

## Effect of fatigue induced by aerobic power training on performance in water rescue

### *Efecto de la fatiga generada por un entrenamiento de potencia aeróbica en el rendimiento en un rescate acuático*

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### ABSTRACT

**Objective:** High-intensity aerobic training improves the physical fitness of lifeguards, but it may induce fatigue when performed prior to an aquatic rescue. This study examines the effect of an aerobic training session on performance during a simulated rescue.

**Methods:** Twenty professional lifeguards performed two 200-meter aquatic rescues, separated by 72 hours. Before the second rescue, half of the participants completed a high-intensity aerobic training session (Experimental Group, EG), while the other half rested (Control Group, CG). Time variables, heart rate, blood lactate concentration, and perceived exertion were measured.

**Results:** No differences were observed between groups in the first rescue, except for extraction time and total time, where EG was faster ( $p < 0.01$ ). In the second rescue, after the training session, EG showed poorer performance in some phases of the rescue. The training session maintained an intensity of 80–95% of maximum heart rate, confirming its high physical demand.

**Conclusion:** A prior aerobic training session can increase fatigue and negatively impact performance in a subsequent aquatic rescue. It is recommended that workload be carefully planned on lifeguards' workdays to avoid potential operational risks.

**KEY WORDS:** physical fitness, fatigue, water rescue, physical performance, lifeguarding,  $VO_{2max}$

## RESUMEN

**Objetivo:** El entrenamiento aeróbico de alta intensidad mejora la forma física del socorrista acuático, pero puede inducir fatiga cuando se lleva a cabo antes de realizar un rescate acuático. Este estudio analiza el efecto de una sesión de entrenamiento aeróbico sobre el rendimiento en un rescate simulado.

**Métodos:** Veinte socorristas profesionales realizaron dos rescates acuáticos de 200 metros con 72 horas de diferencia. Antes del segundo rescate, la mitad realizó un entrenamiento aeróbico de alta intensidad (GE), mientras que la otra mitad descansó (GC). Se midieron variables de tiempo, frecuencia cardíaca, lactato y percepción del esfuerzo.

**Resultados:** En el primer rescate no se observaron diferencias entre grupos, excepto en el tiempo de extracción y tiempo total, siendo GE más rápido ( $p < 0.01$ ). En el segundo rescate, tras realizar el entrenamiento, el GE mostró peores tiempos en algunas fases del rescate. El entrenamiento realizado mantuvo una intensidad del 80–95% de la FC máxima, confirmando su alta exigencia.

**Conclusión:** Una sesión de entrenamiento aeróbico previa puede aumentar la fatiga y afectar negativamente el rendimiento en un rescate acuático posterior. Se recomienda planificar cuidadosamente las cargas en días laborales de los socorristas para evitar posibles riesgos operativos.

**PALABRAS CLAVE:** aptitud física, fatiga, rescate acuático, rendimiento físico, socorrismo,  $VO_{2max}$

## INTRODUCTION

Lifeguards are responsible for ensuring the safety and well-being of users in aquatic environments such as swimming pools, beaches, and water parks (1). Their professional duties require continuous surveillance, rapid decision-making, and a high level of physical preparedness to respond effectively to emergencies that may arise at any time (2,3).

Also, lifeguards are often the first responders in aquatic emergencies, and their capacity to react promptly and execute technically demanding maneuvers under substantial physical strain may determine the difference between a successful rescue and a fatal outcome (4,5). For this reason, their training should not focus exclusively on technical knowledge and rescue protocols but must also emphasize the maintenance of a level of physical fitness consistent with the real-world demands of the profession (6).

The water rescue process is commonly divided into four distinct phases: water entry, approach, victim tow, and victim extraction (7–9). Each phase imposes different physiological demands on the lifeguard. The approach and towing phases require substantial cardiorespiratory endurance (10–12), whereas the extraction phase additionally demands significant muscular strength and endurance, particularly in the lower limbs (13,14).

