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PREDICTION OF 100 m FRONT CRAWL PERFORMANCE THROUGH ANTHROPOMETRICAL CHARACTERISTICS IN YOUTH GREEK SWIMMERS ACCORDING TO GENDER

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Aim. Investigate the predictive relationship between 100 m front crawl swimming performance of youth swimmers and anthropometric characteristics. **Materials and methods.** Fifty-one active athletes (n = 30 male and n = 21 female) participated in the research and for the purposes of the analysis were divided into two categories (13–15 years n = 32, and 16–18 years old, n = 19). The following anthropometric data were used as set of predictive variables (7 longitudinal, 7 skinfolds, 3 circumference and 1 voluminosity variables). **Results.** One prediction model for each gender and age group emerged. The percentage of the explained variance of the dependent variable (100 m front crawl performance time) is 84.6 %, 54.4 %, 71.1 % and 72.7 % respectively for male, female, youth and cadet swimmers. The significant variables for each model were: arm span, biceps skinfold, biceps bracchi circumference in contraction for male swimmers, sitting height for female swimmers, biceps bracchi circumference in contraction and body weight for youth swimmers, triceps skinfold and biceps bracchi circumference in contraction for cadet swimmers. **Conclusion.** Youth swimmers' performance can be predicted by important anthropometric parameters.

Keywords: *youth swimmers, anthropometrics, 100 m front crawl swimming.*

Introduction

Swimming belongs to those sports where training and competing takes place in the water, an environment that is not natural to humans [18]. The way swimmers move in water and the shape of their body can provide them with a better position for more effective swimming in terms of hydrodynamics. Anthropometric characteristics are valuable means of understanding and interpreting the relationships between physical structure and biomechanical and physiological characteristics and are important for success in many sports [9].

In swimming, the method of anthropometry is used to select candidates for each particular event, to monitor and evaluate the training process, to evaluate body development, nutrition control, along with observation of the athlete's rehabilitation [14, 22].

In different swimming events, anthropometrical characteristics have been shown to have a positive or negative effect on the achievement of the competitive results [1, 17, 20].

Some studies examine the relationship between anthropometric characteristics and swimming performance and some others examine other phenomena in swimming [5, 7]. According to available scientific data, elite swimmers are taller, with broader shoulders and narrow pelvis than the rest of the population or swimmers of lower level. Also, arm span has been reported to be associated with swimming performance and specific biomechanical variables [21].

Previous studies also show that swimmers are taller than non-athletes, tennis and soccer players, and athletes of gymnastics [3, 4].

Furthermore, the fact that certain anthropometric characteristics such as body height and the length of the upper and lower limbs are particularly critical for achieving high performance is commonly accepted [22].

The aim of the present study is to investigate the predictive relationship between 100 m front crawl swimming performance of youth swimmers and specific anthropometric characteristics.

Sample

The sample of the research consisted of 51 active athletes (n = 30 male, age = 15.08 ± 1.6 years, and n = 21 female, age = 14.52 ± 1.5 years)

- **BH**, body height expressed in centimeters
- **BW**, body weight expressed in kilograms
- **SH**, sitting height expressed in centimeters
- **AS**, arm span expressed in centimeters
- **SW**, shoulder width expressed in centimeters
- **PW**, pelvis width expressed in centimeters
- **CD**, chest depth expressed in centimeters
- **CC**, chest circumference expressed in centimeters
- **LAL**, left arm length expressed in centimeters

with competitive experience, who participated daily in a training program in their swimming clubs. Their basic technique was the front crawl and they all competed at short distances. The age of the sample was from 13 to 18 years, which for the purposes of the analysis was divided into two categories (13–15 years n = 32, and 16–18 years old, n = 19).

The participation of the athletes was voluntary. After an oral and written briefing on the details of the research process, the athletes signed the document and expressed their consent before the start of the tests.

The research was carried out in accordance with the conditions of the Declaration of Helsinki: Recommendations Guiding Physicians in Biomedical

Research Involving Human Subjects (http://www.cirp.org/library/ethics/helsinki/) and with the approval and consent of the Ethics Committee of the Faculty of Physical Education and Sport, National and Kapodistrian University of Athens.

The participants were asked to continue their daily activities without changing their training habits. The swimming tests were conducted in open or closed swimming pools of Olympic dimensions (swimming pool 50 m) with a constant temperature of water (26 ± 1) °C.

