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ORIGINAL

RELATIONSHIP BETWEEN ANAEROBIC CAPACITY AND CHANGES IN SPEED IN THE 100-M BREASTSTROKE STROKE IN SHORT-DISTANCE BREASTSTROKE SWIMMERS: THE MEDIATING ROLE OF TECHNICAL CHANGE

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ABSTRACT

Objective: By analyzing and summarizing the relationship between anaerobic capacity, technical changes of 100m breaststroke en route and speed changes of short distance breaststroke athletes, the interrelationship and internal pathways between the three are revealed to provide reference for improving athletic performance of short distance breaststroke athletes and provide theoretical basis for anaerobic capacity training. **Method:** Fifteen male short-distance breaststroke athletes (age 19.67±2.61 years, height 178.4±7.04 cm, weight 71.6±7.79 kg) were selected to perform anaerobic power cycling and 100 m breaststroke tests on the upper and lower extremities. The correlations and intrinsic linkage pathways between the three were explored by calculating Pearson correlation coefficients and using a mediating effects model. **Result:** Significant differences existed in speed, stroke rate, cycle time per stroke, and swim efficiency index in the 100 m breaststroke all-out test. There were significant correlations between the rate of anaerobic power decrease in the upper limb and the changes in stroke amplitude, cycle time per stroke, and speed. There were significant correlations between the change in mean stroke rate, the change in cycle time per stroke, the change in swim efficiency index and the change in speed. Anaerobic power indirectly influenced the speed variation during the en-route swim, which was mediated by the technical variation in cycle time per stroke. **Conclusion:** The upper limb anaerobic fatigue resistance of short distance breaststroke athletes is a key factor affecting the technique and speed stability of the 100m breaststroke en route, and the rate of decline in upper limb anaerobic power leads to a decrease in speed by affecting the change in time per stroke cycle.

KEYWORDS: Anaerobic Exercise Capacity; 100m Breaststroke; Technical Variation; Speed Changes

1. INTRODUCTION

Swimming program due to its specificity, the athlete starts to stir off the platform into the water, that is, to reach the maximum speed of the race, and after that, no matter what kind of speed method the athlete uses, the speed in the aquatic environment will inevitably decline. How to control the speed drop of swimmers in the process of swimming, so that the athletes in the maximum effort to maintain a relatively stable swimming speed straight to the finish line, and ultimately get good results, is the coaches, athletes and scientific researchers have always been concerned about the important topic. In short-distance swimming events, the anaerobic capacity of athletes is a key factor affecting sports performance, so anaerobic capacity training occupies an important plate in daily training. A large number of special anaerobic capacity training is one of the daily training tools to improve the performance of athletes in short-distance swimming events. Years of observation have made coaches, athletes and researchers realize that excellent short-distance swimmers often need more detailed anaerobic training to improve their performance, but the correlation between anaerobic capacity and athletes' performance during swimming is still unclear, and anaerobic training in form rather than in practice can have a certain degree of negative impact on athletes. Therefore, it is necessary to investigate the relationship between anaerobic capacity and performance (Elanor, 2023).

Athletes' performance in anaerobic events is directly dependent on the maximum power of ATP production by phosphocreatine hydrolysis and or anaerobic glycolysis. During 100 m all-out swimming, a large portion of the energy consumed comes from anaerobic metabolism, which leads to higher values of lactic acid concentration in the blood of athletes in short-distance swimming events, and due to the production of muscle fatigue that reduces muscle power, athletes are not able to maintain their original fitness during swimming, and their technical movements, speed, and performance are altered to some extent. Combing the results of previous research, it can be seen that through the Wingate anaerobic power test, the researcher concluded that there is a high correlation between the anaerobic capacity related indexes and the swimmers' average speed, speed change, and performance in the short-distance all-out swimming test swimming, especially the average power and peak power, which have a greater impact on the swimmers' average speed, speed decline, and performance. Also, anaerobic capacity has an impact on the technical parameters of the athlete during swimming.

