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Original Article

BIOMECHANICAL, COORDINATIVE, AND PHYSIOLOGICAL RESPONSES TO A TIME-TO-EXHAUSTION PROTOCOL AT TWO SUBMAXIMAL INTENSITIES IN SWIMMING

RESPOSTAS BIOMECÂNICAS, COORDENATIVAS E FISIOLÓGICAS A UM PROTOCOLO DE DUAS INTENSIDADES SUBMÁXIMAS ATÉ A EXAUSTÃO EM NATAÇÃO

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RESUMO
O objetivo deste estudo foi comparar parâmetros biomeânicos, coordenativos e fisiológicos no nado crawl, durante séries de treinamento intervalado realizadas em duas intensidades submáximas até a exaustão. Participaram 11 nadadores, com idade média de 21,0 ± 7,3 anos que realizaram duas séries de treinamento com repetições de 400 m (40 s de repouso passivo) a 90% (v90) e 95% (v95) da velocidade média dos 400 m nado crawl (v400), determinada previamente em um teste máximo de 400 m. Resultados: (i) aumento da frequência média de ciclos de braçadas e redução da distância media percorrida por ciclo entre os trechos e entre as repetições inicial e final nas series v90 e v95; (ii) índice de coordenação e tempo propulsivo aumentaram entre os trechos inicial e final na série v95; (iii) as durações absoluta e relativa da fase de puxada da braçada aumentaram entre as repetições inicial e final da série v95; (d) o esforço percebido, a concentração de lactato e a frequência cardíaca aumentaram entre as repetições inicial e final na v90 e v95. Manter a velocidade nas series v90 e v95 da v400 leva a alterações na organização motora da braçada no nado crawl.
Palavras-chave: Nado crawl. Coordenação. Treinamento. Biomecânica.

ABSTRACT
The aim of this study was to compare biomechanical, coordinative and physiological parameters in the front crawl, during interval training series performed in two submaximal intensities until exhaustion. Eleven swimmers, mean age of 21.0 ± 7.3 years, performed two sets of interval training with repetitions of 400 m (40 s of passive rest) at 90% (s90) and 95% (s95) of the 400 m front crawl mean speed (s400), which was previously determined during a maximum 400 m test. The results were: (i) increase in the stroke frequency and decrease in the stroke length between the trials and between the initial and final repetitions in the s90 and s95 series; (ii) index of coordination and propulsive time increased between the initial and final trials in the s95 series; (iii) the absolute and relative durations of the pull phase increased between the initial and final repetitions of the s95 series; (iv) perceived exertion, lactate concentration and heart rate increased between the initial and final repetitions in s90 and s95. To maintain speed in the s90 and s95 series of s400 leads to changes in the motor organization of the stroke in the front crawl.
Keywords: Front-crawl. Coordination. Training. Biomechanics.

Introduction

The development of aerobic capacity is crucial to swimming and open water swimming performances since the distances (and duration) of competitive events in these modalities range between 50 m (lasting ~21 s) and 1,500 m (lasting ~15 min) in swimming pool and between 5 km (lasting ~1 h) and 25 km (lasting ~5 h) in official open water competitions. Therefore, submaximal intensities (i.e. intensities below the maximal aerobic speed) play an important role in swimming training, and typically, both continuous training and interval training are used to develop the aerobic capacity of the swimmers[1].

When swimmers train in submaximal intensities, swimming until or next to exhaustion, changes in technique are expected[2]. These changes may be related to the intensity itself, drag and propulsive forces[3], or to the development of fatigue[4,5]. To overcome the drag forces, the swimmer can act on three parameters, i.e., the magnitude of the propulsive force, the duration on which the propulsive force is applied, and the rate of application of these forces[3]. Since swimming speed depends on the stroke rate and the stroke length, and these parameters are inversely related to each other[6], sustaining a given speed under fatigue conditions, in which propelling efficiency (and stroke length) are compromised, requires an increase in stroke rate[7]. Moreover, changes in technique under these conditions would probably lead to disturbances in coordination and, therefore, the balance between the relative duration of the propulsive and non-propulsive phases of the arm stroke would adapt to maintain swimming speed[8].

The assessment of blood lactate concentration ([La]), rating of perceived exertion (RPE), and heart rate (HR) would allow a better understanding on the interplay between stroke parameters and coordination while swimmers train or compete under fatigue conditions. Changes in the interplay between these parameters are important to promote specific adaptations (i.e. oxidative power and capacity) related to long and short competitive events[9]. Thus, the aim of this study was to compare biomechanical, coordinative and physiological parameters in front crawl, during interval training sets performed at two submaximal intensities until exhaustion.

