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Relationship between anthropometric characteristics and spatio-temporal parameters in freestyle swimming among swimmers (15-18 years).

علاقة الخصائص الانتربومترية بالمحددات الزمانية و المكانية في السباحة الحرة لدى السباحين (15-18 سنة)

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Abstract : The purpose of this study is to investigate the relationships between spatio-temporal parameters and it'sinterdependencewith some anthropometric measurements.24 swimmers of national level were evaluated in competitive situation, on the 50 m and 100 m freestyle events, using the video recording method. The results show that the swimming speed increases principally as a function of the stroking length (r = 0.82), wich affects in its turn the swimming index for the two distances (r=0.92-0.93), The results highlighted the importance of anthropometric characteristics in particular, height and arm length, in a realization of sprint performance by positively influencing stroke length (r = 0.68-0.78), conversely these characteristics do not explain the increase in stroke rate. Stroke length and swimming index remain to be the best indicators of the propulsive efficiency and level of preparation;therefore it can be used for, control and design training program.

Keywords: Swimming / Stroke length / stroke rate / anthropometric characteristics

الملخص:إن الهدف من هذا البحث يتمثل في دراسة العلاقة بين المحددات المكانية والزمنية و مدى ارتباطها مع بعض القياسات الجسمية. تم تقييم 24 سباح من المستوى الوطني في ظروف المنافسة، في سباقات الـ 50 متر و 100 متر سباحة حرة ، باستخدام طريقة التسجيل المصور.

و لقد أظهرت النتائج أن سرعة السباحة تزداد بشكل أساسي حسب مسافة الدورة (r =0.82) ، والتي تؤثر بدورها على مؤشر السباحة في كلا المسافتين (r =0.92-0.93) ، و من جهة أخرى بينت هذه الدراسة أهمية الخصائص الانتربومترية كالقامة و طول الأطراف العلوية في تحقيق نتائج عالية بسباقات السرعة من خلال تأثيرها الإيجابي على مسافة الدورة (r=0,68-0,78)، و بالمقابل هذه الخصائص لا تفسر ارتفاع تردد الدورة. و من خلال ذلك يمكن أن نعتبر أن مسافة الدورة و مؤشر السباحة من أفضل المعايير التي تدلنا عن فعالية الدفع و مستوى التحضير و بالتالي يمكن استخدامهما في مراقبة و تصميم البرنامج التدريبي.

- الكلمات المفتاحية : سباحة/ مسافة الدورة/ تردد الدورة/ الخصائص الانتربومترية

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Introduction and problematic

Since its beginnings, the evolution of competitive swimming has been marked by a constant progression of swimming techniques and training methods, allowing setting, more and more adapted programs. The progressive rise in performance levels therefore imposes the need to constantly perfect all aspects of the athlete's preparation.

If the purpose of the competition can be summed up as realizing the best possible time, over a given distance, this is considered as an overall result through which one we can judge, in particular, the lap's times, starts and turns. New studies related to biomechanics have made it possible to extend the scope of these measurements to more significant criteria: Stroke length or distance per arm cycle and stroke rate or number of cycles per unit of time. These parameters are extremely useful for setting goals and subsequently developing individualized training programs.

During training sessions the swimming speed can be variable from one track to another for the same series of repetitions of the same distance, which involve significant variations in the stroke length- stroke rate ratio as the principal components of swimming speed, thus compromising the quality of the exercises to achieve the desired goals. Therefore we can understand that a swimmer whose performance is rather random in time cannot determine with certainty the characteristics that give him an advantage and those that have no effect. Conversely, we can assign changes if we know the optimal spatial and temporal parameters for each swimmer and potentially achieve higher levels of performance.

However, spatio-temporal parameters evolve according to several factors, depending on the anthropometric characteristics of the swimmers. (Grimston & Hay, 1986) (Chatard & al. 1987), age and sex (Pelayo & al. 1997)level of expertise (Lerda & al. 1995) (Chatard & al. 2001), style and distance of the race, (Chollet& al. 1996).

Considering these bibliographical trends, and in response to the questions asked, we have advanced that the swimming speed during the 50 m and 100 m freestyle events depends principally on a large stroke length (distance per arm cycle) and consequently the propulsive efficiency will be better. We have also retained that these parameters evolve according to the age of the swimmer and his anthropometric characteristics.

