Relationship between rescue distance and the quality of simulated CPR: a pilot study with lifeguards
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Abstract
Objective: The aim of this research was to investigate if the distance travelled in a ‘rescue’ is associated with differences in the quality of the CPR provided.

Methods: A group of 10 lifeguards performed simulated CPR for 2 minutes at rest. Next, they performed 2 rescues, one of 50 meters and the other of 100 meters. After each rescue, the lifeguards immediately performed simulated CPR.

Results: The time invested in the rescue of 50 meters was significantly lower than in the 100 meters ($P < 0.001$). Simulated CPR at rest obtained high quality values in the compressions (94.8 ± 9.6%) but not in the ventilations (41.0 ± 22.8%). 50 and 100 meter rescues were associated with a significant decline in the overall quality of CPR (68.4 ± 11.0 vs. 51.0 ± 9.3 vs. 49.7 ± 7.2%, $P = 0.002$), correctness of hand position (100% vs. 91.0 ± 7.0 vs. 85.9 ± 12.3, $P = 0.006$), and in the quality of the ventilations (41.0 ± 22.8 vs. 12.0 ± 17.5 vs. 11.0 ± 12.8%, $P = 0.001$). The quality of the above measures was similar in 50 and 100 meter rescues.

Conclusions: Rescues of 50 and 100 meters were similarly associated with a decrease in the quality of simulated CPR vs. at rest simulated CPR. Lifeguards should practice performing CPR following rescue activities with added focus on performing rescue ventilations correctly.

Keywords
Cardiopulmonary-resuscitation; Drowning; Emergency; Lifeguard; Rescue

1. Introduction
Drowning currently causes around 370,000 deaths a year worldwide [1]. The role of the lifeguard is to try to avoid this type of accident taking place [2]. When a lifeguard reaches a person who has suffered water inhalation, the lifeguard must perform the first rescue breaths in the water [3] and immediately complete the rescue as soon as possible and initiate CPR on the mainland [4].

The performance of an rescue attempt causes a high physiological strain in the lifeguard [5, 6], including tachycardia, hyperventilation and the accumulation of lactate [7–9]. Despite this physiological stress, the lifeguard also needs to be able to provide high quality chest compressions and ventilations, in order to provide adequate CPR [10, 11].

Specific materials have been shown to reduce rescue time [12], however, these material do not prevent a significant decrease in the quality of compressions [13] and ventilations [14], caused by the physiological stress incurred during the rescue. Also, evidence shows that lifeguards have a limited awareness of their actual ability to perform CPR and consequently make mistakes when they carry out CPR protocols [15]. Finally, it is important to indicate that the distance at which people require aquatic rescue varies significantly [16].

In this study we wanted to investigate if the distance covered during an aquatic rescue is associated with differences in the quality of the CPR provided by lifeguards.

2. Methods

2.1 Study population
Ten professional lifeguards registered in the official registry of aquatic lifeguards of Galicia (Spain) participated in the study. The selected lifeguards had recently completed their mandatory training to be a professional lifeguard according to Spanish law.

A quasi-experimental design was used to evaluate the rescue process, the lifeguards physiological variables and the overall success of the Cardiopulmonary Resuscitation protocol (Fig. 1). All participants signed an informed consent form agreeing to the use and publication of the data obtained.

The study was approved by the Ethics and Research Committee of the Universidade da Coruña (CEI-UDC). The research was performed in accordance to the Declaration of Helsinki of 1975.
2.2 Rescue tests

At first, all the rescuers performed a simulated CPR test (30 : 2) for 2 minutes. The maximum heart rate of each participant was calculated following the equation of Tanaka \[17\], designed for active adults.

The following day, all rescuers performed 2 pool rescues, one of 50 meters (Rescue 50) and the other of 100 (Rescue 100). In both rescues, the lifeguard had to put on the swimming fins, enter the water, swim 25 or 50 meters of approach through the front crawl swim and 25 or 50 meters of towing swim keeping the victim’s airways above the water. All participants performed the 50-meter rescue first and then the 100-meter rescue. Between both rescues, all participants rested for 2 hours to ensure complete recovery \[7\]. In both rescues, the time invested to put the fins (FT), the approach time (AT), the towing time (TT) and the total time (TotalT) were measured.

