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American Journal of Emergency Medicine xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Original Contribution

Assessing the efficacy of rescue equipment in lifeguard resuscitation efforts for drowning

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ARTICLE INFO

Article history:
Received 17 October 2015
Received in revised form 27 November 2015
Accepted 8 December 2015
Available online xxxx

ABSTRACT

Purpose: The whole drowning process usually occurs within seconds to a few minutes. An early rescue may stop and/or prevent most medical complications. Fins, rescue tube, and rescue board (RB) are the equipment most frequently used by lifeguards. Our objective was to compare, in a water rescue quasiexperimental trial, these different pieces of rescue equipment to define the safest and with the lower rescue time as well as to assess their effects on the lifeguards' physiological state and cardiopulmonary resuscitation (CPR) performance.
Method: A controlled trial was conducted to study the time effect of 4 different rescue techniques and assess CPR quality, along with the physiological effects of each rescue technique (blood lactate and subjective Borg's scale effort perception) on 35 lifeguards.
Results: Among the final sample subjects (n = 23), a total of 92 rescues were completed. Total water rescue time was longer without equipment (NE). The total rescue time was significantly lower using RB ($P < .001$). Similar good quality of CPR before and after water rescue was observed in all trials ($P > .05$), although correct ventilations represented less than 50% of total in all trials. Blood lactate increased after all rescues. The subjective effort Borg's scale showed significantly less effort using RB vs without equipment, fins, and fins and rescue tube.
Conclusion: The use of propelling and/or floating equipment saves precious time with repercussions in the reduction of drowning mortality and morbidity. The RB offers a significant advantage. Lifeguards need more CPR training, especially considering the importance of efficient ventilations for drowning victims.

1. Introduction

Drowning is a leading global killer, particularly among children and young adults. Worldwide, there are approximately 42 drowning deaths every hour, every day [1]. This number highly underestimates the real figures, even for high-income countries [2].

The whole drowning process, from immersion to cardiac arrest, usually occurs within seconds to a few minutes [3]. Therefore, an early and effective rescue may stop the drowning process and prevent the majority of initial and subsequent water aspiration, the respiratory distress, the need to resuscitation, and the medical complications.

Drowning involves principles and interventions that are rarely or not found in any other medical situations. That is stated in the "drowning chain of survival" [4], which refers to a series of water safety interventions. Its third ring refers specifically to the benefits and the importance of providing flotation to the victim stopping the drowning process as early as possible.

It is worldwide accepted that lifeguards would do a fastest, safest, and harmless rescue, both to himself and to the victim, if using rescue equipment [5]. Currently, several water rescue equipment are available providing safety for the rescuer and may impact positively the time to rescue and consequently the victim's outcome. Its choice and use are based on lifeguard's expert opinions and local practices. Based on

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http://dx.doi.org/10.1016/j.ajem.2015.12.006
0735-6757/

Please cite this article as: Barcala-Furelos R, et al, Assessing the efficacy of rescue equipment in lifeguard resuscitation efforts for drowning, Am J Emerg Med (2015), http://dx.doi.org/10.1016/j.ajem.2015.12.006

nonscientific but best practice concepts, many different pieces of rescue equipment have been used to speed up the rescue. The most common water rescue equipment in use are fins (F), rescue tube (T), and rescue board (RB), used by lifeguard services as a personal floatation device to provide to the victim during a water rescue [6-8] but not much is known about the specific efficiency of each equipment. Scientific evidence is needed to fill those knowledge gaps [5].

Our objective was to compare in a quasiexperimental trial, a water rescue performed by surf lifeguards with and without equipment, to evaluate the most efficient—the safest equipment with lower rescue time—as well as to assess the effects of each rescue technique on lifeguards' physiological state and cardiopulmonary resuscitation (CPR) performance—tireless.

2. Materials and methods

A controlled trial was conducted to study the effect of 4 different rescue techniques with and without lifesaving equipment and to assess CPR quality, along with the physiological effects of each rescue technique on lifeguards.

