Assessing the quality of CPR performed by a single lifeguard, two lifeguards and a lifeguard with a bystander after water rescue: a quasi-experimental trial

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ABSTRACT

Background High-quality cardiopulmonary resuscitation (CPR) could improve survival of drowning victims. The purpose of the study is to assess the impact of fatigue caused by water rescue on subsequent CPR quality and the influence of a bystander's participation on CPR quality in a lifeguard rescue.

Methods This was a simulated quasi-experimental study with a sample of 14 lifeguards and 13 laypersons. Each lifeguard performed 2 min single-rescuer CPR as baseline measurement. In three separate trials, a single lifeguard swam 50 m to perform a water rescue in a pool and returned with the manikin another 50 m. After each rescue, 10 min of CPR was performed by a single lifeguard, two lifeguards or a lifeguard with a layperson with no CPR training. Paired t-test and repeated analysis of variance were used to analyse CPR quality variables.

Results Baseline CPR quality was adequate for most measures except compression depth and re-expansion. After water rescue, the single lifeguard trial showed no significant differences compared with baseline. CPR score and ventilation score of the single-lifeguard trial was higher than that of the lifeguard-bystander trial ($p=0.027$, $p<0.001$). Both the two-lifeguard trial ($p=0.025$), and lifeguard-bystander trial ($p=0.010$) had a lower percentage of breaths with correct ventilation volume and higher percentage of breaths with excessive ventilation volume ($p=0.007$, $p=0.011$, respectively) than the single-lifeguard trial. No-flow time of the lifeguard-bystander trial was longer than other trials ($p<0.001$).

Conclusions Although CPR given by the lifeguard was not optimal, fatigue generated by a water rescue has no impact on the quality of subsequent CPR performed by a trained lifeguard for 10 min. Untrained bystanders assisting in CPR in a drowning event is unlikely to be helpful.

> **Key messages**
>
> **What is already known on this subject**
> - Drowning is one of the main causes of unintentional death in the world. The lifeguard is responsible for the rescue and initial resuscitation of drowning victims in water environments. However, it remains controversial whether fatigue caused by water rescue would influence the quality of cardiopulmonary resuscitation given by lifeguards to drowning victims.
>
> **What this study adds**
> - In this simulated rescue environment, water rescue had no impact on the quality of subsequent cardiopulmonary resuscitation (CPR) given for 10 min by a well-trained lifeguard and was superior to two lifeguard CPR or a lifeguard plus untrained bystander. When a lifeguard is available for drowning victim, laypersons are not suitable to participate in the resuscitation.

INTRODUCTION

Drowning is a leading cause of accidental death worldwide, killing approximately 372 000 people annually.[1] An international study has shown that the swimming pool is the main aquatic environment where people under 20 years old drown.[2] The whole drowning process, from submersion or immersion to cardiac arrest, usually occurs in seconds to a few minutes.[3] Timely water rescue may prevent water aspiration, respiratory distress and medical complications. But in some cases, even an early and effective water rescue will not prevent the medical consequences and in these cases, resuscitation may be required.[4]

Lifeguards are responsible for people's safety in a water environment. As Emergency Medical Service takes 5 to 8 min on average to respond,[5] lifeguards may be obliged to perform cardiopulmonaryresuscitation (CPR) for an extended time after a water rescue. A bystander can also be the first witness and responder to a drowning victim. Bystander resuscitation was reported to contribute a positive outcome of drowning victims;[6] while less than 1% of laypersons in China are trained in basic life support (BLS), the outcome is poor if CPR is delayed regardless of whether it is high quality or not.[7] Therefore, bystanders are encouraged to provide emergency assistance for drowning victims who have been removed from water.[6] To our knowledge, however, no study focuses on whether bystanders should participate in a resuscitation when a lifeguard is available.

