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ORIGINAL ARTICLE

The influence of anthropometric characteristics on swimming speed in adolescent swimmers

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Abstract

Swimming speed depends on anthropometric characteristics, biomechanics factors, physical fitness, physiological components, and genetics. Therefore, this study aimed to identify which anthropometric characteristics influence swimming speed in adolescent competitive swimmers. Thirty-eight male swimmers (aged 16.94 ± 0.8 years; body height: 178.3 ± 5.4 cm; body weight 67.7 ± 9.6 kg) and thirty-five female swimmers (aged 17.12 ± 0.7 years; body height: 175.1 ± 6.6 cm; body weight 59.9 ± 7.1 kg) participated in the study. All swimmers have competed at the national level in Serbia for at least three years and have at least five years of training experience. Fifteen variables were measured: arm length, hand length, leg length, foot length, seat height, wrist diameter, ankle joint diameter, elbow diameter, chest circumference, triceps skinfold, forearm skinfold, abdominal skinfold, subscapular skinfold, thigh skinfold, calf skinfold. The measurements were taken by the Martin anthropometer, Omron digital scale BF511, and John Bull caliper. Swimming speed was measured during 50-m and 100-m front crawl swimming. Multiple regression analysis revealed that arm length, wrist diameter, and chest circumference, all together, accounted for 77% of 100-m front crawl swimming speed in male swimmers, while abdominal skinfold accounted for 90% of 100-m front crawl swimming speed in female swimmers. Results showed that anthropometric characteristics could not account for adolescent swimmers' 50-m front crawl swimming speed. However, anthropometric characteristics can influence the result in swimming (100-m front crawl swimming speed) in adolescents and thus should be considered a diagnostic tool in selecting young swimmers.

Keywords: anthropometry · swimming · adolescent · front crawl · competitive level

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Introduction

Swimming is a cyclic sports activity in which the swimmer attempts to go through the water as quickly as possible (Lätt et al., 2010). In addition, swimming involves generating propulsive forces sufficient to overcome the effects of water resistance on the body (Moura et al., 2014) to maintain movement through the water. Therefore, swimmers must manifest strength that develops by engaging the upper and lower extremities. Also, dry-land strength and isometric strength of knee joint muscle flexors and extensors in swimmers are significant predictors for 50-m front crawl swimming speed (Strala et al., 2019). In addition, strength (Keiner et al., 2021), anaerobic power (de Mello Vitor & Böhme, 2010), aerobic power (de Barros Sousa et al., 2017), and flexibility (Saavedra, Escalante, & Rodrigey, 2010) are also critical factors for speed performance on 50-/100-m front crawl swimming speed in adolescent swimmers. Based on the above, we observed a significant contribution of motor ability to the swimming speed in adolescent swimmers. However, according to previous literature (Beretić, Romanov, & Stupar, 2023; Lima-Borges, Portilho, Araujo, Ravagnani, & Almeida, 2022; Ozkadi, Demirkan, Can, Alagöz, & Demir, 2022; Sammoud et al., 2022) anthropometric characteristics are also essential for swimming speed in different swimmer age groups and swimming styles. Body shape and size are considered to influence the hydrodynamic position of a swimmer's body significantly, and adequate hydrodynamic position is a relevant factor when choosing a swimming discipline and achieving results (Li & Zhan, 2015). Furthermore, authors (Nasirzade, Ehsanbakhsh, Argavani, Sobhkhiz, & Aliakbari, 2014; Santos, Junior, de Castro Melo, da Costa AV, & da Costa, 2012) reported that the development of propulsive strength is achieved through the development of dynamic alignment of the body in liquid, technical skill, biomechanical parameters, physical conditioning, and anthropometric characteristics. A previous study (Yarar, Barug, Bostan, Kaya, & Aydin, 2021) showed that anthropometric characteristics (arms length, leg length, and hand length) correlated with 50-m and 100-m freestyle swimming performance and that these anthropometric characteristics were the best predictors for a short distance. In addition, a previous study (Ferraz, Branquinho, Loupo, Neiva, & Marinho, 2020) showed that anthropometric characteristics influence performance in the 400-m freestyle swimming technique. Furthermore, the authors (Kumar & Solanki, 2019) found a correlation between anthropometric characteristics (body height, foot length, and abdominal circumference) with 50-m butterfly swimming performance in male and female swimmers. Based on that, we can observe that anthropometric characteristics influence and correlate with swimming speed in 50-m, 100-m, and 400-m different techniques (freestyle and butterfly). On the other hand, Marković and Ugarković (2010) noted that anthropometric characteristics were not the best predictors for determining the quality of swimming and that several factors influenced the result but could be considered a good indicator in the initial selection of talented swimmers. Furthermore, authors (Figueiredo, Silva, Sampaio, Vilas-Boas, & Fernandes, 2016) found similar results, where physiological factors and swimming technique determining swimming performance in 100-m front crawl predominantly regarding anthropometric characteristics. Based on the above, previous studies refer to swimmers of different ages (from 11 to 21 years), different techniques (freestyle and butterfly), and different swimming lengths (50 m, 100 m, and 400-m). It is known that different swimming styles may need different performance and anthropometric components (Ozkadi et al., 2022). Therefore, there is a gap in research, and it needs to be clarified which anthropometric characteristics influence the 50-m and 100-m front crawl swimming speed in adolescent swimmers of both sexes, also considering the importance of front crawl swimming as one of the most prevalent swimming techniques among adolescents competitive swimmers. Therefore, this study aimed to identify which anthropometric characteristics influence on swimming speed in adolescent swimmers.