Accordingly, it has been established that lifeguards should follow structured training programs combining cardiorespiratory endurance and strength training in order to develop the physical capacities necessary for the effective execution of aquatic rescues (15).

High-intensity aerobic training is widely recommended to improve cardiovascular health, increase maximal oxygen uptake ( $VO_2\text{max}$ ), and optimize performance in endurance-based activities and sports (16,17). However, recent research has shown that acute, high-intensity aerobic exertion may induce temporary fatigue—both central and peripheral (18)—which could impair subsequent physical performance in tasks requiring strength, power, or coordination (19,20).

Accumulated fatigue during a training session may, in the event of a subsequent rescue, delay reaction time and reduce muscular efficiency, potentially compromising both the quality and speed of the intervention. Despite the practical relevance of this issue, scientific literature remains limited. Most studies have focused primarily on identifying the physical (13,21,22) and psychological (3) characteristics of lifeguards.

This raises an important question as to whether an aerobic training session performed prior to an aquatic rescue might negatively affect rescue performance. Furthermore, given that many lifeguards combine work shifts with training sessions within the same day, it is essential to understand the acute effects of exercise on rescue performance to optimize training loads and scheduling.

Therefore, the primary aim of this study was to analyze the impact of an aerobic training session on performance during a simulated aquatic rescue performed by professional lifeguards. Specifically, the study sought to determine whether post-exercise fatigue compromises rescue time and efficiency, thereby providing scientific evidence to optimize physical training planning and periodization in the field of aquatic lifesaving.

## MATERIALS Y METHODS

### *Study Design*

Twenty professional lifeguards registered in the official aquatic lifeguard registry of Galicia participated in this study. Inclusion criteria required participants to be between 18 and 35 years of age and to be physically capable of tolerating the proposed exercise protocol.

Exclusion criteria included failure to demonstrate the physical capacity necessary to tolerate the imposed workload, the presence of psychiatric or neurological disorders that could interfere with adequate comprehension or compliance with the study procedures, and any medical condition identified during screening or testing that could pose a health risk.

The study received ethical approval from the Quality Service of EUM Fray Luis de León, affiliated with the Catholic University of Ávila. All participants provided written informed consent for participation and subsequent use of the collected data. The research adhered to the principles outlined in the Declaration of Helsinki (23).

### *Procedure*

The study was conducted at Oza Beach (A Coruña, Spain). All testing sessions were carried out over two days separated by 72 hours, between 10:00 and 14:00. Environmental conditions were similar on both days, with ambient temperatures ranging from 17–20°C and calm sea conditions.

The study consisted of three distinct phases. Initially, all lifeguards performed a 200-meter aquatic rescue (Rescue1). On the second day, half of the participants completed an aerobic power-oriented training session (Experimental Group, EG = 10), while the remaining participants rested (Control Group, CG = 10). One hour after completing the training session, all lifeguards performed a second 200-meter aquatic rescue (Rescue2).

The 200-meter rescue consisted of: 20 meters of running and water entry, 80 meters of approach swim toward the victim, 80 meters of victim tow, and 20 meters of victim extraction onto the sand, following a protocol similar to that used in previous studies (13). Lifeguards who completed the training session underwent a passive recovery period of one hour without food or fluid intake.

The aerobic power training session included 10 minutes of self-paced warm-up, followed by six sets of running on sand and six sets of freestyle swimming. Each set lasted two minutes, with one minute of recovery between sets.

To ensure appropriate training intensity, participants used a heart rate monitor suitable for both dryland and aquatic training (Garmin Forerunner 735XT®), recording heart rate after each set. Target heart rate intensity was established between 80% and 95% of theoretical maximum heart rate, calculated using the formula proposed by Tanaka et al. (24).

### *Statistical Analysis*

Statistical analyses were performed using SPSS software (SPSS v.27, IBM Corporation, New York, USA). Variables were expressed as absolute and relative frequencies (percentages) or as measures of central tendency and dispersion (mean  $\pm$  standard deviation), depending on variable type.