Breaststroke due to its special swimming technique, underwater leg and arm movement and the timing of arm-leg coordination will bring greater resistance to the swimming process, the athlete's arm, leg movement and arm-leg coordination will affect the speed of swimming, so when training athletes in 100m breaststroke specialty, the breaststroke technique is the primary concern of the coaches. This is because it is one of the most important factors affecting athletes' training performance and future development. Good technique is an important indicator of whether the athlete can maintain the "economy" of movement in the water (Tiago M Barbosa et al., 2010). In summary, the current research on anaerobic exercise capacity found that it has a strong correlation with the athletic performance of short-distance events, but the correlation between anaerobic exercise capacity, technique change and speed change is still unclear, and whether the change of technique in 100 m breaststroke stroke will affect the relationship between anaerobic exercise capacity and speed change needs to be further explored. If the relationship between anaerobic exercise capacity and speed change of athletes will be affected by the change of technique, it will provide new ideas for coaches and athletes in their daily training. Therefore, the purpose of this study was to investigate the correlations between upper and lower limb anaerobic capacity, technical changes in the 100-m breaststroke stroke, and speed changes in short-distance breaststroke athletes. To further clarify the connection between upper and lower limb anaerobic exercise capacity, 100 m breaststroke stroke technique change, speed change of short distance breaststroke swimmers, and to explore their internal pathways.

2. Method

2.1 Participants

The test subjects selected for this study were 15 high level male swimmers, age (19.67±2.61) years, height (178.4±7.04) cm, weight (71.6±7.79) kg, arm span (183.3±6.64) cm, and FINA points (561.1±173.66).

The 15 subjects volunteered to participate in the test and They were in good health. In order to ensure the accuracy of the test data, all the tests were conducted in a single-blind manner, and the experimenters would introduce the experimental procedure to the subjects to minimize the experimental errors caused by unfamiliarity with the experimental procedure and subjective misunderstanding of the subjects, but the subjects had no knowledge of the specific experimental effects of this experiment. The study was approved on 19 April 2018 by the University Ethics. Committee at the South China Normal University, which consented to the conduct of the research as confirmed by Resolution No. SCNU-SPT-2022-119.

2.2 The Wingate Test

Upper limb anaerobic exercise capacity was tested using a modified Mornark model 894E anaerobic power bike with reference to the test protocol given MIHAIL (Kachaunov, Petrov, & Mladenov, 2020). Lower limb anaerobic exercise capacity was tested using a Mornark model 894E anaerobic power bike with reference to the test protocol given by Inbar et al.(Inbar, Bar-Or, & Skinner, 1996) and Guilherme et al. (Guilherme, Guglielmo, & Denadai, 2000). For the upper limb anaerobic capacity test, the subjects were warmed up and prepared. A load of 5% of body weight was used and the bicycle pedals were hand cranked for 30s of anaerobic power testing.

For the lower extremity anaerobic power test, 7.5% of body weight was used as the load. The power bicycle seat was adjusted so that the seat height should be the subject's span height. After the subject warmed up and prepared, he/she performed a 30s maximal speed ride with the test weights available. During the test the subjects did not need to consider the physical distribution and cadence, they performed the test at full speed and relaxed at the end of the test.

2.3 The 100 m Swimming Race

Prior to testing, all subjects underwent a standard warm-up in a standard 25-meter swimming pool. After the warm-up, marker balls were affixed to the subjects. Marker balls were affixed with reference to the breaststroke test protocol proposed by JR Vaz in 2016 (Vaz et al., 2016), and motion data were sampled at 100 samples/second. A Qualisys (Oqus7+) 3D motion capture system was used to capture the athletes' combined in-water and underwater performance using Qualitative Tracking Manager (QTM) software.

The motion capture system used for the 100m breaststroke test encompassed a total of 19 camera devices in both the in-water and under-water, which consisted of 16 motion capture cameras (filming frequency of 100 Hz) as well as 3 high-definition video cameras (24 Hz). The motion of the subject was captured during the 100m breaststroke stroke.

