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Influence of hand paddles and fins on blood lactate, heart rate and perceived exertion behavior

Influência do uso de palmares e nadadeiras no comportamento do lactato sanguíneo, da frequência cardíaca e do esforço percebido

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Abstract – One of the great challenges for swim coaches is proper control of the training intensity. This issue is more complex when using equipment such as paddles and fins. Among intensity control parameters, blood lactate concentration is the standard for monitoring metabolic responses, and heart rate and perceived effort are practical and inexpensive methods. The aim of this study was to compare blood lactate concentration ([LA]), heart rate (HR) and rate of perceived exertion (RPE) in swimming training series without equipment and with paddles and fins. We evaluated 11 swimmers on three different days during sessions in a series of 12 repetitions of 50 m in front crawl. The first session was performed without equipment, maintaining perception exertion at 15 (15 points) of the 6-20 point Borg scale. In the second and third sessions, athletes should swim in the series with: (i) paddles and (ii) fins, at the same swimming speed of the series without equipment, in random order. [LA], HR and RPE at rest (after warm-up and before swimming series) and after the sixth and 12th repetitions were measured and compared. The mean speed for all series was 1.30 ± 0.13 m.s^{-1}; fins and paddles presented lower final [LA] (respectively, 5.9 ± 0.3 and 8.1 ± 0.4 mmol.l^{-1}) and HR values (respectively, 161.1 ± 15, 5 161.1 and 170.3 ± 13.3 170.3 bpm) in comparison to series without equipment (respectively, 10.8 ± 0.7 mmol.l^{-1} and 178.2 ± 4.3 bpm). Fins had lower final RPE values (12.5 ± 0.6 points) in relation to series without equipment (15.8 ± 0.2 points) and similar values in relation to swimming with paddles. Swimming series with equipment produced lower physiological demands in relation to swimming without equipment if performed at the same swimming speed as swimming without equipment.

Key words: Metabolism; Performance; Swimming.

Resumo – *Um dos grandes desafios para treinadores de natação é o adequado controle da intensidade de treino. Essa questão é mais complexa quando utilizados equipamentos como palmares e nadadeiras. Dentre os parâmetros de controle de intensidade, a concentração sanguínea de lactato [LA] é padrão para acompanhamento de respostas metabólicas, e a frequência cardíaca (FC) e o esforço percebido (EP) são métodos práticos e baratos. Esse estudo teve como objetivo comparar a concentração sanguínea de lactato, a frequência cardíaca e o esforço percebido em série de treinamento de natação sem equipamentos, com palmares ou com nadadeiras. Foram avaliados 11 nadadores em três diferentes dias durante série de 12 repetições de 50 m nado crawl. A primeira foi realizada sem equipamentos mantendo a percepção relativa ao escore 15 da escala de 6 a 20 pontos de Borg. A segunda e terceira séries os atletas realizavam (i) utilizando palmares e (ii) utilizando nadadeiras, na mesma velocidade de nado da série sem equipamentos, em ordem aleatória. Foram mensuradas e comparadas [LA], FC e EP nos momentos repouso (pós-aquecimento e antes da série), após a sexta e a 12ª repetições. A velocidade média para todas as séries foi de1,30 ± 0,13 m.s^{-1}; nadadeiras e palmares apresentaram menores valores finais de [LA] (respectivamente, 5,9 ± 0,3 e 8,1 ± 0,4 mmol.l^{-1}) e de FC (respectivamente, 161,1 ± 15,5 e 170,3 ± 13,3 bpm) em relação ao nado sem equipamentos (respectivamente, 10,8 ± 0,7 mmol.l^{-1} e 178,2 ± 4,3 bpm). O nado com nadadeiras apresentou menores valores finais de EP (12,5 ± 0,6 pontos) em relação ao nado sem equipamentos (15,8 ± 0,2 pontos) e similares valores em relação ao nado com palmares. Séries de natação com equipamentos produzem menores demandas fisiológicas em relação ao nado sem equipamentos se realizadas na mesma velocidade de nado que o nado sem equipamentos.*

Palavras-chave: *Desempenho; Metabolismo; Natação.*

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INTRODUCTION

Swimming performance depends on the interrelationship between biomechanical and physiological aspects. In order to swim faster, a swimmer must increase his final propulsion, which depends on the force applied by the swimmer and the drag when moving in the water environment[1]. Thus, swimming training presents different contents (swimming techniques, exits and turns, physiological capacities) and methods (series of continuous and interval swimming at different intensities), which aim at reaching the technical and physiological conditions that allow increasing final propulsion (increase of propulsive force, reduction of drag, or combinations of these) and, consequently, increase swimming speed and performance[2].

