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Natação de salva-vidas: nado crawl e nado de aproximação, eficiência propulsiva da braçada e cinemática

Lifeguard swimming: front-crawl and up-head front-crawl, arm-stroke efficiency, and kinematics

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Abstract: This study compared the arm-stroke efficiency, kinematics, and performance and verified the effects of three weeks of preparatory training on the front-crawl (FC) and the up-head front crawl (UH) performed by lifeguards. Fifty-seven male military lifeguards (33.5 ± 5.9 years; and 8.2 ± 5.8 years of experience) performed two sets of tests in a pond, pre- and post- three weeks of training: (i) 200 m FC all-out (T200), and (ii) two 20 m trials, one in FC and other in UH. We highlight: the arm-stroke efficiency was higher in FC (respectively pre- and post: 26.9±4.3 and 26.8±3.8%) than in UH (respectively pre- and post: 22.0±3.0 and 21.9±2.9%) and the training period did not change the arm-stroke efficiency ($p>0.05$). FC T200 performance has improved after the training period (254±31 vs 247±33 s; $p=0.001$). Three weeks of specific training of lifesaving improved the lifeguards swimming endurance capacity.

Keywords: *Lifesaving; Swimming; Biomechanics; Drowning.*

Resumo: Este estudo comparou a eficiência propulsiva da braçada, a cinemática e o desempenho no nado crawl (FC) e no nado de aproximação (UH) e verificou os efeitos de três semanas de treinamento realizados por salva-vidas. Cinquenta e sete salva-vidas militares do sexo masculino (33,5 ± 5,9 anos; e 8,2 ± 5,8 anos de experiência) realizaram dois conjuntos de testes em um lago, antes e depois de três semanas de treinamento: (i) 200 m de FC (T200) e (ii) dois testes de 20 m, um em FC e outro em UH. Destacamos: a eficiência propulsiva da braçada foi maior no FC (respectivamente pré e pós: 26,9±4,3 e 26,8±3,8%) do que no UH (respectivamente pré e pós: 22,0±3,0 e 21,9±2,9%) e o período de treinamento não alterou a eficiência da braçada ($p>0,05$). O desempenho no T200 melhorou após o período de treinamento (254±31 vs 247±33 s; $p=0,001$). Três semanas de treinamento específico de salva-vidas melhoraram a capacidade de resistência de natação dos salva-vidas.

Palavras-chave: *Guarda-vidas; Natação; Biomecânica; Afogamento.*

1. INTRODUCTION

Drowning is one of the leading causes of accidental death worldwide[1] and between 2010 and 2019, drowning was the cause of more than 2.5 million deaths worldwide[2]. Thus, the activity of lifeguards (LG) is essential in all environments that pose a risk of drowning. The LG activity has specific characteristics, such as the need to have a certain skill in swimming, in addition to knowledge of the environment and specific rescue techniques[3]. Among the phases of an aquatic rescue performed by LG, the approach to the drowned stands out[3]. The swimming approach phase is essential during water rescue, as a fast displacement allows a quick LG's arrival to the drowned and a good approach swim provides a good view of the drowned. In this way, swimming receives great importance in the training period of LG.

Over the approach phase, it is the LG's goal to reach the drowned as quickly as possible. Therefore, LG sometimes uses front-crawl stroke (FC), which is the fastest swimming among the known swimming strokes[4]. On the other hand, to approach the victim, the LG needs to raise his head from the water to keep the victim and the environment in his field of vision, thus, LG performs the up-head front-crawl (UH) stroke[3]. The UH, due to the elevated head, presents a lower hip position, which increases drag[5–6] and energy cost[3].

To our knowledge, there are few studies that have evaluated the LG's swimming technique[3]. As much as swimming is just one of the phases of rescue, it is essential, as it defines the time of arrival to the victim, which can be decisive for the success of the rescue. Given this lack, this study sought to investigate biomechanical parameters of swimming strokes performed by LG who participated in training prior to the summer season. Thus, through the arm-stroke efficiency (ηp)[7–8] and global swimming kinematics (average swimming speed v, stroke rate SR, stroke length SL, and stroke index SI)[9–10], this study sought to characterize the LG swimming kinematics and verify possible effects of three weeks of training for aquatic rescue in LG.

As most of the generated power by the swimmer accelerates water in non-propulsive direction, the ηp is defined as the percentage of force generated by the arm-stroke that takes the body forward[7–8]. It is estimated that the arm-stroke, in the FC, is responsible for approximately 90% of the total swimming speed[11], so the ηp can be assumed to represent the entire efficiency of the front crawl stroke. The ηp can be estimated in a simplified model considering (i) the distance between the center of the shoulder and the center of the hand at the end of the pulling phase, (ii) the v, and the SR[7].

