

# The Relationship Between Anthropometric Variables and Swimming Efficiency in Early Pubescent Female Front Crawl Swimmers

Relación entre las Variables Antropométricas y la Eficiencia de Natación en Nadadoras de Estilo Crol en la Pubertad Temprana

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**BERETIC, I.; ROMANOV, R. & STUPAR, D.** The relationship between anthropometric variables and swimming efficiency in early pubescent female front crawl swimmers. *Int. J. Morphol.*, 41(1):303-307, 2023.

**SUMMARY:** The aim of this study was twofold. The first aim was to examine the association of anthropometric measures on kinematic characteristic which represent stroke efficiency in young female front crawl swimmers. The second aim was to create a prediction model which could provide help to swimming coaches with the purpose of easier and better selection of female front crawl swimmers by measuring and following basic morphological characteristics. Eighty female competitive swimmers all members of the swimming Clubs in province of Vojvodina, Serbia (age  $12.52 \pm 08$  years, years of training involvement  $4.05 \pm 1.2$  and personal best times over 50 m front crawl  $32.79 \pm 0.86$  s) performed 50 m front crawl race. The 50 m front crawl swimming efficiency expressed through stroke index significantly was related to body height ( $r = 0.44$ ,  $p = 0.000$ ), body mass ( $r = 0.402$ ,  $p = 0.000$ ), sitting height ( $r = 0.612$ ,  $p = 0.000$ ) arm span ( $r = 0.576$ ,  $p = 0.000$ ), biacromial diameter ( $r = 0.470$ ,  $p = 0.000$ ), bicrestal diameter ( $r = 0.348$ ,  $p = 0.001$ ) and with chest circumference ( $r = 0.427$ ,  $p = 0.000$ ). Regression equation for stroke index prediction was defined by following variables: body mass, sitting height, arm span, chest circumference with 43.5% explained variance. Additionally by analyzing obtained model the higher the values of SH, ARSP, CHICR and the lower values of BM in a group of early pubescent female swimmers the higher 50 m front crawl efficiency values will be.

**KEY WORDS:** Swimming; Female front crawl swimmers; Anthropometry.

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## INTRODUCTION

Many authors studied anthropometric characteristics and body composition in athletes of different ages and genders (Arriaza *et al.*, 2016; Masanovic, 2019; Viliouta *et al.*, 2021). Research has established that certain morphological characteristics are significantly related to competitive performance in swimming (Jürimäe *et al.*, 2007; Senel *et al.*, 2017). Significant correlations between anthropometric indicators and competitive results among swimmers were recorded in the studies of many authors (Keskinen *et al.*, 1989; Pelayo *et al.*, 1996; Strazala *et al.*, 2005; Jürimäe *et al.*, 2007, Bielec *et al.*, 2019). On a sample of 12-year-old swimmers, Geladas *et al.* (2005), found significant correlations between competitive performance in the 100 m crawl in boys with body mass ( $r=0.65$ ), chest circumference ( $r=0.61$ ), arm span ( $r=0.64$ ), body vision ( $r=0.61$ ), biacromial diameter ( $r=0.61$ ), biiliac diameter ( $r=0.46$ ) and in girls with body height ( $r=0.31$ ), arm span

( $r=0.30$ ), but no significant correlations were found with the amount of subcutaneous fat in either boys or girls. Bielec *et al.* (2019), in their research determined a significant correlation between the results of the 50 m crawl and body height ( $r=0.60$ ), arm length ( $r=0.52$ ), arm span ( $r=0.52$ ) in girls of early puberty age ( $12.1 \pm 0.5$ ). In the study of Lat *et al.* (2010), anthropometrical factors explain 45 % of the variance in 100 m swimming performance on the 25 adolescent male swimmers ( $15.2 \pm 1.9$  years). Saavedra *et al.* (2010), by using multivariate analysis of swimming performance found that anthropometric characteristics such as sitting height followed by physiological and technical characteristics explained 82.4 % competitive performance on a large group of male swimmers 11-12 years of age. In general, it seems that morphological characteristics play an important role in swimming performance in the pubertal age.

