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Influence of Anthropometric Variables for Freestyle Sprinting Performance of Swimming: A Review

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Abstract:
Background*: This field of study based on identifies the main important anthropometric variables that affect for sprinting swimming performance. The intention of this review study is to provide knowledge to freestyle swimmers in order for them to choose the suitable event by discovering physique and anthropometric measures.*
Materials and Methods*: Thirty articles were referred and twenty four were included in this review study. Fifteen articles were recognizes as anthropometric comparison with gender and age, seven articles were recognized as field of biomechanics and kinematics and two books were included in this review.*
Results*: Anthropometric variables affect for the swimming performance. In especially, factors that contribute to have as body height, arm length, arm span, shoulder width, hand width, axilla cross sectional area, hand cross sectional area, leg length, leg frontal area, upper leg length, lower leg length, foot length, foot cross sectional area, chest circumference, sitting height and skinfold thickness.*
Conclusion:*Based on the findings of this study, it is assumed that anthropometric characteristics have a major impact on the Stroking frequency, stroking length and stroking velocity regarding on swimming performance.*
Key Word*:Front crawl;Physical characteristics; Swimmer.*

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I. Introduction

Swimming is a competitive sport in which participants move their entire body through water. It consists of four competitive strokes with varied distances: freestyle, butterfly, backstroke, and breaststroke, as well as a medley (mix) which can be done individually or in a group. Each stroke has its own set of techniques for the start, dive, turn, kick, and arm pull. For all strokes, the arm pull and kick might be separated into a number of comparable phases, although each stroke has its own features.

In the "freestyle stroke" is frequently used interchangeably with "front crawl". Front crawl is the fastest and most efficient of the four main strokes, and swimmers use it in freestyle events almost exclusively[1]. For competitive swimming, freestyle swimming requires the use of both legs and arms, and the swimmer alternately circles the arms forward, kicking the feet up and down. The main purpose of competitive swimming is to accomplish the assigned distance as rapidly as possible. As a result, it is dependent on the timing of starting, stroking, turning, and finishing[2]. Swimmers must increase their reaction speed in order to start the event in less time. Stroking time is also affected by stroke length and rate[2][3].

There are many factors can have an impact on swimming performance to increase speed. Among them Gender, age, physiological characteristics and anthropometric characteristics can be influenced for the swimming performances [4][5][6]. Among those factors, anthropometric variables can be affected strongly for 50m and 100m performance[7][8]. Axilla cross sectional area, arm length, hand cross sectional area, leg length, leg frontal area and foot cross sectional area are the important anthropometric variables that affect to the stroke length and stroke frequency as freestyle performance [1] factors according to the modified theoretical model of Grimston and Hay J.G. (figure 1) [2].

The goal of this review study is to give athletes and coaches with important guidelines in order to select suitable event in freestyle swimming stroke according to swimmers' physique and anthropometrical measurements.