The aim of this study is to define the spatio-temporal parameters: speed, stroke length, stroke rate and swimming index that characterize some Algerian swimmers of national level in the 50 m and 100 m freestyle events in real competition conditions,considering the correlations between them, then examine the relationships that exist between these parameters and some anthropometric characteristics in order to identify the factors that explain performance and to set up criteria for measuring intensity during training based on the requirements of the competition and also Analysis of emerging performance to provide coaches with objective references to help them understand what is being implemented in the action of training and building their young swimmers' project. In order to achieve these objectives we have set the following task:

- Analyze the relationships between the swimming parameters and some anthropometric characteristic.
- Analyze the relationships between the swimming parameters based on the results recorded in competition.

1- Followed Methodologies

1.1- Research methodology

Given the nature and requirements of our research, we opted for a cross-sectional study, which consists of carrying out a descriptive analysis.

1. 2-Subject:

Given the nature and practical requirements of our research, we deliberately relied on a non-probability sampling technique commonly called convenience sampling where subjects are chosen because of their accessibility and proximity to the researcher.

A total of 24 male swimmers of national level, were randomly chosen from 32 swimmers of all the sports clubs of the Wilaya of Constantine who participated in the winter championship (second stage) of the wilaya, their age varies between 15 and 18 years old with. They have been swimming for at least 6 years and train 5 to 6 times a week, performing 5 to 6 km per session.

Table n°1:Physical characteristics of subjects

	Average	Standard deviation
Age / years	16,37	1,13
Weight / Kg	61,23	8,84
Height / cm	170,50	8,30

1.3- Registration method

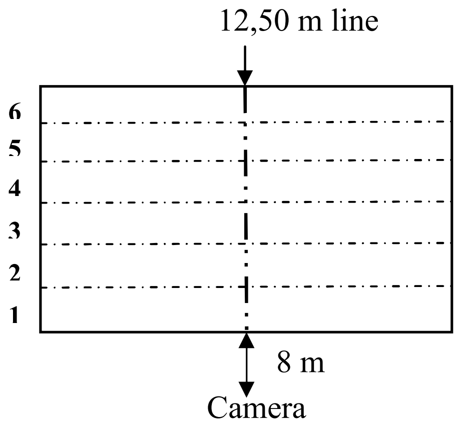
The swimmers were evaluated in competition situations during the Constantine winter championship (second stage) which took place from February 28th to 29th, 2020 at the swimming pool of the Sports Complex, in the 50 m and 100 m freestyle events, using the video recording method.

The events were filmed continuously over a wide shot using a camera *(Action Sport brand camera, Video resolution: HD 16 megapixel, Video compression, format:*

H.264, Video format: Mp4, Len: 170° HD wide-angle lens) equipped with a tripod and set back 8 m from the length of the swimming pool. It is located in the extension of the 25 m middle line and at a height of 10 m from the water surface.

Fig no1: Video recording device on a 25 m 6 line swimming pool.

(Inspired from the model proposed by Deleaval, 1990, p. 52)



1.4-Analysis of the competition

The average speed expressed in meters per second (S), the stroke rate expressed in number of cycles per minute (SR) and the stroke length (SL) expressed in meters per cycle are collected in competition situations on the 50 and 100 m freestyle events from video recordings of these events during the regional interclub of Constantine 2020.

- Average speed

The average speed is the ratio of the distance travelled (D) in meters and the total time in seconds (T) taken to cover this distance (official competition time).

$$S = \frac{D}{T} \ (m/s)$$

The speed includes the temporal benefit of the start but it also includes the rotation time due to the tumble turn.

- Average of the stroke rate

The average of the stroke rate expressed in number of cycles per minute is obtained by taking the time (Tc) of carrying out the number of complete arm cycles (n) for each 50, in areas not influenced by starts or turns.

$$SR = (n \div Tc) \times 60\ (cycles/min)$$

Different marks have been chosen to start and stop the stopwatch:

Start on the entry of the right hand in the water during the first movement of resumption of swimming and Stop on the last movement of the right arm.

- The average of stroking length

Knowing that:$S = \frac{D}{T} = SR \times SL$in meters per second

$\Rightarrow SL = \frac{S}{SR} inmeterspercycle$

The stroke rate is obviously taken in seconds.

