	25.00	13.14	4.19	.620**
Sit-ups	18.00	32.00	24.51	3.43	.443**
T1	62.00	88.00	72.11	6.85	-.428*
T2	47.00	69.00	55.86	5.49	-.514**
RANG	45.09	63.59	53.40	4.26	-

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 2 Results of the multiple regression analyses using physical fitness variables as predictors of the performance final score

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	F	Sig.
1	.829[c]	.687	.657	2.499	22.663	.000

Predictors: Push-ups, Balance with open eyes, T2
Dependent variable: Rang

Table 2 shows a statistically significant relationship between the predictor system and the criteria (p=.00). The technical execution score was correlated with several physical fitness variables. Multiple regression analysis revealed that push-ups, balance with open eyes, and T2 accounted for a large part (.687%) of the variance in the final score.

DISCUSSION

The present study aimed at examining the association between selected physical fitness variables and the competition score in junior synchronized swimmers at the national level. The participants for this study were taken from the population of female swimmers aged 16 to 18. The relationship between the variables for the evaluation of motor abilities and the dependent variable of the ranking is high, so the battery used for the evaluation of their motor abilities is good. The results of the regression analyses confirmed the larger contribution of motor abilities to the variance in the competition score.

The research showed that the highest predictive power for evaluating is related to upper-limb endurance, balance, and the first sport-specific test used to determine the endurance of swimmers. The test was designed with the idea that female swimmers, after very intensive work (diving in this case), have apnea which will be interrupted with a synchro-element. The elements that require explosiveness from female swimmers also require additional effort (with or without breathing) and are easy to control, so they were included in this test. Test T2 contains diving at 25m. Although the freediving training and breathing exercises start on land, the best training is diving in different time intervals and at various depths. The most demanding part of performing figures is the training in apnea, where the muscles work without oxygen, which is also the reason for such a large impact of the specific motor skills on the ranking. The participants with poorer measurement results regarding the speed of element performance in test T1 are also the ones that are, according to the subjective opinion of the coach, "lower-ranked female swimmers." At the same time, the tests which measure the strength of the participants also partially represent their performance technique. The participants with a better result in tests T1 and T2 are also "higher-ranked female swimmers" since their better techniques offer greater utilization of strength (Perić, 2010).

Such results can be attributed to intensive motor training abilities which are especially expressed in the achieved final placement of swimmers. Research has shown that the greatest predictive power for performance evaluation figures has standing tests on one leg along the balance bench and push-ups. Such results are expected, given the specifics of the figures performed at competition. This is supported by previous research that suggests that stability and balance of the body and quality rowing with the hands is necessary for achieving good results in the figures (Homma et al., 2014). Hand strength is an obligatory code for performing all the figures in artistic swimming. Those motor abilities are statistically significant for achieving high sports results, according to the research of the author Labudova (2014). In younger participants, the most significant contribution in the space of motor abilities is realized in the space of endurance, dynamic strength, and static and explosive forces of the upper extremities. Positive changes and a better economy of movement in the water in synchronous swimming allow a higher level of strength. Research results of a large number of authors show that synchronous swimming is a sport that requires strength (Chu, 1999; Hoff et al., 2002; Osteras et al., 2002), but also a high level of flexibility (Tošić et al., 2010).

Analyzing the performances of various elements of technique and composition in synchronous swimming, it can be seen that movements in this sport represent a combination of highly complex motor actions. Therefore, it is compulsory to determine the motor skills and knowledge needed for the successful performance of figures in synchronous swimming. As motor abilities affect both functional abilities and morphological characteristics, it is necessary to develop them to the maximum. Due to the acrobatic elements that are an integral part of the choreography, synchronous swimmers face increasing and more specific requirements (Chu, 1999). The results of many studies undoubtedly confirm the fact that motor skills have a great impact on performing swimmers (Yamamura et al., 1999; Perić & Spasić, 2010; Tošić et al., 2010; Stanković et al., 2015).

CONCLUSION

Based on the results, we can draw several conclusions. Firstly, all research fields significantly affect the final result of female swimmers in terms of statistics. However, the obtained results refer only to the researched sample of participants. Although this is a selected sample, it is obvious from the descriptive statistics that the participants differ significantly on the individual level, both in terms of motor and specific abilities. The research should focus on the analysis of the body composition of a large number of female swimmers, as well as that of female swimmers of other age groups. The motor and specific motor skills directly affect the final result. The obtained results suggest that the motor and the specific motor skills of female artistic swimmers yield better results. Therefore, it is necessary to work on their improvement to achieve good results. The results can have a wide practical application in the physical and technical preparation of female swimmers. It is a fact that the further progress of science will enable us to gain a better understanding of the functioning of female artistic swimmers' bodies. The discovery of new scientific achievements in the framework of this sport or the use of better training means shall contribute to the ever-improving preparation of female athletes, thus enabling the achievement of top results.

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MOTORIČKE SPOSOBNOSTI KAO PREDIKTORI U UMETNIČKOM PLIVANJU: STUDIJA PRESEKA

Cilj ovog istraživanja bio je da se ispita povezanost motoričkih sposobnosti i postignuća kod umetničkih plivača koji se takmiče na republičkom nivou. U istraživanju je učestvovalo 35 juniorskih sinhronih plivača (uzrasta od 16 do 18 godina, visine 165,49±3,57cm i težine 53±4,23kg). Evaluacija motoričkih sposobnosti obuhvatala je jedanaest testova za ukupne i dva testa za specifične motoričke sposobnosti. Analiza podataka je urađena u SPSS 20.0. Rezultati pokazuju statistički značajnu povezanost između prediktorskog sistema i kriterijuma (p=.00). Rezultat tehničkog izvršenja bio je u korelaciji sa nekoliko varijabli fizičke spremnosti. Višestruka regresiona analiza je otkrila da sklekovi, ravnoteža sa otvorenim očima i T2 čine veliki deo (.69%) varijanse u konačnom rezultatu. Rezultati ovog istraživanja su praktično primenljivi u kvalitetnijoj pripremi sinhronih plivača i postizanju maksimalnih rezultata.

Ključne reči: *fizička priprema, uspeh na takmičenju, specifične sposobnosti*