# Anthropometric profile in young swimmers

## Perfil antropométrico en jóvenes nadadores

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### Abstract

The study of body dimensions and proportions through anthropometry is important for the identification of young talents in swimming. Anthropometric studies of swimmers in the Spanish population are scarce. The main objective of this study is the description of anthropometric profile in young swimmers, differentiated by sex and styles. 34 swimmers (19 boys and 15 girls) of national competitive level, aged between 14-17 years were analyzed. Measurements were taken by two accredited anthropometrists following the Society for the Advancement of Kinanthropometry (ISAK) anthropometric protocol. Body composition was calculated using the 4-component model and the Heath-Carter somatotype. The sample was differentiated between swimming strokes to examine possible differences between groups. Significant differences (p <0.05) were observed by sex in basic measurements, folds, perimeters and diameters, but no significant differences were observed by styles. The somatotype of the sample was balanced mesomorphic, being ectomesomorphic in boys and mesoendomorphic in girls, with values similar to those observed in the bibliography. Anthropometric assessment should be considered to monitor the development and detection of possible sports talents in swimming.

**Keywords:** kinanthropometry, swimming, teenagers, body composition, somatotype, sport talent.

### Resumen

El estudio de las dimensiones y proporciones corporales mediante la antropometría es importante para la identificación de jóvenes talentos en natación. Los estudios antropométricos de nadadores en población española son escasos. El objetivo principal del presente estudio es describir el perfil antropométrico en jóvenes nadadores, diferenciado por sexos y estilos. Se analizaron 34 nadadores (19 chicos y 15 chicas) de nivel competitivo nacional, con edades comprendidas entre 14-17 años. Dos antropometristas acreditados tomaron las medidas siguiendo el protocolo antropométrico de la Society for the Advancement of Kinanthropometry (ISAK). Se calculó la composición corporal mediante el modelo de 4 componentes y el somatotipo según Heath-Carter. Se diferenció la muestra entre estilos de natación para examinar posibles diferencias entre grupos. Se observaron diferencias significativas (p<0,05) por sexo en medidas básicas, pliegues, perímetros y diámetros, pero no se observan diferencias significativas por estilos. El somatotipo de la muestra fue mesomórfico balanceado, siendo ectomesomórfico en chicos y mesoendomórfico en chicas, siendo valores similares a los observados en la bibliografía. La valoración antropométrica debe ser considerada para monitorizar el desarrollo y detección de posibles talentos deportivos en natación.

**Palabras clave:** cineantropometría, natación, adolescentes, composición corporal, somatotipo, talento deportivo.

## Introduction

Swimming is a sport whose success is given by the production of strength with a highly coordinated and efficient technique, as well as a good cardiorespiratory ability. This is why a specific anatomy increases the chances of success among swimmers, since they are characterized by having long limbs and with great muscle development (Burke, 2009; Cabañas & Esparza, 2009), allowing them to move a greater amount of water and make the propulsion also greater (Belloch et al., 2013). Competitive swimming is framed in different styles: crawl, breaststroke, back and butterfly, and includes swimming distances of 50, 100, 200, 400, 800 and 1500m in swimming pool (RFEN General Regulation, 2019). Even so, this anatomy offers long and thin limbs that give us little surface to move through the water, so surfaces (such as the length of the hand) will be a factor to consider in such identification (Belloch et al., 2013; Valero et al., 2020). Similarly, a higher percentage of body fat compared to other competitive sports is an advantage in the anthropometry of swimmers and especially swimmers (Cabañas & Esparza 2009; Bagnall & Kellett, 1977). The complexity of swimming as a sport discipline does not only come from being an early initiation sport, but is the only one of the Olympic sports in which it competes outside the natural environment of human life (González Revuelta et al., 1998),therefore, it is necessary to have certain body and functional characteristics in order to reach the speed required for the triumph (Pancorbo & Rodríguez, 1986).

Thus, the study of their dimensions and body proportions allows a classification of the most anatomically predisposed to swimming, starting from a profile suitable for this sport, since a particular feature of elite swimming is the appearance of outstanding athletes from an early age (12-14 years) (Cabañas & Esparza, 2009). This body analysis can be performed through different methods such as anthropometry, electrical bioimpedance or absorptiometry with dual energy X-rays (García et al., 2014; Milsom et al., 2015; Requena et al., 2017). Anthropometry has been used in a wide variety of sports such as football, basketball, volleyball or water polo (Alejandro et al., 2015; Martínez et al., 2015; Milić et al., 2017; Perroni et al., 2015).

In swimming has been used recently in the works of Shaw and Mujika (2018) where they observed that open water swimmers have lower weight and lower index of fat-free mass than pool swimmers, but concluding the great potential of the technique; Morais et al. (2017), which determine that both young men and women improved performance in a 3-year follow-up and conclude that this performance improvement is a multifactorial phenomenon where anthropometry, kinematics and efficiency are determinants; or Figueiredo et al. (2016), where they conclude that anthropometry is the most determinant variable in the performance of sprint in the crawl style in young swimmers, although it is true that there are few studies done in Spanish swimmers in which their anthropometric characteristics are described. Kineanthropometric, the swimmer is defined as a tall, light, broad-shouldered athlete with very long limbs, mainly in the upper limb and hand. They have an ectomesomorphic middle somatotype in men and endomesomorph in women (Cabañas & Esparza, 2009; Martínez-Sanz et al., 2012).