According to several authors the average of the stroking length can be calculated from the average swimming speed; this method of calculation is more precise. (Chollet, 1997, p. 84)

- The swimming index

To define the swimming index (SI) several authors (Pelayo&al. 1997, p. 189);(Wakayoshi&al. 1993, p. 369); (Cholet&al. 1997, p. 234)refer to the swimming index derived from the methodology of D.L Costill (1985) which defines it as the product of speed and stroke length as indicated by the equation:

$$SI = S \times SLinm^2/\text{s/cycle}$$

1.5- Anthropometric method

The biometric parameters selected are those whose affect swimming speed has been recognized by several authors (Bulgakova, 1990); (RIA& al. 1990); (Pelayo

&al. 1997); (Chatard &al. 2001): height , weight, Length of the upper limb, as well as other measures considered necessary for the study, leg length, foot length, difference arm contracted-released and surface area of the hand.

1.6-Statistical processing

The statistical processing of the data in our study consists of calculating the average, minimum, maximum values and standard deviations for all of the measured and calculated data. Simple correlations have been made between the spatio-temporal parameters then between these parameters and the anthropometric characteristics. A regression analysis was applied in order to identify the existence of linear relationships between the variables.

2- Exposure , analyses and result exam :

2.1- Results of spatio-temporal parameters

The overall averages, standard deviations, minimum and maximum values of the spatio-temporal parameters recorded in the 50 m and 100 m freestyle events are presented in Table n°2as follows:

Table n°2 : Averages, standard deviations, max and min values of the different swimming parameters : speed (S), the stroke rate (SR) and the stroke length (SL)

Events	Spatio-temporal parameters	Average ± SD	Min	Max
50m freestyle	Speed (S m/sec)	1,75 ± 0,12	1,45	1,96
	Stroke Rate (SR Cycles/min)	57,35 ± 3,14	53,06	64,89
	Stroke length (SL m/cycle)	1,83 ± 0,17	1,56	2,10
	Swimming index (SI m^{2}/s/cycle)	3,22 ± 0,50	2,38	4,11
100m freestyle	Speed (S m/sec)	1,57 ± 0,09	1,40	1,75
	Stroke Rate (SR Cycles/min)	50,12 ± 2,91	45,94	54,97
	Stroke length (SL m/cycle)	1,89 ± 0,18	1,56	2,12
	Swimming index (SI m^{2}/s/cycle)	2,98 ± 0,42	2,17	3,70

2.2-Relationship between spatio-temporal parameters

The relations between the spatio-temporal parameters and the swimming speed are presented in table n°3

Table n°3: Relationship between spatio-temporal parameters

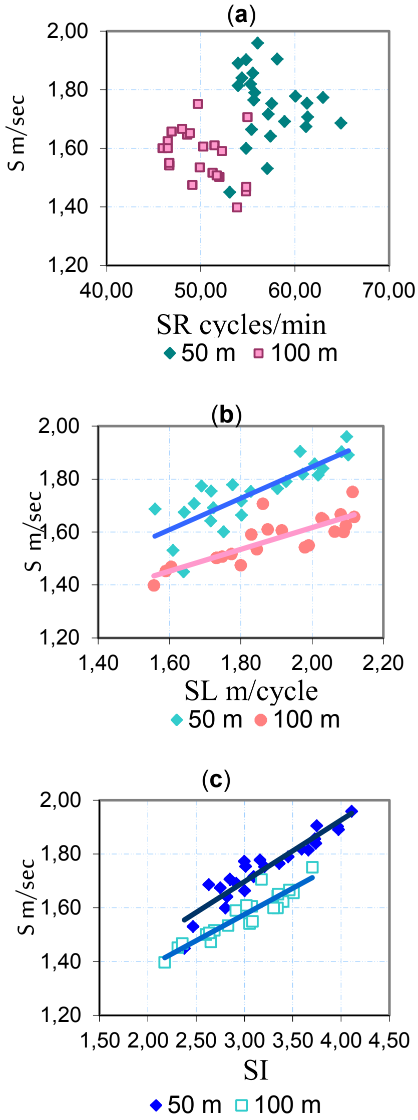
	Spatio-temporal parameters		
freestyle events	Stoke rate (SR Cycles/min)	Stroke length (SL m/cycle)	Stroke Index($m^{2/}$s/cycle)
50 m (m/s)	-0,096 **NS**	**0,828 S*** **	**0,936 S*** **
100m (m/s)	-0,401 **NS**	**0,823 S*** **	**0,929 S*** **

*****: significance level : for p < 0.001 **NS** : not significant

The values presented in Figure :2 show very highly significant correlations ($p < 0.001$), between swimming speed and stroke length on the one side then between speed and swimming index on the other, both for the 50 m and 100 m freestyle races, while there are no correlations between speed and swimming frequency. Through figure 2 (a), we can see a greater dispersion of the point clouds of the swimming frequency compared to that of stroke length(b) which denotes an ascending profile of the linear regression lines for the 50 m and the 100 m freestyle.

