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Anthropometric and Physical Performance Characteristics of Swimmers

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Resumen

Introducción: El estudio de las medidas y proporciones corporales por antropometría es importante para la identificación de jóvenes talentos en la natación. Por lo tanto, el objetivo de este estudio fue a) comparar el perfil de rendimiento físico de nadadores en tierra y en agua yb) comprender la relación entre las pruebas antropométricas y de rendimiento físico. **Métodos:** Para ello, se determinaron 31 variables antropométricas en 6 nadadores masculinos (n=3) y femeninos (n=3) utilizando los protocolos de la Sociedad Internacional para el Avance de la Cineantropometría (ISAK) y pruebas de laboratorio de VO_2max. El fraccionamiento corporal (masa de tejido adiposo, muscular, óseo, residual y de la piel) se determinó utilizando el modelo de fraccionamiento de cinco vías validado de Kerr & Ross para la composición corporal. El análisis de datos incluyó el coeficiente de correlación persona. **Resultados:** La prueba de rendimiento de natación se correlacionó positivamente con la altura del cuerpo, la altura del asiento, la extensión de los brazos, el ancho de los hombros y la pelvis, y la longitud de los brazos y las piernas ($p \leq 0{,}001$). En conclusión, estos estudios revelan algunos posibles factores antropométricos clave en el rendimiento de los nadadores activos. Estos resultados respaldan la opinión de que, si bien los nadadores tienen perfiles antropométricos únicos, los nadadores más exitosos tienden a tener una mayor amplitud de brazos. **Conclusión:** Estos resultados sugieren que las características antropométricas son importantes en el rendimiento de natación. Este estudio concluyó que la mejora en el rendimiento de natación está fuertemente relacionada con los perfiles antropométricos y cineantropométricos.

Palabras Clave: Somatotipo, Antropometría, Endomorfia, Mesomorfia, Ectomorfia, Remeras Femeninas, Nivel Nacional

Abstract

Introduction: The study of body measurements and proportions by anthropometry is important for the identification of young talents in swimming. Therefore, the aim of this study was to a) compare the physical performance profile of swimmers on land and in water and b) understand the relationship between anthropometric and physical performance tests. **Methods:** To this end, 31 anthropometric variables were determined in 6 male (n=3) and female (n=3) swimmers using the International Society for the Advancement of Kinanthropometry (ISAK) protocols and VO2max laboratory tests. Body fractionation (adipose, muscle, bone, residual, and skin tissue masses) was determined using the validated Kerr & Ross five-way fractionation model for body composition. Data analysis included the person correlation coefficient. **Results:** The swimming performance test was positively strongly correlated with body height, seat height, arm span, shoulder and pelvic width, and arm and leg length ($p \leq 0.001$). In conclusion, these studies reveal some potential key anthropometric factors in the performance of active swimmers. These results support the view that while swimmers have unique anthropometric profiles, more successful swimmers tend to have greater arm spans. **Conclusion:** These results suggest that anthropometric characteristics are important in swimming performance. This study concluded that improvement in swimming performance is strongly related to anthropometric and kinanthropometric profiles.

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Keywords: Swimmers, Anthropometric, ISAK, VO_2max, Physical Performance, Talent Identification

