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Original Article

Anthropometric and anaerobic parameters in young female artistic swimmers

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Abstract:
Artistic swimming is a sport that requires combination of aerobic and anaerobic power. There is little data in the literature on the anaerobic capacity of synchronized swimmers. This study aimed to track the observed changes in the anthropometric and anaerobic parameters among young female synchronized swimmers over a one-year period. The study included 9 female artistic swimmers with average values for age 11 ± 2 years, height 148.2 ± 11.1 cm and weight 39.5 ± 9.2 kg at the initial measurement. Measurements were conducted twice within a period of 1 year. The measurements take place in late April, before the participation of the athletes in important key competitions. Body composition assessment, somatotyping, Wingate and Sargent test were performed. Results indicated an increase in the body mass index over the year, attributed to enhanced muscle mass as a result of from training. Their somatotype varied little in the two measurements, but the variations were minor, a statistically insignificant decrease in the mesomorphic component and an increase in the ectomorphic component shows that as a result of synchronized swimming training, female athletes form suggested the formation of a characteristic sports somatotype. Maximum power of the studied group of artistic swimmers progressively increased over the study period and after 12 months was significantly higher than at the beginning of the study. A statistically significant difference between two measurements was observed in vertical jump and calculated peak power (Wilcoxon signed rank test, P value = 0.0039 and P value = 0.0039, respectively). These results are further evidence that finding underscore the profound impact of artistic swimming training has a strong impact on increasing the anaerobic capacity of athletes. Tracking the anthropometric and anaerobic characteristics enables the analysis of changes in artistic swimming athletes allows for the analysis of their changes. Targeted training guided by these observations can contribute to the improvement of specific qualities, in the case of desired changes in body composition and anaerobic capacity. Ultimately, this approach enhances sports form and increasing sports improves athletic performance.
Key Words*:* **female athletes, body composition, somatotype, Wingate test, Sargent test**

Introduction

Synchronized or artistic swimming is unique among aquatic sports, requiring a variety of athletic abilities such as endurance, strength, agility, acrobatics, and flexibility, along with a sense of rhythm and team spirit. Combinations vary in duration from 2 to 5 minutes depending on age and competition category, during which the level of intensity is high and the exercises are performed both with free breathing and with holding the breath. Key characteristics of this sport in terms of energy provision are that it relies on both the aerobic and anaerobic capacities of athletes (Robertson, et al., 2014; Viana, et al. 2019). This is because they spend a large part of their time under water, which leads to long periods of apnea, and at the same time they perform active actions, which largely determines the nature of the energy supply in conditions of lack of oxygen (Davies, et et al., 1995). In recent years, choreographies have included more acrobatic elements, which greatly affects the demands on athletes in terms of their ability to generate more force (Rodríguez-Zamora, 2013).

Long training sessions and technical movements performed in high water resistance require a wide range of cardiovascular and musculoskeletal strength. One of the main skills in artistic swimming is jumping, with athletes using techniques specific to this sport to raise their bodies as high as possible above the surface of the water (Peric et al., 2012; Bentley, et al., 2022). Targeted training on land aimed at improving lower extremity explosive power can significantly improve diving techniques in water (Escrivá-Sellés & González-Badillo, 2020). There is little data in the literature on the anaerobic capacity of artistic swimmers. Most studies in synchronized swimming have focused on heart rate (HR) and blood lactate measurements following the performance of single figures (Gemma & Wells, 1987; Homma 1994; Homma & Takahashi 1999) or a routine training program (Smith 1988; Chatard et al. 1999). The lack of such studies is probably due to the lack of a specific anaerobic test to be conducted in water. Anaerobic capacity is usually determined by the anaerobic Wingate test (Bar-Or, 1987; Vandewalle, et al., 1985). One of the few studies of anaerobic power in artistic

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swimmers, conducted by Jamnik et al. (1986), indicated that their relative power on the Wingate test was 6.0 ± 0.2 watts/kg, which ranked them between the 10th and 20th percentiles for active young women (Maud & Shultz, 1989). But all the data in the literature refer to older athletes.