To analyze differences between the first and second rescues, as well as pre- and post-training effects, a repeated-measures analysis of variance (ANOVA) was conducted with one within-subject factor (Rescue: R1 vs. R2) and one between-subject factor (Group: Experimental vs. Control).

Main effects for both factors and the rescue  $\times$  group interaction were examined to identify differential patterns between groups. Effect sizes were calculated using partial eta squared ( $\eta^2$ ) and interpreted according to conventional thresholds: small ( $\approx 0.01$ ), medium ( $\approx 0.06$ ), and large ( $\geq 0.14$ ).

When significant differences were detected in the mixed ANOVA, post hoc analyses were conducted. Depending on data normality, paired or independent samples Student's t-tests were applied, or their non-parametric equivalents (Wilcoxon signed-rank test and Mann–Whitney U test).

Effect sizes were calculated for all comparisons to estimate the practical magnitude of observed differences. Cohen's d was used for parametric tests, and the r coefficient derived from the Z value was used for non-parametric tests. Effect sizes were interpreted as small ( $d \approx 0.2$ ;  $r \approx 0.1$ ), medium ( $d \approx 0.5$ ;  $r \approx 0.3$ ), and large ( $d \geq 0.8$ ;  $r \geq 0.5$ ). Statistical significance was set at  $p < 0.05$ .

## **RESULTS**

The sample consisted of 20 male lifeguards. Mean age was  $24.2 \pm 3.1$  years, height  $178.3 \pm 6.2$  cm, body mass  $75.0 \pm 7.6$  kg, and BMI  $23.5 \pm 2.1$  kg/m<sup>2</sup>. Resting heart rate was  $58 \pm 5$  bpm, and theoretical maximum heart rate was  $191 \pm 3$  bpm.

No significant differences were found between the control and experimental groups in any anthropometric variable.

Regarding rescue variables, significant differences were observed as a function of rescue in blood lactate levels (LC:  $p = 0.049$ ;  $\eta^2 = .207$ ) and rating of perceived exertion (RPE:  $p = 0.017$ ;  $\eta^2 = .292$ ); as a function of group in extraction time (ET:  $p = 0.023$ ;  $\eta^2 = .269$ ) and total time (TTime:  $p = 0.022$ ;  $\eta^2 = .273$ ); and in the rescue  $\times$  group interaction for extraction time (ET:  $p = 0.006$ ;

$\eta^2 = .365$ ), total time (TTime:  $p = 0.046$ ;  $\eta^2 = .229$ ), and RPE ( $p = 0.006$ ;  $\eta^2 = .364$ ). (Tables 1 and 2).

**Table 1.** ANOVA results for performance variables in both rescues.

Variables	Effect	df	F	p	$\eta^2_p$	Interpretation
RT	Rescue (R1-R2)	(1, 18)	1.971	0.178	.104	No sig. differences
	Group (EG-CG)	(1, 18)	0.826	0.315	.070	No sig. differences
	Rescue x Group	(1, 18)	0.719	0.408	.041	No sig. differences
AT	Rescue (R1-R2)	(1, 18)	0.356	0.558	.021	No sig. differences
	Group (EG-CG)	(1, 18)	1.458	0.244	.079	No sig. differences
	Rescue x Group	(1, 18)	0.990	0.334	.055	No sig. differences
TT	Rescue (R1-R2)	(1, 18)	1.988	0.177	.105	No sig. differences
	Group (EG-CG)	(1, 18)	0.902	0.355	.050	No sig. differences
	Rescue x Group	(1, 18)	0.041	0.843	.002	No sig. differences
ET	Rescue (R1-R2)	(1, 18)	3.412	0.082	.167	No sig. differences
	Group (EG-CG)	(1, 18)	<b>6.253</b>	<b>0.023</b>	<b>.269</b>	<b>Sig. Differences</b>
	Rescue x Group	(1, 18)	<b>9.773</b>	<b>0.006</b>	<b>.365</b>	<b>Sig. Differences</b>
TTIME	Rescue (R1-R2)	(1, 18)	4.370	0.052	.204	No sig. differences
	Group (EG-CG)	(1, 18)	<b>6.396</b>	<b>0.022</b>	<b>.273</b>	<b>Sig. Differences</b>
	Rescue x Group	(1, 18)	<b>4.817</b>	<b>0.046</b>	<b>.229</b>	<b>Sig. Differences</b>