Introduction

It is well known that success in many sports may depend on the physical and physiological characteristics of young athletes (Shahidi et al., 2020a, 2020b; Shahidi et al. 2021). In general, male and female swimmers compete in four different swimming styles: Freestyle, Backstroke, Breaststroke, and Butterfly (Crowley et al., 2017). For successful performance, the athlete undoubtedly needs well-built anthropometric characteristics that meet the requirements of swimming and the particular swimming disciplines in which he/she competes (Shahidi et al., 2022). Swimming is determined by the interaction of anthropometric, physiological, psychological, and technical factors based on individual genetic predisposition and continuously modulated by the training process (Martínez et al., 2011). Swimming technique is controlled by many factors, including age, gender, physical fitness, and years of training (Zhao et al., 2019). In addition, anthropometric characteristics also play an important role in determining an individual's swimming ability (VanHeest et al., 2004). Much work has been done on general anthropometric parameters, which are considered important factors in swimming performance. According to previous studies, an ideal runner is considered to be tall with broad shoulders, long arms, long legs, and a lean and muscular body (Cobb, 1936). Elite swimmers also tend to be long palms and larger palms. Bi-variate studies found that arm span was the anthropometric trait with the highest association with performance in young male subjects, and palms and feet were found to be positively correlated with 100-m performance in young swimmers (Rozi et al., 2018). Based on this biomechanical description, certain anthropometric variables may influence performance. Studies have confirmed that the best perform best-performing the anthropometric characteristics required for swimming (Rejman et al., 2018; Roy et al., 2015). Information about variables in their anthropometric measurements can be used to investigate what a competitive swimmer's body composition should be at different abilities. Unlike land-based sports, swimming emphasizes and rewards upper extremity strength (Bergamin et al., 2013). The aquatic environment presents coaches and sports scientists with a unique set of problems and questions because the physiological responses to training in the water differ from the corresponding responses on land (Benelli et al., 2004). The development of dryland, strength, and resistance training in water over the past five decades has taken the sport to new heights. Therefore, the aim of this study is to a) compare the profile of the physical performance of swimmers on land and in water and b) understand the relationship between anthropometric and physical performance tests. It was hypothesized that there is a relationship between the anthropometric and physical performance characteristics of swimmers.

Materials and Methods

Participants

This study included ten active swimmers (male = 3, female = 3) with at least five years of experience in the sport. Participants typically exercised two to three times per week for 90 minutes during the testing period. All participants were informed of the aims and protocols of this study through an informed consent form. This study was approved by the Ethics Committee of Istanbul Gedik University, Istanbul, where the study was conducted.

Anthropometric

Anthropometric variables were determined according to the International Society for the Advancement of Kinanthropometry (ISAK) protocol. Body composition was calculated using the five-way fractionation model, which divides the body into anatomically defined fat, muscle, residual, bone, and skin tissue masses (Kerr, 1988). The five-way fractionation model has several advantages over traditional models based on two-component hydrodensitometry: (a) it provides information on the components of lean body mass, muscle, and bone; (b) it is based on multiple regression equations, avoiding the problem of sample specificity; (C) it has been validated using cadavers; (D) it is cost-effective (39); (E) it is reliable (the interobserver measurement error in plane anthropometry II is ≤ 5% for skin folds and ≤ 1% for other variables). The proportionality of body mass fractionation was determined using the Phantom Z-score stratagem (Ross & Marfell-Jones, 1991). Carter and Heath's equations were used to calculate anthropometric somatotype. Body mass index (BMI) (body mass in kg/height in m2), the sum of four skinfolds (triceps, subscapularis, biceps, and supraspinalis), the sum of six skinfolds (triceps, subscapularis, supraspinalis, abdomen, thigh, and leg), and the sum of eight skinfolds (triceps, subscapularis, biceps, iliac crest, supraspinalis, abdomen, thigh, and leg) were also calculated.

VO_2max Testing

After the FitMate Pro (Cosmed, Rome, Italy) was calibrated, participants completed a step test on a bicycle ergometer (Monark 928E, Sweden). The Fitmate Pro is supplied by Cosmed and is already calibrated. Before each test, this system undergoes an automatic calibration. Breath-by-Breath data were collected for each test: volume of Oxygen inhaled (VO_2 l/min) and minute ventilation (VE l/min). Heart rate (BPM) was monitored by (Equine Healthcheck, Polar Electro, Kempele, Finland), and a self-reported perceived exertion value of 20 (Borg, 1970) was also recorded each minute to provide another measure of physical exertion. Before and after the test, blood samples were collected from the fingertip using an electrochemical sensor (LACTATE NOVA, Nova Biomedical, USA), which had previously been wiped with isopropyl alcohol. After completion of the test, participants were asked to continue cycling at a low workload. VO_2peak was calculated using the maximum oxygen uptake during the test relative to body weight (ml/kg/min). Participants were verbally encouraged and motivated with music throughout the test. Athletes were asked to inform the laboratory staff of the occurrence of any disturbances or symptoms such as acute weakness, shortness of breath, dizziness, etc. The test was performed within a period of 1 week at approximately the same time of day in a controlled laboratory environment (temperature 20 - 22 $^{\circ}$C, 50% - 60% relative humidity). Since testing was performed to exhaustion using the maximal protocol, athletes were advised to recover from training and competitive activities for 24-36 h before testing.

