Research

Effects of 'rescuer' rotating time on the quality of chest compressions: 1-minute vs. 2-minute intervals

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Abstract

Introduction
Fatigue can influence the quality of continuous chest compression cardiopulmonary resuscitation (CCC-CPR). This study was conducted to compare the effect of 'rescuer' rotating time on the quality of chest compressions at 1-minute and 2-minute intervals.

Methods
The present semi-experimental study was conducted on 70 non-professional 'rescuers' as 35 two-person teams using a crossover design. All teams performed eight 2-minute cycles of CCC-CPR with a rotation of 1 minute and 2 minutes. Quality metrics of the chest compression rate, appropriate depth of compression, and total rate of compressions at the end of eight 2-minute cycles were used to assess the quality of the chest compressions.

Results
The study results showed that the number of chest compressions with an adequate depth performed by the non-professional rescuers in the 1- and 2-minute scenarios were respectively 118.18 and 100.87. There was no significant difference in the number of chest compressions between the two scenarios at the end of the CCC-CPR, but the number of compressions with sufficient depth in the 1-minute scenario was better than that in the 2-minute scenario.

Conclusion
The study showed that although the rate of chest compression had a downward trend in the 1-minute scenario, rescuers maintained 100 to 120 chest compressions after 16 minutes. This means that non-professional rescuers replacement after 1 minute can increase chest compression with sufficient depth.

Keywords:
cardio-cerebral resuscitation; continuous chest compressions; rescuer rotation

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Introduction

Cardio-pulmonary resuscitation (CPR) refers to a series of actions that are done to preserve and restore the life of a person (1). Cardio-pulmonary resuscitation is performed in a range of ways. In the conventional method, after diagnosis of cardiopulmonary arrest in an adult, the 'rescuer' immediately begins to externally compress the chest. After doing 30 compressions on the chest, the rescuer performs two ventilations (2). Although the standard CPR is an international guideline and is used worldwide, recent studies in animal and human subjects have shown that active ventilation of patients suffering from cardiac arrest during CPR may be unnecessary and even harmful (3). These studies have eventually led to the development of new emergency medical services (EMS) protocols for CPR so that the number of ventilations has been minimised (as much as possible), and time taken to perform chest compressions maximised (4,5).

Continuous chest compression CPR (CCC-CPR) is one of the protocols that has been suggested as an alternative method to conventional CPR, with emphasis on immediate chest compression and delayed respiratory ventilation (6). In the 2010 European Resuscitation Council Guideline, CCC-CPR is recommended as an alternative method to conventional resuscitation. Previous studies have shown that in addition to the specific advantages of CCC-CPR, such as its easier learning and implementation, it has a survival rate similar to that of conventional CPR (7).

A major disadvantage of CCC-CPR is the rapid emergence of fatigue following resuscitation, which reduces the quality of resuscitation (8). Some studies have shown that the number of continuous chest compressions does not decrease despite fatigue, but its efficiency (proper depth) decreases without the rescuer's awareness (9,10). Some scholars have carried out research on addressing the fatigue problem. Ashton et al and Huseyin et al reported that in continuous chest compressions, after 1 minute, significant reduction may occur in the quality of compressions due to fatigue (11,12). Therefore, the replacement of the rescuer every minute is essential. However, Manders et al showed that after a total of 8 minutes, there was no significant difference in the effectiveness of chest compressions between 1-minute and 2-minute scenarios. It seems that in the 2-minute scenario, the rescuer may be exhausted due to the continuous effort, and in the 1-minute scenario, replacement action may decrease the effectiveness of continuous compressions (13).

Therefore, a fundamental question to be answered is when rescuers should be replaced to maximise the effectiveness of continuous chest compressions. Although CCC-CPR is an easy and effective approach, early occurrence of fatigue is the main challenge. This study was conducted to compare the effectiveness of chest compressions on a mannequin model by non-professional 'rescuers' using the two approaches of alternating rescuers every 1-minute and every 2 minutes.

Methods

Study design and setting

The present research was a semi-experimental study designed to compare the quality of chest compressions during CCC-CPR with two methods of replacement of rescuers: every 1-minute (1-minute scenario) and every 2 minutes (2-minute scenario).

Selection of participants

The participants included 70 non-professional individuals from Ardabil, Iran, with no experience in CPR.