2.1. Study design

A quasiexperimental design was used to evaluate lifesaving parameters along the rescue process: total rescue time (TRT), lifeguard physiological variables, and CPR (Fig. 1).

2.2. Sample

Thirty-five surf lifeguards were invited to participate in this trial. They were all from the cities of Gijón (Asturias) and Santiago del Teide (Canary Islands), Spain, all working at emergency beach corps and with full certificate in basic life support under the 2010 European Resuscitation Council Guidelines for Resuscitation [9]. Anthropometric and demographic variables were collected to characterize each subject: sex, height, age, weight, and body mass index (BMI).

We excluded lifeguards who had any musculoskeletal or functional mobility issue along the trial and those who did not complete all 4 rescue techniques attempts.

Several instructors were invited to participate as victims and had the following anthropometric characteristics: weight between 80 and 90 kg and height between 170 and 190 cm.

All of them provided written informed consent to participate in the study. The research project was approved by the Ethical Committee of School of Education and Sport Sciences (University of Vigo, Spain).

2.3. Cardiopulmonary resuscitation phase

Participants performed 5 minutes of CPR on a manikin placed on dry sand in 2 circumstances: before the water rescue trial (baseline test of CPR) and immediately after each of the 4 rescues attempted.

2.3.1. Cardiopulmonary resuscitation manikin and variables

The Laerdal ResuciAnne manikin (Stavanger, Norway) with Wireless SkillReporter, software version 1.1 was used. The electronic manikin can evaluate compressions and ventilation efficiency. To evaluate the compressions, it takes into account the compression rate and depth, the decompression depth, and the correct position of the rescuer's hands on the chest. The tidal volume was considered to evaluate ventilation adequacy. The manikin and quality CPR measuring system was programmed according to the 2010 European Resuscitation Council Guidelines for Resuscitation [9]. Good-quality performance feedback was considered when the user accomplished correct compressions and ventilations equal to or higher than 70% using the following parameters [10-14]: 5 to 6 cm for chest compression (CC) depth, 100 to 120 per minute for CC rate, full chest re-expansion, correct chest hand position (yes or no), and 500 to 600 mL (6 to 7 mL/kg) for tidal volume of the rescue breath (Fig. 1).

Quality CPR was calculated as a percentage (%) using the following equation: QCPR (%) = [(QCC (%) + QV (%))/2], where quality chest compression (QCC) in percentage corresponded to the sum of percentage of correct CCs (depth between 5 and 6 cm), plus percentage of correct chest re-expansion (return to the starting point of 0 cm of compression), plus percentage of correct chest hand position, and quality ventilation (QV) was measured as dichotomous variable (yes or no), presented as a percentage (%) of correct ventilations performed within the range of 500 to 600 mL. Compression rate per minute (R), mean tidal volume (TV) in milliliters for 5 minutes, and ventilation rate (VR) per minute were an extra given information by the quality CPR manikin measuring.