CPR causes fatigue, for which both European Resuscitation Council and the American Heart Association recommend rotating the person who performs chest compressions if more than one

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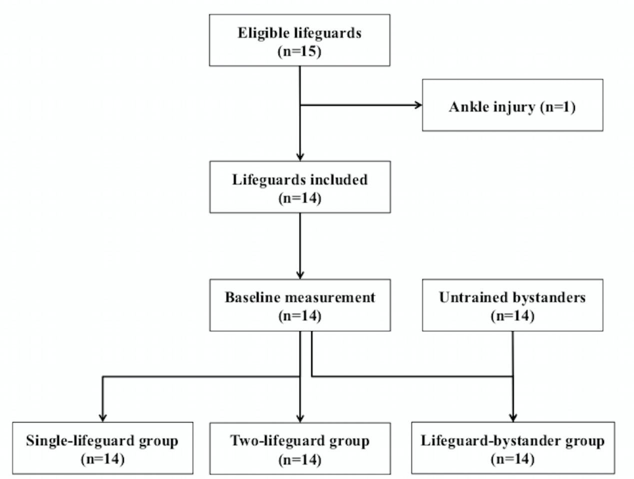

Figure 1 Flowchart of participants' inclusion process.

rescuer is available.[8 9] Water rescue is also physically demanding. However, it remains controversial whether fatigue caused by water rescue would influence CPR quality of lifeguards. Some studies have suggested that the accumulated fatigue during a water rescue could reduce the quality of subsequent CPR as defined by the European Resuscitation Council (ERC) guidelines 2010.[10 11] Claesson *et al* argued that well-trained lifeguards possess the fitness necessary to perform good-quality CPR after a strenuous challenge of water rescue, but the lifeguards in the study were trained under ERC guidelines 2005, in which the compression depth was less than in ERC guidelines 2010.[12]

Based on the findings above, a quasi-experimental study was conducted in an indoor swimming pool to compare the quality of CPR by a rested lifeguard to that performed after water rescue. Additionally, we wanted to assess whether the participation of a second lifeguard or an untrained bystander would improve performance after the rescue.

METHODS

Study design, settings and participants

This was a non-blinded non-randomised quasi-experimental trial conducted in an indoor swimming pool in Dongtai, China, in July 2016. The pool is 50 m long and the water was kept at 25°C to 28°C. Fifteen lifeguards from Shanghai Life Saving Association were invited to participate in this study. All of them have passed the entrance test including 50 m speed swim in less than 50 s and simulated rescue assessment, and have obtained BLS certificate under 2015 American Heart Association (AHA) guidelines for resuscitation.[9] One was excluded for ankle injury, leaving a sample of 14. Fourteen laypersons between ages 18 to 75 years and with no BLS training experience were recruited from cooperative colleges, companies and enterprises, serving as bystanders; health professionals and those physically disabled were excluded. The recruitment process is shown in figure 1. All the lifeguards and the laypersons gave written informed consent to participate in this study.

Study protocol

There was one baseline measurement made at the beginning of the study. Each lifeguard performed CPR for 2 min without any water rescue and baseline measurements of CPR quality were made. Three trials were then carried out, each run 2 days apart

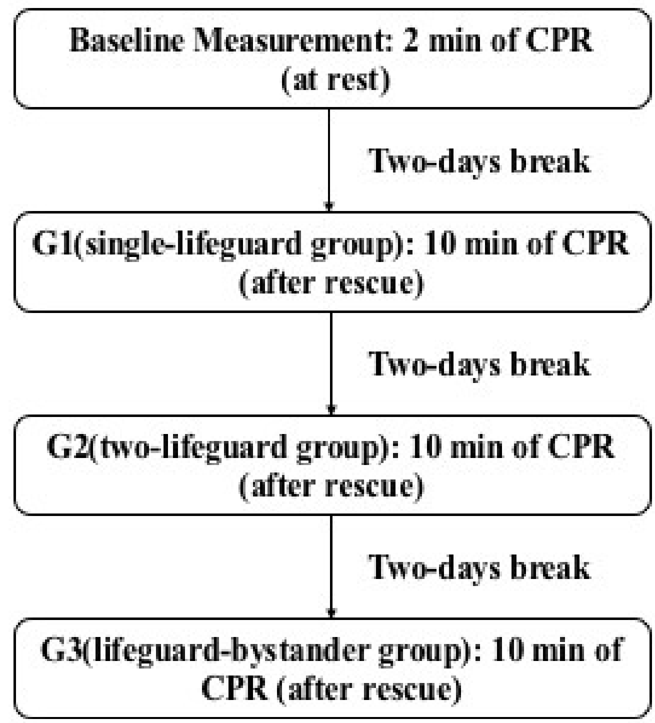

Figure 2 Research sequence. CPR, cardiopulmonary resuscitation.

