Anthropometrics of Adolescent Swimmers Influence Stroking Parameters

Subjects: Others

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Swimming is an individual and cyclic sport that is influenced by a multifactorial group of determinants, from which the biomechanical and energetical factors seem to be the most relevant. Swimming performance is determined by swimmers energetic profile, which is influenced by theirs biomechanical behaviour that, in turn, is affected by individuals anthropometric characteristics. This is known for adult and/or elite swimmers but it cannot be directly applied to younger counterparts since children and adolescents are not mini adults but individuals with specific characteristics and constraints. Anthropometric variables seem to be important for performance, particularly during growth, and there is a need for further study on this topic.

Keywords: biomechanics ; butterfly ; backstroke ; breaststroke

1. Introduction

As swimming velocity equals the product of stroke frequency (number of upper limbs cycles per unit of time) and stroke length (space travelled during a complete upper limbs cycle and is assessed by the velocity vs. stroke frequency ratio [1]), better understanding of the basic kinematical parameters behaviour and its relationship with velocity has been a major point of interest [2][3]. Another variable often explored is the stroke index (obtained by the product of stroke length and velocity) that is considered a valid indicator of swimming efficiency in adult [4] and young swimmers [5][6]. It is assumed that for a given velocity, swimmers moving at a higher stroke length have the most effective swimming technique and describes their ability to move at a given velocity with a lower stroke frequency [4].

Velocity increase or decrease happens due to a combined rise or reduction in stroke frequency and stroke length [1][3]. This relationship can be influenced by several variables, among which the anthropometric characteristics, with somatic attributes being largely inherited and determining swimming technique to a highest degree [7][8]. However, due to the growing process, young and adolescent individuals anthropometrical changes strongly influence these technical indexes and, consequently, performance [7][6][9]. It should be considered that anthropometric characteristics, among other factors that may influence the relationship between stroke frequency and stroke length (and affect swimming velocity), are related to stroke frequency and, more importantly, to stroke length in children [10][11]. This clearly demonstrates that anthropometric and biomechanical variables are associated and should be considered during young and adolescent swimmers performance monitoring.

2. Anthropometrics of Adolescent Swimmers Influence Stroking Parameters

Arm span was one of the variables that was positively related to performance in all four swimming techniques and in individual medley. However, findings demonstrate the importance of having shorter forearm length for better butterfly, backstroke and breaststroke performances [12][13]. Longer extremities allow the swimmer to perform fewer upper limbs cycles for the same distance [14][15] and helps to achieve a higher moment of force (propulsive and resistive) in a single upper limb cycle. In addition, swimmers that have long body segments develop a greater propulsive force as opposed to resistive forces to advancement [16]. On the other hand, longer lever lengths (like the forearm length) could also be mechanically disadvantageous since the involved muscles have to exert greater force and energy when the same drag is associated to a longer lever arm length.

A consistent positive relationship with height and front crawl was found. This could be explained by the fact that a longer body has more streamline properties since the zone of boundary layer separation may be relatively more caudal due to slenderness effect on the Reynolds number, which generates a smaller wake and a reduced wave compared to smaller bodies [17]. On the other hand, the lack of relationship between height and performance can be explained by the fact that the advantage of longer levers was mainly limb-specific rather than a more general whole-body advantage [18] or/and that if muscle mass does not follow a body height increase, the increase in the length is not of great benefit to the swimmer as he is not able to use height (longer levers) to achieve a higher moment of force.

Biacromial and bi-iliac breadths were variables related to performance in all four techniques (r = 0.4–0.7). When a body moves in the liquid environment, a stagnation of flow occurs at its anterior extremity and the pressure drag a swimmer is subjected to is higher at those regions. These occur mainly around the body where there are sudden changes in shape, such as the shoulders, hips and knees [19]. A swimmer with high biacromial breadth values (broad shoulders) and low bi-iliac breadths values (narrow hips) will have a lower drag coefficient [20], as the human body adopts a more hydrodynamic position the closer it is to the form of a drop of water [21]. It was observed that bi-iliac breadths made a positive correlation with performance, which is probably because swimmers with wide shoulders will have a hip proportional to their size, i.e., high values of bi-iliac breadths. Thus, since high bi-iliac breadths values can mean also high biacromial breadth values, the biacromial/bi-iliac diameter index suggested by Clarys [21] should be taken into consideration.