For this reason, the aim of this work is to describe the anthropometric profile in young swimmers, differentiated by gender and style.

## Materials and methods

### Study population

34 adolescent swimmers were evaluated (15 women and 19 men) belonging to 3 clubs of the Valencian Community, competing at the national level, in the modalities of crawl, back, armlet and butterfly with ages between 14 and 17 years (15.44 0.92). With a daily workout of between 2 and 3 hours, completing each week approximately 15 hours of training. The data were taken in pre-competition season. Each participant was explained the nature and purpose of the study, obtaining from all of them informed consent from the heads of the clubs, legal guardians and athletes.

### Instruments y procedures

The body study was based on international standards recommended by the International Society for the Advancement of Kinanthropometry (ISAK), and were taken by accredited anthropometrists ISAK 1 and 2, without exceeding the technical error of intraobserver measurement indicated by the ISAK (5% for folds and 1% for perimeters and diameters) (Cabañas & Esparza, 2009). Measuring instruments were Tanita scale (accuracy 100g), Cescorf anthropometric tape (accuracy 1mm), dermographic pencil, anthropometric drawer, Cescorf plicalimeter (accuracy 0.5mm), Cescorf short branch pachymeter (accuracy 1mm), Siber-Hegner long branch pachymeter (precision 1mm) and segometer (precision 1mm). The body composition (CC) was calculated by means of models of four components: fat mass using the Withers equation, muscle mass through the Lee equation and bone mass with the Rocha equation (Alvero et al. 2010).

For the somatotype calculation, the average somatotype was determined, the Heath-Carter method was followed and its classification according to the somatotypical categories of Duquet and Carter (Cabañas & Esparza, 2009). Data pertaining to anthropometric analysis and somatotype were expressed according to the sex of swimmers as previously done in the existing literature (Lozano-Berges et al., 2017; Martínez et al., 2011; Morais et al., 2013; Zuniga et al., 2011).

### Statistical analysis

A descriptive analysis (mean ± standard deviation) was carried out in each of the dependent variables. A Shapiro-Wilk normal test was applied, obtaining a normal distribution of all variables. For this reason, a T-test of independent muestas was applied in order to observe the differences between men and women. Additionally, an ANOVA-1 factor test was applied in order to observe the differences between the four swimming styles, considering the correction of bonferroni as an ad-hoc test to avoid incurring type II error. The significant value was set to $p<0.05$, except for bonferroni correction ($p<0.008$). Statistical software Statistics Product and Service Solutions (SPSS Statistics Version 15.0; International Business Machines Corp.-IBM-, Madrid, Spain) was used for the analysis.

## Results

Table 1 shows the average anthropometric values obtained in the total sample and divided by sex. In the values of weight, height, wingspan, lean mass, circumference of contracted arm and calf, diameter of the humerus, femur, biceps, triceps, subscapular, supraspinal and thigh, endomorphia and mesomorphia, a significant difference is observed ($p<0.05$) between both sexes. Figure 1 shows the overall result and sex of the somatotype by somatocarte. The somatotype of the total sample is balanced mesomorphic (dominant musculoskeletal development, and relative linearity and relative fat are equal) being, in the case of ectomesomorphic males (where relative linearity predominates, followed by musculoskeletal development, with lower relative fat), and in the case of mesoendomorphic women (where musculoskeletal development predominates, followed by relative fat, with lower relative linearity).

If we divide the swimmers studied by the swimming style in which they are specializing, we find among them a higher percentage in the practice of the crawl style (35.3%) and butterfly (26.5%), against the back styles (20.6%) and breaststroke (17.6%). Table 2 shows the anthropometric variables differentiated by styles and without division by sex. Comparing the crawl and the back, significant differences are found in the supraspinal fold and calf. Similarly, between the crawl and the armhole, and the crawl and the butterfly there are differences in the fold of the calf, but there are no differences by styles in the rest of the anthropometric variables. In addition, there is a significant difference in the value of endomorphia between the four styles. Following this division, in terms of the somatotype represented in the somatocarta of each style and divided by sexes (Figures 2, 3, 4, 5), it is observed in the case of crawl, values similar to that of the total sample, both group and differentiated between sexes. In the case of the back, the total somatotype of the sample is ectomesomorphic. Differentiated by sex, it is found that men present the same somatotype as men in the total sample, whereas women present a central somatotype. In the case of the armlet, a balanced mesomorphic group somatotype is obtained, with a result similar to that presented in the total sample for men, and with different somatotype in women. Finally, in the case of butterflies, endomesomorphic group results similar to those of the total sample differentiated by sex are expressed for both men and women.

