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ORIGINAL RESEARCH

Fatigue and CPR quality in lifeguards: analysis after 100- and 200-meter rescues

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Abstract

Background: The quality of cardiopulmonary resuscitation (CPR) is crucial in aquatic rescues as it directly impacts the survival of drowning victims. Fatigue caused by long rescues may affect CPR effectiveness, especially over longer distances. This study examines how 100-meter and 200-meter rescues on a natural beach impact the quality of CPR performed by lifeguards. **Methods**: Twenty professional lifeguards performed 100-meter and 200-meter rescues, followed by a CPR test. The quality of CPR was evaluated using parameters such as compression rate, depth, and ventilation effectiveness. **Results**: The results showed a significant decrease in CPR quality compared to the baseline test (89.7 $\pm$ 10.6% *vs.* 78.7 $\pm$ 16.1% *vs.* 76.3 $\pm$ 18.6%; p = 0.003), particularly in compression rate (86.8 $\pm$ 16.8% *vs.* 58.5 $\pm$ 18.6% *vs.* 61.5 $\pm$ 18.6%; p = 0.023) and ventilation quality (87.6 $\pm$ 18.9% *vs.* 77.6 $\pm$ 23.5% *vs.* 73.5 $\pm$ 20.2%; p = 0.006). However, no differences were observed between the 100-meter and 200-meter rescues. **Conclusions**: Fatigue resulting from physical exertion in aquatic rescues reduces CPR quality. These findings are critical for improving lifeguard training programs and ensuring effective CPR even under fatigue conditions.

Keywords

CPR quality; Fatigue; Cardiopulmonary resuscitation; Aquatic rescue; Lifeguards

1. Introduction

Cardiopulmonary Resuscitation (CPR) is a critical maneuver for survival in cases of cardiorespiratory arrest, particularly in aquatic environments, where response time and the quality of the initial intervention are key determinants of the victim's neurological prognosis [1].

The quality of CPR is typically assessed using objective parameters such as chest compression rate, compression depth, thoracic recoil, the rate of effective ventilations, and the percentage of time without compressions, known as "no-flow time" [2]. According to the guidelines of the European Resuscitation Council [3], high-quality CPR must maintain a compression rate of 100 to 120 compressions per minute, a depth of 5 to 6 cm in adults, and ensure proper chest recoil after each compression.

CPR quality can be significantly compromised if the rescuer experiences physical fatigue, which is common after highly demanding activities such as aquatic rescues. Previous studies have shown that fatigue considerably reduces the effectiveness of chest compressions, negatively affecting the victim's prognosis [4–6].

The fatigue induced by an aquatic rescue is influenced by the distance covered, especially in natural beaches, where irregular conditions such as waves, currents, unstable sandy bottoms, and variable temperatures are present [7].

The physical demands of an aquatic rescue are also affected by factors such as the use of auxiliary equipment [8, 9], the rescuer's physical fitness, and the victim's weight [10].

Longer rescue distances result in prolonged exposure to continuous effort, leading to an increase in heart rate, oxygen consumption (VO_2), and lactate accumulation—all indicators of muscular fatigue [11]. Studies conducted with professional lifeguards have demonstrated that rescues exceeding 150 meters can induce significant levels of fatigue, directly affecting subsequent technical performance, including CPR quality [12–15].

The primary objective of this study was to analyze whether the distance of an aquatic rescue (100 or 200 meters) in a natural beach environment influences the quality of cardiopulmonary resuscitation (CPR) performed by lifeguards.

2. Materials and methods

2.1 Study design

A quasi-experimental study was conducted. The study included 20 professional lifeguards registered in the official aquatic lifeguard registry of Galicia. All study tests were carried out at Oza Beach (A Coruña), Spain, in June 2024. The inclusion criteria established were being listed in the official register of lifeguards of Galicia, being between 18 and 40 years old, and having no medical condition that would prevent the safe performance of the physical tests. The sample size was determined based on accessibility and convenience criteria, as the study was conducted with all available students enrolled in a refresher training course for lifeguards at a private training school. All participants signed an informed consent document regarding the execution of the tests and the subsequent use of the collected data. The research adhered to the ethical standards set forth in the Declaration of Helsinki [16].