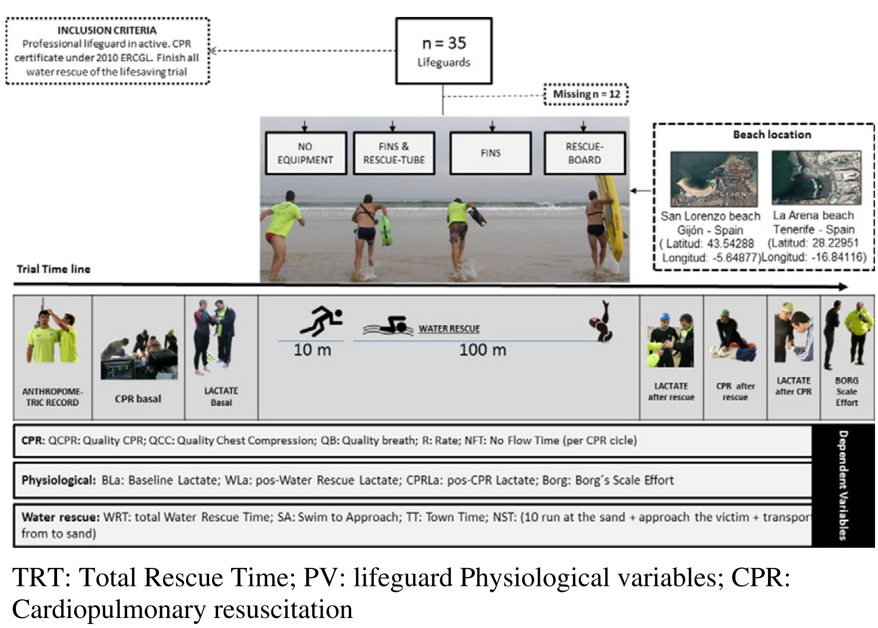

Fig. 1. Flow chart of the experimental design. PV, lifeguard physiological variables.

2.4. Physiological variables

Two variables were evaluated at rest and after each rescue attempt: the subjective perception of effort after each 4 rescue attempt was assessed by means of the Borg's scale [15]. Blood lactate was measured to objectively assess the intensity of the lifeguards' physical effort in each challenge test [11]. Three lactate measurements were made: baseline, after each rescue, and after CPR values expressed in millimoles per liter. Measurements were made immediately using the Lactate Scout (SensLab GmbH, Leipzig, Germany) device.

2.5. Water rescue phase

The 4 most common rescue techniques in surf lifesaving [6-8,11,16-19] were compared in a single controlled trial: rescue with no equipment (NE), rescue using fins (F), rescue using fins and rescue tube (FT), and rescue with rescue board (RB).

Rescue scenario was set with a victim located 100 m from the shore, based on studies [20,21], suggesting 100 m as the top distance for most drowning incidents.

Each participant performed 1 rescue trial with no equipment and 1 rescue with each of 3 pieces of equipment, totaling 4 trials (Fig. 1). The sequence of the 4 rescues was randomized. To standardize the study, lifeguards were briefed to perform the same rescue protocol. A week before the trial, all volunteers performed a CPR and a rescue refreshment with and without equipment. The victims were all conscious, passive, and floating. A technical supervision was carried out by 2 instructors in the water and 2 on the beach to guarantee the victim did not collaborate and that standardized technical protocols were followed. To avoid fatigue interference, each lifeguard performed only 2 rescues per day with a minimum of 2-hour gap between them. When the ocean temperature was less than 15°C, lifeguards were allowed to use wetsuits or single trunk, thickness between 3.2 and 4.3 mm. With water temperatures greater than 15°C, they could use *lycra* T-shirt, but decision was up to each lifeguard.

2.5.1. Equipment characteristics and lifeguards experience

2.5.1.1. Fins. Standard rubber fins with a minimum length of 40 cm and maximum of 80 cm are used. Each lifeguard used their own personal fins (Fig. 2).

2.5.1.2. Rescue tube. Standard RT, with dimensions of 100 × 16 × 9 cm and weight less than 760 g, was used.

2.5.1.3. Rescue board. An RB with 320 × 55 × 19 cm, 225 L of volume, and 11 kg was used.

All lifeguards were trained with the equipment, although they usually work with FT on a daily basis, so they have less experience with RB.

2.5.2. Environmental conditions

The trial was conducted at 2 Spanish beaches (Fig. 1) under similar conditions: calm sea with waves less than 0.5 m (value 0-2 Douglas scale) and wind speed less than 5 m/s. Water temperature ranged from 14C° to 22C°, and average ambient temperature ranged from 21°C to 32°C.

2.5.3. Water rescue variables

Total water rescue time is expressed in seconds. *Swim to approach time* (SA), in seconds, is defined as the time elapsed from the lifeguard entry in the water to the first contact with the victim. *Towing time* (*TT*), in seconds, is defined as the time needed to tow the victim to the shore. No swim time (NST) was the sum of 10-m beach run plus time to approach the victim and transport from water to dry sand.