Method

Participants

Seventy-three competitive-level adolescent swimmers (38 male and 35 female swimmers, ages 17.03±0.75 years) from Vojvodina swimming clubs were included in this study. The inclusion criteria for the study were a minimum training experience of five years. During five years, participants must have competed in the national championship in Serbia for the last three years. All participants trained five days a week (90 min per training session) with an annual break of one month. There were no quantitative or qualitative changes in the food they consumed. The trainers and participants received a detailed explanation of the research's purpose, methods to be used, benefits, and potential risks. In addition, the parents or legal guardians of underage participants

were also informed about the study. The parents or legal guardians signed the informed consent on their behalf. The study was approved by the Ethics Committee of the Faculty of Sport and Physical Education, University of Novi Sad (No-46-12-09/2020-2) according to the Declaration of Helsinki.

Anthropometric characteristics

The anthropometric characteristics were assessed according to the recommendations of the International Biological Program (IBP) (Lohman, Roche, & Martorell, 1991). Body height, arm length, hand length, leg length, foot length, and seat height were measured to the nearest 0.1 cm using a Martin anthropometer (GPM, Switzerland). Seat height was obtained with the participant sitting on an adjustable-height chair at a seat height of 50 cm. The upper part of the Martin anthropometer was used to measure wrist diameter, ankle joint diameter, and elbow diameter. Body weight was measured by Omron digital scale BF511 (Omron, Osaka, Japan). All skinfolds were measured using a John Bull caliper (British Indicator Ltd., Thornaby, UK), accurate to 0.1 mm. The measurement was carried out three times on the right side of the body, and a mean value of three measurements was used for data analysis. A Gulick anthropometric tape (Holtain, UK) with an accuracy of ± 1 mm was used to measure chest circumference. All anthropometric measurements were completed by experienced subjects.

Swimming Tests

Each participant completed both the 50-m and 100-m front crawl tests. Participants were tested in a specific order, in groups of 10 in nearby lanes. Male swimmers were tested first, and then female swimmers afterward. All tests were performed in a 50-m swimming pool (Olympic-size pool) that meets the International Swimming Federation (FINA) standards. Participants took each test 3 times, with a 20-minute rest period in between, and the best results were taken for statistical analysis. Performance in the 50-m and 100-m front crawl was measured with maximum effort, and the start was signaled when the swimmers were in the water (Strzala et al., 2019) To eliminate personal advantage coming from more- or less-skilled block starts and underwater turn phases, the participants were asked to perform in-the-water starts and to shorten the underwater swimming phases after the turn (Strzala et al., 2019). A digital stopwatch (Duisburg, Germany) with 1/100th of a second precision was used. The front crawl swimming was performed according to the FINA regulations.

Statistical analysis

Data are presented as mean ± standard deviation. The Shapiro-Wilks assessed the normality of distribution. Pearson coefficient of correlation was used to determine the correlation between anthropometric variables and swimming performance. Regressive analysis was used to determine the influence of anthropometric characteristics on the speed of front crawl 50-m and 100-m swimming. Statistical analyses were performed with SPSS software (Version 20.0; IBM SPSS, Inc., Chicago, IL, USA). Statistical significance was set at $p \leq 0.05$ for all analyses.