2.2 Procedure

Initially, all lifeguards performed a conventional 2-minute CPR test (30:2) (CPRREST (Cardiopulmonary Resuscitation Test at rest)). During this phase, the maximum heart rate of each participant was also estimated using the equation by Tanaka *et al*. [17], designed for active adults.

The following day, all lifeguards completed two rescue trials on a natural beach: one of 100 meters ($Rescue_{100}$) and another of 200 meters ($Rescue_{200}$). In both rescues, the lifeguards were required to wear fins, perform an open-water entry, swim 50 or 100 meters using a front crawl approach, and then complete 50 or 100 meters of victim transport using a head-hold technique to maintain the victim's airway above water.

A random draw determined the order of the rescue trials (100 meters or 200 meters first). Participants rested for four hours between trials to ensure full recovery [6, 8]. During the procedure, all participants were aware that they would perform two trials, separated by a prolonged recovery period. However, the lifeguards were unaware of which trial the other group was performing at any given time. To ensure this condition, while one group completed the 100-meter rescue, the other group was not present on the beach and had no visual access to the trial. Once the first group had completed their trial, they left the testing area, allowing the second group to perform the 200-meter rescue under similar conditions of isolation. After a four-hour recovery period, the groups switched roles, following the same procedure.

A mannequin with the same specifications as those used in regulated competitions by the International Lifesaving Federation, previously utilized in simulated rescue scenarios [5, 14], served as the victim. The rescues were performed using fins (Cressi Clio, Cressi-Sub©, Italy) [5].

All lifeguards were informed that the test simulated a real drowning scenario and were required to exert both physical and technical effort in accordance with the situation's demands.

The rescue was composed of four consecutive phases, performed without interruption: Running Time, defined as the time interval between the start signal and the moment the fins are positioned in the water; Approach Time, the time elapsed from the moment the fins are placed in the water to the moment the victim is brought under control; Towing Time, the time elapsed from the moment the victim is brought under control to the moment the rescuer stands up in the water; and Extraction Time, the time elapsed from the moment the rescuer stands up in the water to the moment the victim is fully extracted from the water and crosses the finish line.

Immediately after each rescue, the lifeguards performed another 2-minute conventional CPR test (30:2). Throughout all CPR tests, several quality indicators were analyzed, including overall CPR quality (QCPR), the percentage of correct chest compressions (QCC), the percentage of compressions with adequate depth (QDC), chest recoil (CCDC), the percentage of correct ventilations (QV), the total number of ventilations (NAV); total number of correct ventilations (NVA); the heart rate after the CPR test (CPR-HR) and the rating of perceived exertion after the CPR test (CPR-BORG).

CPR quality was assessed using the Resusci Anne® SkillReporter™ (Medical advice, Laerdal Medical AS, Stavanger, Norway), connected to a laptop running Laerdal PC Skill Reporter System Program for Windows (v.1.3.0.4, Laerdal Medical Corporation, Stavanger, Norway). Compressions were considered correct if they met the following criteria: depth of 5–6 cm, proper hand positioning, full chest recoil, and ventilations delivering 500–600 mL of air. CPR performance CPR performance was assessed following the parameters defined for high-quality CPR by Perkins *et al*. [18].

2.3 Statistical analysis

Variables were expressed using measures of central tendency and dispersion (mean and standard deviation). The results were analyzed using statistical software (SPSS, version 26.0, SPSS Inc., New York, NY, USA). Normality was assessed using the Shapiro-Wilk test.

To compare temporal variables between $Rescue_{100}$ and $Rescue_{200}$, paired *t*-tests or the Wilcoxon Signed Rank Test were applied. For CPR outcome comparisons, repeated-measures analysis of variance (ANOVA) or the Friedman test was used, depending on data normality. A significance level of $p < 0.05$ was established.