Interventions

The non-professional rescuers (35 two-person teams) performed both the scenarios on a Laerdal CPR mannequin (Laerdal, Stavanger, Norway), which can effectively mimic the chest compression behaviour during cardiopulmonary resuscitation in humans, and presents the number of chest compressions and the number of chest compressions with sufficient depth. In both groups, each team performed 1-minute and 2-minute scenarios for eight 2-minute cycles. Considering 10 seconds of rest for every 2 minutes, the total time was calculated as 17 minutes and 10 seconds for each scenario. It should be noted that in the 1-minute scenario, the replacement time after 1 minute was considered as part of the total cycle time.

Before starting the CCC-CPR, all teams individually participated in a 45-60 minute training session, which included the presentation and practical education of CCC-CPR. This training program taught the rescuers the concepts of 1-minute and 2-minute scenarios and proper hand-held location, proper compression, sufficient depth as well as the methods of replacement, which was performed in two ways: in the 1-minute scenario the rescuers were moved fast after a 1-minute chest compression. In both scenarios, the rescuers were asked to rest for 10 seconds and move in the meantime after every 2-minute cycle. In all of the procedures, the researcher recorded time and informed the rescuers of the replacement or the 10-second rest. Criteria used to evaluate the quality of chest compressions included the number of chest compressions in 1 minute, the appropriate 5-6 centimeter depth of each compression and the total compression rate at the end of eight 2-minute cycles (14). One of the challenges of this study was the residual effect, or the learning effect, resulting from the implementation of the first method carry-over effect (15). To reduce this effect, half of the teams randomly started the 1-minute scenario, and the other half started the 2-minute scenario first. Each method was performed over at least 2 days to prevent the fatigue caused by the first method from affecting performance during the second method. All procedures were done in the afternoon.

Methods of measurement

The overall resuscitation performance was video-recorded to determine the number and depth of chest compressions. By reviewing the films at the end of the procedure, the researcher counted proper compressions with a sufficient depth as marked by the mannequin monitor.

Data analysis

The data collected were organised in Microsoft Excel. The descriptive statistics (ie. mean, variance and standard deviation) and inferential statistics (ie. t-test and two-way repeated measures ANOVA) were analysed in SPSS-15 (Chicago, IL).

Ethical considerations

Ethics approval was obtained from the Ethics Committee of the Research Deputy at the Ardabil University of Medical Sciences (IR.ARUMS.REC.1395.22). Participants were fully informed about the study purpose before chest compressions began. A written informed consent form was signed by each participant before the video-recording took place.

Results

Characteristics of the study subjects

In this study, to compare the quality of chest compressions in 1-minute and 2-minute scenarios, 70 non-professional 'rescuers' attempted to compress the chest of a simulation mannequin as two-person teams. All the participants were men. Other demographic details are presented in Table 1.

These findings suggest that the rescuers take a mean 2.76 seconds to be replaced when performing the 1-minute scenario. These times were considered as part of the second minute of each 2-minute cycle. The number of chest compressions and the number of chest compression with sufficient depth in the two scenarios are shown in Table 2.

As shown in Table 2 there are no noticeable differences between the two scenarios in the first minute of each cycle in terms of number of chest compressions and chest compressions with sufficient depth. But there are major differences between the two scenarios in the second minute of each cycle in terms of number of chest compressions with sufficient depth.

On examining the number of chest compressions, it was found that there was no significant difference between the two scenarios (Table 3). However, on evaluating the number of compressions with sufficient depth, it was found that a progressive reduction occurred in the number of compressions with sufficient depth over time in both scenarios (Table 2, Table 3). This decrease occurred far more in the groups with the replacement of the rescuers every 2 minutes than in the groups with the replacement of the rescuers every 1-minute (Table 2, Table 3). Also, from the early cycles, a significant difference was seen in the number of chest compressions with sufficient depth in the two scenarios (Table 3). It was also found that in the total of eight cycles, the rescuers in the 1-minute scenario performed 277 more chest compressions with sufficient depth than that performed in the 2-minute scenario (Table 2, Table 3).

Discussion

This study was conducted to compare the efficiency of performing chest compressions on a simulation mannequin by non-professional rescuers using two scenarios of rescuer replacement every 1-minute and every 2 minutes. Given that CCC-CPR is considered as an alternative to the standard CPR in cases of cardiac arrest (4), the effectiveness of chest compressions by non-professional rescuers is crucial for successful resuscitation.

As expected, the results revealed that the number of chest compressions with sufficient depth had a downward trend during both the scenarios. Thus, over time, the number of chest compressions with sufficient depth was reduced.