Previous studies (Jürimäe *et al.*, 2007; Lätt *et al.*, 2009) reported that stroke index is best single predictor of 100-m swimming performance in adolescent male swimmers. Kjendle *et al.* (2011) determined that swimming performance is influenced by body size and that is related to swimmers of all ages i.e. age groups, elite and master swimmers as well. As race time is dependent on starting, turning and swimming actions, authors propose that in all future research, clean swimming speed is a far more valid indicator of performance. The same authors also stated that any investigation of body size and shape or composition and their relationship to performance should use clean swimming speed as the reference (Kjendle *et al.* 2011). In the study of Saavedra *et al.* (2010), on a large sample of male swimmers 11-12 years of age concluded that stroke efficiency index which is the product of stroke length and clean swimming speed is good predictor of overall competitive performance.

The aim of this study was twofold. The first aim was to examine the association of anthropometric measures on kinematic characteristic which represent stroke efficiency in young female front crawl swimmers. The second aim was to create a prediction model which could provide help to swimming coaches with the purpose of easier and better selection of female front crawl swimmers by measuring and following basic morphological characteristics. It was hypothesized that: i) that swimmers with higher values of body height, sitting height, arm span, biacromial diameter, bicrestal diameter, chest circumference and lower values of body mass, triceps skin fold, subscapularis skin fold, supriliaca skin fold, abdominal skin fold, quadriceps skin fold would be able to achieve higher swimming efficiency values in front crawl technique and: ii) morphological characteristics that include longitudinal and transversal dimensions of the skeleton, the volume and amount of subcutaneous fat tissue could be predictors of the stroke efficiency in the front crawl technique in young female swimmers.

## MATERIAL AND METHOD

Study involved 80 female competitive swimmers all members of the swimming Clubs in province of Vojvodina, Serbia. All methods and procedures of this study were approved by Vojvodina Swimming Federation and by the ethical committee of the University of Educons Faculty of Sport and Psychology Novi Sad, Serbia, and confirm with the Code of Ethics of the World Medical Association (Declaration of Helsinki). Subjects means ( $\pm$

SD) of age, years of training involvement and personal best times over 50m front crawl were  $12.52 \pm 06$  years,  $4.05 \pm 1.2$  years and  $32.79 \pm 0.86$  sec, respectively.

The variable sample consists of 12 anthropometric measures and 1 kinematic measure. Anthropometric measures were: body height (BH), body mass (BM), sitting height (SH), arm span (ARSP), biacromial diameter (BIAD), bicrestal diameter (BCD), chest circumference (CHCIRC), triceps skin fold (TRSKF), subscapularis skin fold (SUBSKF), supriliaca skin fold (SISKF), abdominal skin fold (ABDSKF), quadriceps skin fold (QUSKF). Kinematic measure was freestyle stroke index (FRSI).

Anthropometric measures were taken by means of anthropometric procedures which included the following measuring instruments: skinfold caliper (by John Bull), plastic measuring tape (Baseline®), anthropometer (GPM model 100, Seritex), pelvimeter and a decimal scale with sliding weights.

Measuring procedure for swimming efficiency determination was conducted proposed by Durovic *et al.*, (2012). One transverse video camera (SONY HDD, DCR-SR353E) with a frequency of 24 frames/s equipped with a wide angle to obtain a wider field of vision was positioned perpendicular to the long axis of the pool, at 25 m (half of the length). The lane buoys in the pool were used as distance markers. Each race was analyzed with specialized software The Swim Watch Race Analyzer, Version 2.23a ([www.swimwatch.nl](http://www.swimwatch.nl)). Kinematic variable was obtained as a combination based on the obtained data from video analysis and from the times of 50m freestyle races. For the main indicator for the swimming efficiency of the swimming technique, the value of the index of stroke efficiency was taken and calculated by the formula that is proposed by Costill *et al.* (1992):

$$SI = \text{Stroke Length (0.01 m)} \times \text{Swimming Speed (m/s)}$$

To calculate clean swimming speed on 50m freestyle the formula was used:

$SS = (D - dl)/(T - tl)$ ; where (D) is the swimming distance minus the length of the underwater gliding (dl), (T) the swimming time at a distance of 50m minus time of the underwater gliding phase after the start (tl). Stroke length values were obtained by the following procedure which is proposed Maglischo (2003):

Stroke Length =  $(D - dl)/N$ ; swimming distance (D) minus the length of the underwater gliding (dl) divided with (N) number of strokes per D - dl.