Cycling Exercise Test

An incremental cycling test was performed using a cycling ergometer and a Fitmate PRO desktop metabolic analyzer (Cosmed, Italy). Throughout the test, participants had to maintain a cadence above 60 RPM. The bicycle seat and handle height and position were adjusted according to the comfort of each athlete (body height and limb length). The test began with a three-minute warm-up period at 30 watts for men and 20 watts for women. Thereafter, the load was increased every minute by 20 watts for men and 15 watts for women until voluntary exhaustion.

Swimming Beep Test

The swimming pool performance test was performed on a different day, with 72 hours between maximal exercise tests. The Progressive Swim Test corresponds to a series of 400 meters in a 25-meter pool, based on the world record for men (03'32''57; www.fina.org/H2O/) over that distance in a short course pool. A beep indicates the swimming pace, which occurs with a decrease in partial time of 1 second for each lap completed, with a beep at the end of the first lap at 28''30. During the test, heart rate (HR) (beats/min) was measured for 30 seconds immediately after completion of the test using a Polar Heart rate monitor (Equine Healthcheck; Polar Electro, Kempele, Finland). In addition, blood lactate was measured before and after the swim test (LACTATE NOVA, Nova Biomedical, USA).

Statistical analysis

Descriptive statistical analyzes were performed using SPSS (version 26.0, USA). A descriptive analysis of the obtained data was used to estimate the basic functional status of the athletes. The mean (M), standard deviation (SD), and minimum and maximum values were calculated for the measured parameters. In addition, Pearson correlations were performed between anthropometric values and performance. An alpha criterion of $p \leq 0.05$ was used to determine statistical significance.

Results

Descriptive characteristics for age, anthropometric variables, and physical performance tests are shown in Table I.

Table 1. Proportionality and kinanthropometric descriptive characteristics

Variables	**Male (n=3)**			**Female (n=3)**		
Basic Measurements	**Min**	**Max**	**M ± SD**	**Min**	**Max**	**M ± SD**
Body mass (Kg)	63.10	103.60	78.9 ± 21.6	54.60	63.00	58.3 ± 4.2
Stature (cm)	158.00	181.50	172.5 ± 12.6	161.70	165.00	163.2 ± 1.6
Sitting high (cm)	88.00	94.50	91.6 ± 3.3	86.80	91.00	88.4 ± 2.2