Table 1. Individual characteristics of the participants in the 1-minute and 2-minute scenarios

Group	Group members	Average age	Height (cm)	Weight (kg)	BMI	Arm length (cm)	Arm circumference (cm)
Non-professional rescuers (N=70)	Whole group members	28.80	177	78.5	25	64.35	33.21
	First group members*	28.90	177	77.9	24.80	64.10	32.99
	Second group members**	28.70	177	79	25.20	64.60	33.44

*The group that started the chest compression in the 1-minute scenario as the first person.
**The group that performed the chest compression in the 1-minute scenario as the second person.
BMI = body mass index.

Nevertheless, the present results showed that the non-professional rescuers performed, on average, more than 100 chest compressions per minute with a sufficient depth in the 1-minute scenario, which is an acceptable outcome according to the latest CPR guideline proposing approximately 100 to 120 compressions per minute (14). However, in half of the 2-minute scenario cycles, the non-professional rescuers failed to perform chest compressions with a sufficient depth of at least 100 times per minute. The reported number of chest compressions

performed has been different in various studies. In a study by Manders et al, the average number of chest compressions with sufficient depth per minute was reported to be 71.67 and 74.7 in the 1-minute and 2-minute scenarios, respectively (13). However, in similar studies, the number of chest compressions with sufficient depth by professional rescuers was reported to be low (16-18). Various factors can affect the number of chest compressions. . It seems that the efforts of the individuals to implement a high number of chest compressions in the present

Table 2. The number of chest compressions and chest compressions with sufficient depth in 1-minute and 2-minute scenarios

Time	Number of chest compressions		Number of chest compressions	
	Number of chest compressions		Chest compression with sufficient depth	
	1 minute scenario	2 minute scenario	1 minute scenario	2 minute scenario
1st min	130.77	127.40	126.37	122.40
2nd min	130.97	127.34	122.74	101.97
3rd min	129.40	132.14	124.69	123.77
4th min	130.80	130.57	116.83	102.77
5th min	129.11	128.37	122.66	112.71
6th min	130.80	128.00	116.34	89.74
7th min	130.40	132.60	123.46	110.57
8th min	132.14	131.14	119.26	84.89
9th min	131.57	128.57	122.14	115.57
10th min	133.03	128.00	115.89	84.74
11th min	130.80	131.43	117.17	105.97
12th min	132.40	131.57	116.00	81.54
13th min	130.46	130.14	115.06	110.40
14th min	132.49	129.37	108.91	83.23
15th min	130.34	132.34	114.37	106.46
16th min	133.63	131.26	109.11	77.29
Total 16 minutes	2099.11	2080.26	1891.00	1614.03

Table 3. Comparison of chest compression and chest compression with sufficient depth between two scenarios in non-professional groups

Time	Number of chest compressions			Chest compression with sufficient depth		
	1 minute scenario	2 minute scenario	p value	1 minute scenario	2 minute scenario	p value
First cycle	261.74	254.74	0.07	249.11	224.37	0.006
Second cycle	260.20	262.71	0.48	241.51	226.54	0.028
Third cycle	259.91	256.37	0.29	239.00	202.45	0.001
Fourth cycle	262.54	263.74	0.64	242.71	195.45	<0.001
Fifth cycle	264.60	256.57	0.06	238.02	200.31	<0.001
Sixth cycle	263.20	263.00	0.94	233.17	187.51	0.001
Seventh cycle	262.94	259.51	0.22	223.97	193.62	0.004
Eighth cycle	263.97	263.60	0.9	223.48	183.74	0.001
Total 16 minutes	2099.11	2080.26	0.20	1891.00	1614.00	<0.001

Notes: According to Bonferroni correction, the p value of less than 0.0062 was considered significant. The numbers underlined have significant differences in the 1-minute and 2-minute scenarios.

study played a significant role in this difference compared with the previous studies. For example, the present study was based on the 2015 CPR guideline introduced by the American Heart Association (AHA) and the goal of the rescuers was to perform at least 100 to 120 times chest compressions. In some previous studies (13,18), which were based on the 2010 CPR guideline, the maximum number of chest compressions to be performed was 100 (19). Therefore, the primary efforts of the rescuers to carry out more chest compressions may be responsible for the high number of chest compressions in this study. The individual characteristics may also be responsible for the high number of chest compressions in the present study. For example, in the present study, contrary to the previous studies mentioned, all participants were male. The weight, height, arm length and arm circumference of the participants were higher than that in the studies mentioned (13,16-18).