3. Results

The total sample consisted of 20 male lifeguards. The mean age was 23.9 $\pm$ 2.7 years, height 174.4 $\pm$ 8.0 cm, weight 78.3 $\pm$ 9.7 kg, and body mass index (BMI) 25.7 $\pm$ 2.9 kg/m^2. Resting heart rate was 55 $\pm$ 4 beats per minute, and the theoretical maximum heart rate was 191 $\pm$ 2 beats per minute.

The CPR results of the CPR at rest (CPRREST) obtained during the resting test were as follows: overall CPR quality (QCPR, %) = 89.7 $\pm$ 10.6; chest compression quality (QCC, %) = 91.3 $\pm$ 11.8; compression depth (CCD, %) = 98.6 $\pm$ 2.0; compression rate (CCR, %) = 86.8 $\pm$ 16.8; complete chest recoil (CCDC, %) = 88.9 $\pm$ 17.8; total number of compressions (TCC, n) = 156 $\pm$ 10; rescue ventilation quality (QV, %) = 87.6 $\pm$ 18.9; number of ventilations performed (NAV) = 10.2 $\pm$ 0.4; number of adequate ventilations (NVA, n) = 8.8 $\pm$ 1.9; heart rate during CPR (CPR-HR, bpm) = 112 $\pm$ 3; and perceived exertion (CPR-BORG) = 3.1 $\pm$ 0.7.

3.1 Water rescue results

The time required to put on the fins was similar in both cases (Running Time: 14.3 $\pm$ 2.4 s *vs*. 14.7 $\pm$ 2.9 s; $p = 0.277$), although all other time-related parameters were significantly lower in the 100-meter rescue (Approach Time: 19.2 $\pm$ 3.7 s *vs*. 64.0 $\pm$ 8.6 s; $p < 0.001$; Towing Time: 36.7 $\pm$ 5.5 s *vs*. 111.3 $\pm$ 7.1 s; $p < 0.001$; Extraction Time: 31.3 $\pm$ 6.3 s *vs*.

36.6 ± 8.0 s; p = 0.004; Total Time: 101.5 ± 11.9 s *vs.* 226.6 ± 18.8 s; $p < 0.001$).

Additionally, significant differences were observed in the physiological parameters analyzed (Maximum heart rate (HR_{Max}): 180 ± 6 bpm *vs.* 183 ± 5 bpm; p = 0.039; Percentage of maximum heart rate (% Maximum HR): 93.9 ± 2.8% *vs.* 95.7 ± 2.6%; p = 0.041; Borg scale: 7.6 ± 0.5 s *vs.* 8.2 ± 0.5 s; p = 0.011) (Table 1).

3.2 CPR test results

A high level of effectiveness was observed in CPR at rest (CPRREST), both in the percentage of correct compressions (QCC: 91.3 ± 11.8%), compression depth (CCD: 98.6 ± 2.0%), compression rate (CCR: 86.8 ± 16.8%), and chest recoil (CCDC: 88.9 ± 17.8%). Additionally, the percentage of correct ventilations also reached high values (QV: 87.6 ± 18.9%). Finally, physiological values related to exertion indicated low-intensity fatigue at both objective (CPR-HR: 112 ± 3 bpm) and subjective levels (CPR-BORG: 3.1 ± 0.7) (Table 2).

Significant differences were observed in some variables when comparing CPR at rest (CPRREST) with the tests performed after the 100-meter (CPR100) and 200-meter rescues (CPR200). Favoring the resting test (CPRREST), significant differences were found in overall CPR quality (QCPR: 89.7 ± 10.6% *vs.* 78.7 ± 16.1% *vs.* 76.3 ± 18.6%; p = 0.003), correct compressions (QCC: 91.3 ± 11.8% *vs.* 79.1 ± 18.1% *vs.* 78.0 ± 18.2%; p = 0.006), compressions at the appropriate rate (CCR: 86.8 ± 16.8% *vs.* 58.5 ± 18.6% *vs.* 61.5 ± 18.6%; p = 0.023), overall ventilation quality (QV: 87.6 ± 18.9% *vs.* 77.6 ± 23.5% *vs.* 73.5 ± 20.2%; p = 0.006), and the number of adequate ventilations (NVA: 8.8 ± 1.9 *vs.* 7.9 ± 2.4 *vs.* 7.4 ± 3.0; p = 0.008).