Arm span (cm)	152.00	187.00	174.1 ± 19.2	160.50	166.00	164.1 ± 3.1
Lengths (cm)						
Acromiale-radiale	29.50	36.50	34.1 ± 3.9	31.50	32.50	31.9 ± 0.5
Radiale-stylion radiale	21.40	27.30	25.1 ± 3.2	23.00	25.30	24.2 ± 1.1
Midstylion-dactylion	17.00	19.50	18.6 ± 1.4	18.00	18.50	18.2 ± 0.2
Iliospinale height	84.00	112.00	101.3 ± 15.7	59.30	95.00	81.9 ± 19.6
Trochanterion height	78.00	94.90	87.5 ± 8.6	81.40	87.20	83.7 ± 3
Trochanterion-tibiale laterale	36.00	46.40	41.1 ± 5.2	38.50	41.40	40.1 ± 1.4
Tibiale laterale height	41.50	50.00	47 ± 4.8	42.50	45.50	43.8 ± 1.5
Tibiale mediale-sphyrion tibiale	32.00	41.00	37.8 ± 5	34.80	37.50	35.7 ± 1.5
Foot	23.10	28.30	25.9 ± 2.6	23.00	24.50	23.6 ± 0.7
Breadths (cm)						
Biacromial	36.80	42.60	40.5 ± 3.2	35.30	37.50	36.1 ± 1.1
Transverse chest	28.00	35.00	31.4 ± 3.5	26.30	26.70	26.5 ± 0.2
Anterior-posterior chest depth	39.00	43.80	41.2 ± 2.4	35.50	38.10	37.1 ± 1.4
Biiliocristal	27.30	33.00	29.6 ± 2.9	26.50	27.30	26.8 ± 0.4
Humerus (biepicondylar)	6.70	7.00	6.8 ± 0.1	6.20	6.40	6.3 ± 0.1
Femur (biepicondylar)	9.10	10.50	9.8 ± 0.7	8.20	8.90	8.6 ± 0.3
Wrist (bistiloid)	5.40	6.00	5.6 ± 0.3	4.50	5.00	4.7 ± 0.2
Ankle (bimaleolar)	6.30	7.30	6.9 ± 0.5	6.10	6.70	6.3 ± 0.3
Hand	5.50	8.50	7.4 ± 1.7	6.80	7.10	6.9 ± 0.1
Girths (cm)						
Head	54.50	56.00	55.2 ± 0.7	53.00	53.50	53.3 ± 0.2
Neck	35.50	40.00	37.4 ± 2.3	30.40	31.30	30.9 ± 0.4
Arm relaxed	27.50	40.00	32.8 ± 6.4	26.50	28.00	27.3 ± 0.7
Arm flexed and tensed	29.30	40.50	33.7 ± 5.9	27.00	28.00	27.5 ± 0.5
Forearm	25.20	30.50	27.2 ± 2.8	23.30	24.50	23.8 ± 0.6
Wrist	16.10	18.00	17.1 ± 0.9	14.50	15.80	14.9 ± 0.7
Chest	92.00	112.00	99.1 ± 11.1	80.50	86.50	84.1 ± 3.2
Waist (minimum)	77.50	100.00	85.1 ± 12.8	66.00	67.50	66.5 ± 0.8
Abdominal (maximum)	81.00	106.00	90 ± 13.8	72.00	75.00	73.6 ± 1.5
Gluteal (Hip) (maximum)	91.00	109.00	97.3 ± 10.1	91.00	98.00	94 ± 3.6
Thigh (upper)	55.00	67.50	59.3 ± 7	53.50	59.00	55.8 ± 2.8
Mid-thigh	50.00	63.00	55 ± 7	48.00	51.00	49.3 ± 1.5
Calf (maximum)	34.40	43.00	37.9 ± 4.4	32.20	35.20	34 ± 1.6
Ankle (minimum)	20.00	25.50	22.3 ± 2.8	19.00	27.20	22.4 ± 4.2

Skinfolds (mm)						
Triceps	6.00	22.00	14.6 ± 8	17.00	20.00	18.3 ± 1.5
Subscapular	9.00	22.00	16.6 ± 6.8	8.00	12.00	10.3 ± 2
Biceps	3.00	5.00	4.3 ± 1.1	3.00	7.00	5.3 ± 2
Iliac crest	11.00	38.00	22.3 ± 14	10.00	18.00	14.6 ± 4.1
Supraspinale	6.00	28.00	16 ± 11.1	6.00	10.00	8.3 ± 2
Abdominal	13.00	38.00	28.6 ± 13.6	10.00	18.00	14.3 ± 4
Front thigh	6.00	36.00	20 ± 15.1	8.00	26.00	15.6 ± 9.2
Medial calf	3.00	20.00	11.3 ± 8.5	10.00	32.00	21.6 ± 11
Adipose Mass (%)	21.00	32.00	27.6 ± 5.8	29.00	35.00	31.3 ± 3.2
Adipose Mass (kg)	14.60	33.20	22.2 ± 9.7	16.20	19.90	18.1 ± 1.8
Muscle Mass (%)	41.00	45.00	42.3 ± 2.3	35.00	42.00	38.6 ± 3.5
Muscle Mass (kg)	25.60	42.00	33 ± 8.3	20.10	26.50	22.6 ± 3.3
Residual Mass (%)	14.00	17.00	15 ± 1.7	14.00	15.00	14.6 ± 0.5
Residual Mass (kg)	9.10	14.80	12 ± 2.8	8.20	8.80	8.4 ± 0.3
Bone Mass (%)	9.00	11.00	10.3 ± 1.1	9.00	11.00	10 ± 1
Bone Mass (kg)	6.70	9.60	8.1 ± 1.4	5.70	5.90	5.8 ± 0.1
Skin Mass (%)	5.00	40.00	16.6 ± 20.2	5.00	6.00	5.6 ± 0.5
Skin Mass (kg)	3.00	4.10	3.6 ± 0.5	3.10	3.40	3.2 ± 0.1
Body fat %	8.20	30.40	19.7 ± 11.1	14.50	18.80	16.4 ± 2.1
∑ 3 skinfolds (mm)	28.00	88.00	61.3 ± 30.5	24.10	38.00	33 ± 7.7
∑ 6 skinfolds (mm)	43.00	166.00	107.3 ± 61.7	80.00	101.00	88.6 ± 10.9
∑ 8 skinfolds (mm)	57.00	209.00	134 ± 76	93.10	123.00	108.7 ± 14.9
Muscle/Bone Ratio	3.80	4.37	4 ± 0.3	3.40	4.48	3.7 ± 0.6
BMI (Kg/m2)	21.20	32.70	26.4 ± 5.8	20.90	23.10	21.8 ± 1.1
Sitting ht. Index (%)	51.90	55.70	53.2 ± 2.1	53.30	55.20	54.2 ± 0.9
Biacromial/Biiliocristal	1.30	1.50	1.3 ± 0.1	1.30	1.40	1.3 ± 0
Endomorph	1.90	6.50	4.5 ± 2.3	3.70	4.10	3.9 ± 0.2
Mesomorph	3.30	7.30	5.6 ± 2.1	3.40	3.80	3.6 ± 0.2
Ectomorph	0.10	3.70	1.5 ± 1.9	1.80	2.60	2.2 ± 0.4