The arm span/height index suggests a hydrodynamic advantage since it is achieved through high values of biacromial diameter and upper limb length in detriment of torso and lower limbs lengths [21]. Conversely, sitting height made a positive effect in backstroke and front crawl technique performance (r value: 0.5 to 0.7). Since the height of a swimmer is proportional to torso values, the taller a swimmer is, the higher sitting height values are. Thus, the relationship between sitting height and performance can be explained by the fact that swimmers with longer torso values are also taller. In this way, taller swimmers show a decrease in the Froude number and in wave-making resistance, which allows them to cut the water with less resistance and their long bodies give them an automatic edge [22][23].

Advantages in having greater hand width, hand and foot surface areas and lengths for breaststroke, front crawl performance and 200 m medley were reported among studies. Additionally, a positive relationship between hand surface area and front crawl thrust was observed [24]. Upper body and arm lengths also presented a positive association with breaststroke performance, and upper and lower limbs and thigh lengths with front crawl performance (r = 0.2–0.7). These could be mainly due to propulsive force and, hence, swimming performance being positively affected by higher propulsive surface areas. This may increase hydrodynamic lift force to propel the swimmer through the water and allow him to perform fewer upper limbs cycles for the same distance [25].

Having greater limb segment-length ratios (arm length ratio = forearm length/arm length; foot by leg ratio = foot length/leg length) seems to be an advantage for front crawl performance [18]. The negative association between leg and performance may be explained by the fact that longer legs in swimming may alter the flotation of the swimmer, potentially resulting in a sinking of the lower limbs. An increase in the downward inclination of the legs would increase pressure drag, due to an increase in immerged body surface and cross-sectional area of the body of the swimmer and increasing the energy cost of swimming. A greater foot-to-leg ratio, with a greater foot size and a shorter leg length to reduce the downward inclination of longer legs may reduce drag. Conversely, results illustrated that leg length made a positive contribution to backstroke and breaststroke performance [26].

Body mass was one of the common anthropometrics studied in front crawl technique and associations were only found in this swimming technique as well as in the 200 m individual medley (r = 0.3–0.9). In athletes, body mass can be an indicator of the active muscle mass. Consequently, an increase of body mass may be related to a higher muscle mass. However, an increase in body mass can also be an indicator of high values of body fat mass. Muscle mass can represent body strength of the swimmer; if these values are low, a decrease in swimming performance may be expected. It should be considered that body mass does not identify and represent lean body mass or body fat mass proportions and so, for a more detailed evaluation, these variables should be measured independently.

Moreover, fat mass was the only whole body-size characteristic negatively associated with all four techniques velocity [12][13]. The disadvantage of having higher fat mass suggests that swimmers require greater lean body mass and greater muscle strength to propel themselves faster through the water. In parallel, higher fat mass may impose increased values of body cross-sectional area and, consequently, total drag. Regarding more detailed body composition variables, it seems that total sum of skinfolds [27] and biceps skinfold [28][29] compromised front crawl performance. Skinfolds measures are used to assess the skinfold thickness, so that a prediction of the total amount of body fat of the swimmer can be made. Therefore, skinfold measurements reflect adiposity values. Swimmers with a more developed muscular system, have lower skinfold values and, therefore, may have better performances, which can explain the fact that skinfolds impaired performance.

Lean body mass was only related to performance in 200 m breaststroke and in front crawl techniques [7][30][18]. A larger lean body mass and, thus, a greater muscle mass, could positively influence biomechanical values by enhancing the force applied in each upper limbs cycle and the capacity to maintain good SI under exhaustion conditions [31]. Positive associations between biceps circumference in contraction with breaststroke and front crawl performance were also found [29]. This variable is related to muscle mass, thus the higher it is the higher may be the strength of the upper limbs and, possibly, propulsion generation.