Methods

Measurements were divided in two parts:

In the first part (1st session), the anthropometric characteristics of the swimmers were collected. In the second part (2nd session), performance time was recorded after a maximum effort of 100m of front crawl swimming.

The first session involves the measurement of following anthropometric data we used as a set of predictive variables (7 longitudinal, 7 skinfolds, 3 circumference and 1 voluminosity variables):

- **BBC rel**, Biceps bracchi circumference in relaxation expressed in centimeters
- **BBC con**, Biceps bracchi circumference in contraction expressed in centimeters
- **BS**, biceps skinfold, expressed in millimeters
- **TS**, triceps skinfold, expressed in millimeters
- **BrS**, breast skinfold, expressed in millimeters
- **BiaS**, biacromial skinfold, expressed in millimeters
- **BiiS**, biiliac skinfold, expressed in millimeters
- **GS**, gastrocnemius skinfold, expressed in millimeters
- **AbS**, abdominal skinfold, expressed in millimeters

The anthropometric measurement protocol has been developed and recorded by the Anthropometric Standardization Conference in 1985 with the scientific opinion of experts [13].

All anthropometric variables were measured with standard equipment. For measuring body height, an electronic scale of the Sega alpha770 type (Vogel & Halke Hamburg, Germany) was used with a measuring accuracy of 0.1 kg and for body weight a weight scale of Sega Bodymetar 208 (Vogel & Halke Hamburg, Germany). Harpenden Skinfold Caliper (HSP-BI, British Indicators, England) was used to measure the skin folds with a 0.2 mm measurement accuracy, while body diameters were measured with a bone caliper. The above variables were measured in the morning hours with a neutral ambient temperature in order for the participants to feel comfortable with their swim suit.

The second measurement included 100 m front crawl swimming from which the performance time was recorded.

Before the maximum effort, swimmers performed a 1000 m warm up of medium intensity under the supervision and guidance of their coach. After 10 minutes of passive rest, each swimmer performed the maximum effort of 100 m front crawl swimming from the starting block. Performance time of 100 m front crawl swimming was used as criteria variable.

Statistical analysis

The results went through descriptive statistical analysis to reveal the basic statistical parameters (X = Mean, SD = Standard Deviation). For the determination of the impact of the inde-

pendent variables to the dependent variable (criterion variable), Multivariate Regression Analysis (MRA) was applied. Analysis of the data was executed with SPSS 25 statistical software program, while the statistical significance level is defined by 95 % and the probability of a $p < 0.05$ [8].

Results

Descriptive statistics of measured variables are presented in Table 1. In addition, after correlating the variables with performance time in 100 m front crawl swimming, the relationships presented in Table 1 emerged.

According to the results of MRA, one model for each gender and age group emerged. The multiple correlation coefficient for the third model is above 0.730 for all of the four groups which means that the correlation of the linear combination of all variables is very high. The percentage of the explained variance of 100 m front crawl swimming is 84.6 %, 54.4 %, 71.1 % and 72.7 % respectively for male, female, youth and cadet swimmers (Table 2). The significant variables for each model differ but we can observe that BBC is the more often encountered variable,

Table 1

Anthropometric characteristics of sample (Mean and SD) and correlations to performance time