## RESULTS

Table I shows results for the descriptive statistic of the of the observing indicators. The results of Pearson correlation are presented in Table II. The Freestyle stroke index ( $1.09 \pm 0.19$ ) significantly was related to body height ( $152.83 \pm 8.52$ ) with correlation values of ( $r = 0.44$ ,  $p = 0.000$ ) and with body mass ( $45.02 \pm 6.79$ ) with correlation values ( $r = 0.402$ ,  $p = 0.000$ ). The Freestyle stroke index elicited higher relationships with sitting height ( $78.94 \pm 4.55$ ) with correlation values ( $r = 0.612$ ,  $p = 0.000$ ) and with arm spam ( $157.98 \pm 9.01$ ) with correlation values ( $r = 0.576$ ,  $p = 0.000$ ). Moderate but statistically significant relationship was observed between freestyle stroke index with variables which represent transversal characteristics and body volume i.e. biacromial diameter ( $33.07 \pm 2.53$ ) with correlation coefficient ( $r = 0.470$ ,  $p = 0.000$ ), bicrestal diameter ( $24.08 \pm 1.66$ ) with correlation coefficient ( $r = 0.348$ ,  $p = 0.001$ ) and with chest circumference ( $78.56 \pm 6.43$ ) with correlation coefficient ( $r = 0.427$ ,  $p = 0.000$ ). There was no significant

correlation between freestyle stroke index and variables which represents adipose tissue levels such as triceps skin fold, subscapularis skin fold, suprailiaca skin fold, abdominal skinfold as well as quadriceps skin fold ( $p > 0.05$ ).

Table III shows the results of the Multiple regression analysis (Backward method) between Freestyle stroke index and different anthropometric measures. As shown in Table 3, the best model to predict Freestyle stroke index included following variables: body mass, sitting height, arm spam and chest circumference ( $R^2$  adjusted = 0.435). In relation to Freestyle stroke index it is possible to estimate a predictable Freestyle stroke index values from the body mass, sitting height, arm span and chest circumference. Obtained model significantly explains criterion (freestyle stroke index) with standard error of the estimate level of 0.14958 ( $F = 16.229$ ,  $P = 0.000$ , Table III). The equation for predictable freestyle stroke index values was obtained:

$$FRSI = - 2.150 - (BM * 0.012) + (SH * 0.022) + (ARMS * 0.008) + (CHICR * 0.011)$$

Table I. Descriptive statistics of kinematic characteristics and anthropometric measures (n = 80).

Variables	Mean (SD)	Min - Max
FRSI	1.09 (0.19)	0.73 – 1.60
BH	152.83 (8.52)	140 – 176
BM	45.02 (6.79)	36.80 – 66.51
SH	78.94 (4.55)	69.00 – 90.00
ARSP	157.98 (9.01)	139.53 – 179.00
BIAD	33.07 (2.53)	26.00 – 40.00
BCD	24.08 (1.66)	21.43 – 29.75
CHCIRC	78.56 (6.43)	62.54 – 93.21
TRSKF	11.53 (3.51)	6.00 – 25.00
SUBSKF	8.00 (2.71)	3.20 – 17.50
SISKF	14.30 (5.03)	6.50 – 29.40
ABDSKF	10.13 (3.99)	3.40 – 21.50
QUSKF	18.87 (5.29)	11.30 – 37.50

Front crawl stroke index (FRSI), body height (BH), body mass (BM), sitting height (SH), arm spam (ARSP), biacromial diameter (BIAD), bicrestal diameter (BCD), chest circumference (CHCIRC), triceps skin fold (TRSKF), subscapularis skin fold (SUBSKF), suprailiaca skin fold (SISKF), abdominal skin fold (ABDSKF), quadriceps skin fold (QUSKF).

Table II. Pearson's correlation coefficient between kinematic characteristics and anthropometric measures (n = 80).

Variables	FRSI	p
BH	0.447	0.000
BM	0.402	0.000
SH	0.612	0.000
ARSP	0.576	0.000
BIAD	0.470	0.000
BCD	0.348	0.001
CHCIRC	0.427	0.000
TRSKF	-0.049	0.333
SUBSKF	-0.027	0.407
SISKF	-0.083	0.232
ABDSKF	0.100	0.189
QUSKF	-0.051	0.327

Front crawl stroke index (FRSI), body height (BH), body mass (BM), sitting height (SH), arm spam (ARSP), biacromial diameter (BIAD), bicrestal diameter (BCD), chest circumference (CHCIRC), triceps skin fold (TRSKF), subscapularis skin fold (SUBSKF), suprailiaca skin fold (SISKF), abdominal skin fold (ABDSKF), quadriceps skin fold (QUSKF).