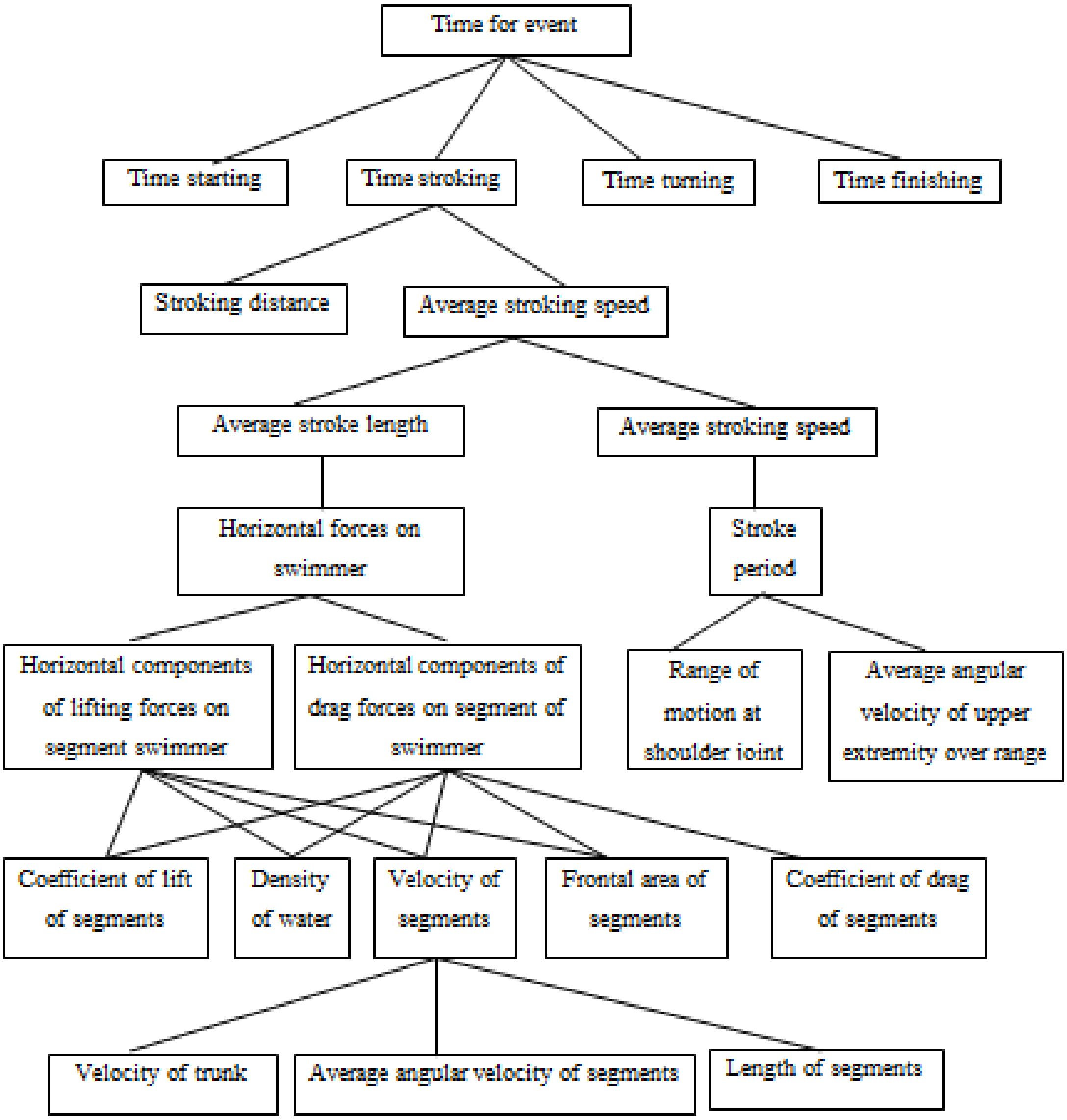

Figure no 01: Modified theoretical model identifying the factors that determine success in completive swimming[2]

According to the figure 1, swimming time depends on the time start, time stroking, time turning, time finishing.

$$Event\ time = Time\ starting + Time\ stroking + Time\ turning + Time\ stroking + \ Time\ finishing$$

The stroking speed totally depends on the stroking distance and the swimmer's average stroking speed ($\bar{S}$) over the distance.

$$Time\ stroking = \frac{Stroking\ distance}{Average\ stroking\ speed\ (\bar{S})}$$

The $\bar{S}$ is determined by the average stroke length (SL) and average stroke frequency (SF). (SL means that average distance travels for each completed stroke and SF means that average number of strokes completed in given time.)

$$(\bar{S}) = Average\ stroke\ length\ (\overline{SL}) \times Average\ frequency\ (\overline{SF})$$

SL is relied on the total horizontal forces acting on the swimmer.

$$\overline{SL} = f(Horizontal\ forces)$$

The horizontal forces acting on the swimmer is equal to the total of the horizontal components of the lift forces (F_{HL}) and the horizontal components of the drag forces (F_{HD}) that acting on the segments of trunk and limb of swimmer at any given instant. Where: N= the number of segments.

$$Horizontal\ forces = \Sigma^{N}(F_{HL} + F_{HD})$$

All these lift and drag forces are determined by the four factors which are,

$$F_{HL} = f(C_L, \rho, A, \vec{V})$$

$$F_{HD} = f(C_D, \rho, A, \vec{V})$$

Where, ρ = the density of water, A = the frontal area of the segment, $\vec{V}$ = the velocity of flow relative to the segment involved, C_L = the segment's coefficient of lift, C_D = the segment coefficient of drag.

Moreover the velocities of the segments are functions of the velocity of trunk, the angular velocity of the segment and the lengths of the segments. Therefore the lengths of the segments, frontal area of the segments are directly influence for the average stroke length, average stroking speed, stroking time and finally total time for the event.