Variables	Male n = 30 (Mean ± SD)			Female n = 21 (Mean ± SD)		
	13–15 (n = 18)	16–18 (n = 12)	Total	13–15 (n = 14)	16–18 (n = 7)	Total
Body height (cm)	165.1 ± 7.8	176.1 ± 6.4	169.5 ± 9.03*	159.9 ± 6.9#	168.7 ± 6.9□	162.8 ± 7.9†
Body weigth (cm)	56.8 ± 7.8	70.3 ± 5.4	62.2 ± 9.6*	51.1 ± 7.8#	60.1 ± 5.1□	54.1 ± 8.1†
Sitting height (cm)	82.4 ± 4.6	90.6 ± 3.5	85.7 ± 5.8*	81.3 ± 4.8#	88.7 ± 1.5	83.8 ± 5.3†
Arm span (cm)	168.2 ± 10.4	180.3 ± 6.9	173.0 ± 10.9*	163.1 ± 10.01#	168.5 ± 5.1□	164.9 ± 8.9†
Shoulder width (cm)	37.5 ± 2.2	41.3 ± 1.5	39.0 ± 2.7*	36.3 ± 2.3#	37.8 ± 1.5□	36.8 ± 2.2†
Pelvis width (cm)	32.05 ± 2.1	33.6 ± 1.2	32.7 ± 1.9*	33.1 ± 2.8	35.4 ± 1.4	33.9 ± 2.6
Chest depth (cm)	20.05 ± 1.8	21.2 ± 1.9	20.5 ± 1.9*	19.1 ± 1.8#	20.3 ± 0.7	19.5 ± 1.6
Chest circumference (cm)	87.3 ± 5.8	96.0 ± 5.02	90.8 ± 6.9*	83.8 ± 6.2#	93.4 ± 1.4□	87.04 ± 6.9†
Biceps bracchi circumference in relaxation (cm)	26.6 ± 2.4	28.8 ± 1.1	27.5 ± 2.3*	25.0 ± 2.5#	28.2 ± 1.3□	26.07 ± 2.6†
Biceps bracchi circumference in contraction (cm)	28.7 ± 2.3	32.0 ± 1.1	30.0 ± 2.5*	27.03 ± 2.7#	30.1 ± 1.5□	28.07 ± 2.7†
Left arm length (cm)	71.5 ± 3.8	77.2 ± 3.5	73.8 ± 4.6*	69.4 ± 4.1#	72.0 ± 2.6□	70.3 ± 3.8†
Breast skinfold	5.8 ± 3.1	4.6 ± 1.6	5.3 ± 2.6*	5.03 ± 1.4	5.8 ± 2.4	5.3 ± 1.7
Biceps bracchi skinfold	7.7 ± 4.8	4.9 ± 1.3	6.6 ± 4.02*	7.6 ± 2.1#	9.2 ± 3.4□	8.1 ± 2.6
Triceps bracchi skinfold	8.5 ± 3.9	5.8 ± 1.7	7.4 ± 3.5*	9.9 ± 2.3#	10.2 ± 3.2	10.0 ± 2.6
Biiliac skinfold	9.1 ± 4.7	7.8 ± 2.3	8.5 ± 3.9*	8.3 ± 1.9	11.0 ± 2.5	9.2 ± 2.4†
Biacrom skinfold	9.7 ± 7.4	8.8 ± 3.6	9.4 ± 6.1*	8.1 ± 3.1	11.0 ± 2.3	9.04 ± 3.1†
Gastrocnemius skinfold	15.8 ± 6.5	12.2 ± 3.5	14.4 ± 5.7*	14.7 ± 4.4#	13.7 ± 3.5	14.4 ± 5.1
Abdominal skinfold	13.6 ± 7.5	11.9 ± 5.3	12.9 ± 6.7*	12.9 ± 4.0#	17.9 ± 3.1	14.6 ± 4.3†
100m front crawl Performance time (s)	67.3 ± 6.1	71.8 ± 6.1	69.3 ± 6.4	59.8 ± 2.9	63.9 ± 2.7	61.3 ± 3.4

Note: † statistical significance at $p < 0.05$ for female swimmers; * statistical significance at $p < 0.05$ for male swimmers; □ statistical significance at $p < 0.05$ for youth swimmers (16–18 years old, n = 32); # statistical significance at $p < 0.05$ for cadet swimmers (13–15 years old, n = 19).

Table 2

Regression analysis for youth and cadet, male and female swimmers

Group	R	R^2	Adj. R^2	SEE	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
Male	0.920[a]	0.846	0.829	2.606	0.069	11.717	1	26	0.002
Female	0.738[b]	0.544	0.520	4.444	0.544	22.677	1	19	0.000
Youth swimmers (16–18 yrs.)	0.847[c]	0.717	0.682	1.963	0.092	5.201	1	16	0.037
Cadet swimmers (13–15 yrs.)	0.853[d]	0.727	0.709	3.488	–0.005	0.547	1	28	0.466

Note: a. Predictors: (Constant), AS, BS, BBC con; b. Predictors: (Constant), SH; c. Predictors: (Constant), BBC con, BW; d. Predictors: (Constant), TS, BBC con.