Methods

Participants

Eleven middle and long-distance swimmers volunteered to participate in this study (mean ± SD: age 21.0 ± 7.3 years, height 1.80 ± 0.67 m, arm span 1.88 ± 0.86 m, body mass 73.2 ± 10.4 kg; percentage of the 400 m freestyle world record = 77.1 ± 4.6% in a 25 m pool). All participants were male and competed at national and international competitions at distances of 400, 800, or 1500 m freestyle and in open water events. Swimmers should have at least four years of competitive experience and train at least 12 hours a week. They were asked to reduce physical exercise levels for a minimum of 24 hours and abstained from consuming any substance containing caffeine 12 hours prior to each of the evaluation sessions.

Procedures and protocol

Participants were informed of all procedures and signed a written consent agreeing to participate in the study. Moreover, this study was approved by the local ethics committee (protocol number 17367) and conducted in accordance to the standards set by the Declaration of Helsinki.

All tests were performed in a 25 m pool, under controlled conditions (water temperature ~29°C; air temperature ~24°C), at the same time of the day (between 2 and 6 p.m.). Swimmers performed a standard warm-up of 800m, followed by a maximal 400 m front crawl test (T400) to estimate maximal aerobic speed (s400)[10]. Then, swimmers performed two interval training sets (n x 400 m), until exhaustion, at 90% and 95% of s400, respectively. Tests were separated by 48 hours and the order of the interval training protocols was randomized.

Participants were asked to maintain the targeted swimming speeds during a set of 400 m repetitions, with 40 s of passive rest inbetween, for the longest time possible, following an underwater visual pacer with flashing lights (resolution of 0.01 m/s). The inability to keep up with the flashing lights was taken as the criteria for the occurrence of exhaustion and led to subsequent interruption of the test. In each interval training set, the total time-to-exhaustion

(TTE) was obtained by summing the duration of each 400 m repetition, excluding the rest intervals.

Stroke parameters and coordination

All stroke and coordinative parameters were assessed by means of dual media video, with underwater and external recording of the sagittal plane of the swimmer (SANYO VPC-WH1; Osaka, Japan; 60 Hz). The underwater camera was positioned ~30 cm below the water surface and the external camera ~20 cm above the water surface and both were fixed to a trolley, which was displaced on a rail by an experienced operator in alignment with the swimmer. Underwater and external cameras were synchronized using a LED triggered simultaneously for both cameras. The images were collected in the middle (between 150 and 200 m) and the end of each repetition (between 350 and 400 m). Videos were analyzed frame by frame by three experienced analysts with stroke and coordinative parameters being assessed in four moments, preceding the 175, 200, 375, and 400m (laps 1, 2, 3, and 4, respectively), in the initial trial (1IT, 2IT, 3IT, and 4IT) and the final full trial (1FT, 2FT, 3FT, and 4FT) for the two interval training protocols.

Stroke frequency (SF; Hz) was calculated from the number of complete strokes performed in the central 10-m and the time taken from the first and last hand entry in the water. From dividing the targeted speed by the corresponding SF, stroke length (SL; m) was calculated. The average swimming speed (ss) was also controlled by taking the time to complete 10 m (from 10 to 20 m after each wall) to assure swimmers were swimming at the targeted speed. As a matter of convenience, SF is expressed in cycles/min.

The duration of the catch, pull, push, and recovery phases of the arm stroke were determined by three experienced analysts and expressed in seconds (absolute values) and percentage of the total duration of one arm stroke (relative values) as previously described by Chollet et al.[11]. Pull and push phases are assumed to be propulsive phases, and the catch and recovery non-propulsive phases. The index of coordination (IdC) was used to assess inter-arm coordination[11], by determining the lag time between the end of the propulsive phase of one arm and the beginning of the propulsive phase of the other. For each lap of the TTE test, three consecutive arm stroke cycles were analyzed.

The total propulsive time per lap ($T_{prop/distance}$; Alberty et al.[3]) was calculated according to Equation 1:

$$Tprop/distance = Tcycle\ (100\% + 2IdC)D\ /\ SL \tag{1}$$

In which T_{cycle} is the total duration of an arm stroke and *D/SL* is the number of arm strokes needed to cover the distance.