Thus, this study compared the arm-stroke efficiency, kinematics, and performance and verified the effects of three weeks of preparatory training on the front-crawl (FC) and the up-head front crawl (UH) performed by lifeguards. We hypothesized that (i) due to the UH body position, better efficiency indicators (ηp and SL) will be found in FC compared to UH; (ii) three weeks of training will be enough to improve the parameters of efficiency and kinematics of both strokes; and (iii) three weeks of training will improve the lifeguards' performance in the 200 m FC test.

2. METHODS

Fifty-seven male military LGs participated in this study (age: 33.5 ± 5.9 years; total body mass: 84.7 ± 10 kg; height: 177.4 ± 5.1 cm; and 8.2 ± 5.8 years of experience as LG). Minimum sample size (52) was previously calculated in G*Power 3.9.9.7 software (Kiel, Germany) for application of factorial ANOVA (2×2): effect size 0.2; alpha: 0.05; statistical power: 0.8. This study was duly approved by the local Research Ethics Committee (nº 75651417.4.0000.5347) and followed the recommendations of the Helsinki protocol for human research ethics.

Data collection

Data were collected at the beginning and the end of the training period (three weeks) for the LG summer season. At the beginning, anthropometric data were measured. Age and experience were obtained from the participants' identification sheets. The swimming tests were carried out in a pond with conditions like those normally encountered by LGs in rescue tasks. On the first evaluation day, after a 10-minute low-intensity swimming warm-up, each LG performed a 200 m FC test (T200) in a straight line with free breathing. The

T200 time was recorded by three experienced timekeepers. On the second day of evaluation, each LG performed two repetitions of 20 m all-out, one in FC (T20FC) and one in UH (T20UH), randomly, with 15 minutes of passive rest interval. In both (T20FC and T20UH), they used a 600 g belt with a 2 m extension rope attached to the rescue buoy, as used in rescue situations.

A straight rope (30 m, stuck between two banks), with markings every 5 m, served as a reference for LG and researchers. Five experienced timekeepers, placed on a parallel platform to the 30 m centre, recorded, in each trial: time to swim the intermediate 10 m and time to perform three complete stroke cycles in the intermediate 10 m. Thus, the kinematic parameters were calculated: mean swimming speed (v, $m \cdot s^{-1}$), mean stroke rate (SR, $cycles \cdot min^{-1}$), mean stroke length (SL, m), and mean stroke index (SI, $m^2 \cdot s^{-1}$).

The mean arm-stroke efficiency (ηp, %) was calculated using the simplified model previously proposed[7–8], where $\eta p = (v \cdot 0.9) / (2\pi \cdot SR \cdot L)$, considering v as the average swimming speed, SR as the mean stroke rate (in Hz), and L as the linear distance (m) between the center of the shoulder and the center of the hand when the hand is just below the shoulder. L, in this study, was assumed to be 0.5 m, as already described[7–8]. Three weeks later, the same tests were performed in the same place, with similar atmospheric conditions (atmospheric temperature ≈ 28ºC and water temperature ≈ 23ºC).

Training weeks

The LG training, over the three weeks, was carried out with a total workload of ≈ 166 hours, 8 hours a day, with 60% of the hours in theoretical and practical training and 40% in supervised rescue training. The practical part was divided into specific physical training, swimming technique, and water rescue technique. Initially, the lifeguards performed an adaptive part of swimming in sheltered waters (pond). From the 5th day of training, they began to perform activities at the sea. The activities in the pond sought to improve swimming techniques, since there is no interference from currents and waves, and it is a more controlled environment. Allied to swimming activities, the LG also performed a routine of running and strength training exercises, aiming to improve their general physical conditioning. From the 2nd week of training, activities began to focus on improving the technique of aquatic rescue and sea waves transposition.

Statistical procedures

The Shapiro-Wilk test was applied and means, standard deviations and limits of the confidence interval of the mean (95%) were calculated. Dependent t test and Cohen's d test were applied to the T200 results. Effect size, by Cohen's d, was categorized as: 0–0.19 trivial, 0.2–0.59 small, 0.6–1.19 moderate, 1.2–1.99 large, 2.0–3.99 very large, >4.0 almost perfect[12]. Mixed model ANOVA (two strokes and two moments) was applied to all variables between the T20FC and T20UH. Interactions between FC and UH and moments (pre- and post-training) were tested. Effect sizes were identified by calculating eta^2 and categorized as[12]: small ($eta^2 \geq 0.01$), medium ($eta^2 \geq 0.06$) or large ($eta^2 \geq 0.14$). To verify results' reliability, Intraclass Correlation Coefficients (ICC) were applied in all paired data (pre- and post-training). Alpha was set at 5% and calculations were performed in SPSS, v. 20.0.