Different means are also used to increase the force used by swimmers against water, such as paddles and fins. These devices artificially increase the propulsive areas of hands and feet, respectively, allowing performing force against greater volume of water[3]. Paddles and fins are used in order to increase the swimmer's strength in a specific way and, in the long-term, improve performance.

There are several studies on the kinematic and kinetic changes in swimming in response to the use of paddles[4,5] and fins[6-8]. However, studies that identify the physiological responses to the use of these devices seem to be scarce[9,10], especially during training series. Blood lactate concentration (LA), heart rate (HR) and rate of perceived exertion (RPE) are variables related to exercise intensity and tend to change in response to metabolic demands and fatigue ([LA][11], HR[12] and RPE[13]). They are control intensity parameters used in the training of various modalities, such as swimming[14].

Swimming teams formed by numerous athletes training simultaneously are a challenge for the proper control of the training intensity. In addition, [LA], although recognized as the standard for monitoring metabolic responses, is often difficult to use in daily training, basically due to economic and logistic issues[15]. On the other hand, HR and RPE are practical and inexpensive methods that can provide important information regarding the intensity used and the physiological status of swimmers[16,17].

In swimming training, it is common to use time (related to swimming speed) as a parameter to control the swimming intensity[18]. Swimming speed depends on the relationship between the average distance traveled for each stroke cycle and the average frequency of stroke cycles[19] and maintaining constant swimming speed can be a challenge for swimmers. Thus, underwater visual pacer has been used in several studies that require constant swimming speed[20-22].

Considering the systematic use of paddles and fins[3] by swimmers of different levels and the need for adequate control of swimming intensities, this study aims to compare blood lactate concentration, heart rate and perceived exertion in a series of swimming training without equipment (free swimming), and with paddles and fins. It has been hypothesized that the use of paddles and fins will reduce the magnitude of the response of intensity indicators ([LA], HR and RPE) when swimming speed is maintained constant and equal to the swimming speed without equipment.

METHODOLOGICAL PROCEDURES

Eleven male swimmers (25.8 ± 5.5 years of age, 75.2 ± 9.0 kg of body weight, 177 ± 6.5 cm of height and 185 ± 7.2 cm of wingspan) affiliated to the Brazilian Confederation of Aquatic Sports participated in this study. All had at least 4 years of competitive experience, trained 4 to 6 times a week for at least 60 minutes per session and had experience in the use of paddles and fins in their training routines. The average performance in the 50 m free-swim competition obtained was 28.51 ± 2.09 s. This study was analyzed and approved by the Research Ethics Committee of the Universidade Federal do Rio Grande do Sul (protocol No. 20442). Participants received detailed information about the research, protocols, risks and benefits, verbally and through a Free and Informed Consent Form (FICF), which was signed by participants.

Swimmers attended three times at the data collection site, for three sessions, at 48 h intervals. A 25 m thermal and indoor pool with water temperature of approximately 29.5°C was used for protocols. In the first session, general information of participants and anthropometric data were obtained. Then, 800 m free swimming and low intensity warm-up was performed, similar to that performed in the daily training of participants in relation to intensity and duration. Ten minutes after warm-up swimming, interval swimming series of 12 repetitions of 50 m in front crawl stroke was performed in perception relative to score 15 of the 15-point (6-20) Borg scale[23] (free swimming series - FSS). This RPE value was based on previous studies that verified the use of RPE in an incremental swimming series[18] and in the training of swimmers' aerobic capacity[24]. All repetitions were timed by two experienced swimming coaches for later calculation of the mean swimming speed (for each repetition, the mean swimming speed was calculated for the quotient between 50 m and the time in seconds to complete 50 m, then mean swimming speed of the series was calculated - MSS). Swimmers were allowed a 30-s interval between each 50-m repetition. Swimmers received no feedback regarding the time of each repetition, but were instructed throughout the series to swim in the recommended perceived effort (Borg 15).

In subsequent sessions (sessions 2 and 3), swimmers repeated the series of 12 repetitions of 50 m in front crawl stroke, but once with paddles (PS, Catalyst TYR® in high density polyethylene of 300 cm^2 of area) and again with fins (FS, Kpaloa®, semi-rigid vulcanized rubber, 488 cm^2 of area). The order of execution of series with paddles and fins was defined in a randomized way among participants. The swimming speed for the performance of series with paddles and fins was the individual MSS, controlled with the use of an underwater visual pacer with lamps placed immediately below the swimmer, on the marking of the pool bottom, one meter apart between each lamp. The lamps lighted up at the programmed individual speed after its determination in the series in free swimming.