Research involving child athletes is rare, but extremely interesting. Our research group is interested in studies of children and adolescents engaged in various sports. On the other hand, it is difficult to conduct research with a control group of non-exercising children of the same age, because parents do not consent to such tests. And as is well known (Borms, 1986), to assess the possible effects of exercise on growth and development, trained and untrained subjects need to be compared. From the point of view of energy provision, there are significant differences between children and adults. The ratio of aerobic to anaerobic contribution to metabolism during exercise depends on its duration, for example, for maximal efforts lasting less than 1 minute, children derive no more than 40% of the total energy consumed from aerobic sources; for adults the figure is about 20%, while a 6-minute effort for children occurs virtually in aerobic conditions (Vrijens, 1982). And although children work mainly in an aerobic mode, our previous studies in other groups of athletes - basketball players (Hadzhiev & Dzimbova, 2020), skiers (Dzimbova & Kirkova, 2020) and gymnasts (Dzimbova & Markov) - show that as a result of targeted training, the anaerobic capacity of adolescent athletes significantly increases.

Therefore, the aim of the present study is to track the changes in the anthropometric and anaerobic parameters of female synchronized swimming competitors over a period of one year, which on the one hand will enable the collection of data in this little-studied sport, and on the other hand will show up to what extent this sport helps increase the anaerobic capacity of adolescent female athletes.

Material & methods

Organization of the study

The research was conducted twice in a period of 1 year. The measurements take place at the end of April, before the participation of the athletes in important competitions. The procedures are carried out in the laboratory of the Center for Functional Studies in Sports and Kinesitherapy - SWU "Neofit Rilski", Blagoevgrad, and the anthropometric measurements were carried out in the morning on an empty stomach, followed by the anaerobic test.

Subjects

The study included 9 female synchronized swimmers from SC "Pirin" - Blagoevgrad with average values for age 11 ± 2 years, height 148.2 ± 11.1 cm and weight 39.5 ± 9.2 kg at the first measurement. The athletes and their parents were informed of all procedures, the parents gave written consent. The study was performed in accordance with the principles outlined in the Declaration of Helsinki and the University Research Ethics Committee of South-West University, Blagoevgrad.

Body composition assessment and somatotyping

Prior to the study, the subjects were asked to abstain from physical activity, food, and fluid intake. Weight and height were measured as well as body composition with bioelectric impedance analyzer Ioi 353. The somatotype was determined using the Heath-Carter method, with three skin folds (triceps, subscapular, supraspinale), two diameters (humerus, femur) and two circumferences (arm and calf). The measurement was carried out two times, at the same time.

Table 1. Anthropometric data of the subjects

ID	Age, years		Height, cm		Weight, kg		PBF, %		MBF, kg		SLM, kg		BMI, kg/m^2	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2
AS1	14	15	161.5	162.0	48.8	51.3	22.3	24.2	10.9	12.4	35.1	35.9	18.7	19.5
AS2	12	13	158.0	160.5	51.7	55.4	20.1	21.1	10.4	11.7	38.3	40.5	20.7	21.5
AS3	12	13	151.0	157.0	35.4	41.1	12.4	11.9	4.4	4.9	28.9	33.8	15.5	16.7
AS4	12	13	158.0	160.5	41	45.9	12.7	16.6	5.2	7.6	33.4	35.6	16.4	17.8
AS5	8	9	145.0	151.0	31.7	35.2	13.2	13.6	4.2	4.8	25.6	28.3	15.1	15.4
AS6	12	13	148.0	150.5	44.1	46.5	21.1	22.4	9.3	10.4	32.3	33.4	20.1	20.5
AS7	9	9	136.0	141.5	29	31.3	16.2	14.8	4.7	4.6	22.6	24.7	15.6	15.5
AS8	9	10	127.0	133.0	26.6	29.7	18.8	16.5	5.0	4.9	20.1	23.1	16.5	16.8
AS9	10	11	149.0	156.0	47.5	48.6	22.3	20.0	10.6	9.7	34.2	36.1	21.4	20.0
Mean	11	12	148.2	152.4	39.5	42.8	17.7	17.9	7.2	7.9	30.1	32.4	17.8	18.2
±SD	2	2	11.1	9.7	9.2	9	4.1	4.2	3	3.2	6.2	5.8	2.5	2.3