RT: Running Time; AT: Approach Time; TT: Tow Time; ET: Extraction Time; TTIME: Total Time.

df: degrees of freedom; F: Fisher–Snedecor F statistic; p: significance value;  $\eta^2_p$ : partial eta squared. Author's own elaboration.

Comparisons showing statistically significant differences are presented in bold.

Post hoc analyses (CG vs. EG) revealed significant differences in the first rescue in favor of the experimental group for extraction time ( $38.2 \pm 5.2$  vs.  $29.9 \pm 5.8$  s;  $p = 0.005$ ;  $d = 1.50$ ) and total time ( $227.9 \pm 12.3$  vs.  $210.8 \pm 10.4$  s;  $p = 0.003$ ;  $d = 1.58$ ). Higher post-rescue lactate levels were also observed in this group ( $17.1 \pm 1.7$  vs.  $19.0 \pm 1.8$  mmol·L<sup>-1</sup>;  $p = 0.031$ ;  $d = -1.08$ ).

In the second rescue, significant differences were found only in perceived exertion, which was lower in the control group ( $8.2 \pm 0.4$  vs.  $8.9 \pm 0.3$ ;  $p = 0.004$ ;  $d = -1.58$ ).

**Table 2.** ANOVA results for physiological and perceived exertion variables during the rescues.

Variables	Effect	df	F	p	$\eta^2_p$	Interpretation
HR	Rescue (R1-R2)	(1, 18)	0.021	0.866	.001	No sig. differences
	Group (EG-CG)	(1, 18)	3.139	0.094	.156	No sig. differences
	Rescue x Group	(1, 18)	0.464	0.505	.027	No sig. differences
HRmax	Rescue (R1-R2)	(1, 18)	1.001	0.331	.056	No sig. differences
	Group (EG-CG)	(1, 18)	4.014	0.061	.191	No sig. differences
	Rescue x Group	(1, 18)	0.050	0.826	.003	No sig. differences
LC	Rescue (R1-R2)	(1, 18)	<b>4.444</b>	<b>0.049</b>	<b>.207</b>	<b>Sig. Differences</b>
	Group (EG-CG)	(1, 18)	1.421	0.250	.077	No sig. differences
	Rescue x Group	(1, 18)	3.072	0.098	.153	No sig. differences
RPE	Rescue (R1-R2)	(1, 18)	<b>7.016</b>	<b>0.017</b>	<b>.292</b>	<b>Sig. Differences</b>
	Group (EG-CG)	(1, 18)	2.612	0.124	.133	No sig. differences
	Rescue x Group	(1, 18)	<b>9.739</b>	<b>0.006</b>	<b>.364</b>	<b>Sig. Differences</b>

Heart Rate Mean; HRmax: Maximum Heart Rate; LC: Lactate levels; RPE: Rate of Perceived Exertion. df: degrees of freedom; F: Fisher–Snedecor F statistic; p: significance value;  $\eta^2_p$ : partial eta squared. Author's own elaboration.

Comparisons showing statistically significant differences are presented in bold.