Associations between arm relaxed and forearm girths and performance were found for all four techniques, in which swimming speed was negatively influenced by arm relaxed girth [13]. The arm girth ratio (forearm girth/relaxed arm girth) was possibly reflecting a measure of muscle strength. Similarly, findings demonstrated that an increase in forearm girth improves breaststroke swimming performance and that having a greater wrist girth impairs performance [32]. A possible explanation can be that a large wrist girth would increase hydrodynamic drag, therefore increasing the energy cost of swimming, and a greater forearm girth seems to generate higher propulsive force and consequently an easier propulsion through water. In addition, an advantage of having greater calf girth and lower values of ankle girth was reported for butterfly swimming [12][13]. The ratio calf girth/ankle girth seems to reflect the greater muscle strength in the legs associated with faster butterfly swimmers.

Moreover, it was mentioned that chest circumference negatively influenced the 100 m front crawl male performance [10]. Swimming velocity is determined by the propulsive force and the hydrodynamic drag force. There are certain resistive segments which should preferably be of small dimensions (e.g., chest circumference). These segments should present the referred characteristics because the hydrodynamic lift drag forces depend on the cross-sectional area of the swimmer's body considering the direction of its displacement. Chest circumference seems to represent part of body cross-sectional area of the swimmer meaning that an increased chest circumference may increase drag values of the swimmer, which may impair performance.

Only six studies investigated associations between upper limbs action and anthropometrical variables, and all of them only focused on the front crawl technique. An advantage in having a greater arm span and height for higher values of stroke length and SI were reported [7][8][6][33][34][35]. Likewise, body mass and lean body mass were positively associated with stroke length and stroke index [7][8][6][35]. Stroke length and stroke index were also positively related to upper and lower limb lengths in all distances (100, 200 and 400 m) [35].

There is a consistent association between arm span, height, upper and lower limb lengths and stroke length. It seems that swimmers with the highest height have higher arm span and surface areas as well. Once the linear distance covered per revolution by a given landmark during angular motion is a function of the angular displacement and its linear distance to the fulcrum, in swimmers, longer extremities allow them to perform fewer upper limbs cycles for the same distance [14][15]. In addition, these surface areas, when properly oriented, induce an increase in propulsive forces. By consequence, such swimmers can achieve a higher stroke length and consequently a higher velocity [2][36]. A few studies also found an association between body mass, lean body mass and upper limbs cycle-related parameters, being observed that arm muscle area and lean body mass were positively associated with arm propulsive force (tethered swimming) in front crawl [37].

3. Conclusions

Anthropometric variables seem to be important for performance, particularly during growth, and there is a need for further study on this topic. For the front crawl technique, there seems to be a consensus among studies on the advantage of having higher values of height and arm span. Associations between anthropometrical characteristics and upper limbs cycle parameters were only found in front crawl. Stroke length and stroke index seem to benefit from higher values of height and arm span. In addition, higher values of body mass and lean body mass also appear to improve these upper limbs action variables.

References

1. Craig, A.B.; Pendergast, D.R. Relationships of stroke rate, distance per stroke, and velocity in competitive swimming. Med. Sci. Sports 1979, 11, 278–283.
2. Figueiredo, P.; Morais, P.; Vilas-Boas, J.P.; Fernandes, R.J. Changes in arm coordination and stroke parameters on transition through the lactate threshold. Graefe's Arch. Clin. Exp. Ophthalmol. 2013, 113, 1957–1964.
3. Toussaint, H.M.; Carol, A.; Kranenborg, H.; Truijens, M.J. Effect of Fatigue on Stroking Characteristics in an Arms-Only 100-m Front-Crawl Race. Med. Sci. Sports Exerc. 2006, 38, 1635–1642.