Mean - average; ± SD - standard deviation; 1 – measurement in April 2021, 2 – measurement in April 2022.

Wingate test

The test was performed with a Monarch 828 E bicycle ergometer. The system includes a bicycle ergometer and software. The test involved 30 seconds of maximum load on the leg. After 5 minutes of warm-up the subject stopped for a three-minute recovery. The test started with maximum speed rotation without any load. After reaching the maximum pedal speed, a fixed weight of 7.5% of the weight of the subject was applied. The pedalling with this weight lasted for 30 seconds, striving for maintaining the maximum speed of pedalling, respectively maximum power. After the end of the test, peak power was determined for 5 seconds. This represented the maximum power that a person could develop in the first 5 seconds. The relative maximum power was determined by dividing the maximum power by the subject's weight. The test was performed twice.

Sargent test

Sargent test, also known as vertical jump, is suitable for tracking the development of elastic leg strength. The subject stood against the wall with extended hand, indicating the position in cm of the stretched arm. Then, from a static position, the subject jumped as high as possible, extending the hand again and touching the wall. Three consecutive jumps were made and the highest value was taken. The difference between first and second position of the hand on the wall in cm was determined. The test was performed twice.

Data analysis

GraphPad Prism (Ver. 3.0) was used for data processing and analysis. Means and standard deviations of all variables were calculated using descriptive statistics. Experimental data are presented in two ways: - as mean values ± SD; and – as individual values for each subject. Statistical software GraphPad Prism was used for statistical analysis of the results (Wilcoxon signed rank test).

Results

Measurements were made twice in the period of one year. The results of the conducted research are presented in the tables below.

Anthropometric data included height, weight, BMI, body fat percentage and mass, and muscle mass and are presented in Table 1.

There is a statistically significant difference in height for both measurements (Wilcoxon signed rank test, P value = 0.0039), weight (P value = 0.0039), SLM (P value = 0.0039), but there were no statistically significant changes in the percentage of adipose tissue and its weight, as well as BMI.

Table 2. Somatotype components of the subjects.

ID	endo		meso		ecto	
	1	2	1	2	1	2
AS1	3.6	2.7	3.4	4.6	3.8	3.3
AS2	3.1	2.6	5.4	5.4	2.5	2.1
AS3	1.9	1.5	4.2	3.7	5.2	4.7
AS4	2.7	1.8	3.6	3.2	4.5	4.2
AS5	2.2	1.7	4.5	3.7	4.9	5.1
AS6	5	3.6	6.1	6.1	2.1	2.1
AS7	2.8	2.1	5.8	5.6	3.9	4.2
AS8	3.4	1.9	6.4	6.3	2.6	2.9
AS9	4.5	2.6	6.7	5.1	1.5	2.7
Mean	3.2	2.3	5.1	4.9	3.4	3.5
±SD	1.0	0.7	1.2	1.1	1.3	1.1

Mean - average; ± SD - standard deviation; 1 – measurement in April 2021, 2 – measurement in April 2022.

The somatotype components are presented in Table 2. A statistically significant decrease of the endomorphic component was observed during the studied period (P value = 0.0039). Despite a slight decrease in the mesomorphic component and a slight increase in the ectomorphic component, they are not statistically significantly different. These data also confirm the anthropometric data.