The data were captured and processed by Visual 3D software, and the collected data were analyzed. The raw data were smoothed using low-pass word filtering after the data acquisition was completed, and the up to frequency of 6 Hz was used for analysis. Comprehensively referring to Minchang Kim's (Kim & Ryu, 2020), Yuan Guanghui's (Guanghui, 2022) and Wu Xiaobin's (Wu Xiaobin, 2016) test protocols for the 100m breaststroke, the kinematic parameters were calculated by selecting the average values of the three complete cycles of the subjects' pre and post 50m en route swims, and the kinematic parameters of the pre and post segments of the subjects' 100m breaststroke en route swims were comparatively analyzed.

2.4 Stroke Parameters

Swim velocity (m · s^{-1}) was defined as the mean forward velocity of the greater trochanter, to the nearest 0.01 m · s−1 , from the time when the greater trochanter entered to when it left the 10-m testing section; Stroke frequency (stroke·min^{-1}) was defined as the number of stroke cycles performed in 1 min, to the nearest 0.01 strokes · min−1 calculated as the mean over each of the 10-m testing sections; SL (m·$cycle^{-1}$) was defined as the distance that the participant's greater trochanter travelled in one stroke cycle, to the nearest 0.01 m, computed from the swim velocity and the SR values; stroke cycle time (s) was defined as the time taken to complete one complete stroke cycle, calculated as the mean stroke cycle time over the 10-m testing sections (to the nearest 0.02 s); stroke index (SI).

2.5 Statistical procedures

Statistical analyses were conducted using SPSS 26.0 (SPSS, Inc., Chicago, IL, USA). Paired samples t-test was performed on the obtained data to test whether there were differences in the kinematic parameter parameters before and after the 100-meter segment.

The effect size (ES) of the paired samples t-test was represented by the d-value proposed by Cohen. Pearson's simple correlation analysis was used to test the correlation between anaerobic exercise capacity, changes in technical parameters, and changes in speed. $p<0.05$ was considered to be a significant correlation. The criteria for the degree of correlation were then defined as 1) high correlation:$|R|>0.70$; 2) moderate correlation:$|R|=0.40$ to 0.70; and 3) low correlation:$|R|<0.40$.

Mediation effect analysis using PROCESS 3.0 plug-in. Based on the correlation analysis, the explanatory and predictive relationships among the three variables of anaerobic exercise capacity, technique change and speed change were further explored. Speed change was used as the dependent variable and anaerobic exercise capacity as the independent variable to test whether technical change played a mediating effect.

3. Result

Significant decreases in front and back stroke speed occurred during the 100-meter breaststroke en route swim ($P < 0.01$, Es = 0.25). Significant decreases in mean stroke rate ($p < 0.05$, Es = 0.143), mean stroke length ($p < 0.01$, Es = 0.099), and swim efficiency index ($p < 0.05$, Es = 0.266) occurred in the before-and-after stroke comparison, and a significant increase in water-holding time in the arm-leg coordination index ($p \le 0.05$, Es = 0.55) occurred in the before-and-after stroke comparison (Table 1).

Table 1: Mean ± SD values and difference for swim velocity, SL, SR, stroke cycle time， SI, arm and leg stroke phases and arm–leg coordination expressed as a percentage for athletes (n = 15) over the two laps of the 100-m swim

	LAP1	LAP2	Δ	Δ%	SIG.	ES
SL(M/C)	1.50±0.53	1.32±0.44	-0.18±0.18	-0.11±0.12	0.001*	0.099
SR(C/S)	1.57±0.54	1.40±0.49	-0.17±0.27	-0.08±0.16	0.028*	0.143
STROKE CYCLE TIME（S）	1.40±0.14	1.47±0.16	0.08±0.24	0.07±0.19	0.232	0.416
SI（M/S²）	2.14±0.58	1.71±0.50	-0.43±0.50	-0.17±0.24	0.003*	0.266

**Denotes a statistically significant difference between the 1st and 2nd lap.*
SL: stroke length; SR: stroke rate; SI: stroke index;

The change in speed during the 100-meter breaststroke showed a positive correlation with the rate of decline in anaerobic power in the upper limb ($r=0.56$; $p<0.05$), and no correlation with peak power, mean power, and minimum power in the upper limb ($r=-0.04\sim0.18$; $p>0.05$). The change in speed during the 100-meter breaststroke showed no correlation with the rate of decline in peak power, mean power, minimum power, and anaerobic power in the lower limb ($r=-0.31\sim0.37$; $p>0.05$). correlation ($r=-0.31\sim0.37$; $p>0.05$) (Table 2, Table 3).