Table 3

Equations of prediction according to age and gender through anthropometric variables

	Equations of prediction	R^2	SEE	p
Time 100 m (male)	125.700 – armspan • 0.182 + biceps skinfold • 0.597 – biceps bracchi circumference contracted • 1.129	0.846	2.61	0.000
Time 100 m (female)	143.427 – sitting height • 0.885	0.544	4.44	0.000
Time 100 m (16–18 yrs.)	109.360 – biceps bracchi circumference contracted • 1.104 – body weight • 0.202	0.717	1.96	0.000
Time 100 m (13–15 yrs.)	111.241 + triceps skinfold • 1.075 – biceps bracchi circumference in contraction • 1.849	0.727	3.49	0.000

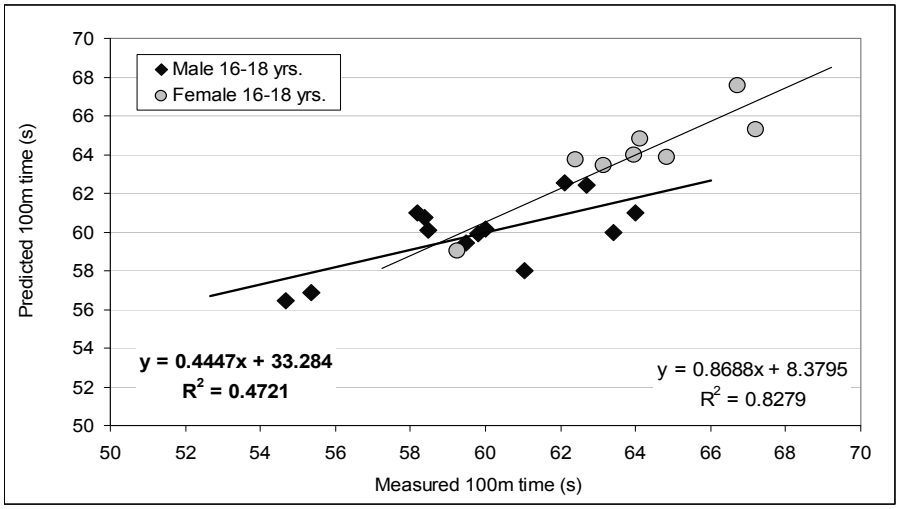

Fig. 1. Relations between measured and predicted performance time in youth male and female swimmers (16–18 yrs.)

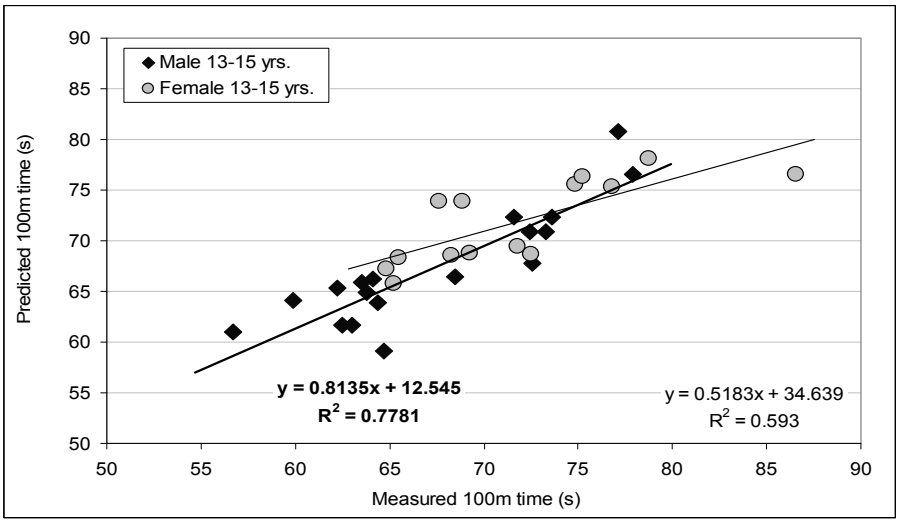

Fig. 2. Relations between measured and predicted performance time in cadet male and female swimmers (13–15 yrs.)

except for female (Table 2). This fact confirms the importance of this variable in 100 m front crawl performance. Triceps skinfold comes next. The rest variables are encountered once in the equations.

The equations of prediction for the four groups are presented in Table 3.

In Figs. 1, 2 measured and predicted performance times are presented for each gender and age group.