Furthermore, the average stroke frequency is the reciprocal of the average stroke period,

$$Average\ stroke\ period = \frac{1}{\overline{\overline{SF}}}$$

The average stroke period is governed by the range of motion at the shoulder joint and the average angular velocity of humorous over that range. Therefore he segment length influence for the average stroke period, stroke frequency, stroke length, stroking time and total time of the event.

On that account this review study is providing various specific anthropometrical measurements that influence for the swimming speed and swimming time.

II. Material And Methods

The all data were collected from published articles in journal of movement and exercise, journal of pediatric exercise and science, journal of sport science and medicine, European journal of sport science, journal of science and sport, international journal of sport medicine, journal of human sport medicine, journal of human kinetics, journal of sports, international journal of environmental research and public health and books. All the published articles were searched through research gate, PubMed and Google scholar under the topic of Impact of anthropometric variables for freestyle performance.

Procedure methodology

After reviewing all the searched articles, some articles was ignored which did not full fill the required objective and those articles were excluded. All other accurate articles were selected after observing abstract, introduction, results and discussion. To figure out more articles under the topic, references were searched related to freestyle performance and factors influence for swimming performance. Reviewed articles were categorized in to sub topics according to anthropometric variables.

III. Result

As reviewed articles, anthropometric variables have an impact on swimming performance and swimming performance change especially with body height, arm length, arm span shoulder width, hand width, axilla cross sectional area, hand cross sectional area, leg length, leg frontal area, upper leg length, lower leg length, foot length, foot cross sectional area, chest circumference, sitting height and skinfold thickness.

IV. Discussion

Results and findings from these reviewed articles discussed through special anthropometric variables and those variables are categorized in to subtopics as body height, body weight, upper body, upper limbs, arm span, lower limbs, and skin fold thickness.

4.1 Body Height

The stadiometer is used to measure the height of the body and its measurements gets form top of the head to feet of the body[9][10].The link of stature with swimming performance is attributed to taller swimmers that might potentially glide better over the water and there is a negative correlation between body height and 50m swimming time, which means that one's height rises, the time it takes to swim 50 meters decreases [10]. But a previous study showed that body height is highly correlated with 100m freestyle swimming performance[11][7][12]. In other way body height is negative correlation between 100m freestyle performance could be attributed to the fact that propulsive force[13] that act of moving body forward. In the findings of[14] has been shown that 82% of anthropometrical variables influences for the 200m swimming performance and the body height was also included as a variable that has affected to the 200m performance. In a major advance in [15][16] surveyed that boys and girls who are classed as fast swim speed are significantly taller than slow swimmers. The study of [3] are well documented that it is also well acknowledged that on 100-m sprints height is known to be correlated to stroking characteristics especially for 100m sprint is correlated stroke length, stroke rate and velocity. With The summary of previous studies of relationship between body height and performance is showed in table 1.

Table no 01: Body height and its correlation between 50m, 100m and 200m freestyle swimming performance taken from previous studies.

Author	Correlation of 50m performance	Correlation of 100m performance	Correlation of 200m performance
• (Geladas, Nassis, &Pavlicevic, 2005)	-	-0.61**	-
• (Zampagni, Casino, Benelli, Visani, Marcacci, & De Vito, 2008)	-0.52**	-0.50**	-0.56**
• (Lätt , Jarek, &Haljaste, 2010)	-	-0.536*	-
• (Bond, Goodson, Oxford, Nevill, & Duncan, 2015	-	-0.654**	-
• (Nasirzade, et al., 2015)	-	-	-0.71**
• (Yarar, Hakan, & Erbil, 2021	-0.606*	-0.489*	-

Statistically significant correlation P<0.05*, p<0.01**

4.2 Body Weight

The body weight is analyzed by the digital scalar or bioelectrical impedance analyzer in most of the articles, which used in current study[11][15]. In[17] investigated that anaerobic power is strongly correlated with body mass which is highly significant short distance swimming. As same as in the findings of [13] has been showed that body mass is negatively correlated with sprinting swimming time of 100m freestyle male swimmers. Therefore we can assume that if sprinting swimmers has grater bodyweight it will cause to increase performance by reducing sprinting time but most early study of [3] showed that body weight is correlated with velocity of 400m freestyle swimming performance. In addition, a previous study predicted performance by measuring biceps bracchi circumference in contraction and weight of 16- 18 years old 100m freestyle sprinters. That study was showed that the biceps bracchi circumference is the most significant parameter which is related to total body muscle mass [18]. Apart from that the study of [19] have emphasized that body mass is positively associated with arm propulsive force. In contrast that unnecessary body weight negatively affects for swimming performance[20].