Physiological parameters

Blood samples were taken from the distal index finger and [La] was assessed immediately after the end of each 400 m repetition using a portable lactate analyzer (Accusport, Boehringer Mannheim, Germany). A heart rate sensor (Polar S810, Polar Electro Oy, Finland) was attached to the swimmer, who should remain in the upright position inside the swimming pool during the resting intervals, and HR) was assessed. During this time period swimmers also reported the general RPE using the 15-point RPE Borg-Scale[12].

Statistical analysis

The Shapiro-Wilk test was used to check the normality of the distribution of each set of data, then means and standard deviations were calculated. To analyze the stroke and coordinative parameters, ANOVA with two factors (trials and laps) and Bonferroni post hoc between moments and laps were applied. The effect size was determined by the η^2. Student's *t* tests for paired data were used to compare the physiological parameters between the initial (first repetition) and final (state of exhaustion). Cohen's d effect sizes (ES) were computed[13] and interpreted as: from 0 to 0.2: trivial; from 0.21 to 0.6: little; from 0.61 to 1.2: moderate; from 1.21 to 2.0: very big, and < than 2.0: very big. The level of statistical significance was set at $p < 0.05$.

Results

The average swimming speed for the T400 was 1.45 ± 0.08 $m \cdot s^{-1}$. Therefore, the average speed for 90% and 95% were 1.30 ± 0.11 $m \cdot s^{-1}$ and 1.37 ± 0.01 $m \cdot s^{-1}$, respectively. The TTE was 54.5 ± 28.2 min, five to 15 400 m repetitions at 90% of s400, and 17.5 ± 9.1 min, two to five 400 m repetitions at 95% of s400.

Figure 1 shows the values of, SL, SF and v preceding 175, 200, 375, and 400 m in the initial (laps 1IT, 2IT, 3IT, and 4IT) and final trial (laps 1FT, 2FT, 3FT, and 4FT) for both submaximal swimming intensities.