Discussion

Relationship between anthropometrics and performance. In the present study it was found that for male swimmers performance at 100 m front crawl swimming was highly correlated with all the anthropometric variables measured. Body height, arm span and left arm length were the variables with the highest coefficients of correlation ($r = –0.817$, $–0.849$, $–0.804$, $r < 0.05$, Table 1). This means that body shape and structure parameters (circumferences, length and skinfolds) play a very important role for male swimmers.

Practical meaning of the results obtained can be explained that swimmers with the highest body height, weight, sitting height, arm span, larger shoulder width, pelvis width, chest circumference, biceps bracchi circumference, and arm length swim faster than the other swimmers. A positive statistically significant relationship of performance with the skinfolds of the limbs and trunk was also noticed, which means that swimmers with lower skinfold values at the upper and lower extremities had a faster performance time. This finding may be connected with the fact that stronger male, with more developed muscular system, have lower skinfold values, therefore faster performance time. Furthermore, swimmers of same chronological but different biological age may have important differences both in anthropometrical values and performance time.

Female swimmers presented no relationship of pelvis width, chest depth, breast, biceps, triceps and gastrocnemius skinfolds with performance time. From these results, it is shown that upper body lengths and circumferences as well as skinfolds of the trunk (biiliac, biacromial and abdominal skinfolds) are of great importance for female swimmers of this age. Sitting height, Chest circumference and biceps bracchi circumference relaxed and contracted are the variables with the highest coefficients of correlation with 100 m sprint performance.

Concerning swimmers of 16–18 years, sitting height, pelvis width and chest depth were not correlated with performance, while biceps was the only skinfold to be related. It could be mentioned that biceps bracchi circumference in contraction, that was the variable with the highest coefficient of correlation for this age group, together with biceps skinfold, play a decisive role for 100 m performance youth female swimmers.

Cadet swimmer's (13–15 years old) performance was related to all lengths and circumference of the trunk apart from pelvis width. Biceps and triceps skinfold, gastrocnemius and abdominal skinfolds were related to performance.

These results are confirmed in several previous studies.

Latt et al., (2010) [11] found that height and arm span were statistically significant correlated to performance at 100 m in 15 years old swimmers ($r = 0.536$, 0.557 respectively), while weight was not. Morais et al., (2016) [14] found a moderate correlation of performance at 100 m front crawl swimming with the arm span of swimmers aged 12–13 years. In another study, Vitor and Bohme (2010) [23] found a high correlation between the 100 m front crawl swimming and age, weight, height, and shoulder width but not between arm span, pelvis width, triceps and subscapular skinfold.

In accordance with this study, Saavedra, Escalante and Rodriguez (2010) [19] found a statistically significant relationship of sitting height to performance ($r = 0.579$) in 13 years old swimmers, while height, arm span, weight, arm length, width of pelvis and shoulders, chest circumference, biceps circumference, total sum of skinfolds did not show statistically significant relationship with performance for male. For 11 years old female swimmers there was no correlation between swimming performance and anthropometric characteristics.

A high correlation of height and total body height (in horizontal position) with performance at 100 m front crawl swimming in adolescents and young children ($r = 0.73$ and 0.55, respectively) and with male swimmers aged 16 years was found by Garrido et al (2012) [6] and Strzala and Tyka (2009) [21], respectively.

Geladas, Nassis and Pavlicevic (2005) [7] observed that for males the variables associated with performance at 100 m front crawl swimming were: weight, chest circumference, length of the upper limbs, height, shoulder width, arm span, length of the foot and width of the pelvis. Females had high correlations with body height, length of hand, shoulder flexibility and horizontal jump.

The most often observed relationship between speed and height [7, 19, 23] can be explained by the fact that the Froude value depends on the height of the swimmer. Higher swimmers have lower Froude values and lower resistance to waves, but the fact is that tall swimmers perform their turn and finish actions with their center of gravity furthest away from the wall, so they swim shorter distance than shorter swimmers [10].

Prediction of performance. In the present study, performance of young male swimmers of 100 front crawl could be predicted only by measuring arm span, biceps skinfold and biceps bracchi circumference in contraction. Performance of young female swimmers could be predicted measuring sitting height. Performance of swimmers 16–18 years old could be predicted measuring biceps bracchi circumference in contraction and weight and of swimmers 13–15 years old, triceps skinfold and biceps bracchi circumference in contraction.