2.6. Statistical analysis

All analyses were performed using SPSS statistical package for Mac, version 20 (SPSS, Inc, Armonk, NY, USA). The following tests were conducted: (*a*) Kolmogórov-Smirnov test was used to check normal distribution of data; (*b*) repeated-measures analysis of variance with Bonferroni test was used to analyze CPR, physiological data, and rescue times; (*c*) variables were described using measures of central tendency (mean) and dispersion (SD). A significance level of $P < .05$ was considered for all analyses.

3. Results

3.1. Demographic data

From the 35 lifeguards recruited, 11 were excluded because of not having completed 1 of the 4 rescues or 1 of the 5 CPR trials. The final study sample (n = 23) consisted of 21 men (91%). Mean age was 30 ± 6.77 years; height, 177 ± 10.0 cm; weight, 76 ± 7.72 kg; and BMI, 24.12 ± 2.02 kg/m^2. There was no significant age difference between men and women, only in height ($P < .001$) and weight ($P = .02$) (Table 1).

3.2. Cardiopulmonary resuscitation quality

Results of CPR quality variables at baseline and after each water rescue trial are shown in Table 2. In terms of CC depth, participants delivered CPR of similar quality before and after the rescues, regardless of the equipment used. However, after rescue, an increase was observed in CC rate, especially with FT ($P = .01$). The percentage of correct ventilations was less than 50% before and after all rescue trials, with no significant differences ($P > .05$).

3.3. Lifeguard physiological response

Table 3 shows the results of lactate measurement at 3 different times: at baseline, just after the water rescue, and after CPR. Blood lactate increased significantly after all rescue techniques. In case of RB, the peak value of lactate was slightly lower than in case of NE, F, or FT ($P > .05$). According to the subjective Borg's scale, significantly less effort was found using RB compared to NE ($P < .001$), F ($P = .003$), and FT ($P = .001$).

Fig. 2. Pictures of the rescue equipment used in the study.

Please cite this article as: Barcala-Furelos R, et al, Assessing the efficacy of rescue equipment in lifeguard resuscitation efforts for drowning, Am J Emerg Med (2015), http://dx.doi.org/10.1016/j.ajem.2015.12.006

Table 1
Demographic characteristics of the 23 lifeguards with correspondent descriptive statistics

	All (n = 23)		Male (n = 21)		Female (n = 2)		P
Variables	Mean	SD	Mean	SD	Mean	SD	
Age[a]	30	6.77	30	7.0	31	2.8	.69
Height[b]	177	10.0	178	6.4	162	1.4	.02*
Weight[c]	76	7.72	77	8.4	60	18.4	<.001*
BMI[d]	24.12	2.02	24.8	.4	22.80	6.6	.81

[a] Age in years.
[b] Height in centimeter.
[c] Weight in kilograms.
[d] Body mass index in kilograms per square meter.
* Statistically significance for $P < .05$.

3.4. Water rescue trial

A total of 92 rescues were performed along the study. Total water rescue time was longer when NE was used. No significant differences were observed between F and FT groups. When the lifeguards carried out an RB rescue, TRT was significantly lower compared to the other 3 groups ($P < .001$). Total water rescue time with NE was 50.5% higher than with RB. Differences persisted when the TRT components (SA + TT + NST) were compared (Table 4). The TT was 68.7% of TRT in trials with NE, 62.8% with F, 56.0% with FT, and 53.4% with RB (Table 4).