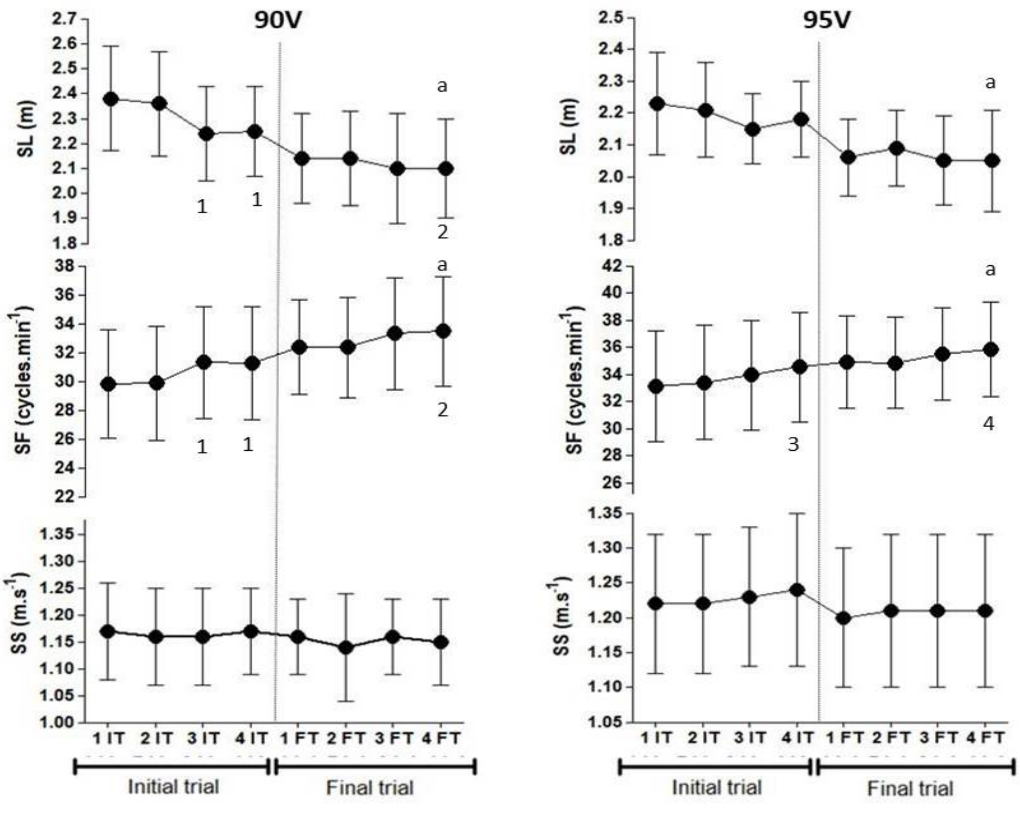

Figure 1. Mean ± SD the values of stroke length (SL), stroke frequency (SF), and swimming speed (SS) in the initial (laps 1IT, 2IT, 3IT, and 4IT) and final trial (laps 1FT, 2FT, 3FT, and 4FT) of interval set at the percentage of 90V and 95V.

Note: [a] Significant difference ($p < 0.05$) between the initial and final trial (for both, 90V and 95V); [1] significant difference to laps 1IT and2IT (90V – initial trial); [2] significant difference to laps 1FT and2FT (90V – final trial); [3] significant differences to laps 1IT and2IT (95V – initial trial); [4] significant difference to laps 1FT and 2FT (for both, 90V and 95V – final trial); n = 11.
Source: Authors

At 90% of s400, SF was higher at 3IT and 4IT when compared to laps 1IT and 2IT ($F_{3.8} = 14.111$; $p < 0.01$; $\eta^2 = 0.841$). The same pattern was observed at 95% of s400, in which SF was higher at 4FT than at 1FT and 2FT ($F_{3.8} = 5.574$; $p < 0.05$; $\eta^2 = 0.676$). Also, SF

increased from the initial to the final repetitions both at 90% of s400 ($F_{1.10}$ = 10.465; $p < 0.01$; $\eta^2 = 0.511$) and 95% of s400 ($F_{1.10}$ = 6.768; $p < 0.05$; $\eta^2 = 0.404$). Inversely, SL decreased from the initial to the final repetitions at 90% ($F_{1.10}$ = 17.945; $p < 0.01$; $\eta^2 = 0.642$) and 95% of s400 ($F_{1.10}$ = 11.280; $p < 0.01$; $\eta^2 = 0.530$). No significant differences in SL were found between laps, for each repetition, at 95% of s400. However, it significantly decreased at 4IT when compared to laps 1IT and 2IT, and at 4FT compared to lap 1FT ($F_{3.30}$ = 12.369; $p < 0.001$; $\eta^2 = 0.553$). Finally, swimming speed did not change neither between nor within repetitions in both submaximal swimming intensities (p > 0.05).

Figure 2 shows the IdC and $T_{prop/distance}$ obtained every 25 m prior to 175, 200, 375 and 400 m (1, 2, 3, and 4, respectively) of the initial and final trial for both submaximal swimming intensities. The IdC ($F_{1.10}$ = 8.402; $p < 0.05$; $\eta^2 = 0.457$) and $T_{prop/distance}$ ($F_{1.10}$ = 8.780; $p < 0.05$; $\eta^2 = 0.434$) increased from the the initial to the final trials only at 95% of s400, with no changes between trials at 90% of s400 (p > 0.05).