No significant differences between Rescue1 and Rescue2 were observed in the control group. In contrast, the experimental group showed significantly worse performance in extraction time ( $29.9 \pm 5.8$  vs.  $34.5 \pm 5.0$  s;  $p = 0.001$ ;  $d = -1.73$ ), total time ( $210.8 \pm 10.4$  vs.  $221.0 \pm 12.1$  s;  $p = 0.025$ ;  $d = -0.91$ ), post-rescue lactate levels ( $19.0 \pm 1.8$  vs.  $17.0 \pm 2.5$  mmol·L<sup>-1</sup>;  $p = 0.026$ ;  $d = 0.90$ ), and perceived exertion ( $8.3 \pm 0.5$  vs.  $8.9 \pm 0.3$ ;  $Z = -2.43$ ;  $p = 0.015$ ;  $r = -0.73$ ).

## DISCUSSION

The findings of the present study demonstrate that a high-intensity aerobic training session significantly impairs subsequent physical performance in a simulated aquatic rescue among professional lifeguards. Specifically, increases in total rescue time and fatigue-related physiological markers—such as post-rescue blood lactate concentration and perceived exertion—were observed, suggesting that exercise-induced fatigue compromises operational efficiency in subsequent interventions.

This finding is particularly relevant in real-world contexts, where lifeguards may be required to perform rescues after engaging in moderate-to-high intensity physical efforts, including logistical tasks, prolonged surveillance patrols, or multiple consecutive interventions (8). The data therefore support the hypothesis that rescue performance depends not only on technical proficiency but also on the capacity to sustain effective performance under fatigued conditions.

Exercise physiology research has consistently shown that high-intensity aerobic exercise, particularly above the anaerobic threshold, can induce fatigue states that impair subsequent performance (25,26). Although relatively brief, the aquatic rescue protocol employed in this study imposes substantial physiological demands, engaging both aerobic and anaerobic energy systems (7,10,11,13), while also requiring technical precision and effective respiratory control.

From a biomechanical perspective, fatigue may reduce movement efficiency in water, increase the likelihood of technical errors, and alter neuromuscular coordination patterns (27,28). Previous research has demonstrated that accumulated fatigue can negatively affect swimming technique, reduce propulsion, and increase the energetic cost of aquatic movement (29).

One of the most relevant practical contributions of this study lies in its implications for lifeguard training design. While most physical preparation guidelines in aquatic lifesaving emphasize general fitness development (15), the present findings suggest that it is equally important to incorporate training sessions simulating interventions under fatigue conditions. Such an approach may facilitate both physiological and psychological adaptation to realistic rescue scenarios.

The inclusion of prior-load training sessions (e.g., running, swimming, or functional training) followed by simulated rescues or CPR drills may enhance specific endurance and the ability to maintain operational effectiveness under adverse conditions (7,30).

From a psychophysiological standpoint, it is also important to consider the potential effects of fatigue on decision-making and emotional regulation. Although not directly assessed in this study, research in emergency performance contexts indicates that fatigue may negatively affect concentration, risk assessment, and adherence to safety protocols (31,32). Future research should therefore explore cognitive performance during rescues performed under pre-existing fatigue conditions.

## **LIMITATIONS AND FUTURE DIRECTIONS**

Despite the standardized aerobic stimulus employed, individual differences in recovery rate and physiological profile were not controlled. Additionally, although the sample was representative of professional lifeguards, larger sample sizes would increase statistical power in future investigations.

Future studies should replicate this protocol using different pre-load stimuli (e.g., high-intensity interval training or resistance-based sessions) to examine their differential impact on rescue performance.

The present study demonstrates that fatigue induced by a prior aerobic-oriented training session may compromise performance in a subsequent aquatic rescue. These findings have important implications for both training program design and workload management during actual surveillance shifts.

Overall, the results provide a robust empirical foundation for reconsidering physical preparation strategies in aquatic lifesaving, integrating specific training elements under controlled and progressive fatigue conditions.

In conclusion, recognizing prior fatigue as an operational risk factor—and implementing strategies to mitigate its impact—may ultimately make a critical difference in survival outcomes and intervention success during aquatic rescues.

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