Table 3
Analysis of the effort variables associated with rescues and CPR

Rescues (n = 92), lifeguards (n = 23)					
		Mean	SD	95% CI	Sig (Bonferroni test)
BLa	NE[a]	1.62	.15	1.51-1.74	
	F[b]	1.69	.54	1.28-2.10	
	FT[c]	1.63	.50	1.25-2.02	a, b, c, d >.05
	RB[d]	1.63	.19	1.48-1.78	
WLa	NE[a]	11.01	2.06	9.43-12.60	
	F[b]	10.52	2.18	8.85-12.20	
	FT[c]	11.59	2.36	9.77-13.41	a, b, c, d >.05
	RB[d]	8.91	1.78	7.55-10.28	
CPRLa	NE[a]	9.11	2.15	7.46-10.77	
	F[b]	9.48	1.61	8.24-10.72	
	FT[c]	9.72	2.10	8.11-11.34	a, b, c, d >.05
	RB[d]	8.84	1.75	7.50-10.19	
Borg	NE[a]	8	.77	7.99-8.87	a * d <.001
	F[b]	8	1.03	7.26-8.45	b * d = .003
	FT[c]	8	.83	7.45-8.41	c * d = .001
	RB[d]	6	1.19	5.53-6.90	d * a <.001, b = .003, c = .001

Abbreviations: BLa, baseline lactate; WLa, post–water rescue lactate; CPRLa, post-CPR lactate; Borg, Borg's scale effort.

4. Discussion

In drowning, the safer and faster a rescue is accomplished, the better to prevent the asphyxia and decrease the severity of outcomes. To

Table 2
Analysis of variables associated with CPR quality

	CPR (n = 115), lifeguards (n = 23)					
			Mean	SD	95% CI	Sig (Bonferroni test)
Quality variables (QCC + QV)/2		Basal	64	15.28	54.79-73.26	Basal, a, b, c, d >.05
	QCPR* (%)	NE[a]	52	17.73	40.04-63.85	
		F[b]	51	19.69	37.58-64.04	
		FT[c]	42	17.09	30.25-53.22	
		RB[d]	62	22.91	45.25-78.03	
CC variables	QCC* (%)	Basal	82	18.85	70.63-93.42	Basal, a, b, c, d >.05
		NE[a]	72	32.17	50.59-93.81	
		F[b]	56	35.31	32.04-79.49	
		FT[c]	53	28.87	33.23-72.02	
		RB[d]	76	22.10	60.78-92.41	
	Depth* (50-60 mm) in mm	Basal	53	4.14	50.04-52.00	Basal, a, b, c, d >.05
		NE[a]	56	2.95	53.93-57.89	
		F[b]	51	6.41	46.42-55.03	
		FT[c]	51	5.47	47.78-55.13	
		RB[d]	52	4.49	49.12-55.48	
	R* per minute	Basal	112	3.81	109.62-114.23	Basal, a, b, d >.05
		NE[a]	119	6.99	113.94-123.33	
		F[b]	123	10.24	115.76-129.52	
		FT[c]	125	9.84	118.66-131.88	c‡ Basal = .01
		RB[d]	123	14.24	113.21-122.78	
Ventilations variables	QV* (%)	Basal	46	22.56	32.39-59.66	Basal, a, b, c, d >.05
		NE[a]	32	34.98	8.20-55.19	
		F[b]	46	26.60	27.99-63.73	
		FT[c]	31	26.20	13.24-48.44	
		RB[d]	47	30.90	24.58-68.79	
	TV* (mean in 5 min, in mL)	Basal	631	156.94	536.39-726.07	Basal, a, b, c, d >.05
		NE[a]	564	300.36	362.58-766.15	
		F[b]	581	122.81	498.04-663.05	
		FT[c]	662	150.30	560.66-762.61	
		RB[d]	680	302.76	463.15-896.25	
	VR† per minute	Basal	5.00	0.34	4.80-5.20	Basal, a, b, c, d >.05
		NE[a]	4.78	1.61	3.70-5.86	
		F[b]	5.25	1.44	4.29-6.22	
		FT[c]	5.27	0.60	4.87-5.67	
		RB[d]	5.28	0.78	4.72-5.84	

QCPR (%) = [QCC (%) + QV (%)]; QCC (%) [correct chest compression = depth (50-60 mm) and chest re-expansion (return to the starting point of 0 mm of compression) and correct chest hand position (in the center of chest)]; Depth (monitored in millimeters); R, compression rate (per minute); QV (goal standard between 500 and 600 mL); TV, tidal volume mean; VR, ventilation rate.
* In 5 minutes.
† Per 1 minute.
‡ Variable vs variable.