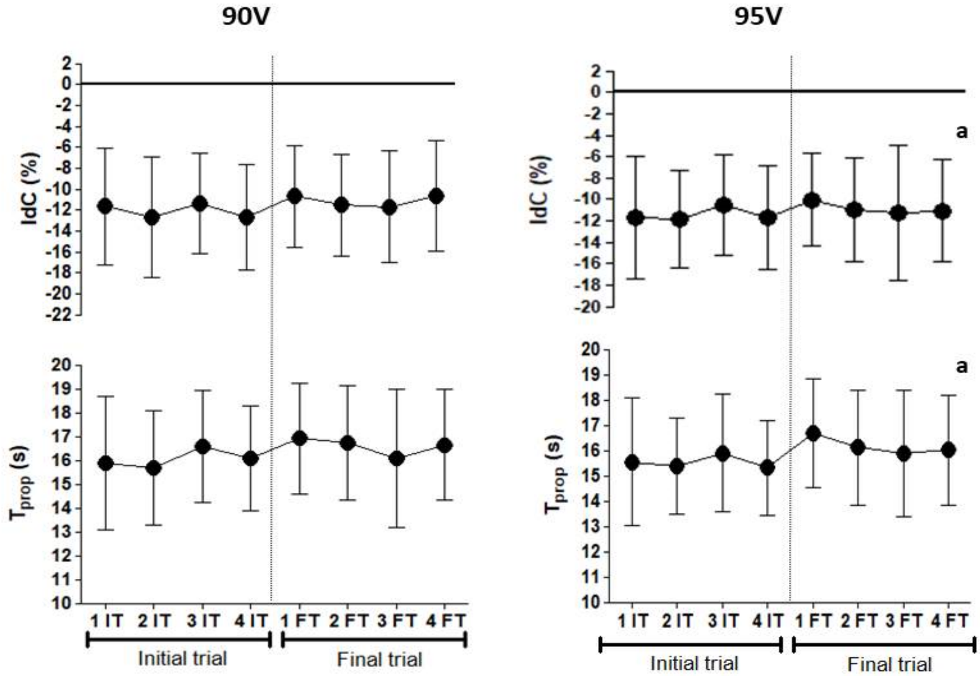

Figure 2. Mean ± SD the values of index of coordination (IdC) and time allotted to propulsion per distance unit was estimated ($T_{prop/distance}$) the initial (laps 1IT, 2IT, 3IT and 4IT) and final trial (laps 1FT, 2FT, 3FT and 4FT) of interval training in the percentage of 90V and 95V.

Nota: [a]Significant difference (p < 0.05) between the initial and final trial, . *N* = 11.
Source: Authors

Figure 3 shows the absolute and relative duration of the arm stroke phases, obtained 25 m prior to 175, 200, 375, and 400 m (1 2, 3, and 4, respectively) at the initial and final trials for both submaximal swimming intensities. No differences in absolute duration of the arm stroke phases between laps either at 90% or 95% of s400. When comparing the initial and final trials, the absolute duration of the pull phase increased only at 90% of s400 ($F_{1.10}$ = 8.976; $p < 0.05$; $\eta^2 = 0.473$) with no changes in the absolute duration of the other arm stroke phases (p > 0.05). On the other hand, the absolute duration of the arm stroke phases did not change from the first to the last trial at 95% of s400 (p > 0.05). No difference was found between repetitions either at 90% or 95% of s400. The relative duration of the pull phase has increased from the initial to the final trial at 90% of s400 ($F_{1.10}$ = 7.686; $p < 0.05$; $\eta^2 = 0.435$). However, no changes were observed in the relative duration of the other arm stroke phases (p

> 0.05). Also, the relative duration of the arm stroke phases did not change between trials at 95% of s400 (p > 0.05).