Correlations were found between the endomorphic component and percent fat mass (Pearson r = 0.85, p = 0.0038), fat mass (Pearson r = 0.72, p = 0.0278) and BMI (Pearson r = 0.79, p = 0.0102) at the first measurement and the second (Pearson r = 0.86, p = 0.0028, percent fat mass; Pearson r = 0.76, p = 0.0160, fat mass and Pearson r = 0.78, p = 0.0140, BMI).

Data from the Wingate test are presented in Table 3, with data including peak power and relative peak power in both measurements.

There is a statistically significant increase in maximal and relative power (Wilcoxon signed rank test, P value = 0.0039 and P value = 0.0078, respectively). There is a statistically significant difference between two measurements of vertical jump and calculated peak power (Wilcoxon signed rank test, P value = 0.0039 and P value = 0.0039, respectively).

Correlations were found between data of Wingate and Sargent tests (Pearson r = 0.74, p value = 0.002 and Pearson r = 0.71, p value = 0.03 for the first and second PP (Wingate test) and CP (Sargent test), respectively.

Table 3. Peak power and average peak power valuesn of the subjects.

ID	PP, W		APP, W/kg	
	1	2	1	2
AS1	226.43	276.37	3.14	5.42
AS2	314.48	339.65	5.21	4.84
AS3	297.41	370.92	8.50	9.05
AS4	174.14	327.00	3.52	7.27
AS5	80.48	123.63	2.11	3.08
AS6	119.56	185.73	2.23	4.04
AS7	71.79	169.19	2.48	5.46
AS8	58.51	85.46	1.72	2.95
AS9	127.44	221.77	1.99	4.62
Mean	147.12	210.17	3.19	4.87
±SD	104.39	119.92	2.20	2.10

Mean - average; ± SD - standard deviation; 1 – measurement in April 2021, 2 – measurement in April 2022

Table 4. Date from the vertical jump test.

ID	VJ, cm		Calculated power, W	
	1	2	1	2
AS1	30.0	34.0	1976.6	2332.7
AS2	35.0	38.0	2411.5	2761.2
AS3	33.0	37.0	1551.7	2052.7
AS4	36.0	38.0	1987.5	2330.9
AS5	29.0	30.0	1141.3	1360.6
AS6	30.0	38.0	1763.7	2358.1
AS7	25.0	27.0	776.2	1001.8
AS8	30.0	36.0	971.0	1475.6
AS9	29.0	32.0	1857.1	2089.0
Mean	27.8	31.2	1443.8	1776.5
±SD	9.9	10.9	718.3	824.0

Mean - average; ± SD - standard deviation; 1 – measurement in April 2021, 2 – measurement in April 2022

Discussion

A study of the anaerobic capacity of artistic swimmers was conducted. There are no data on similar values in the same age group in the literature. This makes the study extremely important as it enriches the literature with such data. An attempt was made to track the changes in anthropometric and anaerobic indicators in female synchronized swimmers over a period of 1 year. As can be seen from the obtained results, the subjects increased their height and weight, which was expected. The low percentage of fat in the studied athletes, which managed to remain unchanged during the studied period, is striking. Another important finding is the fact that for the 1-year period during which the study was conducted, there were statistically significant differences in anthropometric indicators among individuals, as they were in an age of active growth and development (Malina et al., 2004; Genc & Cigerci, 2020).

The group is not homogenous in terms of height and weight, as this age normally has the most variation, and BMI varies the least. Although artistic swimmers are generally thin and have a low body mass index (Parlov, et al., 2020), it is noticeable that it increases over a year, and this is due to an increase in the muscle mass as a result of training. This shows that the change in weight is mainly related to the increase in muscle mass.

By determining the somatotype, the dynamic changes in the human body that occurred as a result of purposeful training activity are tracked. It is a prerequisite for the determination of a rational sports technique and the achievement of high sportsmanship. Knowing the athlete's somatotype allows for individualization in the training process, tailored to the athlete's anthropometric characteristics. In the table 2, it is clearly visible that the subjects have a pronounced mesomorphic type. The balanced type is the type that is characteristic of artistic swimmers, as shown in a number of studies (Rodríguez-Zamora, et al., 2012; Bante et al., 2007; Chu, 1999). Their somatotype varied little in the two measurements, but the weak statistically insignificant decrease of the mesomorphic component and increase of the ectomorphic component shows that as a result of synchronized swimming training, female athletes form the characteristic sports somatotype.