Significant differences were also found in physiological effort-related values. Both at the objective level (CPR-HR: 112 ± 3 bpm *vs.* 158 ± 6 bpm *vs.* 158 ± 6 bpm; $p < 0.001$) and subjective level (CPR-BORG: 3.1 ± 0.7 *vs.* 5.5 ± 0.8 *vs.* 5.9 ± 1.1; $p < 0.001$) (Table 2).

Conversely, no significant differences were found in any of the variables when comparing the CPR test performed after the 100-meter rescue (CPR100) with that after the 200-meter rescue (CPR200) (Fig. 1).

4. Discussion

The quality of resting CPR analyzed in this study exceeds the "gold standard" of 70% quality [18]. Likewise, performing a high-intensity effort (aquatic rescue) led to a significant decrease in CPR quality, as observed in previous studies [5, 9, 13, 14], However, in this case, quality remained above 70%.

Scientific literature supports the hypothesis that, due to the effect of accumulated fatigue, the greater the rescue distance, the lower the quality of CPR performed by the lifeguard. Barcala-Furelos *et al.* [19] found a significant decline in compression quality (from 86% to 66%) after a 75-meter pool rescue. A year later, Barcala-Furelos *et al.* [9] observed that after a long-distance rescue, lifeguards exhibited a significant reduction in compression depth and frequency, along with an increase in compression-free time. A significant decline in compression quality (from 82% to 56%) was also observed after a 200-meter rescue with fins on the beach [9]. Similarly, Abelairas-Gómez *et al.* [5] reported a significant drop (from 89% to 61%) after a 150-meter rescue with fins, also on the beach.

Another aspect demonstrated by scientific evidence is that the total number of compressions after a rescue increases compared to those performed at rest [14, 19]. Similarly, in our study, both rescues led to an exaggerated increase in compression rate, which resulted in a significant decrease in the percentage of compressions performed at the correct rate ($p < 0.05$).

On the other hand, in cases of drowning, effective ventilation is a critical and primary factor in reversing cardiac arrest [7]. In this study, post-rescue ventilation quality significantly declined, similar to findings in other studies with lifeguards [5, 14]. However, in this case, the drop in ventilation quality did not fall below the 70% threshold.

Heart rate (HR) and rating of perceived exertion (RPE) confirm the high metabolic demand that an aquatic rescue places on a lifeguard [8, 20]. In our study, the 200-meter rescue lasted almost twice as long as the 100-meter rescue, yet no significant differences were found in any of the CPR variables

TABLE 1. Descriptive analysis and comparison of 100- and 200-meter rescues.

Variables	100 m		200 m		p value
	Mean	SD	Mean	SD	
Running Time (s)	14.3	2.4	14.7	2.9	0.277*
Approach Time (s)	19.2	3.7	64.0	8.6	**<0.001***
Towing Time (s)	36.7	5.5	111.3	7.1	**<0.001***
Extraction Time (s)	31.3	6.3	36.6	8.0	**0.004****
Total Time (s)	101.5	11.9	226.6	18.8	**<0.001***
Rescue Max HR (beats/min)	180	6	183	5	**0.039***
% Maximum HR (%)	93.9	2.8	95.7	2.6	**0.041***
Borg Scale at Rescue	7.6	0.5	8.2	0.5	**0.011****

**Dependent samples t-test. **Wilcoxon signed-rank test. Statistically significant differences are shown in bold.*
Max: Maximum; SD: Standard Derivation; HR: heart rate.

TABLE 2. Analysis and comparison of performance achieved in the CPR tests.