and all participants were involved in all three trials (see figure 2). All the trials began with same water rescue process: a single lifeguard jumped into the water from the side of the pool, swam 50 m to the manikin in freestyle, caught the manikin and towed it back 50 m to the shore. The lifeguards wore swimming trunks without buoyancy. For the single-lifeguard CPR trial (T1), one lifeguard performed the water rescue, and immediately after that, performed CPR (compressionand ventilation) for 10 min. In the two-lifeguard trial (T2), one lifeguard performed the water rescue, another lifeguard performed the first 2 min of CPR ashore after water rescue, the rescue lifeguard performed the next 2 min CPR and they took turns for 10 min. The CPR process included compression and ventilation. In the lifeguard-bystander trial (T3), the rescue lifeguard retrieved the manikin, performed two ventilations and then gave instructions to the bystander for performing the first 2 min of compression-only CPR. The lifeguard completed the first 2 min of two breaths and then continued to perform the next 2 min CPR (including ventilation) and then they alternated every 2 min for a total of 10 min. As per recommendations, the untrained bystander was told to deliver chest-compression-only CPR.[7] CPR was performed following airway-breathing-circulation approach, and all ventilations were mouth-to-mouth.

In each trial, the rescue order of lifeguards was randomised. The lifeguards and the bystanders were randomly matched in pairs by computer. The participants received no feedback on their performance during the trial. The bystander instructions were self-designed based on the Advanced Medical Priority Dispatch System protocol (AMPDS V.11.1, Priority Dispatch Inc., Salt Lake City, Utah, USA) and another CPR protocol used in previous studies (see online supplementary appendix).[13 14]

For the water rescue, we used the standardised manikin adopted by the International Life Saving Federation (ILSF) to organise competitions, whereas CPR was performed on Laerdal Resusci Anne (Stavanger, Norway) with central Q-CPR devices.

Table 1 Participants' demographic characteristics

Variables	Lifeguards	Bystanders
Gender, n (%)		
Male	14 (100)	8 (57.1)
Female	0 (0)	6 (42.9)
Age (years), mean±SD	20±0.7	28±5.6
Height (cm), mean±SD	175±3.6	170±7.0
Weight (kg), mean±SD	71±8.8	63±10.1
BMI (kg/m^2), mean±SD	23±2.2	22±2.3
Previous CPR training times, mean±SD	2±1.6	–
Months since last training	4±2.9	–
Previous rescue experience	0	0

BMI, body mass index; CPR, cardiopulmonary resuscitation.

Laerdal PC Resusci Anne Wireless SkillReporter software, V.2.0, was used to collect the data of CPR quality.

Measurements

Measurements for CPR quality included (a) CPR score: overall CPR score, compression score and ventilation score; (b) chest compression: mean compression depth, percentage of compressions with correct depth, mean compression rate, percentage of compression with correct rate, percentage of adequate re-expansion, percentage of correct hand position and chest compression fraction; (c) ventilation: percentage of ventilation with correct volume, percentage of ventilation with insufficient volume and percentage of ventilation with excessive volume and (d) no-flow time. The overall CPR score is equal to 2/3 of the compression score plus 1/3 of the ventilation score. The software only provides variables in the total of time, so to obtain data for 2 min intervals, we had to briefly interrupt CPR every 2 min. The participants performed all the trials with a minimum break of 2 days.

Correct CPR was defined as adherent to 2015 AHA guidelines: compression depth 5 to 6 cm, compression rate 100 to 120 min^{-1}, chest compression fraction ≥60%, no-flow time ≤10 s, correct ventilation volume 500 to 600 mL. To our knowledge, the exact clinical cut-off value of proportion of correct chest compression and ventilation has not been well established. A minimum level of 70% of correct compressions and ventilations may be taken to represent effective life support, and this level is accepted by Royal College of General Practitioners of the UK and used by several studies.[15 16] In this study, percentage of correct chest compression and ventilation above 70% was defined as high-quality CPR.

Statistical analysis

The statistical analysis was performed using SPSS (V.20 for Mac, Inc, Armonk, New York, USA). The continuous variables were described as mean±SD, as the Shapiro-Wilk test showed all of them were normally distributed. The categorical variables were described as frequencies (%). Difference in CPR quality before and after water rescue was examined by paired student's t-test. Repeated analysis of variance was used to examine statistical difference among time groups and analysis of variance (ANOVA) with Bonferroni method was performed for comparing the difference among three trials. A p value less than 0.05 was considered statistically significant.

Patient and public involvement statement

No patient involved.