On average, males were taller and heavier, had higher sitting height, arm span, muscle mass, and bone mass, and had higher Vo2max and swimming peep tests compared with females (as shown in Tables 1 and 2).

Table 2. Physical performance descriptive characteristics

Variables	Male (n=3)			Female (n=3)		
	Min	Max	M ± SD	Min	Max	M ± SD
Age	21.4	25.4	22.8 ± 2.3	19.8	25.3	22.5 ± 2.8

Laboratory Test						
Watt	230.0	250.0	236.6 ± 11.5	140.0	170.0	155 ± 15
Hear rate (b/m)	179.0	188.0	184 ± 4.6	181.0	200.0	189.3 ± 9.7
Lactate (mmol)	15.0	20.0	18.3 ± 2.9	16.0	20.0	18 ± 2
Borg Scale (6-20)	11.1	12.4	11.7 ± 0.7	8.1	12.7	10.9 ± 2.5
Ventelation (L/min)	114.5	155.9	128.7 ± 23.5	68.1	84.6	75.4 ± 8.4
VO_2max % (ml/kg/min)	29.9	56.8	45.2 ± 13.9	32.6	36.1	34.3 ± 1.8
Swimming Beep test						
Distance (meter)	125	300	233 ± 94	125	200	166 ± 38
Hear rate (b/m)	162.0	178.0	170 ± 8	188.0	189.0	188 ± 0.5
Lactate (mmol)	11.5	13.6	12.2 ± 1.1	9.0	14.4	11.5 ± 2.7
Borg Scale (6-20)	15.0	18.0	17 ± 1.7	18.0	18.0	18 ± 0

The reliability of all measurements was high, with all anthropometric variables having intraclass correlations greater than 0.90. Technical measurement error was less than 2% for all skinfolds and less than 1% for all bone widths and limb circumferences and lengths. The anthropometric and body composition profiles are shown in Table 1. A descriptive analysis of the anthropometric values and VO_2max is shown in Table 2. There was a significant correlation between some anthropometric variables and the swimming performance test (see Table 3 for all correlations and Figure 2). In addition, women and men have specific and different somatotypes. Figure 1 is a somatochart of the mean somatotypes for women and men.