**Table 1. Values of mean and standard deviation of anthropometric variables by sex**

| | Men (n=19) | Women (n=15) |
|---|---|---|
| Weight (kg) | 67.3±6.8* | 56.7±4.8* |
| Height (cm) | 176.0±6.0* | 165.0±4.0* |
| BMI (kg/m²) | 21.6±1.6 | 20.9±1.4 |
| Wingspan (cm) | 180.8±5.6* | 168.4±5.9* |
| Fat mass (%) | 11.7±2.6 | 14.1±3.5 |
| Lean mass (%) | 45.0±2.0* | 39.2±2.1* |
| Relaxed arm perimeter (cm) | 28.9±1.9 | 27.5±1.6 |
| Contracted arm perimeter (cm) | 30.9±2.1* | 27.7±1.4* |
| Waist perimeter (cm) | 75.2±3.8 | 68.2±3.9 |
| Hip perimeter (cm) | 91.2±3.9 | 91.2±4.0 |
| Perimeter thigh (cm) | 50.7±2.9 | 48.4±2.3 |
| Perimeter of leg (cm) | 36.1±1.9* | 34.1±1.3* |
| Diameter of the humerus (mm) | 7.0±0.2* | 6.1±0.2* |
| Femur diameter (mm) | 9.7±0.4* | 8.6±0.3* |
| Biceps fold (mm) Specifications | 4.1±0.8* | 8.3±2.4* |
| Triceps fold (mm) Specifications | 8.9±2.0* | 14.7±2.9* |
| Subscapular fold (mm) | 8.1±1.6* | 11.3±3.3* |
| Crete Pleat fold(mm) | 11.8±4.1 | 18.8±6.3 |
| Supraspinal fold (mm) | 7.6±2.4* | 12.7±5.4* |
| Abdominal fold (mm) | 12.5±4.0 | 19.3±6.3 |
| Thigh fold (mm) | 15.3±4.6* | 24.4±3.8* |
| Leg fold (mm) | 10.0±2.8 | 15.4±3.8 |
| Endomorphy | 2.4±0.5* | 4.1±1.1* |
| Mesomorphy | 4.5±0.7* | 3.5±0.5* |
| Ectomorphy | 3.1±0.8 | 2.9±0.8 |
| Femur length (cm) | 44.6±2.0 | 42.3±1.8 |

* $p < 0.05$ between men and women.

**Table 2. Values of mean and standard deviation of anthropometric variables by styles**

| | Crawl (n=12) | Backstroke (n=7) | Breaststroke (n=6) | Butterfly (n=9) |
|---|---|---|---|---|
| Weight (kg) | 65.3±8.6 | 58.4±6.8 | 63.8±7.8 | 61.5±7.6 |
| Height (cm)**/*** | 173.0±8.0 | 169.0±6.0 | 172.0±6.0 | 169.0±10.0 |
| BMI (kg/m2) | 21.7±1.8 | 20.3±1.3 | 21.4±1.7 | 21.4±1.2 |
| Wingspan (cm)**/***/**** | 175.2±8.2 | 174.9±7.1 | 176.9±3.7 | 174.8±12.3 |
| Fat mass (%) | 13.7±2.6 | 11.3±2.5 | 11.2±3.3 | 13.7±4.0 |
| Lean mass (%) | 41.9±3.4 | 43.5±4.4 | 43.9±3.0 | 41.4±3.5 |
| Relaxed arm perimeter (cm) | 28.9±2.3 | 26.9±1.5 | 28.4±1.8 | 28.4±1.3 |
| Contracted arm perimeter (cm) | 30.1±2.9 | 28.2±1.5 | 30.0±2.8 | 29.5±1.9 |
| Waist circumference (cm) | 72.9±5.8 | 69.6±1.8 | 72.5±6.0 | 72.8±5.5 |
| Hip circumference (cm) | 92.4±3.6 | 88.9±4.5 | 90.4±4.1 | 92.1±3.3 |
| Thigh perimeter (cm) | 50.4±2.8 | 48.4±3.7 | 50.1±2.4 | 49.4±2.8 |
| Leg perimeter (cm) | 36.1±2.2 | 34.5±1.7 | 35.3±1.6 | 34.6±1.8 |
| Diameter of the humerus (mm) | 6.6±0.5 | 6.6±0.4 | 6.7±0.5 | 6.5±0.5 |
| Femur diameter (mm) | 9.2±0.5 | 9.0±0.7 | 9.4±0.5 | 9.2±0.8 |
| Biceps fold (mm) | 6.0±2.3 | 5.4±2.4 | 4.7±2.2 | 7.2±3.4 |
| Triceps fold (mm) | 11.9±2.9 | 10.4±3.1 | 9.3±3.6 | 13.1±5.0 |
| Subscapular fold (mm) | 9.9±2.4 | 7.9±2.3 | 8.4±3.4 | 10.8±3.3 |
| Iliac crest fold (mm) | 14.7±4.5 | 12.7±4.6 | 12.2±5.6 | 18.5±8.4 |
| Supraspinal fold (mm) | 10.1±2.8[a] | 7.6±2.6[a] | 8.9±3.6 | 11.8±7.6 |
| Abdominal fold (mm) | 15.7±3.7 | 12.4±3.5 | 13.1±6.1 | 19.1±8.7 |
| Thigh fold (mm) | 20.7±5.2 | 18.8±5.9 | 16.7±6.8 | 19.6±7.7 |
| Leg fold (mm) | 20.7±5.2[a,b,c] | 11.9±4.5[a] | 9.9±3.1[b] | 12.4±3.9[c] |
| Endomorphy | 3.2±0.1[a,b,c] | 2.6±0.1[a,e] | 2.7±0.1[b,f] | 3.7±0.1[c,e,f] |
| Mesomorphy | 4.1±0.9 | 3.9±0.7 | 4.4±0.8 | 4.1±0.4 |
| Ectomorphy | 2.9±0.9 | 3.3±0.5 | 2.9±0.8 | 2.8±0.8 |
| Hand length (cm)*/*** | 19.6±1.1 | 19.2±0.6 | 19.3±0.6 | 19.1±1.5 |
| Length of femur (cm) *** | 43.7±1.9 | 42.6±1.3 | 43.9±2.2 | 44.0±3.2 |
| Thigh perimeter (cm) | 50.4±2.8 | 48.4±3.7 | 50.1±2.4 | 49.4±2.8 |