The search for higher speed requires preserving an optimal stroking rate for higher stroking length. This relationship is expressed through the swimming index which considering swimming speed and the stroking length (SI = S*SL) which is very strongly correlated with the speed. Graph (c) expresses this relationship by a significant approach of the points of the cloud making perfectly ascending straight lines.

Fig n°2 : Relationship speed stroke rate (a), stroke length (b) and swimming index (c) in freestyle



2.3- Anthropometric Results

The results recorded through the anthropometric measurements are presented in the following table no4.

Table n°4: Averages, standard deviations, maximum and minimum values of anthropometric measurements

	Average ± SD	Min	Max
Age / years	16,37±1,13	15	18
Weight / Kg	61,23 ± 8,84	45,8	76,3
Height / cm	170,50± 8,30	150,5	184,5
Length of the upper limb./ cm	78,13 ± 4,86	68,3	87,7
Length of lower limbs / cm	140,04 ± 9,12	97,5	159,4
Foot length / cm	25,43 ± 1,16	23,4	27,8
Dif. arm contracted-released / cm	3,05 ± 1,02	1,7	5
Surface of the hand / cm^2	14,59 ± 1,3	13,04	17,3

The swimmers in our sample are characterized by an average age of 16.37 ± 1.13 years and an average weight of 61.23 kg, with a dispersion of 8.84 kg. Height values vary between 150.5 cm and 184.5 cm, with an average height of 170.50 cm ± 8.30. We also note that most of the anthropometric variables are characterized by very large standard deviations, particularly for the weight, height and length of the lower limb, the extent and standard deviations recorded for the different measurements in Table 4, may tell us about the heterogeneity that characterizes the subjects of our study for most of the anthropometric variables.

2.4-Relation between spatio-temporal parameters and anthropometric characteristics:

The reading of the following table5 and 6 consists in observing the relations between the anthropometric characteristics and the swimming speed and then to determine with which component of the speed these characteristics are correlated, let us recall that: $S = \frac{D}{T} = SR \times SL \text{m/s}$

Table n°5: Correlation coefficients between spatio-temporal parameters and anthropometric measurements in the 50 m events

	S (m/s)	SR (cycles/min)	SL (m/cycle)	SI (m^2/s/cycle)
Age / years	**0,74 S*** **	**-0,59 S** **	**0,89 S*** **	**0,87 S*** **
Weight / Kg	**0,60 S** **	**-0,53 S** **	**0,76 S*** **	**0,73 S*** **
Height / cm	**0,66 S*** **	-0,403 NS	**0,74 S*** **	**0,73 S*** **
Length of the upper limb./ cm	**0,63 S** **	-0,36 NS	**0,68 S*** **	**0,69 S*** **
Length of lower limbs / cm	**0,48 S* **	-0,13 NS	**0,44 S* **	**0,46 S* **
Foot length / cm	**0,44 S* **	**-0,42 S* **	**0,57 S** **	**0,53 S** **
Dif. arm cont-rele / cm	**0,52 S* **	**-0,42 S* **	**0,64 S*** **	**0,61 S** **
Surface of the hand / cm^2	0,32 NS	-0,18 NS	0,34 NS	0,34 NS

* : significance level for : $p < 0.05$ ** : for $p < 0.01$ *** : for $p < 0.001$ NS : not significant

Table n°6: Correlation coefficients between spatio-temporal parameters and anthropometric measurements in the 100 m events

	S (m/s)	SR (cycles/min)	SL (m/cycle)	SI (m^2/s/cycle)
Age / years	**0,74 S*** **	**-0,48 S* **	**0,73 S*** **	**0,77 S*** **
Weight / Kg	**0,64 S** **	**-0,59 S** **	**0,73 S*** **	**0,73 S*** **
Height / cm	**0,56 S** **	**-0,70 S*** **	**0,75 S*** **	**0,71 S*** **
Length of the upper limb./ cm	**0,61 S** **	**-0,70 S*** **	**0,78 S*** **	**0,75 S*** **
Length of lower limbs / cm	0,33 NS	**-0,50 S* **	**0,48 S* **	**0,44 S* **
Foot length / cm	0,40 NS	**-0,42 S* **	**0,49 S* **	**0,47 S* **
Dif. arm cont-rele / cm	**0,50 S* **	**-0,79 S*** **	**0,78 S*** **	**0,70 S*** **
Surface of the hand / cm^2	**0,46 S* **	**-0,55 S** **	**0,59 S** **	**0,56 S** **