4.3 Upper Body

Sitting height, shoulder width and chest circumference are the three anthropometric variables that expect to discuss on this section. According to the sitting height, it is influenced for the female young swimmers to have a greater swimming performance but it is not correlated with performance of 16-18 years old both male and female swimmers[18]. Taking the point of shoulder width, it is discussed on the findings of [17] has been showed that anaerobic power which is sort of action that necessitates a relatively brief period of time spent exerting muscular effort and it is strongly correlated with biacromial breadth (shoulder width) and biacromial breadth is determined by the genetically. Moreover in the previous studies have emphasized that negative correlation between chest circumference, biacromial breadths, and 100m freestyle sprint time indicates that a large body cross-section area in swimmers could be associated to sprint performance time but these two anthropometrical variables are highly related to the boys sprinting swimming performance time [13].

4.4 Upper Limbs

The arm length is measured distance from the middle fingertips to the lateral part of the acromial process point when body stood straightly with arm hanging close to the body. In the most of previous studies and they showed that, there is statistically significant correlation between 100m performance time and arm length[10]. One of the previous studies has showed that, the left arm length is one of the variables with the highest coefficient of correlation which played an important role for male swimmers in performance[18]. Furthermore, the study of [13] has suggested that upper extremity length and shoulder breadth combined might be related to biomechanical aspects essential to propulsion and upper extremity length and hand length are significantly associated with the 100m freestyle performance for only girls. The most thorough research has revealed that the axilla XSA (cross sectional area) has the largest influence on stroke length and stroke frequency which is substantially affected by training but there are other predictions of arm length, hand XSA that affected for the stroke length and stroke frequency which are determined by the genetics but axilla XSA can be changed by training which is related component of stroking speed[2]. Hand length is a part of variable that contribute to maximize 100m freestyle swimming performance[15] but In[17] investigated that anaerobic power is highly correlated with hand width which is significant for 50m and 100m freestyle performance. The hand surface area of the dominant hand is one of factors in the theoretical path flow model, which is designed by the [21] in figure 2.

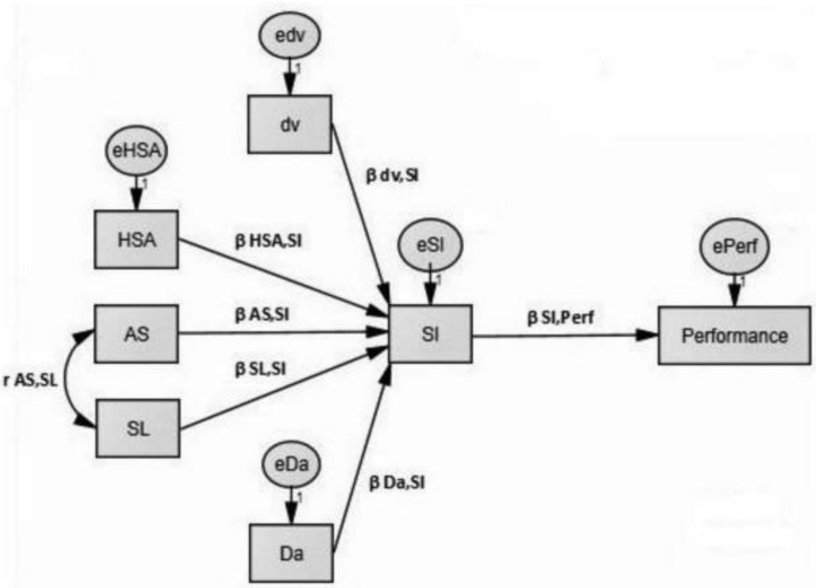

Figure no 02: Theoretical path-flow model[21]

Where: AS-arm span; SL-stroke length; dv-speed fluctuation; HAS-hand surface area; Da-active drag; SI-stroke index; β xi,yi-beta value for regression model b xi,yi-beta value for regression model between exogenous (xi) and endogenous (yi) variables; e_{xi}-disturbance term for a given endogenous variable; $_{rxi,yi}$-correlation coefficient between two variables; xi®yi- variable yi depends from variable(s) xi; xi«yi- variable yi is associated to variable xi.