Table 2：The correlation between the change of swim velocity and upper body anaerobic for athletes (n = 15)

		PP	AP	MP	PD
SWIM VELOCITY($M\cdot S^{-1}$)	**R**	0.18	0.03	-0.40	0.56*
	p	0.53	0.92	0.14	0.03

** significant relationship between the analyzed indices with p < 0.05.*
PP: Peak Power; AP: Average Power; MP: Minimum Power; PD: Power Drop

Table 3: The correlation between the change of swim velocity and lower body anaerobic for athletes (n = 15)

		PP	AP	MP	PD
SWIM VELOCITY($M\cdot S^{-1}$)	**R**	0.04	-0.17	-0.31	0.37
	p	0.89	0.55	0.26	0.18

** significant relationship between the analyzed indices with p < 0.05.*
PP: Peak Power; AP: Average Power; MP: Minimum Power; PD: Power Drop

The rate of decline in upper limb anaerobic capacity power showed a positive correlation with the change in mean stroke amplitude of the en-route swim (r=0.62; p<0.05) and with the change in stroke cycle time (r=0.71; p<0.05). There was no correlation between the mean power of the upper limb and changes in paddling parameters (r=0.10-0.35; p>0.05); peak power of the upper limb and changes in paddling parameters (r=0.10-0.35; p>0.05); peak power of the upper limb and changes in paddling parameters (r=0.10-0.35; p>0.05); peak power of the upper limb and changes in paddling parameters were not correlated (r=0.10~0.35; p>0.05) (Table 4).

Table 4: The correlation between the change of performance and upper body anaerobic for athletes (n = 15)

		PP	**AP**	**MP**	**PD**
SR(M/C)	R	0.10	-0.03	-0.38	0.45
	p	0.72	0.92	0.16	0.10
	n	15	15	15	15
SL(C/S)	R	0.30	0.21	-0.28	0.62*
	p	0.27	0.45	0.32	0.01
	n	15	15	15	15
STROKE CYCLE TIME（S）	R	0.35	0.17	-0.31	0.71***
	p	0.20	0.55	0.26	0.00
	n	15	15	15	15
SI（M/S²）	R	0.13	0.04	-0.38	0.48
	p	0.64	0.90	0.17	0.07
	n	15	15	15	15

** p < .05, ** p < .01, *** p < .001*

PP: Peak Power; AP: Average Power; MP: Minimum Power; PD: Power Drop

There was no correlation between the change in mean stroke rate and the peak power, mean power, minimum power, and power decline rate of lower limb anaerobic capacity (r=0.-0.31~0.33; p>0.05); there was no correlation between the change in mean stroke amplitude and the peak power, mean power, minimum power, and power decline rate of lower limb anaerobic capacity (r=0.-0.37~0.35; p>0.05); and there was no correlation between the paddling cycle.

There was no correlation between time change and peak power, mean power, minimum power, and power decline rate of lower limb anaerobic capacity (r=0.-0.10~0.44; p>0.05); and there was no correlation between change in swim efficiency index and peak power, mean power, minimum power, and power decline rate of lower limb anaerobic capacity (r=0.-0.42~0.44; p>0.05) (Table 5).