In the three series (free, paddles and fins), lactate concentration (LA), heart rate (HR) and rate of perceived exertion (RPE) data were collected at three moments: (i) at rest, at which point athletes sit for 10 minutes resting before resuming warm-up; (ii) immediately after the sixth repetition of 50 m (rep6); and (iii) immediately after the last repetition of 50 m (rep12). At all collection times, participants remained in the water, standing upright, with water approximately at the height of the xiphoid appendix, on a depth-reducing platform.

[LA] was determined by means of a drop of blood obtained from the distal end of the right hand index finger. Blood was analyzed on a portable lactometer (Accutred Plus, Roche®). HR was measured by means of a cardiotacometer (Polar FT1), which belt was placed on the swimmer's chest at collection times. HR was measured immediately after the swimmer arrived at each time of analysis and did not take more than 2 s between completing the repetition and starting the HR recording. The highest HR in each record was used. RPE, determined based on the 15-point (6-20) Borg scale, was obtained by means of a poster with the scoring and scale attributes. The poster was easily viewed by participants at all collection times. Participants were previously familiarized to using the Borg scale in their training. Figure 1 shows the time sequence of procedures.

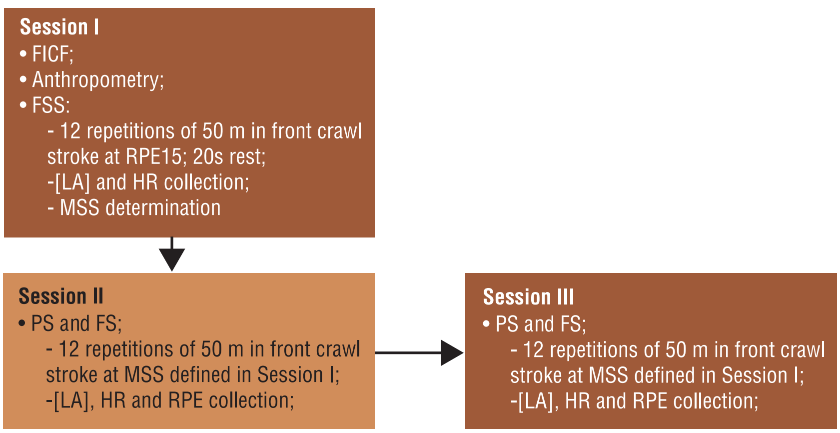

Figure 1. Design of experimental procedures; FICF: free and Informed Consent Form; FSS: free swimming series; PS: paddles swimming series; FS: fins swimming series; [LA]: blood lactate concentration; HR: heart rate; RPE: rate of perceived exertion and MSS: mean swimming speed.

For the data analysis, normality and sphericity were tested, respectively, with Shapiro-Wilk and Mauchly tests. Mean, deviations and confidence intervals of the means (95%) were calculated. In order to identify if swimmers started free swimming in similar conditions, swimming with paddles and fins, a repeated measures ANOVA was performed on [LA], HR and RPE at rest. To identify if the swimming speed was stable in the 12 free-swimming repetitions in REP 15, a repeated-measures ANOVA was performed with speed values of each 50-m repetition. ANOVA in a mixed model with two factors (3x2) was used to verify the possible effects of swimming conditions (free swimming, paddles and fins), evaluation moments (rep6 and rep12) and possible interactions between these factors on [LA], HR and RPE. When necessary, and identified by the degrees of freedom of the Fischer's exact test, Greenhouse-Geisser's Epsilon correction factor was used. Deployments were performed whenever interaction was significant, with application of repeated measures ANOVA, either for swimming condition factor or for evaluation moment. To compare RPE, simple Student t tests were applied between the value 15 (free swimming) and the values identified in (rep6 and rep12) of each series (paddles and fins). Principal effects were identified with Bonferroni test and effect size was calculated with eta^2 statistic. The eta^2 interpretation followed: small effect size ($eta^2 \geq 0.02$), medium ($eta^2 \geq 0.13$) or large effect size ($eta^2 \geq 0.26$)[25]. Analyses were performed using the SPSS 23.0 software, for alpha <0.05.