3. RESULTS

Figure 1 shows the ηp of both T20FC and T20UH, at the two evaluation moments (panel A) and the performance at T200 (panel B). The mean ηp limits of the confidence interval in the FC were, respectively, pre- and post-training: 25.8 to 28.1% and 25.7 to 27.8%. For the UH, the limits were, respectively, pre- and post-training: 21.4 to 23.0% and 21.1 to 22.7%. For the ηp, the three weeks training had a medium, but not significant effect ($p = 0.093$; $eta^2 = 0.049$), the swimming stroke (FC and UH) had a large and significant effect ($p < 0.001$; $eta^2 = 0.60$) and there was no interaction between swimming and moment ($p = 0.65$; $eta^2 = 0.004$). In the FC, for the ηp, the ICC was 0.96 ($p<0.001$), and in the UH, for ηp, the ICC was 0.94 ($p<0.001$). The FC T200 performance limits of the confidence intervals were, respectively, in the pre and post moments, 245.7 to 262.8 s and 238.6 to 256.9 s. Performance improvement can be seen at the FC T200 ($p = 0.001$) with moderate effect size ($d = 0.61$) of the three weeks of training. For the FC T200 performance, ICC was 0.94 ($p<0.001$).

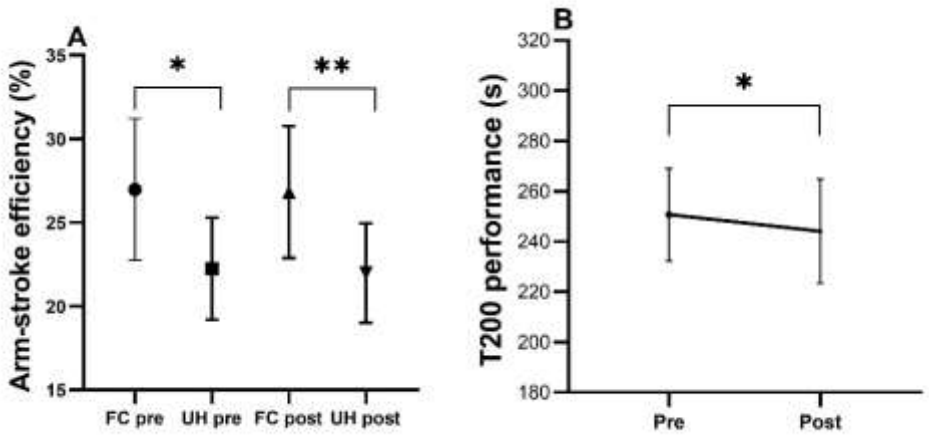


Figure 1. *(A) Arm-stroke efficiency in T20FC and T20UH, pre- and post-training period; n = 57. * and ** p < 0.001. (B) FC Performance on the T200 pre- and post-training period; n = 57; * p = 0.001; d = 0.61.*

Table 1 shows the kinematic data of both FC and UH, in the pre- and post-training period. There were no statistical training effects (small effect sizes), nor statistical interaction between strokes and moments. On the other hand, FC presented higher values than UH, with large effect sizes, in v ($p < 0.001$; $eta^2 = 0.34$), SL ($p < 0.001$; $eta^2 = 0.6$) and SI ($p < 0.001$; $eta^2 = 0.64$), and lower SR values than UH ($p < 0.001$; $eta^2 = 0.36$). In the FC, the ICC results varied from 0.96 to 0.97 (all $p<0.001$) and in the UH, ICC results varied from 0.93 to 0.97 (all $p<0.001$).

Table 1. *Means ± standard deviations [means limits of the confidence interval – 95%] of mean swimming speed (v), stroke rate (SR), stroke length (SL), and stroke index (SI) of front-crawl and up-head front crawl, pre- and post-training period; n = 57.*

	Front crawl (T20FC)		Up-head front crawl (T20UH)	
	Pre	**Post**	**Pre**	**Post**
v **(m·s⁻¹)**	1.11 ± 0.11 [1.08; 1.14]	1.11 ± 0.10 [1.09; 1.14]	1.04 ± 0.09 [1.02; 1.07]	1.04 ± 0.08 [1.02; 1.06]
SR **(cycles·min⁻¹)**	45.6 ± 7.4 [43.6; 47.6]	45.5 ± 6.8 [43.7; 47.4]	51.5 ± 7.2 [49.6; 53.4]	52.1 ± 6.8 [50.3; 53.9]
SL **(m)**	1.49 ± 0.23 [1.43; 1.56]	1.49 ± 0.21 [1.43; 1.54]	1.23 ± 0.16 [1.20; 1.28]	1.22 ± 0.16 [1.17; 1.26]
SI **(m²·s⁻¹)**	1.68 ± 0.35 [1.58; 1.77]	1.66 ± 0.33 [1.57; 1.72]	1.30 ± 0.24 [1.23; 1.36]	1.28 ± 0.24 [1.21; 1.36]