The heart rate (HR) measurement was carried out with a Sunnto® pulsometer with a strap placed on the chest that sent the data recorded in real time to a computer. The values achieved at the end of each rescue and at the beginning and end of each simulated CPR test were selected. A modified Borg Scale (from 1 to 10) was used to measure the rating of perceived exertion (RPE). Each lifeguard had to point a finger at the level of fatigue after each rescue and each simulated CPR sequence.

A mannequin with the same characteristics as the one used in competitions regulated by the International Lifeguard Federation, was used. This mannequin was used also in other studies as a victim \[18, 19\]. The rescues were carried out with fins (Cressi Clio, Cressi-Sub ©, Italy).

All the rescuers were informed that the test simulated a real drowning situation and they had to exert themselves physically and technically according to the demands of the situation.

2.3 Simulated CPR tests

At the end of each of the rescues, lifeguards immediately performed a 2-minute simulated CPR test. During all simulated CPR tests, the following parameters were recorded: the general quality (QCPR), the percentage of correct compressions (QCC), the percentage of compressions with adequate depth (QDC), the position of the hands (HP), the decompression of the thorax (CD), the percentage of correct ventilations (QV) and the mean volume of air insufflated (TV).

The CPR quality was analyzed with the Resusci Anne® SkillReporterTM connected to a laptop with the Laerdal PC Skill Reporter System Program software for Windows (Laerdal Medical Corporation, Stavanger, Norway). Compressions with a depth of 5-6 centimeters, with correct hand position,
complete re-expansion of the chest, and ventilations with 500-600 mL of insufflated air were recorded as correct. CPR quality was calculated as a percentage (%) using the following equation: QCPR = \((\text{QCC} + \text{QV})/2\), as previously used in other studies [20].

2.4 Statistics

The variables were expressed by measures of central tendency and dispersion (mean and standard deviation). The results of the tests were analyzed using statistical software (SPSS, version 22.0, SPSS Inc.). Normality was verified by the Shapiro-Wilk test.

For the comparisons of the temporary variables between Rescue50 and Rescue100, paired sample t-tests or the Wilcoxon Signed Rank Test was applied, and for comparisons between the simulated CPR results, ANOVA with repeated measures was applied. A level of significance was established at \(P < 0.05\).

3. Results

The total sample was 10 male lifeguards. The mean age was 22.9 ± 2.4 years, the weight 78.3 ± 9.7 kg, the height 174.37 ± 8.0 cm and the BMI 25.7 ± 2.9 kg/m². The theoretical maximum heart rate was 191 ± 2 beats per minute [17].

3.1 Rescue results

The time spent in fitting the fins was similar in both cases (TF: 9.8 ± 2.5 s. vs. 10.6 ± 2.3 s; \(P = 0.443\)), although the rest of the temporal parameters were lower in the Rescue50 group (AT: 16.8 ± 3.7 s. vs. 36.0 ± 5.1 s; \(P < 0.001\); TT: 29.2 ± 4.0 s. vs. 62.5 ± 5.5 s; \(P < 0.001\); TotalT: 55.8 ± 8.4 s. vs. 109.2 ± 10.1 s; \(P < 0.001\)). All results are shown in Fig. 2.

3.2 Simulated CPR results

The results of the baseline simulated CPR test (CPRBASELINE) were of good/high quality standard [21]. A high effectiveness in the percentage of correct compressions (QCC = 94.5 ± 5.7%) was observed, due to a high effectiveness of the compressions adequate depth (CCP = 88.7 ± 13.2%) and with a maximum effectiveness in the hand position (PM = 100%).

However, although the mean volume of insufflated air was maintained between the recommended values (VT: 540 ± 87 mL), the percentage of correct ventilations did not reach 50% effectiveness threshold (QV = 45.0 ± 21.6%) (Fig. 3).