Please cite this article as: Barcala-Furelos R, et al, Assessing the efficacy of rescue equipment in lifeguard resuscitation efforts for drowning, Am J Emerg Med (2015), http://dx.doi.org/10.1016/j.ajem.2015.12.006

Table 4
Rescue time recorded by phases and material

Rescues (n = 92), lifeguards (n = 23)					
		Mean	SD	95% CI	Sig (Bonferroni test)
TRT	NE[a]	307	48.52	285.54-327.51	a * d <.001
	F[b]	291	38.15	274.68-307.67	b * d <.001
	FT[c]	289	43.82	270.44-308.34	c * d <.001
	RB[d]	204	37.44	187.72-220.10	d * a <.001, b <.001, c <.001
SA	NE[a]	88	11.22	81.22-94.78	a * b = .01, c = .002, d <.001
	F[b]	78	8.90	72.40-83.14	b*a = .001, d <.001
	FT[c]	77	8.37	72.40-82.52	c * a = .002, d <.001
	RB[d]	52	6.40	48.52-56.25	d * a < .001, b <.001, c <.001
TT	NE[a]	211	22.73	197.4-224.89	a * b = .005, c <.001, d <.001
	F[b]	183	23.32	169.14-197.32	b * a = .005, c = .006, d <.001
	FT[c]	162	20.96	149.34-174.66	c * a <.001, b = .006, d <.001
	RB[d]	109	28.04	92.21-126.10	d * a < .001, b <.001, c <.001
NST	NE[a]	37	8.17	31.76-41.63	a * c = .006, d = .007
	F[b]	39	7.27	34.46-43.24	b * c = .03
	FT[c]	48	9.53	42.70-54.22	c * a = .006, b = .03
	RB[d]	45	9.32	39.52-50.78	d * a = .007

achieve this goal, several pieces of equipment that improve floating and/or reduce rescue times have been recommended and are available for use by surf lifeguards [5,17,22]. Rescue material can support floating (RT), provide propulsive (F), or have mixed functions (such as RB).

Our study, conducted under controlled and simulated conditions, using 4 different rescue techniques, on a calm water scenario that resembled a typical event on crowded beaches, was able to give new evidence to the subject. The use of rescue material (propulsion and/or flotation) demonstrated better results on rescue total time. We observed that equipment with both propulsion and floating properties saved time in reaching the victim and taking the victim to shore. This information provides new evidence to recommend a water rescue equipment classification system, which has the potential to contribute to the way we evaluate their performance and to assist lifeguards choose between all available tools for rescue. This system consists of 3 equipment categories based on 2 variables (floatation and propulsion). When the total water rescue time was considered, our group demonstrated in a previous study [8] that, with the help of FT [13], trained lifeguards spared 16% of time in a 75-m water rescue trial. Claesson et al [18] and Prieto et al [16] reported similar results using an RT and torpedo buoy, respectively. However, in the present 100-m rescue trial, the use of FT saved only 6% of TRT. On the other hand, our study has demonstrated that using RB lifeguards achieved a significant (33%) reduction of TRT compared to NE ($P < .001$). This equipment can save more than 1.5 minutes to tow the victim to the shore, providing a higher chance of better outcome in a real situation. When the components of TRT were analyzed separately, all equipment saved more time than NE.

Should the rescue equipment be recommended for routine use by surf lifeguards? Our study shows that each equipment was helpful in saving time but the RB provided significantly better results in surf conditions of less than 0.5 m and within 100 m from shore in a rested lifeguard. Other factors such as weather conditions, physical fitness, previous practice with the equipment, and training may influence the results in real-life situations and need to be further evaluated.