Table 5: The correlation between the change of performance and lower body anaerobic for athletes (n = 15)

		PP	AP	MP	PD
SR(M/C)	R	0.01	-0.17	-0.31	0.33
	p	0.98	0.54	0.25	0.23
	n	15	15	15	15
SL(C/S)	R	-0.04	-0.12	-0.37	0.35
	p	0.89	0.66	0.17	0.21
	n	15	15	15	15
STROKE CYCLE TIME （S）	R	0.31	0.07	-0.10	0.44
	p	0.26	0.80	0.73	0.11
	n	15	15	15	15
SI（M/S^2）	R	0.01	-0.14	-0.42	0.44
	p	0.98	0.62	0.12	0.10
	n	15	15	15	15

** p < .05, ** p < .01, *** p < .001*

PP: Peak Power; AP: Average Power; MP: Minimum Power; PD: Power Drop

In the 100-meter breaststroke en route swim, there was a large degree of positive correlation between the change in speed and the change in stroke rate (r=0.97;p<0.001), indicating that the change in stroke rate in the en route swim is a key element affecting the change in speed; there was a large degree of positive correlation between the change in speed and the change in stroke cycle time (r=0.9;p<0.001), and a large degree of positive correlation with the change in swim efficiency index (r=0.7;p<0.001). large degree of positive correlation (r=0.7; p<0.001) (Table 6).

Table 6: The correlation between the change of swim velocity and variations of performance for athletes (n = 15)

		SR(M/C)	SL(C/S)	STROKE CYCLE TIME（S）	SI（M/S^2）
SWIM VELOCITY (M·S^{-1})	R	0.97***	0.44	0.9***	0.79***
	P	<.001	0.1	<.001	<.001
	n	15	15	15	15

** p < .05, ** p < .01, *** p < .001*

PP: Peak Power; AP: Average Power; MP: Minimum Power; PD: Power Drop

The anaerobic power decline rate in upper limb anaerobic exercise capacity has a significant positive correlation with the speed drop in the 100-meter breaststroke stroke. Therefore, the relationship between the upper limb anaerobic power decline rate, technical parameter change, and speed change was further explored. The mediation effect waystroke test process adopts the mediation test steps proposed by Wen Zhonglin (Wen Zhonglin & Ye Baojuan, 2014). In this paper, Bootstrap method is used, and 5000 times of repeated sampling are selected, combined with Table 8 and Figure 1, the total effect does not contain 0 in 95% confidence interval, and the total effect is significant; the indirect effect does not contain 0 in 95% confidence interval, and the indirect effect is significant; and the direct effect contains 0 in 95% confidence interval, and the direct effect is not significant. It indicates that there is a mediating effect, and that the upper limb anaerobic power decline rate and speed change is mediated by the per stroke cycle time change. That is, the athletes' upper limb anaerobic power decline rate caused a decrease in speed to occur by influencing the change in technical parameters of the 100-m breaststroke stroke en route (Figure 1).

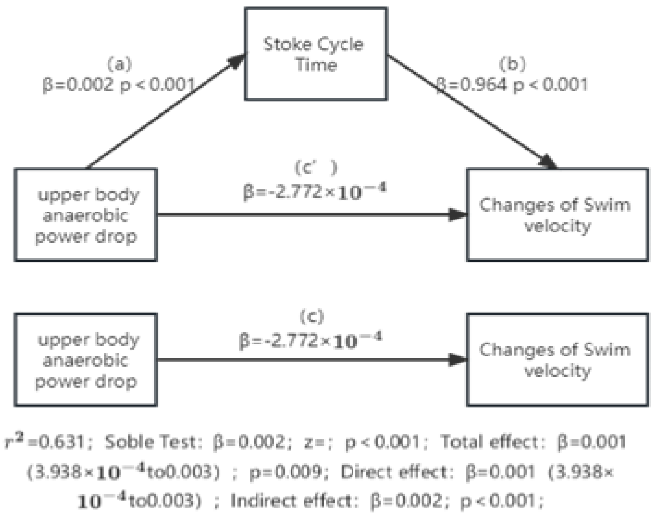

Figure 1: Mediation models illustrating the level of mediation effects of the relation between the independent variables of: upper body anaerobic and the changes of swim velocity and corresponding p-values are presented. β of total (c), direct (c'), and indirect (a,b) effects are presented with 95% confidence intervals, p-value

4. Discussion

In this study, we focused on the relationship between athletes' anaerobic power, changes in technical parameters, and changes in speed during the 100-meter breaststroke stroke, and attempted to explore the intrinsic connection between the three. The main findings were that the rate of decline of the athlete's upper limb anaerobic power had a correlation with the change of speed, the change of average stroke length, and the change of time per stroke cycle during the 100-meter breaststroke stroke, and that the change of stroke rate, the change of stroke length, and the change of time per stroke cycle during the

100-meter breaststroke stroke had a significant correlation. The rate of decline in upper extremity anaerobic power was caused by influencing the change in the athlete's time per stroke cycle, which led to a decrease in speed.