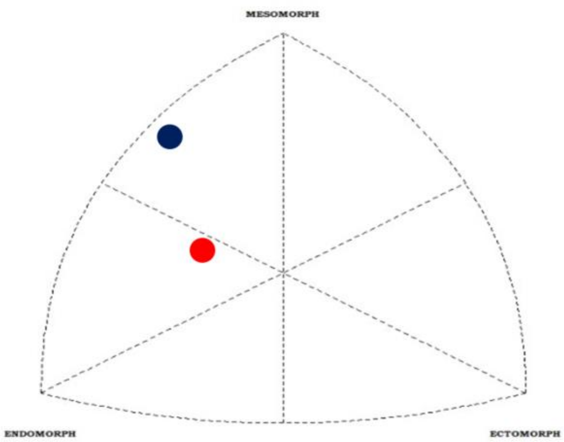

Figure 1. Somatotype chart of the study

Note. The red circle represents females and the blue circle represents males

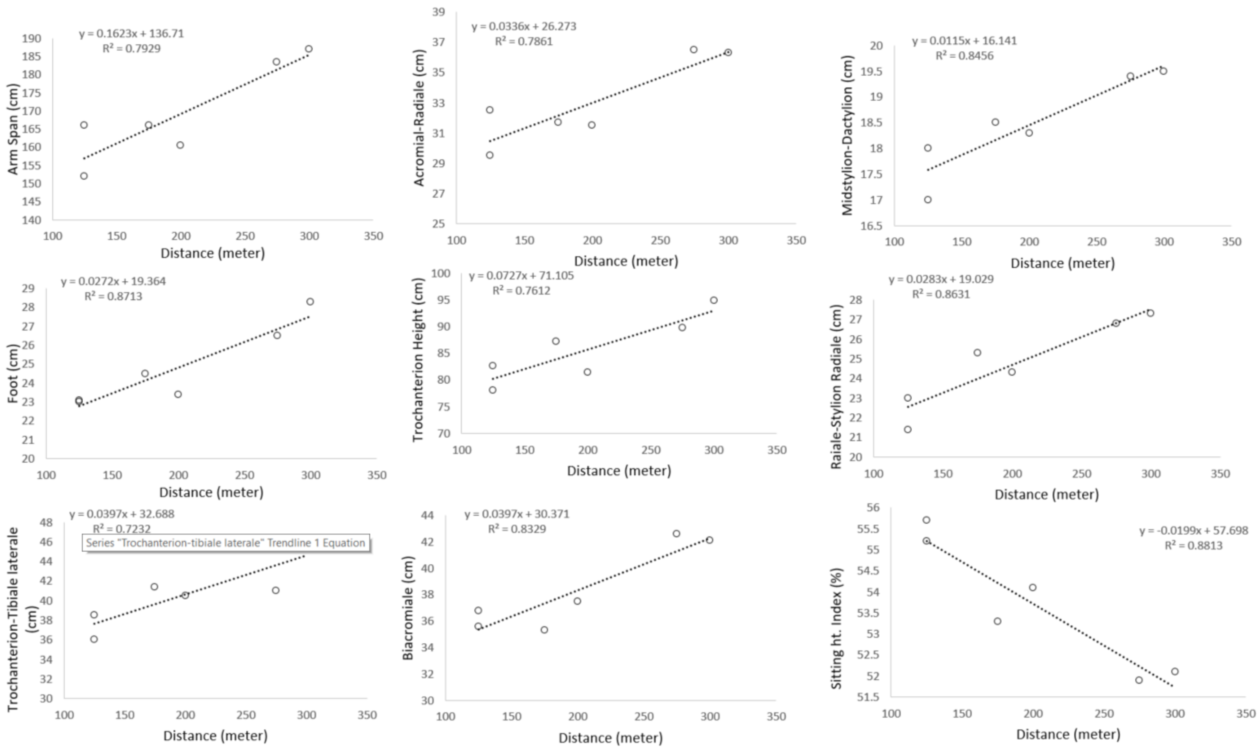

Figure 2. Pearson correlation between swimming beep test and anthropometric profile