Table 2 Analysis of 2 min CPR quality before and after a water rescue

Variables	Baseline	T1	P value
CPR score			
Overall CPR score	95.57±3.89	89.00±4.24	0.163
Chest compression score	95.00±3.62	86.00±4.84	0.141
Ventilation score	97.29±3.85	98.36±2.10	0.338
Chest compression			
Mean compression depth, mm	53.64±3.82	52.57±5.52	0.253
Percentage of correct depth, %	69.50±2.35	65.57±5.41	0.682
Mean compression rate, min^{-1}	107.79±6.15	106.4±8.85	0.316
Percentage of correct rate, %	83.07±3.13	65.00±6.30	0.130
Percentage of adequate re-expansion, %	67.86±3.95	73.93±5.51	0.342
Percentage of correct hand position, %	98.57±5.35	94.79±4.16	0.261
Chest compression fraction, %	71.14±2.51	70.86±3.21	0.749
Ventilation			
Percentage of correct volume, %	78.36±2.65	75.29±4.54	0.693
Percentage of insufficient volume, %	10.21±2.85	15.29±1.73	0.582
Percentage of excessive volume, %	9.54±2.71	8.54±4.68	0.855
No-flow time, s	7.29±0.99	7.57±1.16	0.453

CPR, cardiopulmonary resuscitation.

RESULTS

Demographic data

The demographic characteristics of the 14 lifeguards and the 14 bystanders are summarised in table 1. None of the lifeguards had previous rescue experiences.

CPR performance of baseline measurement

In the baseline measurement (performed only by lifeguards), the CPR scores including overall CPR score, chest compression score and ventilation score, were above 95 points (table 2), but the mean correct ratio of compression depth (69.5%) was slightly lower than 70%.

Comparison of CPR quality before and after water rescue

For the water rescue with the single-lifeguard trial (T1), comparison of the CPR quality of the baseline measurement and the first 2 min after water rescue are shown in table 2. No significant difference was detected in the CPR quality variables before or after the rescue although there was a non-significant decrease in the overall CPR score after rescue. There was no significant decrease in any CPR quality variables during the 10 min post-rescue for the single-lifeguard trial (table 3).

Similarly, there was no significant decrease in any CPR quality variables for the two-lifeguard trial (T2) during 10 min (ANOVA) (table 4). In the lifeguard-bystander trial (T3), however, the CPR performance of bystanders was worse than that of lifeguards throughout 10 min CPR quality, mainly in compression depth and chest compression fraction. The CPR quality of T3 for the entire 10 min period are shown in table 5 and figure 3.

Comparisons of rescue time and CPR quality among the three trials

Rescue time previous to CPR and CPR quality of the three trials is presented in table 6. There was no significant difference in rescue time among three trials. Overall CPR score and ventilation score of the single-lifeguard trial were higher than that of the lifeguard-bystander trial. The compression rate of single-lifeguard trial was lower than that of the two-lifeguard trial and the lifeguard-bystander trial, but there was no statistical

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Table 3 CPR quality of single-lifeguard trial over 10 min

Variables	2 min CPR	4 min CPR	6 min CPR	8 min CPR	10 min CPR	P value
CPR score						
Overall CPR score	89.00±4.24	89.00±3.86	88.41±3.77	87.32±3.75	86.70±3.65	0.642
Chest compression score	86.00±4.84	86.82±4.40	86.19±4.29	85.32±4.20	84.99±4.09	0.870
Ventilation score	98.36±2.10	97.46±2.82	97.02±3.52	96.79±3.58	96.79±3.47	0.709
Chest compression						
Percentage of correct depth, %	65.57±5.41	64.14±5.54	62.50±5.56	59.29±5.53	57.23±5.59	0.106
Percentage of correct rate, %	65.00±6.30	65.61±6.39	65.17±6.35	66.00±6.25	66.69±6.10	0.867
Percentage of adequate re-expansion, %	73.93±5.51	75.57±5.37	73.19±5.21	71.20±5.20	69.94±5.18	0.089
Percentage of correct hand position, %	94.79±4.16	96.61±3.11	96.29±3.22	96.29±3.06	96.29±2.83	0.617
Chest compression fraction, %	70.86±3.21	70.68±3.62	70.71±3.89	70.21±4.12	69.91±4.23	0.283
Ventilation						
Percentage of correct volume, %	75.29±4.54	77.36±3.88	75.93±3.89	75.23±4.18	75.00±4.09	0.856
No-flow time, s	7.57±1.16	7.46±1.26	7.48±1.37	7.58±1.44	7.70±1.49	0.217

CPR, cardiopulmonary resuscitation.

difference in the percentage of correct compression rate among three trials. However, both the two-lifeguard trial and lifeguard-bystander trial had a lower percentage of breaths with correct ventilation volume than the single-lifeguard trial.