According to the figure 2, hand surface area and the arm span are directly affected to the stroke index [21] which is defined as the product of average velocity$\overline{(V)}$ and stroke length and it is considered as an indicator of swimming efficacy[22].

$$SI = \bar{V} \times SL$$

Therefore, it has an effect for swimming performance by increasing stroke index through increasing arm span and hand surface area because arm surface area is known that the propulsive surface is the key variable in increasing propulsive forces[21].

4.5 Arm Span

In most of previous studies, the arm span is measured from middle finger tips of both arms while standing with arms wide open parallel to the floor and hand was leaning against the wall[10]. The [6] estimated a statistical significant effect on the 50m butterfly and freestyle have a predictor variable of arm span not only that they investigated that none of predictor variable has no statistically significant effect on the criterion variable 50m backstroke and breaststroke. In addition to that the study of [19] has emphasized that arm span is positively associated with arm propulsive force. In the investigation of [11] has been proved arm span and height are the two anthropometrical variable correlated with 100m swimming performance and [23] has suggested that arm span is positively associated with swimming speed of freestyle swimmers but[8] have emphasized that arm spam of boys negatively correlated with 50m freestyle swimming performance time. In additionally more recent evidence [21] reveals that induction of swimming efficiency leads to a performance and arm span influences the swimming efficiency. Even though the study of [7] has been proven the best anthropometrical indicator is the arm span for swimming sprinting performance and it is directly connected with stroke length and [6] Showed that stroke length is directly proportional to the arm spam and swimmers with longer strokes can generate more propulsive force, leading to faster swimming and higher performance. Not only that but also the findings of[3] have been reported on 50-m and 100-m races arm span is found to be associated to stroking characteristics especially for the stroke length and stroke rate. This has been discussed by a great number of authors in literature. The substantial association between 100-m and 50m performance and arm span, which is consistent with earlier reports. The summary of previous studies of relationship between arm span and performance is showed in table 2.

Table no 02: Arm span and its correlation between 50m and 100m freestyle swimming performance taken from previous studies

Author	Correlation of 50m performance	Correlation of 100m performance
• (Yarar, Hakan, & Erbil, 2021)	-0.562	-0.433
• (Dimitric, Cokorilo, &Bogdanovski, 2016)	-1.234	-
• (Lätt , Jarek, &Haljaste, 2010)	-	-0.557
• (Nasirzade, Ehsanbakhsh, Argavani, Sobhkhiz, &Aliakbari, 2014)	-0.50	-

Statistically significant correlation ($p \leq 0.05$)

4.6 Lower Limbs

The leg length was measured distance between trochanterion and ground while footing anatomical position in the vast majority of the articles, which used in current study. The leg length and shank length are statistically correlated with 50m freestyle performance[10] because long legs body rotation could be smaller and stream line position also could be better with long stroke length for female swimming performance in 50m freestyle.[6]. On the other hand lower limbs and thigh length presented a positive association with freestyle swimming performance because it could be generated a higher propulsive force due to higher propulsive surface area[24]. In a major advance in [15] interviewed that boys had larger foot and lower leg than girls which are influenced for swimming performance and upper leg length and lower leg length were the variables that can be explained 63% in 100 m maximal freestyle swimming performance. In addition to that, the findings of [2] has been showed that foot XSA (cross sectional area), leg FA (frontal area) and leg length are significantly related to either or both the stroke length and stroke frequency and also these variables are genetically determined to stroke length and stroke frequency used for freestyle swimmers to reduce performance time.

4.7 Skin Fold Thickness

Most of reviewing articles has used the right hand side of the body using Harpenden Skinfold skin fold caliper from the triceps, biceps, subscapular, iliac crest, supra spinale, mid abdominal, front thigh and medial calf sites to measure skin fold thickness. Individual skinfolds were added together to form a total amount of skinfolds that reflected overall adiposity. Individual skinfolds were added together to form a total amount of skinfolds that reflected overall adiposity[15][9][18][11]. In [15][24] investigated that swimmers who has lower total sum of skinfold thickness may influence to greater swimming speed.[24] Even though Triceps skinfold is the one of predictors for performance timing in 100m freestyle swimming[11][15] but the findings of [18] has been showed that the triceps skinfold can be used to predict swimming performance in 13–15-year-old male and female swimmers and male swimmers' performance could be predicted as an acceptable and simple screening approach by assessing biceps skinfold thickness.