Discussion

The purpose of this study was to evaluate body composition and performance characteristics in active swimmers and the relationship between performance characteristics. To the best of the author's knowledge, this is the first scientific article describing an anthropometric model of fivefold body fractionation to investigate the relationships between physical performances. The results of this study show that the anthropometric characteristics of swimmers are important factors that contribute to performance. The main findings of this study are: Nine anthropometric parameters that have a strong positive correlation with swimming performance are body height, seat height, arm span, acromial-radial length, midstylion-dactylion length, foot, pelvic width, trochanteric height, and shoulder width ($P \leq 0.001$), as shown in Table and Graph 1. Arm span was one of the variables positively associated with performance in all four swimming techniques and in the individual medley (Rejman et al., 2018). In the present study, it was confirmed that body height and arm span, as well as arm height, were highly related to performance in the swimming peep test. This is likely due to the fact that taller swimmers glide through the water better and, in addition, taller swimmers have a greater arm span, which benefits swimming efficiency. The continued significance between upper limb length and swimming performance in previous and current studies suggests that this factor prioritizes propulsion in the water (Nicol et al. 2022; Pan et al. 2023; Redón Jordán et al., 2022). Biaromial and bi-iliac width were variables related to performance in all four techniques. When a body is moving in a fluid environment, flow stagnates at the front extremities and the pressure resistance a swimmer faces is higher in these regions (HOUARI & KHEIRA). a 1-cm increase in biacromial width and biiliocristal width increased 100-butterfly speed by 48.9% and 29.2%, and 100-m breaststroke speed by 56.5% and 40.3%, respectively (Altavilla et al., 2020; Beretic et al., 2023). In the current study, seat height was significantly correlated with swimming performance. Previous studies have shown that seat height has a significant correlation with arm strength.

Therefore, based on the current study and previous research, greater torso length may be correlated with greater swimming efficiency. There are several predictors of swimming performance in elite athletes, such as physiological, psychological, and anthropometric factors, so anthropometric assessment is one of the best parameters for talent identification. The results of the current study were consistent with previously reported values for an elite athlete such as height and limb length, which are associated with higher levels of performance. This study shows that active swimmers have a specific kinanthropometric profile that is related to their performance. This study showed that different characteristics of anthropometric measures are correlated with performance parameters. The current study showed interesting results, yet there are limitations that should be considered and addressed in future research. Laboratory and aquatic performance were not considered due to the small number of participants. In addition, performance on land and in water are completely different and it is not worth comparing them. In conclusion, the results of the present study suggest that anthropometric characteristics have a fundamental influence on the performance of young swimmers. It seems that swimmers with the highest height also have greater arm span and surface area. The specific anthropometric characteristics that are most important are arm span and length, shoulder and pool width, and leg length.

References

Altavilla, C., Sellés- Pérez, S., Comino, I., Comeche Guijarro, J. M., Caballero, P., & Tuells, J. (2020). Comparisons of summer break effect on anthropometric profile, body composition and somatotype between adolescent swimmers and less active adolescents. *Revista Andaluza de Medicina del Deporte*, 13(3). http://dx.doi.org/10.33155/j.ramd.2019.12.004

Benelli, P., Ditroilo, M., & De Vito, G. (2004). Physiological responses to fitness activities: Acomparison between land-based and water aerobics exercise. *The Journal of Strength & Conditioning Research*, 18(4): 719-722. https://doi.org/10.1519/00124278-200411000-00006

Beretic, I., Romanov, R., Stupar, D., Beretic, I., Romanov, R., & Stupar, D. (2023). The Relationship between Anthropometric Variables and Swimming Efficiency in Early Pubescent Female Front Crawl Swimmers. International Journal of Morphology, 41(1): 303-307. https://doi.org/10.4067/S0717-95022023000100303

Bergamin, M., Ermolao, A., Tolomio, S., Berton, L., Sergi, G., & Zaccaria, M. (2013). Water-versus land-based exercise in elderly subjects: effects on physical performance and body composition. *Clinical Interventions in Aging*, 2013: 1109-1117. https://doi.org/10.2147/CIA.S44198

Cobb, W.M. (1936). Race and runners. *The Journal of Health and Physical Education,* 7(1): 3-56. https://doi.org/10.1080/23267240.1936.10627128

Crowley, E., Harrison, A.J., & Lyons, M. (2017). The impact of resistance training on swimming performance: A systematic review. *Sports Medicine,* 47: 2285-2307. https://doi.org/10.1007/s40279-017-0730-2

Houari, G., & Kheira, B.A. (2022). The impact of morphological indices on some swimming parameters (Case of Algerian Sprinters swimmers). *Sport system journal,* 9(1): 222-233.