*important values in crawl; **important values in backstroke; ***important values in breaststroke; **important values in butterfly; a: $p<0.05$ between crawl and backstroke; b: $p<0.05$ between crawl and breaststroke; c: $p<0.05$ between crawl and butterfly; d: $p<0.05$ between backstroke and breaststroke; e: $p<0.05$ between backstroke and butterfly; f: $p<0.05$ between breaststroke and butterfly.

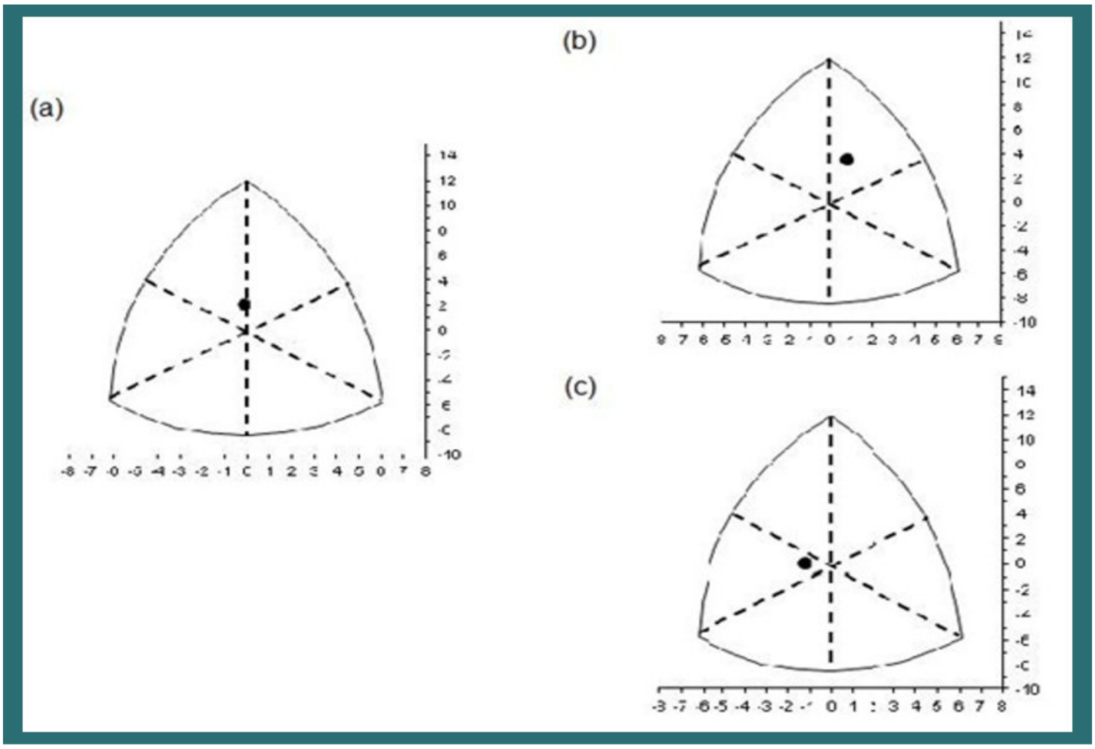


**Figure 1. Somatochart of the total sample (a), and differentiated between men (b) and women (c)**

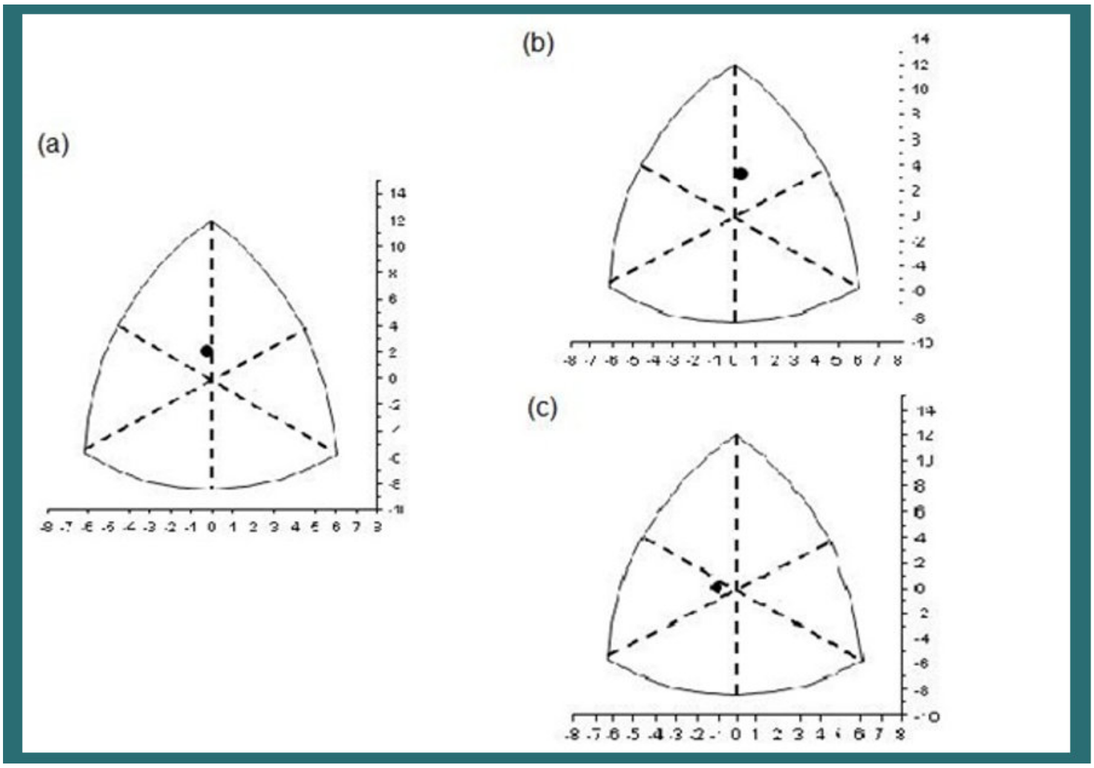


**Figure 2. Somatochart of the crawl group (a), and differentiated between men (b) and women (c)**

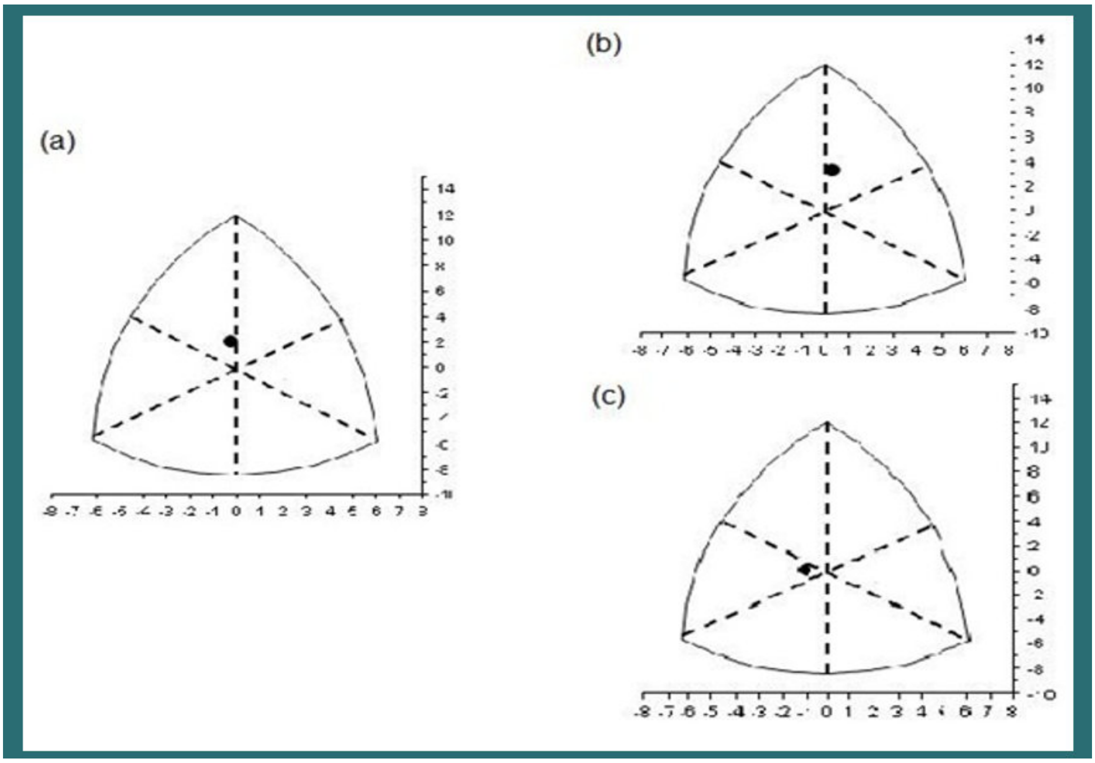


**Figure 3**. **Somatochart of the backstroke group (a), and differentiated between men (b) and women (c)**

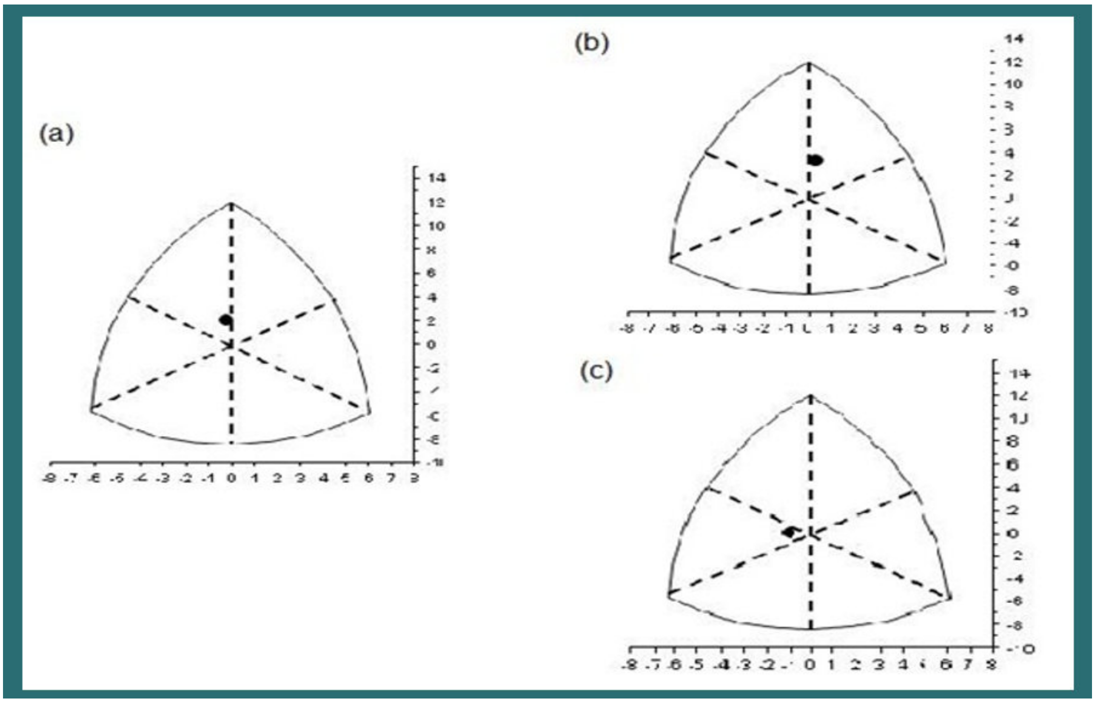


**Figure 4**. **Somatochart of the breaststroke group (a), and differentiated between men (b) and women (c)**

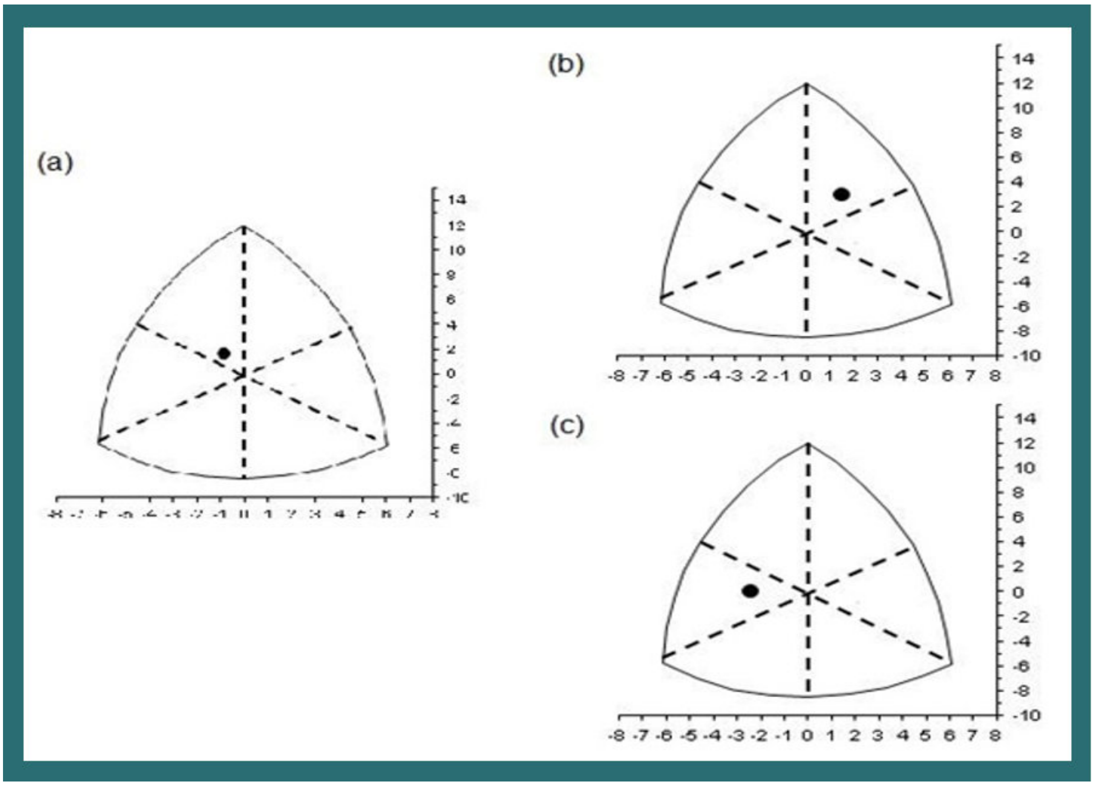


**Figure 5. Somatochart of the butterfly group (a), and differentiated between men (b) and women (c)**

## Discussion

Among the main results obtained in this study, we found significant differences (p<0.05) in the values of weight, size, wingspan, lean mass, contracted arm and calf perimeter, humerus diameter, femur, biceps, triceps, subscapular, supraspinal and thigh, endomorphia and mesomorphia, which