RESULTS

When rest was analyzed, no significant differences were found for [LA] ($p> 0.05$, $F = 2.40$), HR ($p> 0.05$, $F = 2.60$) and RPE ($p> 0.05$, $F = 1.24$), demonstrating that athletes started the tests always under the same conditions. MSS, identified in the free-swimming series and maintained in the paddles and fins series, was presented as mean and standard deviation, 1.30 ± 0.13 $m.s^{-1}$. The swimming speed in the swimming series without equipment at EP 15 was constant, with no effect of repetitions ($F_{11.110} = 0.98$, $p = 0.46$). Considering the average swimming speed and the intervals, the three series (free-swim, paddles and fins) lasted approximately 13 min. Table 1 shows the two moments of analysis, under conditions without equipment, with paddles and fins when the physiological variables [LA], FC and RPE were evaluated.

For [LA], swimming without equipment presented higher lactate concentrations compared to swimming with paddles and fins. For HR, swimming with fins had lower beats per minute compared to swimming with paddles and without equipment. Finally, for RPE, there were differences in relation to the effort 15 of swimming without equipment and rep6 and rep12 of swimming with paddles and rep6 and rep12 of swimming with fins (Table 1).

DISCUSSION

The aim of this study was to compare [LA], HR and RPE in free-swimming (swimming series performed without equipment) and with paddles and fins, always in front crawl stroke. For this, the mean swimming speed relative to the perception 15 of the Borg scale was identified, in series of 12 repetitions of 50 m, without equipment. Keeping this speed controlled and constant, two other series at the same volume were carried out: one with paddles and the other with fins. The main results of this study are, when swimming speed is constant (compared to the mean swimming speed performed at RPE 15 without equipment) and controlled: (i) swimming with fins has lower [LA], HR and RPE values in relation to free swimming; (ii) swimming with paddles has lower [LA], HR and RPE values in relation to free swimming; and (iii) swim with fins has lower [LA] and HR values compared to swimming with paddles. In this way, the hypothesis that the

Table 1. Mean ± standard deviation and upper and lower limits of the confidence interval of the mean (95%) blood lactate concentration, heart rate and perceived exertion values.

		REP6	REP12	Comparison between REP 6 and REP 12 in the same condition
[LA]	FSS	10.1 ± 2.9 (8.2 – 11.9)	10.8 ± 2.5 (9.1 – 12.5)	F1,10=4,01; p=0,07; eta^2=0,3
	PS	7.6 ± 1.4 (6.6 – 8.5)	8.1 ± 1.7 (7.1 – 9.3)	
	FS	5.7 ± 1.1 (5.1 – 6.4)	5.9 ± 1.1 (5.2 – 6.7)	
Comparison between (SE, CP CN) in the same repetition		F2.20=12.8; p=0.001; eta^2= 0.56	F2.20=16.6; p=0.001; eta^2= 0.65	Interaction F2.20=0.41; p=0.66; eta^2=0.04
HR	FSS	173.7 ± 13.7 (164.4 – 182.9)	178.9 ± 14.7 (168.26 – 188.1)	F1,10=4,36; p=0,06; eta^2=0,3
	PS	169.7 ± 14.9 (159.3 – 179.5)	170.3 ± 13.2 (161.4 – 179.2)	
	FS	157.9 ± 15.2 (147.6 – 168.1)	161.1 ± 15.5 (150.7 - 171.5)	
Comparison between (SE, CP CN) in the same repetition		F2.20=16.9; p=0.001; eta^2= 0.62	F2.20=20.8; p=0.001; eta^2= 0.67	Interaction F2.20=0.68; p=0.51; eta^2=0.06
RPE	FSS	15 Prescribed value	15 Prescribed value	
	PS	14 ± 2 (13 – 15)	14 ± 1 (13 – 15)	
	FS	12 ± 2 (11 – 14)	13 ± 2 (11 – 14)	
Comparison between (FSS, PS, FS) in the same repetition		t10=-2.71; p=0.02	t10=-3.63; p=0.01	
Comparison between (PS and FS) in the same repetition		t10=-5.01; p=0.01	t10=-3.83; p=0.03	

[LA] blood lactate concentration, HR heart rate, RPE rate of perceived effort at moments after the 6th repetition (rep6) and 12th repetition (rep12), under conditions without equipment (FSS), with paddles (PS) and with fins (FS).

use of fins and paddles, when swimming speed is kept constant and equal to the swimming speed without equipment, produces lower metabolic indicators values ([LA], HR and RPE) was confirmed.