* : significance level for : $p < 0.05$ ** : for $p < 0.01$ *** : for $p < 0.001$ NS : not significant

The results recorded in Table 5 show significant correlations between anthropometric characteristics and most of the spatio-temporal parameters. In the 50 m freestyle events the swimming speed (S) is strongly correlated with the age (r = 0.74) and height of the swimmer (r = 0.66) at a significance level $p < 0.001$, (S) also depends on weight (r = 0.60) and arm length (r = 0.63), the swimming speed at the 100 m freestyle (table n°6) shows very highly significant correlations with the age of the swimmers (r = 0.745 for $p < 0.001$) for a lower significance level ($p < 0.01$) speed in this event is also correlated with weight, height and upper limb length.

We can also observe that the measurements which characterize the upper limb (difference arm contracted- released surface area of the hand) show significant correlations with speed in the 50 m event according to a percentage of error lower than 5%.

the stroking length measured at 50 m event show very highly significant correlations ($p < 0.001$) with age (r = 0.89), weight (r = 0.76), height (r = 0.74), upper limb length (r = 0.68), and difference arm contracted- released (r = 0.64). To a lesser extent stroke length is also depending on the length of the foot with a correlation coefficient r = 0.57 for $p < 0.01$. Conversely, negative correlations can be observed between stroke rate in the 50m freestyle and anthropometric measurements. These relationships are highly significant with age and weight (respectively r = 0.59, = 0.53 for $p < 0.01$)

Regarding the 100 m freestyle events, speed increases mainly with age (r = 0.73), weight (r = 0.73), height (r = 0.75), upper limb length (r = 0.78) and the difference arm contracted- released (r = 0.79) according to a highly significant level ($p < 0.001$). Secondly, the swimming speed depends on the surface of the hand. We can also note positive correlations at $p < 0.05$ with the length of the lower limbs and the foot length, while the mean of the stroke rate evaluated in the same race shows negative correlations with anthropometric measurements, in particular with height, length of the upper limbs and arm development.

2.5-Discussion

2.5.1-Relationship between speed, stroke rate, stroke length and swimming index

The results of this study show the close relationship between swimming speed in competition and its two components, we have recorded very highly significant correlations between swimming speed and stroke length, but the relationship with stroke rate is very weak.

These observations are in accordance with those of. (Kennedy & al. 1990, p. 191) ; (Arellano & al. 1994, pp. 194-195) who reported that the fastest swimmers are those with the greatest stroke length, affirming that this one is the best indicator of performance in trained swimmers. As reported by (BENHADID, 2014, p. 57)distance per cycle is the result of the use of the swimmer's propulsive force in the context of underwater efficiency, associated with the reduction of drag.

The results also show very highly significant correlations between speed and swimming index. The swimming index is a representative parameter of the level of practice in either performance or technique (Pelayo & al. 1997, p. 192).

Regression equations

The regression equations were developed to identify linear relationships between the variables of the study and to allow estimation and prediction of results.

- Swimming speed at 50 meters freestyle = 0.2284 * swimming index of 50 m freestyle + 1.0121
- Swimming speed at 100 meters freestyle = 0.1945 * swimming index of 100 m freestyle + 0, 9915

2.5.2-Relationship between spatio-temporal parameters and anthropometric characteristics

-Age

Age is at the top of the list of variables most correlated with swimming speed. It can be noted that the improvement in speed from 15 to 18 years can be explained firstly by an increase in the stroke length characterizing mainly the level of practice. These observations are similar to those found in the academic field (Pelayo & al 1997, p. 191) ;(Amara&al. 2013), and also at the highest level where performance is characterized by a high variability of stroke length in relation to stroke rate. (Kennedy & al. 1990, p. 188) ; (Lerda, & al. 1995, p. 28). The slightly important and irregular evolution of frequency according to these authors may possibly be due to excitability and mobility of nervous processes during growth.