Results

Table 1 shows the results of descriptive statists for male and female swimmers in anthropometric variables and swimming performance. The Shapiro-Wilks test (S-W) showed that data were normally distributed.

Table 1. Descriptive statistics and distribution normality of the applied variables for male and female swimmers

Variable	Male (N = 38)		Female (N = 35)	
	Mean±SD	S-W	Mean±SD	S-W
Body height (cm)	178.28±5.41	0.50	175.14±665	0.15
Arm length (cm)	82.06±26.70	0.60	77.90±29.77	0.94
Hand length (cm)	19.57±5.06	0.61	18.82±6.97	0.29
Leg length (cm)	102.56±5.64	0.06	98.10±5.28	0.10
Foot length (cm)	27.27±13.43	0.12	25.71±14.17	0.22
Seat height (cm)	75.71±64.28	0.10	77.39±76.78	0.10
Wrist diameter (mm)	51.70±3.33	0.07	48.78±2.71	0.10
Ankle joint diameter (mm)	78.30±4.95	0.57	63.33±3.24	0.20
Elbow diameter (mm)	74.32±8.62	0.08	65.67±3.68	0.25

Table 1. Descriptive statistics and distribution normality of the applied variables for male and female swimmers (continued)

Variable	Male (N = 38)		Female (N = 35)	
	Mean±SD	S-W	Mean±SD	S-W
Body weight (kg)	67.67±9.56	0.17	59.86±7.14	0.11
Chest circumference (cm)	86.24±8.91	0.06	82.01±3.86	0.09
Triceps skinfold (mm)	94.36±38.73	0.21	88.89±22.42	0.67
Forearm skinfold (mm)	57.76±15.40	0.19	59.85±14.57	0.08
Abdominal skinfold (mm)	70.91±14.31	0.08	81.48±13.11	0.61
Subscapular skinfold (mm)	79.18±11.07	0.11	82.93±9.54	0.36
Thigh skinfold (mm)	76.09±14.93	0.40	76.04±16.10	0.38
Calf skinfold (mm)	51.91±16.99	0.30	58.30±20.54	0.07
50 m front crawl swimming speed (s)	26.97±1.13	0.50	28.46±1.23	0.15
100 m front crawl swimming speed (s)	58.71±2.04	0.51	64.32±2.18	0.56

The correlation between the obtained variables is presented in Table 2. Several significant and negative correlations ($p \leq 0.05$) between the 50-m front crawl swimming speed and anthropometric variables of male swimmers were observed. Furthermore, significant and negative correlations ($p \leq 0.05$) were observed between variable 50-m front crawl swimming speed and anthropometric variables in female swimmers.

Table 2 shows the significant and negative correlations ($p \leq 0.05$) between the 100-m front crawl swimming speed and anthropometric variables of male swimmers and females. However, we observed a significant positive correlation between 100-m front crawl swimming speed and two anthropometric variables (abdominal and calf skinfold) in male and female swimmers.

Table 2. Correlations between swimming performance and anthropometric variables

Variable	50-m front crawl swimming speed		100-m front crawl swimming speed	
	Male	Female	Male	Female
	r	r	r	r
Body height (cm)	-0.52*	-0.57*	-0.43*	-0.67*
Arm length (cm)	0.07	-0.50*	-0.36*	-0.54*
Hand length (cm)	-0.21	-0.49*	-0.48*	-0.54*
Leg length (cm)	0.01	-0.19	-0.11	0.04
Foot length (cm)	-0.53*	-0.61*	-0.39*	-0.54*
Seat height (cm)	-0.44	-0.32*	-0.26	-0.56*
Wrist diameter (mm)	0.20	0.09	-0.30*	-0.19
Ankle joint diameter (mm)	0.11	-0.24	-0.08	-0.46*
Elbow diameter (mm)	0.27	0.01	0.09	0.10
Body weight (kg)	-0.19	-0.29	-0.40*	-0.42*
Chest circumference (cm)	-0.07	-0.08	-0.19	0.07
Triceps skinfold (mm)	-0.13	0.31	0.09	0.30
Forearm skinfold (mm)	0.07	-012	0.06	-0.04
Abdominal skinfold (mm)	-0.24	-0.27	0.29*	0.42*
Subscapular skinfold (mm)	0.01	-0.02	-0.08	0.04
Thigh skinfold (mm)	0.17	-0.03	0.05	0.05
Calf skinfold (mm)	0.12	-0.18	0.39*	-0.02

In Table 3 results show anthropometric variables in male and female swimmers not determined by the criterion variables (50-m front crawl swimming speed) (P=0.28; P=0.09).