4. Costill, D.L.; Kovaleski, J.; Porter, D.; Kirwan, J.; Fielding, R.; King, D. Energy expenditure during freestyle swimming: Predicting success in middle-distance events. Int. J. Sports Med. 1985, 6, 266–270.
5. Fernandes, R.J.; Sousa, M.; Pinheiro, A.; Vilar, S.; Colaco, P.; Vilas-Boas, J.P. Assessment of individual anaerobic threshold and stroking parameters in swimmers aged 10–11 years. Eur. J. Sport Sci. 2010, 10, 311–317.
6. Jürimäe, J.; Haljaste, K.; Cicchella, A.; Lätt, E.; Purge, P.; Leppik, A.; Jürimäe, T. Analysis of swimming performance from physical, physiological, and biomechanical parameters in young swimmers. Pediatr. Exerc. Sci. 2007, 19, 70–81.
7. Lätt, E.; Jürimäe, J.; Haljaste, K.; Cicchella, A.; Purge, P.; Jürimäe, T. Physical development and swimming performance during biological maturation in young female swimmers. Coll. Antropol. 2009, 33, 117–122.
8. Lätt, E.; Jürimäe, J.; Haljaste, K.; Cicchella, A.; Purge, P.; Jürimäe, T. Longitudinal Development of Physical and Performance Parameters during Biological Maturation of Young Male Swimmers. Percept. Mot. Ski. 2009, 108, 297–307.
9. Zamparo, P.; Lazzer, S.; Antoniazzi, C.; Cedolin, S.; Avon, R.; Lesa, C. The interplay between propelling efficiency, hydrodynamic position and energy cost of freestyle in 8 to 19-year-old swimmers. Eur. J. Appl. Physiol. 2008, 104, 689.
10. Geladas, N.D.; Nassis, G.P.; Pavlicevic, S. Somatic and Physical Traits Affecting Sprint Swimming Performance in Young Swimmers. Int. J. Sports Med. 2005, 26, 139–144.
11. Poujade, B.; Hautier, C.; Rouard, A. Determinants of the energy cost of freestyle swimming in children. Eur. J. Appl. Physiol. 2002, 87, 1–6.
12. Sammoud, S.; Nevill, A.M.; Negra, Y.; Bouguezzi, R.; Chaabene, H.; Hachana, Y. Allometric associations between body size, shape, and 100-m butterfly speed performance. J. Sports Med. Phys. Fit. 2018, 58, 630–637.
13. Nevill, A.M.; Negra, Y.; Myers, T.D.; Sammoud, S.; Chaabene, H. Key somatic variables associated with, and differences between the 4 swimming strokes. J. Sports Sci. 2020, 38, 787–794.
14. Potdevin, F.; Bril, B.; Sidney, M.; Pelayo, P. Stroke frequency and arm coordination in front-crawl swimming. Int. J. Sports Med. 2006, 27, 193–198.
15. Zenić, N.; Grčić-Zubčević, N. Ability grouping–advances in a swimming curriculum. Kinesiol. Int. J. Fundam. Appl. Kinesiol. 2005, 37, 173–181.
16. Grimston, S.K.; Hay, J.G. Relationships among anthropometric and stroking characteristics of college swimmers. Med. Sci. Sports Exerc. 1986, 18, 60–68.
17. Truijens, M.; Toussaint, H. Biomechanical aspects of peak performance in human swimming. Anim. Biol. 2005, 55, 17–40.
18. Nevill, A.M.; Oxford, S.; Duncan, M.J. Optimal body size and limb-length ratios associated with 100 m PB swim speeds. Med. Sci. Sports Exerc. 2015, 47, 1714–1718.
19. Vilas-Boas, J.P. Mechanical basis of swimming. Swimming: Specific experiences and basic theoretical knowledge. Colect. Textos 1997, 1, 281–352. (In Portuguese)
20. Fernandes, R.J.; Barbosa, T.M.; Vilas-Boas, J.P. Determinant kineanthropometric factors in pure sport swimming. Rev. Bras. Cineantropometria Desempenho Hum. 2002, 4, 67–79. (In Portuguese)
21. Clarys, J.P. Human morphology and hydrodynamics. In Swimming III; Terauds, J., Beddingfield, W., Eds.; University Park Press: Baltimore, Maryland, 1979; Volume 8, pp. 3–41.
22. Chatard, J.C. Influence of morphological factors and training on energy efficiency. In Les Messages de l'Association Reflection Natation, Compte Rendue des Journées Natation; L'Association: Paris, France, 1985; pp. 53–63. (In French)
23. Toussaint, H.M.; Hollander, A.P. Mechanics and Energetics of Front Crawl Swimming. In The Elite Young Athlete; Karger, A.G.S., Ed.; Karger Publishers: Basel, Switzerland, 2015; Volume 39, pp. 107–116.
24. Morais, J.; Barbosa, T.M.; Lopes, V.P.; Marques, M.C.; Marinho, D.A. Propulsive Force of Upper Limbs and its Relationship to Swim Velocity in the Butterfly Stroke. Int. J. Sports Med. 2021, 42, 1105–1112.
25. Boulgakova, N. Sélection et Préparation des Jeunes Nageurs; Vigot: Paris, France, 1990.
26. Sammoud, S.; Nevill, A.M.; Negra, Y.; Bouguezzi, R.; Helmi, C.; Hachana, Y. Key somatic variables in young backstroke swimmers. J. Sports Sci. 2018, 37, 1162–1167.
27. Bond, D.; Goodson, L.; Oxford, S.W.; Nevill, A.M.; Duncan, M.J. The Association between Anthropometric Variables, Functional Movement Screen Scores and 100 m Freestyle Swimming Performance in Youth Swimmers. Sports 2015, 3, 1.
28. Rozi, G.; Thanopoulos, V.; Geladas, N.; Soultanaki, E.; Dopsaj, M. Anthropometric characteristics and physiological responses of high level swimmers and performance in 100 m freestyle swimming. Mov. Sport Sci.-Sci. Mot. 2018, 3, 3–