In the 100-meter breaststroke, fatigue is an important factor that affects an athlete's race sport performance. In swimming, speed is directly related to the effective mechanical power output generated by the athlete. Previous studies have shown that a decrease in speed in the stroke is associated with a decrease in maximum power output (Toussaint, Carol, Kranenborg, & Truijens, 2006). In breaststroke events, the role of the athlete's upper limb is often overlooked, and it is widely believed that the lower limb is the main factor in generating propulsive force, ignoring upper limb exercises (Yeater, Martin, White, & Gilson, 1981). However, a growing body of research suggests that arm movements and leg movements produce similar propulsive forces during each complete breaststroke cycle. For example, in tethered swimming tests, the peak and mean values of tether forces measured during propulsion induced by the upper and lower limbs are similar (Yeater et al., 1981). The breaststroke stroke does not produce a dominant propulsive force, and leg stomps can produce roughly the same propulsive force as the stroke, but previous research has shown that breaststroke swimmers accelerate their bodies with their arms for a longer period of time than with their legs throughout the cycle of the maneuver, which is clearly an important propulsive force in breaststroke (Maglisho, 2003). Therefore, upper limb anaerobic capacity is also a key factor influencing breaststroke performance. In this study, the anaerobic power decline rate of upper limb anaerobic capacity has a significant correlation with speed change, indicating that athletes' upper limb anaerobic anti-fatigue capacity is correlated with speed change. The speed change of the 100-meter breaststroke has always been one of the main focuses of the research related to the en route swim of short-distance swimmers, and the speed change of the en route swim can reflect the change of the athlete's physical performance. Upper limb anaerobic power decline rate reflects the fatigue resistance of the athlete's muscles in anaerobic state. With the increasing distance of the en route swim, the athlete's consumption becomes larger, and the muscle fatigue accumulates, which leads to the speed decline (De, 2013).

The greater the athlete's anaerobic anti-fatigue capacity, the more fatigue the body is able to take on, and the smaller the change in speed.The 100m breaststroke is dominated by anaerobic energy supply, and the athlete's anaerobic metabolism results in a lactate concentration of the blood of 10-20 mmol during the swim. Accumulated hydrogen ions interfere with the mechanism of muscular contraction, which leads to a decrease in the muscular strength produced by the athlete, and consequently, the athlete's inability to maintain his or her initial technique. Thus the level of fatigue in the athlete's upper limb correlates with the change in the average stroke length of the en route swim, i.e. the higher the level of fatigue, the greater the change that occurs in stroke length. The correlation between the level of fatigue and the change in stroke length has been demonstrated in several studies where a decrease in stroke length in incremental tests showed an increase in energy expenditure and the athlete developed a state of fatigue, demonstrating laterally the correlation between the level of fatigue and the change in stroke length. The breaststroke is the most technically complex and the least "economical" of the four strokes, and Barbosa has shown in her research that breaststroke swimmers may experience fatigue earlier in the stroke than other strokes due to the least "economical" nature of the breaststroke. The 100m breaststroke is an anaerobic based sport, and the anaerobic capacity of the athlete has an impact on stroke technique, therefore, the anaerobic capacity of short distance breaststroke swimmers correlates with the change in stroke length and the change in stroke duration per stroke cycle in the stroke en-route (Reis et al., 2010).