Martínez, S., Pasquarelli, B.N., Romaguera, D., Arasa, C., Tauler, P., & Aguiló, A. (2011). Anthropometric characteristics and nutritional profile of young amateur swimmers. *The Journal of Strength & Conditioning Research*, 25(4): 1126-1133. https://doi.org/10.1519/JSC.0b013e3181d4d3df

Nicol, E., Pearson, S., Saxby, D., Minahan, C., & Tor, E. (2022). The Association of Range of Motion, Dryland Strength–Power, Anthropometry, and Velocity in Elite Breaststroke Swimmers. *International Journal of Sports Physiology and Performance,* 17(8): 1222–1230. https://doi.org/10.1123/ijspp.2021-0544

Pan, Q., Zhu, R., Qiu, J., & Cai, G. (2023). Construction of an anthropometric discriminant model for identification of elite swimmers: an adaptive lasso approach. *PeerJ*, 11, e14635. https://doi.org/10.7717/peerj.14635

Redon Jordan, B., Hernández Camacho, J., Sospedra, I., Ferriz Valero, A., Soriano, J. M., Martínez Sanz, J. M., & Jiménez Alfageme, R. (2022). Anthropometric profile in young swimmers. *Cultura_Ciencia_Deporte [CCD],* 17(52): https://doi.org/10.12800/ccd.v17i52.1845

Rejman, M., Tyc, Ł., Kociuba, M., Bornikowska, A., Rudnik, D., & Kozieł, S. (2018). Anthropometric predispositions for swimming from the perspective of biomechanics. *Acta of bioengineering and biomechanics,* 20(4): 151-159.

Roy, A., Dalui, R., Kalinski, M., & Bandyopadhyay, A. (2015). Anthropometric profile, body composition and vertical jump score in boxers and swimmers. *International journal of medicine and medical research,* 1(1): 49-53. https://doi.org/10.11603/ijmmr.2413-6077.2015.1.2854

Rozi, G., Thanopoulos, V., Geladas, N., Soultanaki, E., & Dopsaj, M. (2018). Anthropometric characteristics and physiological responses of high level swimmers and performance in 100 m freestyle swimming*. Movement & Sport Sciences-Science & Motricite,* (101): 3-7. https://doi.org/10.1051/sm/2018007

Shahidi, S.H., Kingsley, J.D., Svensson, M., Taşkiran, M.Y., & Hassani, F. (2021). Training Wiser Instead of Training Harder: A Complex Training Program (CPX). *Journal of Health and Sport Sciences*, 4(1): 15-18.

Shahidi, S.H., Kingsley, J.D., & Taşkiran, M.Y. (2022). Talent Identification Pathway "Coaches, Family, and Environment Eyes". *Journal of Health and Sport Sciences*, 5(1): 17-20.

Shahidi, S.H., Kordi, M.R., Rajabi, H., Malm, C., Shah, F., & Quchan, A.S.K. (2020). Exercise modulates the levels of growth inhibitor genes before and after multiple sclerosis. *Journal of Neuroimmunology,* 341: 577172. https://doi.org/10.1016/j.jneuroim.2020.577172

Shahidi, S.H., Williams, J.S., & Hassani, F. (2020). Physical activity during COVID-19 quarantine. *Acta Paediatrica (Oslo, Norway: 1992),* 109(10): 2147-2148. https://doi.org/10.1111/apa.15420

VanHeest, J.L., Mahoney, C.E., & Herr, L. (2004). Characteristics of elite open-water swimmers. *The Journal of Strength & Conditioning Research,* 18(2): 302-305. https://doi.org/10.1519/00124278-200405000-00018

Zhao, K., Hohmann, A., Chang, Y., Zhang, B., Pion, J., & Gao, B. (2019). Physiological, anthropometric, and motor characteristics of elite Chinese youth athletes from six different sports. *Frontiers in Physiology*, 10: 405. https://doi.org/10.3389/fphys.2019.00405

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Conflicts of Interest

The Authors declare that they have no competing interests.

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