4. DISCUSSION

This study was carried out to compare the arm-stroke efficiency, kinematics, and performance and verified the effects of three weeks of preparatory training on the front-crawl (FC) and the up-head front crawl (UH) performed by lifeguards, considering the specificities of the techniques performed by lifeguards. The FC presented higher values of arm-stroke efficiency (ηp), swimming speed (v), stroke length (SL), and stroke index (SI) and lower values of stroke rate (SR) than the UH. The three-week preparatory training was not able to significantly alter these parameters, although T200 performance has improved. Thus, the first and third hypotheses of this study were confirmed (respectively, better efficiency indicators will be found in FC compared to UH; and three weeks of training will improve the lifeguards' performance in the 200 m FC test). However, the second hypothesis was refuted (three weeks of training will be enough to improve the parameters of efficiency and kinematics of both strokes).

LG should, when locating and approaching a possible drowning victim, perform the UH to keep the victim and the environment in their field of vision. However, when keeping the head high, with the face out of the water, the hips and lower limbs tend to sink, which increases the drag[6]. This characteristic of the UH is the possible cause of the lower values of ηp, v, SL and SI, and the higher SR in relation to FC. As drag increases, the swimmer, to keep a similar speed, must increase the force applied to the water. However, if the technique is not adequate, this change will not be effective, leading to an increase in the SR, which causes the decrease in the ηp, SL, and SI. Previous study[3] has already identified that UH has a greater energy cost than the FC (≈20% higher) in LG performing 100 m in swimming pool (1.90±0.33 kJ·min^{-1} vs. 1.51±0.24 kJ·min^{-1}). In this way, LG must choose the best moment, in a rescue situation, to change from FC to UH to reach the victim quickly and in a position to carry out the rescue safely.

When comparing to studies that assessed the ηp with the same simplified method, the ηp of the present study was lower in both FC and UH (≈ 26 and ≈ 22%), even at a slower v (≈1.11 and ≈1.04 m·s^{-1}): 38.0 ± 6.0% (mean v = 1.32 m·s^{-1})[7]; 38.6 ± 1.1% (mean v = 1.52 m·s^{-1})[8], and 36.0 ± 7% (mean v = 0.95 m·s^{-1})[13]. In open water, but over a 2 km test, ηp varied between 34 and 36% (mean v 0.94 to 1.14 m·s^{-1})[14]. The low ηp results in the FC can be explained by the level of the swimmers: competitive in the cited studies[7–8–12–14] and LG in the present study. In the UH, the supposed increased drag leads to even less efficient technique. For both FC and UH global swimming kinematic parameters indicated that LG are, in general, less proficient in swimming than competitive swimmers[9–15–16]. The time dedicated to the modality, the specifics of the LG activity, and the type of training performed justify these differences.

The three-weeks training period, targeting the summer season, did not cause changes in the global kinematic parameters of both techniques, FC and UH, when the T20FC and T20UH were performed. On the other hand, performance on the T200 improved (moderate effect size). The tests carried out in this study are related to power/speed (T20) and endurance/speed (T200), so it can be affirmed that the three training weeks could improve the anaerobic/aerobic endurance of the LG (T200 performance has improved), but not the anaerobic power (same speed in 20 m, for FC and UH). Thus, considering the effects of training[17], if the objective is to increase swimming speed over shorter distances, it is suggested that swimming training, whether FC or UH, also focuses on anaerobic capacities, while controlling the ηp, with swimming technique training, so that the LG does not decrease its efficiency throughout the process[17–18].

5. CONCLUSION

In lifeguards, the arm-stroke efficiency is greater in the FC than in the UH stroke. Three weeks of lifesaving training were not able to improve kinematic parameters and arm-stroke efficiency but improved the total time in the 200 m front crawl test.

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7. APROVAÇÃO ÉTICA

O estudo foi aprovado pelo Comitê de Ética em Pesquisa da UFRGS (CAAE 75651417.4.0000.5347).

8. CONTRIBUIÇÕES DOS AUTORES (CREDIT)

L.F.I.: Conceituação, Metodologia, Coleta de dados, Análise dos dados, Redação do manuscrito, Revisão do manuscrito

F.A.S.C.: Conceituação, Metodologia, Coleta de dados, Análise dos dados, Redação do manuscrito, Revisão do manuscrito

9. CONFLITOS DE INTERESSE

Os autores declaram não haver conflito de interesse.

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