Breaststroke is a stroke in which the upper and lower limbs work together to collaborate to move the body through the water, and according to the FINA swimming rules, the breaststroke cycle loop must be a sequence of one arm movement and one kick movement. All movements of the arm action should be performed simultaneously and at the same level, without alternating movements. (De, 2013; Vorontsov & Binevsky, 2002) Therefore, the study of upper limb anaerobic capacity versus lower limb anaerobic capacity is important to fully reflect the essential characteristics of the program. In the present study, there was no correlation between lower limb anaerobic capacity and the change in swim speed in the 100-meter breaststroke, and it was shown that leg movements in breaststroke are capable of generating greater hydrodynamic forces than arm movements due to the legs having a significantly greater propulsive surface area and the muscle groups of the legs being significantly stronger than the arms, but that these characteristics play a secondary role in creating an effective propulsive force in breaststroke (Vorontsov & Binevsky, 2002) Therefore, this may be one of the reasons why there is no correlation between lower limb anaerobic capacity and the change in swim speed in the 100 m breaststroke, which laterally confirms the importance of upper limb motor performance during the breaststroke stroke. Secondly, there was no significant correlation between lower limb anaerobic capacity and the change of 100m breaststroke stroke technique, probably because the correlation was affected by age and body weight (Kachaunov & Petrov, 2020). A study of the correlation between anaerobic and aerobic capacity on performance in 100m and 200m breaststroke swimmers found that physiological tests of direct vanadium dioxide measurements and blood lactate assessment could provide some explanation for the performance ability of breaststroke swimmers, and that combining these anaerobic and aerobic capacity test metrics with the subject's body weight and height accurately predicted the performance of the 100m breaststroke event (De, 2013; Reis et al., 2010). In the study on the correlation between anaerobic capacity and breaststroke stirrup performance, age was used as a covariate to correlate the athlete's anaerobic capacity indexes with the average stirrup frequency, stirrup length, and speed of the breaststroke stirrup. It indicates that body weight and age are important influencing factors in the study of correlation between lower limb anaerobic capacity and 100m breaststroke performance (T.M Barbosa et al., 2006; Strzała et al., 2012).

Whether the anaerobic exercise capacity of athletes is a factor that directly affects the speed change of the 100-meter breaststroke stroke, which directly determines the content selection of athletes and coaches in daily training. Breaststroke, as the most technically complex stroke, whether athletes can accomplish reasonable technical movements also directly determines the athletic performance. Therefore, this study investigated for the first time the mediating role of technical changes between athletes' own anaerobic capacity and speed changes (Demarie, Chirico, Gianfelici, & Vannozzi, 2019). The results showed that anaerobic capacity indirectly affected the speed change during the en route swim, which was mediated by the time per stroke cycle in the technical change (Papoti et al., 2013).The direct effect between upper limb anaerobic capacity and speed change in the 100-m breaststroke stroke was not significant, i.e., the pathway of "upper limb anaerobic capacity → speed change in the 100-m breaststroke stroke" was not established, and the upper limb anaerobic fatigue resistance did not directly affect the speed change; "upper limb anaerobic capacity → change in cycle time per stroke → change in cycle time per stroke" was not established. The path of "upper limb anaerobic capacity → change in time per stroke cycle → change in speed in the 100-m breaststroke stroke" was not valid, i.e., the breaststroke swimmers' upper limb anaerobic capacity led to the decrease in speed by influencing the technique during the stroke. This may give us an important reminder that anaerobic capacity, as an important ability affecting breaststroke swimmers' short-distance performance, influences performance, but stroke technique is a key factor in stabilizing swim speed.

5. Conclusion

Upper limb anaerobic fatigue resistance of short distance breaststroke swimmers is a key factor affecting the stability of 100m breaststroke stroke technique and speed. The stronger the upper limb anaerobic fatigue resistance, the abler they are to maintain a certain stroke length and stroke cycle time in the backstroke of the stroke, and the smaller the speed change. The upper limb anaerobic power decline rate of breaststroke swimmers led to the decrease of speed by affecting the change of the time per stroke cycle, and the time per stroke cycle was closely related to the stroke rate, the upper limb anaerobic fatigue resistance is the key to affect the ability to maintain the technique of the en-route swim, and the 100m breaststroke swimmers need to combine the anaerobic endurance with the technique training in the daily training in order to counteract the decrease of the speed in the en-route swimming process.

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