Table no 03: Summary chart of the reviewed articles (The articles are organized by year of publication)

Author	Sample size (n)	Swimming event	Discussed anthropometric variable for swimming performance
(Grimston K. & Hay, 1985)	12-male	50m and 100m freestyle	Axilla XSA, arm length, hand XSA, leg length, leg FA, foot XSA
(Pelayo, Sidney, Kherif, Chollet, &Tourny, 1996)	303-male 325- female	50m,100m,200m,400 m,800m and 1500m freestyle	Body height, arm span, body weight
(Geladas, Nassis, &Pavlicevic, 2005)	178-male 85- female	100m freestyle	Body height, body mass, arm length, hand length, foot length, chest circumference
(Zampagni, Casino, Benelli, Visani, Marcacci, & De Vito, 2008)	135- both	50m, 100m, 200m, 400m, 800 m freestyle	Body height
(Lätt , Jarek, &Haljaste, 2010)	25- male	100m freestyle	Body height, arm span
(De Mello Vitor &Böhme, 2010)	24- both	100m freestyle	Body mass, body height, hand width, biacromial breadth
(Zuniga, et al., 2011)	38-male 31-female	Swimming sprinting	body weight , body height, fat-free weight , percentage of body fat
(Morais, et al., 2012)	73 male 41 female	100m freestyle	Arm span
(Morais, Garrido, Marques, Silva, Marinho, & Barbosa, 2013)	62 male 64 female	100m freestyle	foot surface area, hand surface area
(Nasirzade, Ehsanbakhsh, Argavani, Sobhkhiz, &Aliakbari, 2014	23-male	50 freestyle	Body height, arm span
(Nasirzade, et al., 2015)	22-male	200m freestyle	body height, body mass, body mass index, arm span, shoulders width, thigh, leg and upper arm lengths
(Bond, Goodson, Oxford, Nevill, & Duncan, 2015)	21 male 29 female	100m freestyle	Total sum of skinfolds, upper leg length, lower leg length, hand length, total height
(Dimitric, Cokorilo, &Bogdanovski, 2016)	22- female	50m freestyle, backstroke, breaststroke, butterfly	Arm span, arm length
(Rozi, Thanopoulos, Geladas, Soultanaki, &Dopsaj, 2018)	25 male	100m freestyle	Arm span, body height, triceps skinfold, shoulders width
(Rozi, Dopsaj, &Platanou, 2019)	30- male 21-female	100m freestyle	Body weight, arm span, biceps skinfold and biceps bracchi circumference, triceps skin fold, sitting height.
(dos Santos, et al., 2021	50-male 35-female	50m freestyle	Arm span
(Oliveira, Henrique, Queiroz, Salvina, Melo, & Moura dos Santos, 2021	53-male 75-female	Freestyle	Body mass, stature, arm span
(Yarar, Hakan, & Erbil, 2021)	15- male	50m and 100m freestyle	Stature, arm length, arm span, leg length, and shank length.
(Dimitric, Kontic , Versic , Scepanovic, &Zenic , 2022)	85-both	Water polo, 25m, 100m,400m freestyle	Body height, arm span and body fat mass
(Alves, Carvalho, Fernandes, & Vilas-Boas, 2022)			Body height, arm span, body mass and lean body mass

V. Conclusion

Different authors conducted extensive research on freestyle swimming performance discover the science behind the event to improve performance through scientific understanding and select the unique swimming stroke belongs to the swimmers anthropometric variables. Many tests have been conducted on this topic, but there are still limitations and critical analysis to undertake research on the effect of anthropometric variables and physiological variables on stroke characteristics. The recommendations and correlation presented by this study have a broad practical applicability, allowing many trainers and athletes to select their appropriate stroke based on body characteristics. According to the present study, body height, arm length, arm span shoulder width, hand width, axilla cross sectional area, hand cross sectional area, leg length, leg frontal area, upper leg length, lower leg length, foot length, foot cross sectional area, chest circumference, sitting height, bicep skinfold thickness and triceps skin fold thickness have huge involvement to swimming performance. These variables are affected to the Stroking frequency, stroking length and stroking velocity regarding on swimming performance.

Among the reviewing anthropometric measurements body height, axilla XSA, arm span, arm length, hand XSA, leg length, leg frontal area and foot XSA are significantly effect on the stroking length, stroke frequency and stroke velocity. More precisely, arm length, leg length, hand XSA, and foot XSA are genetically determined factors however the axilla XSA variable can be modified by training. Finally, the findings of this study could be used to the selection and identification of all swimmers.

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