Variables	CPRREST		CPR 100 m		CPR 200 m		*p* value	CPRREST *vs.* CPR100	CPRREST *vs.* CPR200	CPR100 *vs.* CPR200
	Mean	SD	Mean	SD	Mean	SD				
QCPR (%)	89.7	10.6	78.7	16.1	76.3	18.6	**0.003****	**0.008**	**0.002**	0.648
QCC (%)	91.3	11.8	79.1	18.1	78.0	18.2	**0.006****	**0.005**	**0.018**	0.648
CCD (%)	98.6	2.0	99.7	0.6	99.9	0.3	0.102**	--	--	--
CCR (%)	86.8	16.8	58.5	18.6	61.5	18.6	**0.023****	**0.014**	**0.045**	0.584
CCDC (%)	88.9	17.8	80.0	21.2	74.1	28.3	0.767**	--	--	--
TCC (compressions)	156	10	161	16	162	13	0.526**	--	--	--
QV (%)	87.6	18.9	77.6	23.5	73.5	20.2	**0.006***	0.100	**0.006**	0.420
NAV	10.2	0.4	10.1	0.4	10.1	0.3	0.549**	--	--	--
NVA	8.8	1.9	7.9	2.4	7.4	3.0	**0.008****	0.201	**0.011**	0.201
CPR-HR (bpm)	112	3	158	6	158	6	**<0.001***	**<0.001***	**<0.001***	1.000
CPR-BORG	3.1	0.7	5.5	0.8	5.9	1.1	**<0.001***	**0.001**	**<0.001***	0.457

QCPR: cardiopulmonary resuscitation quality; QCC: percentage of correct chest compressions; CCD: percentage of compressions with adequate depth; CCR: percentage of compressions with adequate rhythm; CCDC: chest recoil; TCC: Total number of compressions; QV: percentage of correct ventilations; NAV: Total number of ventilations; NVA: Total number of correct ventilations; CPR-HR: Heart rate after the CPR test; CPR-BORG: Rating of Perceived Exertion after the CPR test; SD: Standard Derivation; CPRREST: Cardiopulmonary Resuscitation Test at rest; CPR: cardiopulmonary resuscitation.
**Repeated measures ANOVA. **Friedman's two-way analysis. Statistically significant differences are shown in bold.*