are observed between both sexes and are detailed in Table 1. It has also been found that the somatotype of the total sample is balanced mesomorphic, but in the case of males it is ectomesomorphic and by females, mesoendomorphic.

Studying the body composition of athletes is useful to assess their evolution, growth, influence of training, dietary planning, as well as the selection and orientation of potential talents (Cabañas & Esparza, 2009), since the morphological state of swimmers significantly affects performance, and causes some predisposition of the organism for the technique of said sport (Popo et al., 2010; Valero et al. 2020). When a person reaches physical maturity, it is too late to start an effective training program in the pool, so anthropometric assessment should begin to be performed in the preadolescence or pre-pubert (Bagnall & Kellett, 1977; Carter & Ackland, 1994; Ramírez & Rivera, 2006). Tanner stated that the lack of a suitable physique can make, despite the diversity that can be observed, practically impossible for an athlete to achieve success (Tanner, 1964). On the other hand, Lee (1993) argues that children grow at different rates at different ages, and change their body proportions, which can put limitations on their execution abilities. Nevertheless, the analysis of body composition should help to quantify the individual potential for success in certain sports (Ramírez & Rivera, 2006; Stager & Babington, 1997).

An article analyzing different performance variables in young swimmers states that the main predictive variables are anthropometric measurements (especially in men), followed by physical fitness (aerobic speed and resistance) and technical domains (especially in women) (Saavedra et al., 2010). In another study conducted on 10 selected swimmers of the national team of Bosnia and Herzegovina that aimed to determine the relationships between some morphological characteristics and the result in swimming to facilitate a system of selection of young swimmers, found that anthropometric measurements directly affect endurance, dynamism, body position in water, technique, motor skills, speed, strength, coordination, functional capacity, etc. and morphological variables were found to have a direct impact on swimming results (Valero et al. 2020). It must also be recognized that there are other important factors such as nutrition, training, technique, facilities, etc. (Burke, 2009; Stager & Babington, 1997).

The importance of the higher height lies in the fact that the wave of water generated by the movement has a lower amplitude than in the case of its smaller competitors (Toussaint & Truijens, 2005), there are studies that show that the best swimmers tend to be taller and have longer limbs (Pacheco, 1996). The greater weight that swimmers have compared to their sedentary peers is due to the greater muscle mass compared to fat mass, presenting a general ectomesomorphic somatotype (Carter & Ackland, 1994; Peltenburg et al., 1984), predominantly ectomesomorphic in men, and endomesomorphic in women (Cabañas & Esparza, 2009). In addition, McNeill and Livson (1963) have suggested that height/weight ratios are indicative of "construction linearity" are evident at age six and persist during adolescence.

In terms of body composition, the literature shows that men have greater osteomuscular development than women, which, on the contrary, present a higher content of fat mass than men (Cabañas & Esparza, 2009; Bagnall & Kellett, 1977), something that is confirmed in the present work. This tendency to a high muscle development associated with a strong linearity is more noticeable with the level increase of swimmers (Fernandes et al., 2002). In addition, studies conducted in athletes present a greater mesomorphia than non-athletes (Pacheco, 1996). On the other hand, a higher quantity of fat mass provides advantages such as greater buoyancy, resulting in energy savings (Pendergast et al., 1977). The values of fat mass and muscle mass from various studies and compared with the study performed are similar. Even so, the average value of the fat and muscle percentage is not established, since it has not been possible to relate a specific percentage with a higher sports performance (Cabañas & Esparza, 2009; Burke, 2009).