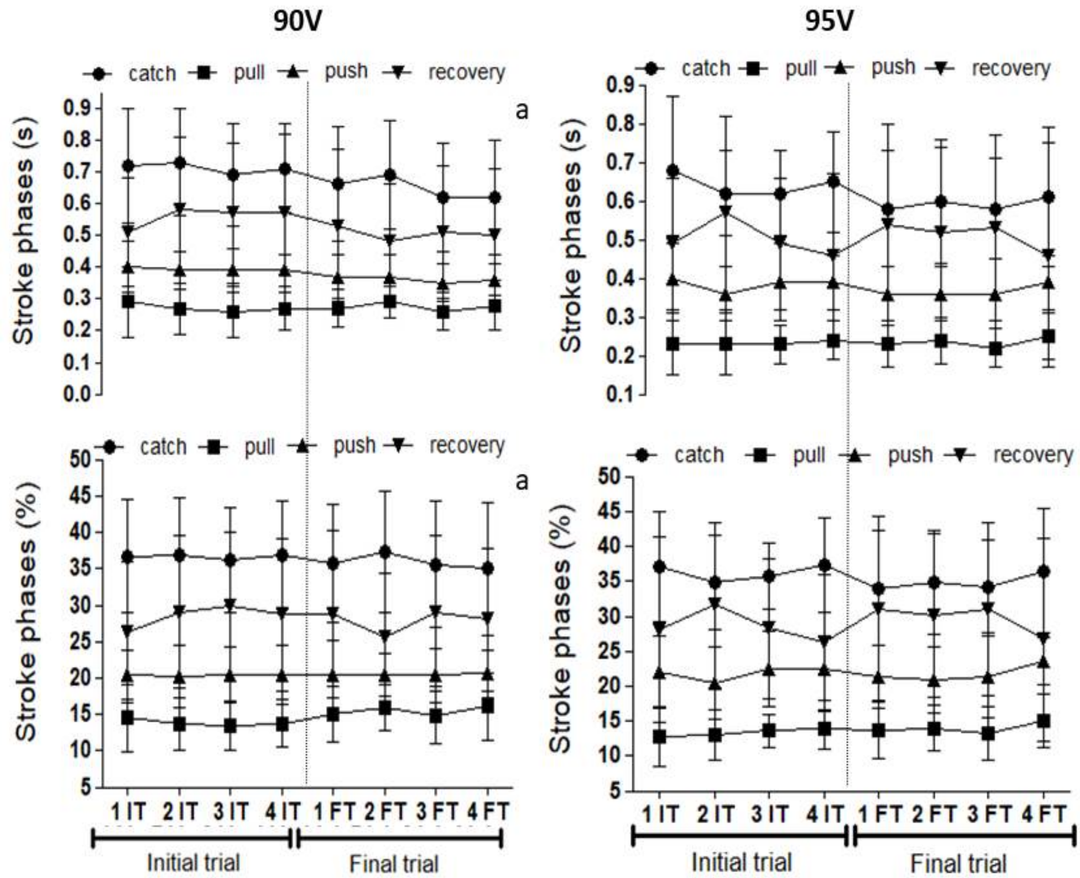

Figure 3. Mean ± SD the relative and absolute values of stroke phases (catch, pull, push, and recovery), the initial (laps 1, 2, 3, and 4) and final trial of interval training in the percentage of 90V and 95V.
Nota: [a]Significant difference (p < 0.05) between to the initial and final trial,. *N* = 11.
Source: Authors

The RPE, [La], and HR significantly increased from the initial to the final repetition both at 90% and 95% of s400 (p<0.05; and ES = between 0.76 and 3.90), as shown in Table 1.

Table 1. Mean values ± standard deviations (SD) (minimum and maximum values) of and the rating of perceived exertion (RPE), blood lactate concentration ([La]), heart rate (HR) in the initial and final repetitions, in the 90V and 95V series; comparisons were carried out in the same intensity (n=11)

	90V	95V
RPE Initial	11.85 ± 1.46 (9-14)	14.14 ± 1.74 (10-16)
RPE Final	18.21 ± 1.80* (15-20)	18.42 ± 1.60* (16-20)
[La] Initial (mmol·l^{-1})	3.58 ± 1.05 (2.80-4.60)	5.30 ± 1.75 (3.40-9.50)
[La] Final (mmol·l^{-1})	5.30 ± 2.28* (4.20-11.70)	6.81 ± 1.44*(5.40-13.2)
HR Initial (bpm)	155.00 ± 16.51 (130-179)	171.78 ± 10.59 (150-193)
HR Final (bpm)	175.71 ± 9.54* (159-193)	179.57 ± 9.84* (167-197)

Note: * indicates significant increase (p < 0.05) to the initial value at same intensity
Source: Authors

Discussion

The aim of this study was to compare biomechanical, coordinative and physiological parameters in front crawl, during interval training sets performed at two sub-maximal intensities until exhaustion, at 90% and 95% of s400 in front crawl. The main findings were: (a) SF increased and SL decreased between the first and final 400 m trials, and between the initial and final sections of each repetition for both submaximal intensities; (b) the IdC and the $T_{prop/distance}$ increased between the initial and final trials only at 95% of s400; (c) the absolute and relative durations of the pull phase increased from the initial to the final repetition at 90% of s400, although no changes were observed at 95%; (d) RPE, [La] and HR increased from the initial to the final repetition in both submaximal intensities.

The effect of fatigue on the duration of the arm stroke phases and IdC was analyzed in 200 m at maximum intensity[14] and by imposed paces[3,15,16]. Alberty et al.[14] found an increased relative values for pull and push phases per stroke when compared the end and the beginning of the test. In the study of Alberty et al.[3], 10 swimmers swam three times until exhaustion, at 95, 100, and 110% of s400 and for all intensities, SF increased and the SL decreased, as well as the IdC and T_{prop} decreased.

The SF, the IdC, and $T_{prop/distance}$ increased between repetitions, which may be explained by a reduction in the ability to apply the necessary force to maintain speed. Moreover, Alberty et al.[3] found that time in non-propulsive stroke phases (catch and recovery) decreased with the development of fatigue, when the SF, the IdC, and T_{prop} increased. Pelarigo et al.[15] analyzed the duration of the arm stroke phases, in a 30-min continuous protocol at 100% and 102.5% of the maximal lactate steady state (88.6 ± 1.1%, and 91.3 ± 1.1% of s400, respectively). They observed an increase only in the relative duration of the pull phase from 10 to 13 min, at 102.5% of the MLSS. These results are in agreement with our findings in which regards the interval training protocol at 90% of s400 (i.e. an increase in duration of the pull phase between the initial and final repetitions). However, our results did not show any changes in duration of the arm stroke phases at 95% of s400.