DISCUSSION

This study, conducted under controlled and simulated conditions in a swimming pool, is able to give new evidence on whether the fatigue generated by water rescue would influence the quality of subsequent CPR. CPR performance of three trials were observed and compared with to identify the strategy resulting in higher quality of CPR.

The ILSF proposed that the lifeguard should be able to rescue a victim 100 m from the coast.[10] Some studies suggest the distance from the shore in which the persons are drowning is between 50 m and 100 m.[17 18] The China Life Saving Association was founded in 2005; National Life Saving Competition Rules (2017 edition) require 50 m manikin life-saving for routine training and competition.[19] Therefore, in this study, the lifeguards towed a rescue manikin a 50 m distance.

The CPR performance of the lifeguards in baseline test was barely satisfactory, as the percentage of correct depth was below 70% slightly. High-quality CPR is not an easy task, and it requires not only skill but also strength, especially when CPR has to be maintained for a long time. Several studies have reported that health personnel and those with duty to assist, and individuals with different backgrounds have difficulties satisfying the criteria for high-quality CPR.[16] Abelairas-Gómez *et al*[20] designed a simple strength training programme and confirmed its effectiveness to improve the quality of chest compression to achieve the goal of 70% and maintain this level throughout 10 min test time. Such strength training should be considered as an addition to BLS training programmes.

Another reason that the lifeguards didn't achieve better CPR quality might be lack of familiarity with QCPR manikin. CPR real-time audio and video feedback has also been shown to improve adherence to guideline recommendations on CPR quality and was necessary for measurement in this study .[21 22] Their conventional CPR training uses a manikin without feedback device. Additionally, the lifeguards had no real-life rescue experience.

There was no significant difference in quality in the first 2 min of CPR before and after a water rescue and the CPR quality of the single-lifeguard trial did not decrease along the 10 min period, indicating that fatigue generated by a water rescue in an indoor swimming pool has minimal impact on the quality of subsequent

Table 4 CPR quality of two-lifeguard trial over 10 min

Variables	2 min CPR	4 min CPR	6 min CPR	8 min CPR	10 min CPR	P value
CPR score						
Overall CPR score	88.91±7.85	88.93±2.67	86.14±3.79	89.07±9.81	86.14±8.09	0.367
Chest compression score	92.17±5.97	89.79±2.63	87.93±4.92	90.86±1.27	91.64±8.98	0.481
Ventilation score	92.36±7.03	90.86±3.98	89.79±2.67	92.43±3.57	90.64±1.54	0.489
Chest compression						
Mean compression depth, mm	57.69±3.12	53.71±5.37	55.57±5.64	54.79±5.06	55.57±4.40	0.423
Percentage of correct depth, %	65.17±3.81	69.18±2.49	65.82±2.92	65.33±6.56	66.67±6.33	0.642
Mean compression rate, min^{-1}	113.77±9.01	111.92±7.01	114.00±8.21	115.93±7.17	116.79±8.56	0.439
Percentage of correct rate, %	58.18±5.53	72.57±3.72	64.00±3.86	73.50±3.44	64.79±4.05	0.224
Percentage of adequate re-expansion, %	75.38±3.19	74.62±3.43	70.00±3.87	73.64±4.54	70.43±4.07	0.278
Percentage of correct hand position, %	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	
Chest compression fraction, %	67.15±6.08	68.43±3.76	67.43±4.22	67.36±3.79	67.57±6.62	0.685
Ventilation						
Percentage of correct volume, %	69.43±4.75	75.25±2.27	64.55±8.99	66.77±9.32	66.08±3.92	0.260
No-flow time, s	8.07±1.39	8.00±1.15	8.14±1.35	7.93±1.73	7.57±1.60	0.608

CPR, cardiopulmonary resuscitation.