It is obvious that biceps bracchi circumference in contraction is a very important parameter in swimming, which is related to the total body muscle mass [12]. In addition, total body muscle mass has been related to total body strength. Furthermore, it was previously mentioned that arm muscle area was highly related with propulsive force in tethered swimming (r = 0.68) in swimmers of 13–15 years old [15]. It was found, also that fastest swimmers had denser muscles, including triceps bracchi [16]. In this point it should be mentioned that total body strength and total body muscle mass are strongly affected by the biological maturation stage of each swimmer, which was not an objective of the current study.

Geladas, Nassis and Pavlicevic (2005) [7] found that 59 % of performance variability is explained by the combination of the length of the upper limbs, the horizontal jump and the handgrip strength of swimmers aged 12–14 years. In a study by Bond et al., (2015) [2] the sum skinfolds, the length of the thigh and the tibia, the length of the hand and body height, were able to account for 63,8 % of the performance variance of 100 m front crawl swimming in males and females 11–16 years old.

In a multivariate analysis of the swimming performance of swimmers aged 11–13 years of high national level, it was found that anthropometric (sitting height), physiological (aerobic speed and endurance) and biomechanical factors (stroke index, SI) explained 82.4 % of performance for male, while for female the age, aerobic speed and endurance and average speed explained 85 % of performance [19]. On the contrary, in the present study, sitting height was included as a predictive variable for female.

Earlier published data showed that biomechanical factors explain 90.3 % of 100 m front crawl performance, anthropometric 45.8 %, and physiological factors 45.2 % in 15 years old swimmers [11].

Conclusions

The most important findings of this research were:

- performance at 100 m free in new age swimmers can be predicted with high precision and low standard error, by measuring simple anthropometrical variables;
- performance of young male swimmers could be predicted, as an applicable and easy screening procedure, only by measuring arm span, biceps skinfold and biceps bracchi circumference in contraction. Performance of young female swimmers could be predicted measuring sitting height. Performance of swimmers 16–18 years old could be predicted measuring biceps bracchi circumference in contraction and body weight and finally, performance of swimmers 13–15 years old can be predicted by measuring triceps skinfold and biceps bracchi circumference in contraction.

Coaches should always measure and follow the changes in body shape of their swimmers and use them as important screening predictors.

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ПРОГНОЗИРОВАНИЕ ВЫПОЛНЕНИЯ 100 м КРОЛЕМ НА ГРУДИ С ИСПОЛЬЗОВАНИЕМ АНТРОПОМЕТРИЧЕСКИХ ХАРАКТЕРИСТИК У МОЛОДЫХ ГРЕЧЕСКИХ ПЛОВЦОВ В ЗАВИСИМОСТИ ОТ ПОЛА

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Цель. Целью данной статьи является выявление предсказательной способности взаимоотношений между выполнением 100 м кролем на груди и антропометрическими характеристиками молодых пловцов. **Материалы и методы.** Пятьдесят один действующий спортсмен (n = 30 – мужчины, n = 21 – женщины) принял участие в исследовании. С целью анализа спортсмены были разделены на две категории (13–15 лет n = 32, 16–18 лет, n = 19). В качестве предсказательных переменных были использованы следующие антропометрические данные: 7 переменных – параметров длины, 7 переменных – параметры кожных складок, 3 переменных – параметры обхвата, 1 переменная – показатель объема). **Результаты.** Разработана одна предсказательная модель для каждой из групп, выделенных по полу и возрасту. Процент объясненной дисперсии зависимой переменной (время выполнения 100 м кролем на груди) составляет 84,6%, 54,4%, 71,1% и 72,7% для мужчин, женщин, младшей и старшей возрастной групп соответственно. Значимыми переменными для каждой модели выступали: размах рук, кожная складка бицепса, обхват бицепса при сокращении мышц для мужчин-пловцов, рост сидя для женщин-пловцов, обхват бицепса при сокращении мышц и масса тела для пловцов младшей возрастной группы, кожная складка трицепса и обхват бицепса при сокращении мышц для пловцов старшей возрастной группы. **Заключение.** Результативность молодых пловцов можно предсказать по важным антропометрическим показателям.

Ключевые слова: *молодые пловцы, антропометрия, 100 м кроль на груди.*

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