Regarding the IdC, there were no changes between trials. Given that the duration of the pull phase is related to the application of a propulsive force by the swimmer[3], its reduction implies in a new temporal organization of the stroke phases, as the swimmer increases the proportion of at least one propulsive phase to keep the same speed.

It is noteworthing that the relation between the energy cost of swimming and speed is not linear[17], and, therefore, a small increase in speed requires greater metabolic demand and probably different swimming strategies to maintain speed constant. According to Craig and Pendergast[6], and further confirmed by Alberty et al.[3], the magnitude of changes in stroke parameters under fatigue depends on the intensity. Furthermore, Figueiredo et al.[16] evaluated coordinative and kinematic parameters at five different moments in a 30-minute test swimming at the maximal lactate steady state (0%, 25%, 50%, 75% and 100%), reporting an increase in the SF and a decrease in the SL only from the first to the last moment.

Our results, regarding the TTE at 90% and 95% of s400, are in agreement with previous findings. Ribeiro, Lima and Gobatto[4] verified, in swimming series at the 100% of the critical velocity, TTE of 21.0 ± 3.1 min in three swimmers who were not able to reach five 400 m repetitions and TTE of 32.0 ± 1.3 min in nine swimmers who reached the five repetitions. Already, Dekerle et al.[18] found TTE of 48.9 ± 14.1; 24.3 ± 7.7; and 8.6 ± 3.1 min in series at 95, 100, and 105% of critical velocity, respectively, and 53.9 ± 2.7 min at 100% of the critical velocity.

RPE, [La], and HR showed increase between initial and final repetitions at 90% and 95% of s400 (Table 1), results similar to those reported by Ribeiro, Lima and Gobatto[4], who found an increase in values of HR, and RPE over five 400 m repetitions, with 90-s passive rest intervals, at the intensity corresponding to the critical velocity (1.27 ± 0.07 $m \cdot s^{-1}$) of nine competitive swimmers. Still, the behavior of these variables was not similar to that reported by Dekerle et al.[18], who found only RPE increment and stabilization of [La] in a series of ten repetitions of 400 m, with passive rest intervals of 40 s, but only seven individuals were able to complete the proposed series, that is, the analysis statistical analysis was performed with n = 7, which could compromises the analysis performed or justified the difference between our study.

The identified increase in [La] indicates that there was no equilibrium state between the need and metabolic energy production in the series. The comparison of the results of the present study related to the physiological variables was done with studies based on critical velocity, because there are few studies using the s400, which is a quality of the present study. Besides that, while the swimmers of the present study usually train in swimming pools with higher temperatures than the pool where the stydy was carried out (29ºC), we discard the possible effect of the water temperature in the physiological results[19].

The stroke, coordinative, and physiological parameters changed in response to the development of fatigue process and to the swimming intensity. According to Craig and Pendergast[6], at higher speeds, the number of possible combinations of SF and SL is reduced. This could explain the reasons for the changes in duration of the pull stroke only at 90% of s400, decreasing from the lowest to the highest speed in this study. Simultaneous analysis of biomechanical, coordinative and physiological parameters, in swimming, allows best performance understanding. Such analysis is possible just in simulated situations of competition or training. Although not being the focus of the present study, one should consider that while swimming speed is constant, there was: (i) decrease in the stroke length, (ii) increase in the stroke frequency and (iii) increase in the rate of perceived exertion, blood lactate concentration and heart rate. These behaviors indicate the relationship between the biomechanical and physiological domains.

Conclusions

The findings of this study indicate that: at 90% and 95% of s400 (severe intensity domain and at constant swimming speed) there is an increasing in *SF* and decreasing is *SL*, as well as an increasing in physiological responses. However, the pull phase duration increases only at 90% of the s400. Furthermore, increases in the IdC and T_{prop} only occur in the 95% of the s400. Our results demonstrate that maintaining the swimming speed at 90% and 95% of s400 leads to changes in the motor organization of the front crawl. This new coordination should be considered by the coaches in a training project.