Table 5 CPR quality in lifeguard-bystander trial over 10 min

Variables	2 min CPR*	4 min CPR	6 min CPR*	8 min CPR	10 min CPR*	P value
CPR score						
Overall CPR score	60.46±8.85	87.85±2.08	79.00±4.17	86.62±1.17	75.46±7.42	0.003
Chest compression score	56.69±6.02	88.62±5.58	78.00±8.77	87.54±4.83	73.23±4.67	0.004
Ventilation score	72.08±2.64	91.31±4.64	87.08±4.30	89.92±2.41	88.15±3.37	0.006
Chest compression						
Mean compression depth, mm	48.15±1.71	55.23±5.15	51.85±7.29	55.69±4.54	52.38±8.72	0.011
Percentage of correct depth, %	31.08±3.46	53.46±3.61	34.62±7.72	54.23±4.05	35.62±2.44	0.030
Mean compression rate, min^{-1}	110.85±2.55	118.77±1.85	117.00±4.28	121.08±9.88	122.46±4.59	0.022
Percentage of correct rate, %	44.46±4.32	63.08±3.07	48.00±8.22	52.77±4.01	38.00±8.02	0.164
Percentage of adequate re-expansion, %	75.69±2.44	71.54±7.06	81.23±8.75	64.08±9.62	75.62±2.48	0.447
Percentage of correct hand position, %	99.15±3.05	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	0.417
Chest compression fraction, %	71.00±4.28	68.15±3.85	69.54±5.49	68.62±4.56	68.54±5.14	0.011
Ventilation						
Percentage of correct volume, %	36.00±5.45	62.69±8.92	46.54±4.21	47.62±4.77	55.92±9.20	0.066
No-flow time, s	13.23±3.40	7.31±1.60	7.31±1.25	7.23±1.17	7.31±1.38	0.391

*2 min CPR, 6 min CPR and 10 min CPR were performed by bystanders under instruction of lifeguards. (4 min CPR and 8 min CPR were performed by lifeguards).
CPR, cardiopulmonary resuscitation.

CPR when a well-trained lifeguard performed the rescue and resuscitation. This is in line with the findings of Claesson *et al*.[12] Lifeguards are likely to have a higher level of fitness than the general public and the workload of CPR was experienced as easier than performing a water rescue.[12] However, we would be cautious in generalising this finding to other environmental conditions, where waves, and temperatures may influence lifeguards' performance.

The quality of CPR performed over 10 min by a single lifeguard was higher than that performed by a lifeguard and a bystander. There was no significant difference in the chest compression score, which indicates bystanders could grasp the skill of chest compression under instructions on scene. It is in line with the AHA guidelines that compression-only CPR is preferred for 'just-in-time' teaching for untrained lay rescuers.[9] However, the performance of ventilation in two-lifeguard trial and lifeguard-bystander trial were not satisfactory. The reason may be the uncoordinated teamwork. Besides, some of the no-flow time of lifeguard-bystander trial was over 10 s, exceeding the cut-off value recommended by guidelines.[7 8] Gyllenborg *et al*[23] found that bystanders could not achieve the goal of CPR pauses below 10 s, even with feedback from the Zoll AED. If a bystander needs to perform CPR alone, the instruction for the bystanders should be to focus on minimal interruptions.

No difference in CPR scores was detected between the single-lifeguard trial and the two-lifeguard trial, which was unexpected. Teamwork may be better than single working alone generally, so as to reflect the value of extra labour. Effective cardiac arrest resuscitation requires a highly organised team-based process to best coordinate the efforts of several providers. Out-of-hospital emergency providers often face chaotic environments, so lifeguards should practice teamwork in various simulated conditions. Recent studies have reported that the implementation of a systematic, team-focused CPR (TFCPR) protocol could improve survival with good neurological outcome[24] or the return of spontaneous circulation and hospital admission rates.[25] TFCPR is a choreographed approach where prehospital responders know and practice a predetermined role and responsibility determined by the order of their arrival on scene. This approach could be introduced in teamwork training of lifeguards to achieve better collaboration.

Another finding of this study is that both two-rescuer trials had a lower percentage of breaths with correct ventilation volume than the single-lifeguard trial, even though the ventilations of the lifeguard-bystander trial were delivered by the very same lifeguards as the single-lifeguard trial. The percentages of correct ventilation volume of the two-rescuer trial were also below 70%, whereas the single-lifeguard trial achieved the high-quality criterion. Further analysis showed that both two-rescuer trials were more likely to give excessive-volume ventilation than the single-lifeguard trial. The lifeguard might experience psychological relaxation when another person is available to help, thus decreasing the ventilation quality. A previous study showed that strength training led to overventilation,[20] suggesting physical relaxation might also be the explanation for higher percentage of excessive ventilation volume of the two-rescuer trial. Nonetheless, large tidal volume could cause gastric inflation and lung injury, so teamwork training should also focus on monitoring chest rise during ventilations, in order to ascertain that the lungs are inflated but not overinflated.