While the swimming speed in the paddles and fins series was kept constant and equal to the mean swimming speed of the free-swimming series, the relationship between final propulsion, propulsive force and drag[1] should be considered to more fully understand the results found here. The final propulsion of a swimmer is the difference between the force applied to the water and the drag found when moving. Swimmers, in the paddles and fins series, obtained greater force applied to a same drag (considering that the drag is dependent on the product between the squared speed and a constant that incorporates anthropometric, environmental characteristics and gravity). Thus, as the average speed was the same without and with equipment, swimmers applied greater propulsive force and received the same drag, resulting in greater final propulsion, but with less physiological demand. It is also worth mentioning the possible contribution of both paddles and fins in the best position of the body, which could contribute to less drag at the same swimming speed[7].

For the present study, no spatiotemporal variables were measured, such as mean stroke rate and mean distance traveled per stroke cycle . However, it should be noted that at maximum swimming intensity, the use of paddles may cause stroke rate decreases, in hand speed during underwater movements and increases in mean distance traveled per stroke cycle and mean swimming speed[9,26]. It is believed that the higher swimming speed with paddles is not dependent on high energy production, but rather on high propulsive efficiency generated by the artificial increase of the swimmer's hand area[11]. When spatiotemporal variables were analyzed with the use of fins, it was observed that their use is associated with approximately 20% stroke rate reductions when compared to conventional swimming at equal swimming speeds[8]. The decrease in stroke rate may be due to both the increase in the production of lower limb propulsive forces, which may influence strokes, and lower limb movements during crawl swimming, which attenuate the vertical oscillations of the hip[3,6].

The [LA], HR and RPE values reached in all series are indicators of intensity of at least anaerobic threshold[18]. However, the reduced duration of series (≈13 min; 600 m), the interval of 30 s between each repetition lasting approximately 34.5 s; the age of swimmers (≈25.5 years) and the time dedicated to daily training (≈60 min) should be considered. That is, even though the swimming series has been reduced compared to what is normally prescribed for high-level swimmers in anaerobic threshold series[18], swimmers in this study performed all series at high intensity. However, the lower physiological demands observed in paddles and fins series indicate that the free swimming series was more intense and with greater anaerobic participation in relation to series with equipment.

Lower [LA], HR and RPE values throughout the paddles series, both in comparison to free-swimming and swimming with fins, may be related to the better horizontal position of the swimmer's body, greater propulsive efficiency of lower limbs[6-8] and greater swimming economy at submaximal velocities (small fins)[6-8]. With paddles, but especially with fins, it is assumed that the energy used could be predominantly from aerobic routes, compared to free-swimming series. On the other hand, the greater similarity between free and swim with paddles in relation to [LA] was previously identified when conditions with and without paddles were compared at the same stroke frequency at submaximal intensities[26], at swimming speeds below, above and at maximum aerobic velocity[27,28] and at maximum swimming speed[9].

The HR results of the present study were similar to those found in continuous swimming tests (values of 178 ± 8 beats per minute) performed by Zacca et al. (2016) at critical speed determined by an equation of four parameters and intensity close to the anaerobic threshold in young swimmers[15]. The larger effect size of the swimming conditions on HR (0.73 compared to [LA] (0.63)) is highlighted. In other words, HR seems to be a more sensitive than LA and RPE to the use of equipment when swimming speed is constant and controlled. It was observed that FSS swimming represents a higher physiological demand in relation to [LA], HR and RPE compared to PS and FN swimming. It could be even postulated that they represent domains of distinct intensities. However, for greater certainty of this sentence, oxygen uptake information is needed[29,30].

Considering the results of this study, when paddles and fins are used, in order to increase load, coaches should be attentive to the lower metabolic demands when swimming is performed at a speed similar to free swimming. As paddles and fins require lower [LA], HR and RPE, these implements may depend on the training purpose, they do not represent the physiological reality of the intensity, swimming speed that the coach wants when comparing swimming without and with equipment. In order to achieve the objectives of such equipment, the swimming speed must be increased in series with paddles and fins. In addition to the non-invasive physiological parameters (HR and RPE) and swimming speed, coaches could monitor, throughout the training series, the frequency of stroke cycles and the distance traveled by the swimmer's body at each stroke cycle[19]. This control in order to guarantee that the swimming speed is reached in a technical way with these equipment, that is, the smaller frequencies and to greater distances traveled with each stroke cycle.

CONCLUSION

Swimming series in crawl swimming with controlled and constant swimming speed with paddles present lower [LA], and RPE in comparison to swimming without equipment. Swimming with fins showed lower [LA], HR and RPE compared to swimming without equipment. Swimming with paddles showed higher [LA] and HR compared to swimming with fins. Heart rate and blood lactate concentration are intensity control parameters that are more sensitive to the use of these equipments in swimming training.

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