References

1. Pyne D, Sharp R. Physical and energy requirements of competitive swimming events. Int J Sport Nutr Exerc Metab 2014;24:351-359. Doi: 10.1123/ijsnem.2014-0047
2. Dekerle J, Paterson J. Muscular fatigue swimming intermittently above and below critical speed. Int J Sports Physiol Perform 2016;11(5):602-607. Doi: 10.1123/ijspp.2015-0429
3. Alberty M, Sidney M, Pelayo P, Toussaint HM. Stroking characteristics during time to exhaustion tests. Med Sci Sports Exerc 2009;41(3):637-644. Doi: 10.1249/MSS.0b013e31818acfba
4. Ribeiro LFPR, Lima MCS, Gobatto CA. Changes in physiological and stroking parameters during interval swins at the slope of the d-t relationship. J Sci Med Sport 2010;13(1):141-145. Doi: 10.1016/j.jsams.2008.10.001
5. Oliveira MFM, Caputo F, Dekerle J, Denadai BS, Greco CC. Stroking Parameters during Continuous and Intermittent Exercise in Regional-Level Competitive Swimmers. Int J Sports Med 2012;33:696–701. Doi: 10.1055/s-0031-1298003

6. Craig AB, Pendergast DR. Relationships of stroke rate, distance per stroke and velocity in competitive swimming. Med Sci Sports Exerc 1979;11(3):278–283.
7. Laffite LP, Vilas-Boas JP, Demarle A, Silva J, Fernandes R, Billat VL. Changes in physiological and stroke parameters during a maximal 400-m free swimming test in elite swimmers. Can J Appl Physiol 2004;29(1):S17–S31.
8. Schnitzler C, Seifert L, Ernwein V, Chollet D. Arm coordination adaptations assessment in swimming. Int J Sports Med 2008;29(6):480–486. Doi: 10.1055/s-2007-989235
9. Costill D, Kovaleski J, Porter D, Kirwan J, Fielding R, King D. Energy expenditure during front crawl swimming: predicting success in middle-distance events. Int J Sports Med 1985;6:266-270. Doi: 10.1055/s-2008-1025849
10. Zacca R, Fernandes RJ, Pyne DB, Castro FAS. Swimming training assessment: The critical velocity and the 400-m test for age-group swimmers. J Strength Cond Res 2016;30(5):1365-1372. Doi: 10.1519/JSC.0000000000001239
11. Chollet D, Chalies S, Chatard JC. A new index of coordination for the crawl: description and usefulness. Int J Sports Med 2000;21:54-59. Doi: 10.1055/s-2000-8855
12. Borg GAV. Psychophysical bases of perceived exertion. Med Sci Sports Exerc 1982;14:377-81.
13. Hopkins WG. [Internet]. A new view of statistics. Internet Society for Sport Science. [access in March 27, 2018]. Available in: http://www.sportsci.org/resource/stats/; 2000
14. Alberty M, Sidney M, Huot-Marchand F, Hespel JM, Pelayo P. Intracyclic velocity variations and arm coordination during exhaustive exercise in front crawl stroke. Int J Sports Med 2005;26(6):471-5. Doi: 10.1055/s-2004-821110
15. Pelarigo JG, Denadai BS, Greco CC. Stroke phases responses around maximal lactate steady state in front crawl. J Sci Med Sport 2011;14:168.e1-168.e5. Doi: 10.1016/j.jsams.2010.08.004
16. Figueiredo P, Nazario R, Sousa M, Pelarigo JG, Vilas-Boas JP, Fernandes R. Kinematical Analysis along Maximal Lactate Steady State Swimming Intensity. J Sports Sci Med 2014;13(3):610-5.
17. Capelli C, Pendergast D, Termin B. Energetics of swimming at maximal speed in humans. Eur J Appl Physiol 1998;78:385-93. Doi: 10.1007/s004210050435
18. Dekerle J, Brickley G, Alberty M, Pelayo P. Characterising the slope of the distance–time relationship in swimming. J Sci Med Sport 2010;13:365-370. Doi: 10.1016/j.jsams.2009.05.007
19. Bradford CD, Lucas SJ, Gerrard DF, Cotter JD. Swimming in warm water is ineffective in heat acclimation and is non-ergogenic for swimmers. Scand J Med Sci Sports 2015;25 Suppl 1:277-286. Doi: 10.1111/sms.12351

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