Currently, the Wingate Anaerobic Test under laboratory conditions with an ergometer is accepted as the gold standard for determining anaerobic capacity. This test has been shown to be reliable and valid in children and adolescents with a variety of chronic conditions. The average age of the studied group was 11 ± 2 years. The literature has no data on research in this age group of artistic swimmers. However, studies have been conducted with children who do not engage in sport (Chia, et al., 1997) and the value measured by the authors for mean peak power was 168 ± 33.7 W. In our first measurement at the beginning of the study, the mean maximum power value of the subjects was 147.11 ± 104.39 W, which is lower to that of the literature. The maximum power of the studied group of artistic swimmers progressively increased during the studied period and after 12 months was significantly higher than that of untrained children (average maximum power at the second measurement was 210.17 ± 119.92 W). These results are further evidence that artistic swimming training has a strong impact on increasing the anaerobic capacity of athletes.

Comparison of our vertical jump data obtained with literature data indicated that the subjects had significantly higher values of both vertical jump and calculated peak power than those of individuals in the same age group (Taylor, et al., 2010). The subjects reached and even exceeded the maximum vertical jump value for the respective age presented in the norms by Taylor, et al. (2010). Comparing for example with female gymnasts of the same age (Markov & Dzimbova, 2023) their vertical jump is significantly lower.

There is a correlation between data of Wingate and Sargent tests (Pearson r = 0.74, p value = 0.002 and Pearson r = 0.71, p value = 0.03 for the first and second PP (Wingate test) and CP (Sargent test), respectively, while no dependencies of the Wingate data and the height of the vertical jump were found. These dependencies show that the Sergeant test can be used to quickly assess the anaerobic capacity of artistic swimmers, even in the training place, as it can be performed without the need for expensive equipment and is not time-consuming. Of course, the calculated maximum power must be taken into account, because it also depends on the mass of the subject. The increased values of both the vertical jump and the calculated maximum power indicate that, as a result of targeted training, the anaerobic capacity of the subjects increases.

Conclusions

As a result of our study, the anthropometric and anaerobic characteristics of young female synchronized swimmers were measured over a period of one year. Data on athletes in this age group and in this sport is lacking, which is a significant contribution and could support the research of other researchers as well.

The analysis of the data shows that as a result of purposeful training in artistic swimming, the corresponding adaptations and characteristics of the athletes in this sport are reached. Athletes' bodies are shaped in a certain way - their somatotype changes to a more balanced type characteristic of artistic swimmers (from 3.2-2.3-5.1 at the beginning of the study period to 4.9-3.4-3.5 at the end of the study).

Physical exertion during training leads to an increase in their anaerobic capacity. The Wingate test shows a statistically significant increase in maximum power (from 147.12 W at the beginning of the study period to 210.17 W at the end of the study, Wilcoxon signed rank test, P value = 0.0039), and in the Sargent test, the height of the rebound also increases (from 27.8 cm at the beginning to 31.2 cm at the end of the study period, Wilcoxon signed rank test, P value = 0.0039), and the calculated maximum power (from 1443.8 W at the beginning to 1776.5 W at the end of the study period, Wilcoxon signed rank test, P value = 0.0039). These values are significantly higher than those measured in untrained individuals of the same age.

Measurements of anthropometric and anaerobic characteristics of artistic swimmers should be applied continuously over a period of time. This will enable coaches to monitor changes in body composition and anaerobic capacity of athletes and, if necessary, apply an individualized approach to training with each athlete individually.

Conflicts of interest: The authors declare that there is no conflict of interest.

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