In Table 1 it can be observed that the comparison between the three CPR tests: Baseline (CPRBASELINE); post 50 meters-rescue (CPR50) and post 100 meters-rescue (CPR100). Significant differences were found in the overall quality of the CPR at CPRBASELINE, CPR50 and CPR100 respectively (QCPR: 69.8 ± 11.4 vs. 47.2 ± 16.4 vs. 46.5 ± 14.4%; \(P = 0.010\)), the correct chest compressions (QCC: 94.5 ± 5.7% vs. 78.8 ± 16.8% vs. 77.6 ± 13.9%; \(P = 0.004\)), the total number of compressions (TCC: 134 ± 20 vs. 151 ± 11 vs. 154 ± 10; \(P = 0.001\)), the compressions with adequate rhythm (CCR: 89.5 ± 11.1% vs. 48.0 ± 46.1% vs. 39.0 ± 39.5%; \(P = 0.005\)), the hands position (HP: 100% vs. 94.8 ± 7.3 vs. 92.0 ± 8.5; \(P = 0.018\)), the quality of the ventilations (QV: 45.0 ± 21.6 vs. 15.5 ± 32.7 vs. 14.2 ± 21.6%; \(P = 0.021\)) and the tidal volume (VT: 540 ± 87 vs. 709 ± 83 vs. 736 ± 96 mL; \(P < 0.001\)).

There were significant differences between the CPRBASELINE and the CPR50 as well as between the CPRBASELINE and the CPR100. There were significant differences between CPR50 and CPR100 only in two parameters, CCR (48.0 ± 46.1% vs. 39.0 ± 39.5%; \(P = 0.022\)) and CHP (94.8 ± 7.3% vs. 92.0 ± 8.5%; \(P = 0.044\)) (Fig. 4).
Table 2 shows the results of the HR and the rating of perceived exertion (RPE) after the efforts made in the rescue and simulated CPR. It was found that HR and RPE values were lower in the 50-meter rescue compared to the 100-meter rescue (HR: 164 ± 7 vs. 174 ± 7, \(P = 0.002\), RPE: 7.3 ± 0.6 vs. 8.3 ± 0.6, \(P = 0.011\)). However, the values of HR and RPE did not show significant differences after completing the simulated CPR, in both the 50 meter and 100 meter rescues (HR: 128 ±
4. Discussion

It has been shown that the efficacy of CPR significantly affects the chances of survival in a victim with cardiorespiratory arrest [22].

The quality of baseline simulated CPR of these lifeguards is close to the “gold standard” [21] of 70% quality, however, we have seen in our study and others that performing a high intensity effort (such as an aquatic rescue) can cause significant physiological stress of the lifeguard and that this is associated with a decrease in the quality of CPR [14, 18, 19, 22].

The quality of correct chest compressions was very high (> 90%), however, it decreased significantly after performing the 50 meter and 100 meter rescues ($P < 0.05$). Other studies have also shown that after performing an aquatic rescue, the number of correct chest compressions is significantly reduced.

Barcala-Furelos et al. [22] found a significant decrease in the quality of compressions (86% to 66%) after performing a rescue of 75 meters in a swimming pool setting. Two years later, the same author also reported a significant decrease in the quality of compressions (82% to 56%) after performing a 200-meter rescue with fins on the beach [20]. Finally, Abelairas-Gómez et al. [19], found a significant decrease in compression quality (from 89% to 61%) after a rescue of 150 meters with fins, also on the beach.

It has been shown that the total number of compressions after an aquatic rescue increases with respect to those performed in a simulated baseline CPR setting [18, 22]. Similarly, in our study, the total number of compressions increased significantly after the two rescues with respect to baseline simulated CPR, which caused an exaggerated increase in the rate of compressions leading to a significant decrease in the percentage of compressions with adequate rhythm ($P < 0.05$).