Table 3. Prediction model of multivariate regression analysis of 50-m and 100-m front crawl speed in male and female swimmers

Variable	50-m front crawl swimming speed				100-m front crawl swimming speed			
	Male	Female	Male	Female	Male	Female	Male	Female
	β	pβ	β	pβ	β	pβ	β	pβ
Body height (cm)	-0.12	0.95	1.12	0.72	0.15	0.91	1.11	0.67
Arm length (cm)	0.31	0.21	0.09	0.76	-0.41	0.04*	0.01	0.98
Hand length (cm)	-0.12	0.71	0.14	0.58	0.09	0.69	-0.14	0.50
Leg length (cm)	0.12	0.66	-0.24	0.64	-0.17	0.40	-0.27	0.53
Foot length (cm)	-0.59	0.11	-0.30	0.27	001	0.98	-0.09	0.69
Seat height (cm)	-0.13	0.44	0.28	0.73	0.11	0.81	-0.25	0.70
Wrist diameter (mm)	0.16	0.49	-0.07	0.87	-0.55	0.01*	-0.51	0.16
Ankle joint diameter (mm)	0.01	0.98	-0.02	0.96	-0.26	0.21	0.04	0.92
Elbow diameter (mm)	-0.08	0.76	-0.18	0.65	0.30	0.13	0.17	0.60
Body weight (kg)	0.10	0.98	-3.86	0.52	-1.41	0.69	-2.82	0.57
Chest circumference (cm)	-0.06	0.82	-0.20	0.43	-0.49	0.02*	-0.10	0.65
Triceps skinfold (mm)	-0.43	0.15	0.75	0.06	0.27	0.23	0.23	0.44
Forearm skinfold (mm)	0.12	0.72	-0.09	0.81	-0.26	0.32	-0.11	0.72
Abdominal skinfold (mm)	-0.41	0.10	-0.22	0.45	0.15	0.42	0.64	0.03*
Subscapular skinfold (mm)	-0.24	0.34	0.20	0.54	0.19	0.34	0.36	0.22
Thigh skinfold (mm)	-0.05	0.85	0.28	0.26	-0.03	0.90	0.20	0.32
Calf skinfold (mm)	0.23	0.43	-0.32	0.27	0.30	0.18	-0.24	0.32
R	0.78		0.92		0.87		0.95	
R^2	0.61		0.85		0.77		0.90	
P	0.28		0.09		0.02*		0.03*	

Legend: β - regression coefficient; pβ - the level of significance of the regression coefficient;
R – multiple correlation coefficient; R^2 – coefficient of determination; P - significance of the multiple correlation coefficient

The same table also shows that anthropometric variables (arm length, wrist diameter, and chest circumference) in male swimmers had R^2=0.77 and accounted for 77% of the variance of criterion variables (100-m front crawl swimming speed) (P=0.02). Furthermore, the anthropometric variable (abdominal skinfold) in female swimmers had R^2=0.90 and accounted for 90% of the variance of criterion variables (100-m front crawl swimming speed) (P=0.03).

Discussion

This study aimed to identify which anthropometric characteristics influence adolescent swimmers' swimming speed. The main finding of this study is that anthropometric characteristics (arm length, wrist diameter, chest circumference, and abdominal skinfold) determined 100-m front crawl swimming speed for both genders with a range of 70% to 90%. In addition, the study finds that anthropometric characteristics are not defined by 50-m front crawl swimming speed in adolescent swimmers (both genders).

A similar study (Vorontsov, Dyrco, Binevsky, Solomant, & Sidorov, 1999) confirms previous findings, where the influence of the anthropometric characteristics on the 100-m front crawl speed range from 61% to 90% in male swimmers (18 years). In addition, authors (Zampagni et al., 2008) reported that anthropometric characteristics determined short-distance events (50- and 100-m) with a range of 63% to 84% in elite male and female swimmers. Based on the above, our finding partially agrees with the result of the study by Zampagni et al. (2008). In our study, anthropometric characteristics did not determine 50-m front crawl swimming speed in adolescents, only 100-m front crawl swimming speed. It is assumed that swimmers from this study could not develop swimming speed during short distances of 50 m. In addition, swimmers who have