Another major objective of this study was to determine whether fatigue is a significant limiting factor for CPR quality if the lifeguard needs to provide CPR after a rescue [6,18]. Is the fatigue somehow related with the use of equipment? What is the physiological cost of a water rescue? Past research emphasized the need for good physical condition and training under the possibility of fatigue [6,7,13]. Abelairas-Gomez et al [23] reported in a previous study of 75-m water rescue with lifeguards that blood lactate levels were very high, indicating a strenuous workload with use of the anaerobic metabolic pathway. Similar results were found by Barcala-Furelos et al [11] in another research in water rescue with beach polices. The present study indicates that lactate levels just after the rescue were high independently of the rescue method, with mean values of 10.5 to 11.6 mmol/L but slightly lower (8.9 mmol/L) in RB use. All those rescue techniques use legs except for the RB. The overexertion of swimming using larger muscles (legs) while towing the victim might explain these higher values. Although no significant difference was found among these 92 trials, a larger sample may show differences. After CPR, lactate values were quite similar in all groups (around 9 mmol/L) because lower extremities lactate was washed out from the body and all were using arms. Nevertheless, the subjective perception of effort (Borg's score) [15] and lactate results suggest that RB was less demanding, and this may mean better aptness for a subsequent rescue in real life or even for the extra effort to perform CPR.

Regarding QCPR, this study demonstrates that there was no significant difference ($P > .05$) in performance between basal and after rescue techniques, indicating that the rescue effort using different techniques had no effect on CPR quality when applied for 5 minutes after a single rescue. Results should be carefully considered as preliminary because lifeguards are usually physically fit. A layperson participating in a rescue trial under similar conditions might show different results of QCPR. Basal QCC measurements were considered good (>70%) [10], suggesting that all lifeguards in this study were well trained. Other studies have found similar results [6,7,11]. An intriguing result was the fact that NE sustains a good CC performance after the rescue, whereas F and FT did not. This can be due to the randomized occurrence for the NE evaluation. Chest compression was faster after rescue, and this may be a result of the rescue effort to speed things up. Quality ventilations showed to be lower than 70%, at basal and after all rescues, although no statistical difference ($P > .05$) among them was observed. This suggests poor-quality ventilation training, but with no statistical effect after rescue effort under this trial circumstances. Similar results have been reported elsewhere [6-8,11,13,18].

This study suggests that a well-trained lifeguard is able to deliver good-quality CPR even after a strenuous challenge of water rescue at 100 m offshore. In addition, the use of propelling and/or floating water rescue equipment, specially the rescue-board, offers a statistical significant advantage considering 1 single rescue.

4.1. Limitations

The research has been carried out in relatively controlled and simulated conditions that resemble the lifeguards' usual work environment. It could be presumed that the level of expertise is a significant factor, but the results achieved for RB suggest the opposite. No subject on this trial was used to this equipment, and still, the results were highly efficient. This result could be different with surf conditions more than 0.5 m, and additional studies are needed.

In this study, sex variables were not analyzed because the female sample was anecdotal.

5. Conclusions

The use of propelling and/or floating equipment saves time during water rescue, entailing saving more lives. The use of any equipment is better than no use. Among the use of rescue equipment, the RB offers a significant advantage when compared with F or FT under studied conditions. Water rescue is a demanding effort even for trained surf lifeguards, regardless of the rescue technique applied. However, this is not a handicap to perform good-quality CPR after rescue. Still, lifeguards need more CPR training, especially when considering the importance of efficient ventilation for drowning victims.

Conflict of interest statement

No conflicts of interest to be declared.

Please cite this article as: Barcala-Furelos R, et al, Assessing the efficacy of rescue equipment in lifeguard resuscitation efforts for drowning, Am J Emerg Med (2015), http://dx.doi.org/10.1016/j.ajem.2015.12.006

Acknowledgments

We would like to thank all lifeguards and instructors involved in this trial and Ana Catarina Queiroga, Manuela Sestayo Fernandez, and Violeta González Salvado for helping in the review.

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