There are several limitations of this study. First, manikin and simulated studies could not represent the real conditions. Lifeguards might be nervous or panic when they encounter emergencies, especially for those who have never experienced rescues. Second, the sample size of this experimental trial is small. A large sample study is needed to verify the impact of fatigue on CPR quality. Third, all the lifeguards recruited in this study are male, although a previous study found that gender does not significantly influence CPR quality, either at rest or at fatigue condition.[10] The lifeguards had no rescue experience in this study so may not be representative. Fourth, a learning effect could not be diminished completely, even though it was a randomised experiment and the participants performed all the trials with a break of minimum 2 days. The non-blinded design may cause experimental bias. Lastly, our study was carried out in the controlled conditions of an indoor pool. The open water currents and different distance were likely to have a deleterious effect on the CPR quality.

The lifeguards did not achieve 70% quality of all CPR measures at baseline, and thus the quality after rescue was compared with suboptimal quality initially. Also, in retrospect, the 2 min CPR baseline measurement was not comparable to the 10 min CPR sessions and quality may have been better (or worse) with more

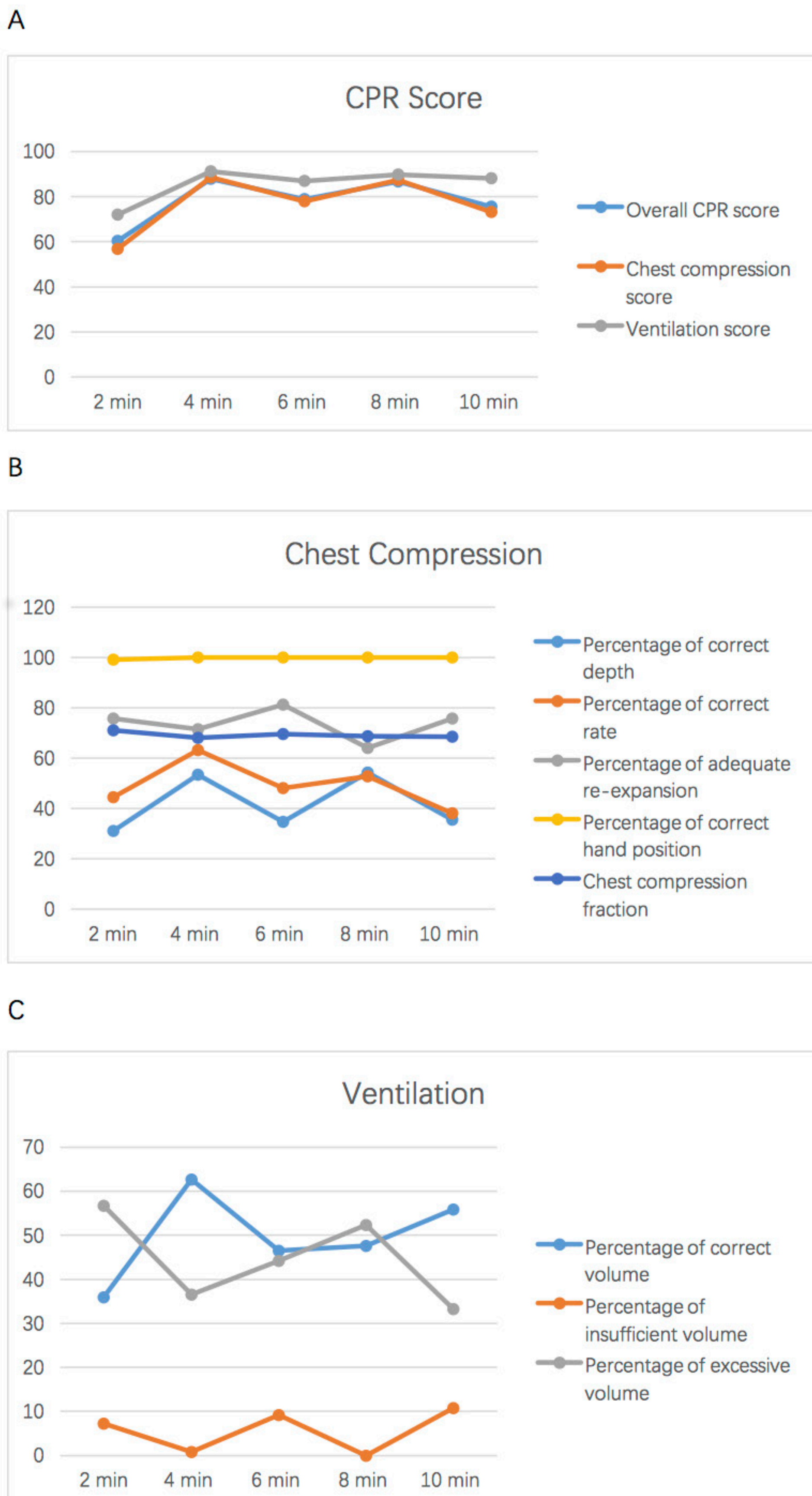

Figure 3 The CPR quality variation of the lifeguard-bystander group along 10 min period. (A) The variation of CPR scores; (B) the variation of chest compression variables; (C) the variation of ventilation. CPR, cardiopulmonary resuscitation.

Table 6 Analysis of 10 min CPR quality among the three trials

Variables	T1	T2	T3	*p*-value	Multiple Comparisons
Rescue time before CPR	111±8.34	116±9.21	114±8.76	0.647	
CPR score					
Overall CPR score	86.70±13.33	86.07±8.34	77.98±13.17	0.025	T1/T3 p=0.027
Chest compression score	84.99±16.72	89.10±8.23	76.86±17.75	0.049	–
Ventilation score	96.79±3.47	89.87±9.63	85.64±11.47	<0.001	T1/T3 p<0.001
Chest compression					
Mean compression depth, mm	52.57±5.52	55.01±3.96	53.20±6.46	0.424	
Percentage of correct depth, %	57.23±31.23	53.86±20.57	40.24±26.48	0.095	–