The literature also describes the somatotype of elite swimmers as 2-5-3, belonging to an ectomesomorphic somatotype (Fernandes et al., 2002), while for swimmers it is reported as 3-4-3, belonging to a central somatotype (Stager & Babington, 1997), coinciding with the values obtained in this study. In a study of potential Olympic swimmers, it was observed that the whole group was limited to one area in the somatotype graph, which is consistent with what Tanner described (1964), being the low endomorphic component, the mesomorph quite high and with average values in ectomorphy, obtaining results similar to those shown in this study. In terms of ectomorphy the two sexes are similar (Bagnall & Kellett, 1977).

Comparing different similar studies with the present study, we observed values similar to the somatotype proposed for elite swimmers, being superior the endomorphia in the swimmers studied with respect to the reference somatotype, but staying within the same area within the somatocarta despite this difference. Over time, it appears that all swimmers become less endomorphic and more mesomorphic and ectomorphic (Carter & Ackland, 1994).

By differentiating according to the swimming style, Ackland (1999) explains the size and weight are different between elite swimmers of different swimming styles, so, breaststroke swimmers are inferior to crawlistas and backstroke swimmers in terms of size, without significant differences in weight, but still have a lower body weight than crawlista and espaldista. This statement is not met in the data obtained in the study because no significant differences in height and weight were found among swimmers of different styles, as was observed in the study of the Galician plan of sports technification (Ramiro & Rivera, 2006). However, in the anthropometric study of swimmers and waterpolists aged 13 to 16 years, a weight, size and size of crawlistas were significantly higher than those of Backstroke swimmers and Breaststroke swimmers. Brachians present the smallest measures for these variables (Ltt, 2011). Other studies have reported significant differences in function of the somatotype divided by styles and distance of the specialty of each swimmer (Carter & Ackland, 1994; Clarys, 1975; Tanner, 1964).

In another bibliographic review by Fernández & Alvero (2006) in which anthropometric data on body composition and somatotype of Spanish publications were collected from 1984 to 2005, values of fat percentage of 23 are obtained in one of the studies,9% using the Siri equation, in teens. In another study of this bibliographic review, values of 24-28% in butterfly swimmers and 26-29% in crawl swimmers were obtained using the Carter equation, and in other values of 10.7% in breaststroke, 10.8% in butterfly, 11.1% in back and 10.8% in crawl with the Faulkner equation (Fernandez & Alvero, 2006). Likewise, somatotype values are referenced by various studies, obtaining values of 3,20-3,41-3,03 in adolescent swimmers; 2,2-4,8-3,0 in crawl swimmers, 2,4-5,0-2,7 in backstroke swimmers, 2,1-5,1-2,7 in breaststroke swimmers and 2,2-5,2-2,6 in butterfly swimmers, in high level swimmers, among other studies referenced (Fernandez & Alvero, 2006), these data are similar to those found in the present work: 3,2-4,1-2,9 for crawl swimmers, 2,6-3,9-3,3 for backstroke swimmers, 2,7-4,4-2,9 for breaststroke swimmers and 3,7-4,1-2,8 for butterfly swimmers.

Finally, they are highlighted as limitations of the study that was not considered the maturing moment of swimmers and swimmers being this one of special importance for obtaining more solid conclusions. Another limitation is the size of the sample, since there were only 19 men and 15 women, which made it difficult to make comparisons of styles by sex. In addition, the study design did not consider other factors that condition the development of sports talent such as: psychological factors, physical exercise, diet, social, etc. This research generates relevant knowledge to continue a line of research on anthropometric measures and their possible relationship with sports performance and identification of sports talent.

As conclusions of the present study, it is found that the related kineanthropometric parameters that can show relation with the sport performance in swimming and characterize the swimmers are the size, the length of the extremities and the body surfaces, along with a high muscle development and a percentage of fat slightly higher than the rest of athletes. In addition, the swimmers included in the present study have a balanced mesomorphic somatotype, being this ectomesomorphic in men and mesoendomorphic in women. These anthropometric variables should be considered to monitor the development and detection of potential sports talents in swimming.

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## Conflicts of interest

The authors declare that there are no conflict of interest.

## Contribution of the authors

J.M.M.-S., J.M.S., B.R.J. and R.J-A. desgined the study; J.D.H.C., A.F-V. and I.S. review and supervised the study; J.M.M.-S., B.R.J. and R.J-A. carried out the data collection; I.S., J.M.S., J.D.H.C. and A.F-V. interpreted the data; J.M.M.-S., J.M.S., A.F-V., I.S. and B.R.J. wrote the manuscript. J.M.M.-S., J.M.S., J.D.H.C. and R.J-A. reviewed and edited the manuscript. All authors approved the final version of the manuscript. All authors have read and accepted the published version of the manuscript.

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