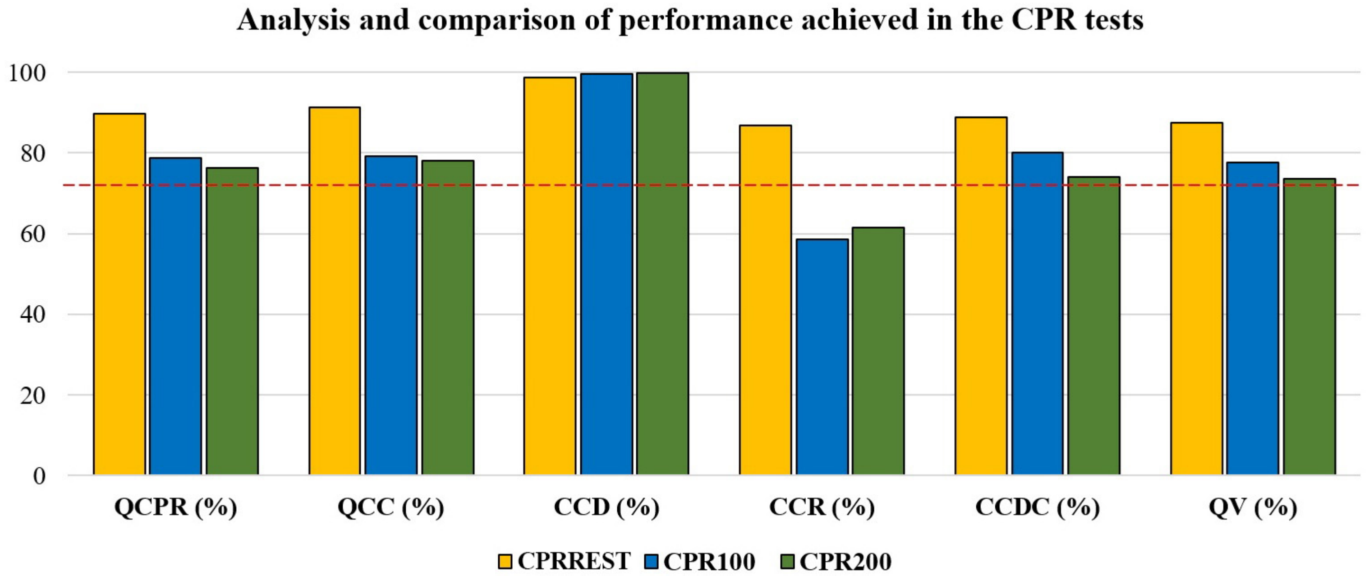

FIGURE 1. Analysis and comparison of performance achieved in the CPR tests. QCPR: cardiopulmonary resuscitation quality; QCC: percentage of correct chest compressions; CCD: percentage of compressions with adequate depth; CCR: percentage of compressions with adequate rhythm; CCDC: chest recoil; QV: percentage of correct ventilations; CPRREST: Cardiopulmonary Resuscitation Test at rest; CPR: cardiopulmonary resuscitation.

measured after the rescues. This finding may provide valuable insights for lifeguard training, suggesting that in certain cases, what truly impacts CPR quality is proficiency in resuscitation techniques and the intensity applied during the rescue, rather than the distance covered.

Heart rate after the rescues exceeded 95% of the theoretical maximum, which may have affected CPR performance. For this reason, some authors recommend not exceeding 70% of VO_{2max} during the rescue [21]. Conversely, other researchers argue that a lifeguard should be able to perform high-quality CPR even under fatigue [9, 12].

Regarding this aspect, Maia *et al*. [22] found that lactic acid levels and heart rate following prolonged rescues are directly correlated with a reduction in CPR quality, particularly during the first 60 s of the procedure. This phenomenon may be explained by the depletion of muscular energy systems and loss of motor precision, which hinder the ability to maintain proper CPR technique [13]. Furthermore, perceived exertion also plays a role, as fatigued lifeguards tend to overestimate the quality of their intervention, even when objective data indicate otherwise [23].

Therefore, we can determine that there is an inverse relationship between rescue intensity and resuscitation effectiveness, which has important implications for lifeguard training, specific physical conditioning, and technical preparation.

5. Conclusions

Both 100-meter and 200-meter rescues performed in a natural beach setting resulted in a significant decline in CPR quality compared to the resting condition, affecting both chest compressions and ventilations. However, no significant differences were found between the two rescue distances. Therefore, it can be concluded that performing a water rescue negatively impacts subsequent CPR quality, regardless of whether the distance covered is 100 or 200 meters.

These findings aim to provide evidence on how the physical demands of a rescue affect the subsequent immediate medical response. particularly in high-demand real-life scenarios. Additionally, this study seeks to generate useful knowledge for designing more effective training programs that incorporate endurance elements, techniques under fatigue, and real-life rescue simulations, ensuring high-quality intervention even in adverse conditions.

Validating this hypothesis could enable aquatic rescue institutions to enhance operational standards and bridge the gap between theoretical training and real-life emergency response, ultimately contributing to higher survival rates in aquatic accidents.

6. Limitations

This study represents an initial approach to analyzing the relationship between rescue distance, applied intensity, and CPR effectiveness. However, since the study was conducted in a simulated setting, the results may not be directly generalizable to real-life rescue scenarios. This limitation should be taken into account when interpreting the findings. Future research should explore longer distances or different aquatic environments and test a larger sample, as these factors may influence the level of fatigue experienced by rescuers during CPR. Finally, a larger sample of active rescuers could provide further insight into this topic.

AVAILABILITY OF DATA AND MATERIALS

The data used to support the findings of this study are available from the corresponding author upon request.

AUTHOR CONTRIBUTIONS

BRL and PDF—designed the study. BRL and PCA—collected the data. BRL and SLG—analyzed the data; wrote the manuscript. PDF and PCA—analyzed the results. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The research was approved by the Quality Commission of the "Fray Luis de León" University School of Teaching, affiliated with the Catholic University of Ávila. All research procedures were conducted in accordance with the Declaration of Helsinki. All participants signed an informed consent document regarding the execution of the tests and the subsequent use of the collected data.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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