Mean compression rate, min^{-1}	106.4±8.85	117.54±9.20	117.62±12.60	0.017	
Percentage of correct rate, %	66.69±37.15	66.29±32.58	51.44±32.52	0.529	–
Percentage of adequate re-expansion, %	69.94±26.88	69.54±24.08	71.93±21.39	0.938	–
Percentage of correct hand position, %	96.29±8.01	100.00±0.00	99.50±1.36	0.236	–
Chest compression fraction, %	69.91±4.23	67.50±2.78	69.26±4.13	0.059	–
Ventilation					
Percentage of correct volume, %	75.00±16.75	54.79±25.48	50.81±30.82	0.006	T1/T2 p=0.025, T1/T3 p=0.010
Percentage of insufficient volume, %	9.30±8.58	3.91±6.16	6.66±7.06	0.073	–
Percentage of excessive volume, %	15.90±20.11	42.86±27.26	42.51±34.73	0.003	T1/T2 p=0.007, T1/T3 p=0.011
No-flow time, s	7.70±1.49	7.94±0.93	10.25±1.78	<0.001	T1/T3 p<0.001, T2/T3 p<0.001

CPR, cardiopulmonary resuscitation.

time. Because the Laerdal software cannot provide variables in 2 min increments during 10 min CPR, the CPR was interrupted every 2 min which might have allowed for some rest.

CONCLUSIONS

This quasi-experimental trial demonstrated that a well-trained lifeguard was able to perform single-rescuer CPR without a significant decrease in quality for at least 10 min after a water rescue. When a lifeguard is available for drowning victim, laypersons are not suitable to participate in the resuscitation. Nevertheless, overall CPR performance by trained lifeguards, especially chest compression depth and re-expansion, needs to be improved.

Collaboration of two lifeguards was not superior to a single lifeguard. This indicates teamwork training is necessary for lifeguards and should be strengthened during and after BLS programmes.

Contributors I worked with my team to conduct our research. This paper adopted an experimental design for LG and SL. SL was responsible for the study conception and design, the analysis and interpretation of the data and the drafting of the manuscript. TK also participated in the implementing experiment and the analysis of the data. ZG and CC performed the data collection of the research. LG, TK and SL made critical revisions for important intellectual content of the paper. LG supervised the study and provided administrative support.

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