Table III. Backward method multiple-regression analysis of the association of kinematic characteristics with significant predictor variables (n = 80).

Variables	Unstd.Beta	Beta	t	p	R	R <sub>adjust</sub>	Std.Err.Est.	F	P
BM	-0.012	-0.487	-2.539	0.013					
	0.022	0.494	3.772	0.000					
ARSP	0.008	0.348	2.725	0.008					
CHCIRC	0.011	0.368	2.244	0.028	0.681	0.435	0.14958	16.229	0.000

Body mass (BM), sitting height (SH), arm spam (ARSP), chest circumference (CHCIRC), Unstd. Beta = Unstandardized regression coefficients values, Beta = Standardized regression coefficients values, t = Standardized regression coefficients significance test, p = Standardized regression coefficients level of significance, R = Multiple correlation coefficient, R<sup>2</sup><sub>adjust</sub> = Adjusted determination coefficient, Std. Err. Est. = Standard error of the estimate, F = Multiple regression analysis significance tests, P = Multiple correlation level of significance.

## DISCUSSION

In the early pubescent female front crawl swimmers present data showed a significant relationship between 50m freestyle stroke efficiency and 7 from 12 anthropometric variables assessed (Table II). Swimming efficiency was significantly correlated with body height, body mass, sitting height, arm span, biacromial diameters, biiliac diameters, chest circumference. These results coincides with the results of previous studies (Grimston *et al.* 1986; Klentrou *et al.* 1991; Geladas *et al.* 2005). In the study of Pelayo *et al.* (1996), on the group of female swimmers (n=325), body height (r=0.72) correlated significantly with performance for the 100m front crawl events. In the same study authors found that stroke length and arm span (r=0.83, r=0.69) correlated significantly with 50 m front crawl performance and body height and arm span (r=0.57 and r=0.5) correlated significantly with 100 m performance (Pelayo *et al.* 1996). In our study, 50 m front crawl swimming efficiency was significantly related to body height and arm span (r=0.447, r=0.576). This relationship between body height and swimming efficiency is in agreement of previous studies (Pelayo *et al.* 1996; Geladas *et al.* 2005; Jürimäe *et al.*, 2007) and can be explained by the fact that taller swimmers seem to glide better through water (Kjendle *et al.* 2011). In the study of Bielec *et al.* (2019), authors concluded when a young athlete is acquainted with the freestyle technique, longer extremities would be an advantage, giving a more effective pull and slide (Bielec *et al.* 2019) which was confirmed by the results of present study. The significant association between arm span and swimming efficiency in present study can be explained by the fact that propulsive force and swimming efficiency is positively related to larger upper extremity length which is in agreement with another investigation (Geladas *et al.* 2005; Bielec *et al.* 2019).

Regarding chest circumference, biiliac diameters, biacromial diameters correlated positively and significantly with the swimming efficiency in female front crawl swimmers. This results seems to be explained by the fact that larger body cross-sectional area in swimmers may be related to better swimming efficiency (Saavedra *et al.* 2010) and sprint performance (Mazza *et al.* 1993; Geladas *et al.* 2005). The significant correlation between 50m swimming efficiency and arm span and biacromial diameters consistent with a previous studies (Geladas *et al.*, 2005; Saavedra *et al.*, 2010), suggests that the length of the upper extremities and shoulders diameter combined may be related with biomechanical factors relevant to swimming efficiency.

In the present study, the sitting height was significantly correlated with swimming efficiency. Moura

*et al.* (2014), who studied 56 competitive swimmers aged 9-17 years found that sitting height significantly correlated with arm propulsive force (r=0.36) while in present study sitting height estimated slightly higher correlation with swimming efficiency (r=0.612) in a front crawl. Based on the results of Moura *et al.* (2014) and the results in present study it can be concluded that major trunk length may be related with higher arm propulsive force (Moura *et al.* 2014) and higher swimming efficiency as well.