- The weight

The weight of the swimmers is one of the factors most correlated with swimming speed. This relationship is explained by significant correlations between weights and stroking length for the two events, conversely weight does not explain the increase of the stroke rate.

Weight is a concept that must be interpreted with some restriction, according to (Vandervael ,1980, p.55), it is a sum of variable elements, it includes firstly a relatively fixed part represented by the weight of the skeleton, nervous system, skin and viscera, secondly a highly variable part represented by muscles, fat and water infiltration of tissues, in the sense that possible variations in weight from one period to another (lifestyle, nutrition, fasting etc.) can give different results.

-Height

Many authors have demonstrated the importance of height in the achievement of performance in sprint swimmers (Grimston &Hay, 1986, p.65); (Chatard &al.1987, p.83) ; (Ria &al. 1990, p.209) According to these authors, height is a favorable factor for short-distance swimmers, a great height is often associated with a high vital capacity and therefore excellent buoyancy, it is also accompanied by a higher muscle weight and therefore a better ability to sprint. However, the results of our study agree with these observations according to the significant correlations recorded between height and swimming speed ($r = 0.66$ for p 0.001 at 50 m, $r = 0.56$ for $p < 0.01$ at 100 m).It can therefore be deduced that a great height favors gains in stroking length which systematically lead to higher swimming speeds.

- Length of upper limbs:

The length of the upper limbs is also an important factor for the achievement of swimming performance. Several authors have shown that the length of the upper limbs has a specific effect on the energy cost; for the same height, a difference of 4 cm in the length of the upper limbs corresponds to a 12% gain in the energy cost (Chatard &al., 1991, p. 48). The results of our study show indeed significant correlations between the swimming speed and the length of the upper limbs for the two distances, these relations appear mainly with the stroke length, while they are not significant with the stroke rate.

- Length of lower limbs

The results of our study show that the spatio-temporal parameters depend in part on the length of the lower limbs. This measure represents an important factor in short distance races (50 m and 100 m freestyle), it is significantly related to the stroke length ($p < 0.05$) which in its turn influences the swimming speed.

- Foot length

The importance of the foot length is mainly affirmed for the two events studied; it partly reflects the size of the feet, bigger they are,higher is the speed, this is explained by the significant correlations observed between the length of the foot and the stroke length in this swimming mode.

- Difference arm contracted-released

The difference between the perimeter of the contracted arm and relaxed is a measure that attests to the level of development of the arm, and can tell us indirectly about their capacity of force, it is positively correlated to the stroke length for $p < 0.001$ and negatively correlated to the stroke rate for $p < 0.05$, also more the swimmer has a good capacity of force and more he can push the water over a greater distance so he swims in length and conversely his stroke rate is lower.

- Surface of the hand

The results of our study show that the surface area of the hand is significantly correlated to the swimming speed only at 100m freestyle, this is explained by a positive relationship to the stroke length and negative to the stroke rate, Indeed larger is the propulsive surface area, better will be the propulsion, according to (Bar-Or&al. 1994, p. 199) it seems quite logical to think that a large propulsive surface will develop a greater force.

3- Finding and propositions results

The relationships between the variables studied show that the increase the stroke length is the main factor in improving performance on a long term. we can we can also add that the swimming index as a witness of propulsive efficiency is very strongly correlated with performance for all the events, the major interest of this index is that a single parameter taking into account primarily the swimming speed and secondarily the distance per cycle and can be used globally as an objective indicator of performance.This study shows that swimming speeds are the result of large individual differences in the frequency/amplitude ratios used; these differences are to be related to the various factors, in particular the anthropometric characteristics. The age, height, weight and length of the upper limbs are the most important factors determining performance, the latter influence in particular the swimming stroke length, contrary they have no significant relationship with the stroking rate.

The data collected from the competition allows us to individually model the stroke rate stroke length, they allow us to identify if the swimmer uses during the heats the right cadences in relation to the swimming speed.

Once the swimmer has learned his best swim index, he should try to work in areas corresponding to that index during training

When performing these exercises, the age of the swimmer as well as his anthropometric characteristics must be taken into account, particularly the height and length of the arms, which are favorable factors for sprinters

The increase in stroke length implies the interference of more force, the specificity of the exercises during the development of the latter in dry and in water should be the subject of more attention.

In terms of this study we can say that swimming as fast as possible always implies spatio-temporal parameters, their implementation according to the requirements of the competition influences the training dosage, therefore the manner of swimming by pushing back fatigue as much as possible.

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