7.

29. Rozi, G.; Dopsaj, M.; Platanou, T. Prediction of 100 m freestyle performance through anthropometrical characteristics in youth Greek swimmers according to gender. Человек. Спорт. Медицина 2019, 19, 57–64.
30. Strzala, M.; Stanula, A.; Głab, G.; Glodzik, J.; Ostrowski, A.; Kaca, M.; Nosiadek, L. Shaping physiological indices, swimming technique, and their influence on 200m breaststroke race in young swimmers. J. Sports Sci. Med. 2015, 14, 110–117.
31. Pelayo, P.; Sidney, M.; Kherif, T.; Chollet, D.; Tourny, C. Stroking characteristics in freestyle swimming and relationships with anthropometric characteristics. J. Appl. Biomech. 1996, 12, 197–206.
32. Sammoud, S.; Nevill, A.; Negra, Y.; Bouguezzi, R.; Chaabene, H.; Hachana, Y. 100-m Breaststroke Swimming Performance in Youth Swimmers: The Predictive Value of Anthropometrics. Pediatr. Exerc. Sci. 2018, 30, 393–401.
33. Strzala, M.; Tyka, A. Physical endurance, somatic indices and swimming technique parameters as determinants of freestyle swimming speed at short distances in young swimmers. Med. Sport. 2009, 13, 99–107.
34. Morais, J.E.; Jesus, S.; Lopes, V.; Garrido, N.; Silva, A.; Marinho, D.; Barbosa, T.M. Linking Selected Kinematic, Anthropometric and Hydrodynamic Variables to Young Swimmer Performance. Pediatr. Exerc. Sci. 2012, 24, 649–664.
35. Mezzaroba, P.V.; Machado, F.A. Effect of Age, Anthropometry, and Distance in Stroke Parameters of Young Swimmers. Int. J. Sports Physiol. Perform. 2014, 9, 702–706.
36. Carvalho, D.D.; Soares, S.; Zacca, R.; Sousa, J.; Marinho, D.A.; Silva, A.J.; Vilas-Boas, J.P.; Fernandes, R.J. Anaerobic Threshold Biophysical Characterisation of the Four Swimming Techniques. Int. J. Sports Med. 2020, 41, 318–327.
37. Oliveira, M.; Henrique, R.S.; Queiroz, D.R.; Salvina, M.; Melo, W.V.; dos Santos, M.A.M. Anthropometric variables, propulsive force and biological maturation: A mediation analysis in young swimmers. Eur. J. Sport Sci. 2021, 21, 507–514.