The results of this study provide support for the efficiency of anthropometric measurements to predict swimming efficiency on 50 m front crawl in early pubescent female swimmers. The major advantage of this finding exists in his practical application offering safe and time efficient method for predicting swimming efficiency on 50 m front crawl (R<sup>2</sup> adjust = 0.435, Std. Err. Est. = 0.14, F = 16.229, P < 0.000, Table III). Equation for 50m front crawl swimming efficiency prediction is defined by variables that measures longitudinal dimension of body (SH, ARSP) as well as body mass and body volume (BM, CHIRC). Based on obtained model in this study, by inserting values of sitting height, arm span, body mass and chest circumference in the equation, coaches can calculate the swimming efficiency level by particular swimmer for 50 m front crawl at the probability level of 43 % and prediction accuracy range 0.14 for swimming efficiency values in early pubescent female swimmers. The results of this study provide a coach with information on the type of swimmer in relation to the measured morphological characteristics aimed at 50 m front crawl efficiency prediction. Obtained model represents one of the possible helping tools which coaches can use to control process of selection in the early pubescent female swimmers. The fact is that with defined equation of the specification, along with used anthropometrical variables (SH, BM, ARSP, CHCIRC), 43.5% efficiency values can be predicted while swimming 50m front crawl. In the study of Latt *et al.* (2010), anthropometrical factors explained 45.8 % of 100m front crawl swimming performance which is on similar prediction level with the results in the present study. However, the obtained model represents available and easy to use model for swimming efficiency prediction limiting factors of this study are lack of informations regarding to % body fat, fat free mass for more precise 50 m front crawl efficiency determination. In previous studies (Jurimae *et al.*, 2007; Latt *et al.*, 2009; Saavedra *et al.*, 2010) the fat mass and lean mass showed significant contribution on the performance of the swimmers. The outcome of this shows that morphological characteristics obtained by performing the simple anthropometrical measurements do relate to 50 m front crawl swimming efficiency and can be used by swimming coaches to control and improve selection process. Morphological characteristics indicators in young female swimmers

included consideration: BH, BM, SH, ARSP, BIAD, BCD, CHCIRC showed significant correlation with 50 m freestyle swimming efficiency. By analyzing obtained model the higher the values of SH, ARSP, CHCIRC and the lower values of BM in a group of early pubescent female swimmers the higher 50 m front crawl efficiency values will be. The strongest single predictor of swimming efficiency was SH. Young female swimmers who had greater upper body length expressed through the values of SH showed greater potential for better swimming efficiency.

**BERETIC, I.; ROMANOV, R. & STUPAR, D.** Relación entre las variables antropométricas y la eficiencia de natación en nadadoras de estilo crol en la pubertad temprana. *Int. J. Morphol.*, 41(1):303-307, 2023.

**RESUMEN:** Este estudio tiene dos objetivos principales. El primer objetivo fue examinar la asociación de las medidas antropométricas con las características cinemáticas que representan la eficiencia de la brazada en nadadoras jóvenes estilo crol. El segundo objetivo era crear un modelo de predicción que pudiera ayudar a los entrenadores de natación con el propósito de seleccionar mejor y más fácilmente a las nadadoras crol midiendo y siguiendo las características morfológicas básicas. Ochenta nadadoras competitivas, todas miembros de los clubes de natación en la provincia de Vojvodina, Serbia (edad  $12,52 \pm 8$  años, años de participación en el entrenamiento  $4,05 \pm 1,2$  y mejores tiempos personales en 50 m estilo crol  $32,79 \pm 0,86$  s) realizaron una carrera de 50 m estilo crol. La eficiencia de nado crol de 50 m expresada a través del índice de brazada se relacionó significativamente con la altura del cuerpo ( $r = 0,44$ ,  $p = 0,000$ ), la masa corporal ( $r = 0,402$ ,  $p = 0,000$ ), la altura sentado ( $r = 0,612$ ,  $p = 0,000$ ) y el brazo.  $r = 0,576$ ,  $p = 0,000$ ), diámetro biacromial ( $r = 0,470$ ,  $p = 0,000$ ), diámetro bicrestal ( $r = 0,348$ ,  $p = 0,001$ ) y con perímetro torácico ( $r = 0,427$ ,  $p = 0,000$ ). La ecuación de regresión para la predicción del índice de brazada se definió mediante las siguientes variables: masa corporal, altura sentada, extensión de los miembros superiores, circunferencia del pecho con una varianza explicada del 43,5 %. Además, al analizar el modelo obtenido, cuanto más altos sean los valores de SH, ARSP, CHCIRC y los valores más bajos de BM en un grupo de nadadoras púberes tempranas, mayores serán los valores de eficiencia de crol de 50 m.

**PALABRAS CLAVE:** Natación; Nadadoras estilo crol; Antropometría.

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