been in training minimum of 5 years (like in this study) have very little subcutaneous fat, and they are uniform according to this anthropometric characteristic, so this characteristic does not affect the result in this study. Additionally, it is essential to note that the age of the participants is different (participants from this study are aged 16-18 years), while in the study of Zampagni et al. (2008), participants were 40-80 years old. Besides, the testing protocol is completely different. For example, in this study, testing was performed during the training, while in the previous research (Zampagni et al., 2008) participants were tested during competition. It is well known that mental and especially physical stress associated with sports competition induces a significant release of stress hormones which is not relevant for normal training (Páez & Martínez-Díaz, 2021). A recent study (Ozkadi et al., 2022) shows that motor ability, as well as strength and aerobic endurance, are dominant predictive parameters for 50-m front crawl swimming speed in both genders, while anthropometric characteristics could appear as predictive variables for the breaststroke and backstroke swimming style in adolescent swimmers. Furthermore, Nasirzade et al. (2014) show that 50-m front crawl swimming performance can be generally explained by biomechanical and muscular parameters rather than anthropometric characteristics in male swimmers. However, skinfolds were significant predictors of 50-m freestyle swimming performance in children (aged 12-13 years) (Dos Santos et al., 2021). According to the author's knowledge, the adolescent period is the time of physical and psychosocial maturation of a person, and it is marked by violent morphological changes in both genders. However, the participants from this study are in the period of middle adolescence (age 15 - 17 years) and late adolescence (18 years), when major anthropometrical changes come to an end and growth and development slow down. Therefore, the result from this study can be generalized to the adolescent and adult population, not younger. Thus, it can be concluded that it is not anthropometric characteristics in the adolescent period that influence swimming speed in 50-m front crawl, but other characteristics like motor abilities (Strzala et al., 2019) and biomechanics parameters.

This study shows that 90% of anthropometric characteristics, especially abdominal skinfold, predicted the 100-m front crawl swimming speed in female swimmers. Furthermore, in male swimmers, 77% of anthropometric characteristics (arm's length and chest circumference), excluding abdominal skinfold, predicted the 100-m front crawl swimming speed. A previous study (Martínez et al., 2011) shows that female swimmers seem to benefit from these anthropometric characteristics because they have greater body fat compared to male swimmers. Greater fat content in female swimmers may provide certain advantages such as greater floatation and, therefore, lower energy expenditure (Fernandes, Barbosa, & Vilas-Boas, 2002). This is not the case with male swimmers. Male swimmers in this study had better results on 100-m front crawl tanks to arm length and chest circumference. The study by Dimitrić, Čokorilo, and Bogdanovski (2016) also supports previous evidence, where these anthropometric variables of swimmers effect on swimming speed through the length of stroke, stroke frequencies, propulsive surface size, propulsive force, resistance during swimmer movement through the water, and many others. Arm length and joint diameter must be accompanied by a certain muscular mass of male or female swimmers without subcutaneous fat. Such a swimmer's constitution significantly influences the hydrodynamic position of their body when swimming the front crawl (Volčanšek, 2002).

This study has many scientific benefits and also a practical application. Results from this study may help coaches make a better swimmer selection for training and competition. Adolescent swimmers with higher values of seat height, upper arm circumference, triceps skinfold, and body width have better predispositions for swimming (Rozi, Thanopoulos, Geladas, Saoultanaki, & Dopsaj, 2018; Leko & Grčić-Zubčević, 2004) and achieve better competition results. In addition, results from this study may help conditioning coaches in planning and programming training by indicating which anthropometric characteristics positively and negatively influence swimming speed. Despite many benefits observed in this study, there are a few limitations. First, data on swimming speed at 50-m and 100-m was collected manually, but data collection has evolved over the past decades from manual to fully automated real-time image recognition technologies. Second, we analyzed only swimmers from one club (small sample size) from Serbia. Third, biology maturation was not considered in the calculation for this study. Future studies should consider the influence of conative characteristics, physiological characteristics, biomechanics parameters, swimming technique, and motor abilities on swimming speed.

Conclusion

In conclusion, the present study showed the influence of anthropometric characteristics on 100-m front crawl swimming speed in adolescent swimmers. However, the findings of this study indicated that anthropometric characteristics did not influence 50-m front crawl swimming speed in adolescent swimmers. These findings prove that anthropometric characteristics play a significant role in swimming speed at a distance of 100-m in this period of life. It is also important to note that the effect that selection during this period at a shorter distance may not be justified.

Conflict of interest

The authors declare that they have no conflict of interest.

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