An additional parameter that was significantly reduced following the 50 and 100 meter rescues was the correctness of the hand position. It is not clear why this was observed, because in previous studies this parameter has not analyzed in-depth. However, it has been shown that physical fatigue significantly affects the technical performance [23, 24], and, given that CPR is a technical skill, it could happen that physical fatigue caused by the rescue could affect the concentration of lifeguard at the time of placing the hands on the chest at start the resuscitation techniques.

Performing ventilations effectively is a critical and fundamental element for performing high quality CPR in people who have inhaled water in a drowning incident [4], however, the studied lifeguards did not reach a quality of 50% in terms of ventilation during the simulated CPR sequence. This result was not surprising, since previous research has also showed
that ventilation quality provided by attending lifeguards in a CPR setting is often sub-optimal [14, 20].

After the 2 rescues, the quality of the ventilations diminished significantly, consistent to that reported in other work studying lifeguard CPR provision [18, 19]. The decrease in the quality of the ventilations is mainly due to an excessive increase in the amount of insufflated air [14, 25]. It is important to avoid the excessive insufflation of air as it can cause a massive gastric inflation which can lead to further complications [25].

Heart rate (HR) measurement and the subjective rating of perceived exertion (RPE) confirms the high metabolic demand associated with performing an aquatic rescue [7, 8]. In our study we observed significant differences in both parameters in the 50 and 100 meter rescues (P < 0.05).

The 100-meter rescue lasted practically twice as long as the 50-meter rescue, although that did not cause significant differences in any of the CPR variables measured after the rescues. This can provide relevant information for the lifeguard training, since it seems that what really affects the quality of the CPR is the technical mastery in the resuscitation maneuvers and the intensity applied during the rescue; not so much the distance traveled.

The heart rate after the rescue of 50 meters exceeded 85% of the theoretical maximum [HRmax = 208.75-(0.73 × age)] [17], and 90% after the rescue of 100 meters. The intensity generated during the rescue can affect the performance of the CPR, for this reason some authors recommend not surpassing 70% of the VO2max during the rescue [6]. Other authors, however, argue that a lifeguard should be able to perform quality CPR even under extreme physiological stress/fatigue [14], which further justifies the need for good aerobic and anaerobic fitness in lifeguards, such that they can perform CPR appropriately in a rescue setting [26].

5. Limitations

This study aimed to be the first to approach the analysis of the distance traveled in an aquatic rescue and its relationship to the effectiveness of simulated CPR.

One of the main limitations of this study is small sample size. This study was carried out after the completion of a training course to be a professional lifeguard and very few days before the start of the working season on the beaches, so we could only count on the participants of this course for three days. The absence of women in the sample is justified since there were none in that course.

Another limitation is the absence of materials to measure other physiological parameters (oxygen saturation, lactate, etc.) that would allow a more complete analysis of how the fatigue generated in both rescues can affect the performance of CPR.

It would be interesting to use other distances or to carry out rescues in other aquatic spaces, since there are other aspects that can affect the fatigue with which the lifeguard copes with CPR, such as the waves on a beach. In addition, including a larger sample can provide more relevant information on this topic.

6. Conclusions

Two different rescues caused a similar decrease in the quality of the simulated CPR. In addition, it has been shown in our study that lifeguards have more consistently perform high quality compressions vs ventilations, which often did not reach 30% of the required quality. As such, ventilations were the most negatively affected action associated to CPR in the aquatic rescue setting.

We suggest that it is the presence of an aquatic rescue that affects the quality of simulated CPR and not the distance of the rescue. We also argue that CPR training provided to lifeguards should focus more on improving the quality of ventilations (vs. compressions), both of which are essential in the acute management of a drowning victim.

AUTHOR CONTRIBUTIONS

Brais Ruibal-Lista and Sergio López-Garcia designed the study. Brais Ruibal-Lista collected the data. J. Enrique Moral-García analyzed the data. J. Enrique Moral-García and Sergio López-Garcia analyzed the results and Brais Ruibal-Lista and Sergio López-Garcia drafted the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the Ethics and Research Committee of the Universidade da Coruña (CEI-UDC). The research was performed in accordance to the Declaration of Helsinki of 1975.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

DATA AVAILABILITY

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

REFERENCES