In this study, chest compressions were compared in the 1-minute and 2-minute scenarios in two phases. The number of chest compressions by professional and non-professional groups was examined, leading to a finding that in all eight cycles, the number of chest compressions in both scenarios was almost equal. On examining the number of chest compressions with sufficient depth, the results showed that there was a significant difference in both scenarios. For instance, the number of chest compressions with sufficient depth performed in the 1-minute scenario was considerably greater than that performed in the 2-minute scenario in all cycles as well as in the total 16 minutes. The non-professional rescuers therefore completed 277 more compressions at the end of 16 minutes in the 1-minute scenario compared to the 2-minute scenario. This means that the rescuers at the end of 16 minutes will perform one cycle more by performing the 1-minute scenario compared with the 2-minute scenario, which is very important from a clinical point of view. Other studies have shown contradictory results in this regard. For example, Gianotto-Oliveira et al showed that rescuers performed more chest compressions with sufficient depth in the 1-minute scenario (16). In another study, which replaced the rescuers at 1 minute and 2 minutes with the same method, no significant difference was found between the 1-minute and 2-minute scenarios in a total of four cycles (8 minutes) (13). In a similar study, no differences were seen in the number of chest compressions with appropriate depth between the 1-minute and 2-minute scenarios within the first 8 minutes. But after 8 minutes it became clear that the 1-minute scenario was better than the 2-minute scenario (12). In contrast to these studies, we witnessed a difference between the two scenarios from the first cycle. Trying to perform a high number of chest compressions in this study, and the rescuers' characteristics, seem to have played an important role in making the difference apparent in the first minutes compared with the previous studies (12,13). In another study conducted by Ki Min et al to determine the effectiveness of two scenarios of 10 seconds rest after 100 compressions (10/100) and 10 seconds rest after 200 compressions (10/200), results contradictory with this

study were obtained. In their methodology, the non-professional rescuers performed both resuscitation methods as a single rescuer (18). Their results showed that from the first minute to the tenth minute, the 10/200 scenario recorded a significantly greater number of compressions than the 10/100 scenario (18). Various reasons can be enumerated for the contradiction between the two studies. For example, in the 10/100 scenario, after 100 chest compressions the rescuers rested compulsorily for 10 seconds, and this time (10 seconds) is a longer period relative to the replacement time of rescuers after 1 minute in the present study (2.76 seconds), which leads to a reduction in the number of chest compressions. On the other hand, the conditions of the rescuers such as the number of rescuers, height, weight and other physical features in the present study could have caused this difference. For example more height (177 cm vs. 170.2 cm) and weight (78.5 vs. 66 kg) played a key role in obtaining a relatively higher number of chest compressions in the present study compared to that found by Min et al (18).

The analysis of the various minutes of the resuscitation procedure showed that in the 1-minute scenario the number of chest compressions and the number of chest compressions with sufficient depth were the same in the first minute and the second minute in all cycles. But in the 2-minute scenario, the quality of chest compressions began to decrease in the second minute in comparison with the first minute (Table 2). This suggests that despite a 2.76 seconds interruption while rotating the two rescuers during the 1-minute scenario, not only does it not reduce the quality of the chest compressions but it also improves it compared with the 2-minute scenario. Similar studies comparing the quality of chest compressions in the 2-minute scenario achieved similar results. They demonstrated that the quality of chest compression decreases in the second minute compared with the first minute (11-13). For example, Menders et al showed that the average number of chest compressions with sufficient depth was 73.7 in the first minute and 53.5 in the second minute (13).

Limitations

The rescuers' performance could have been improved in the absence of the present study limitations, including the use of a mannequin and the stress-free environment for chest compressions by the participants. Moreover, time and rescuer replacements were controlled by the researchers, which could have helped the rescuers focus only on chest compressions. The present findings might have also been affected by the fact that only male subjects were included with a greater strength than the average non-professional rescuers.

Conclusion

The study found that replacing the rescuers every 1-minute is more effective than replacing them every 2 minutes during two-

rescuer CCC-CPR performed by non-professional teams. Also, this study demonstrated that there is a significant decrease in the rate of chest compression with sufficient depth in the second minute of each cycle in the 2-minute scenario. This emphasises the need for the replacement of non-professional rescuers every 1-minute in two-rescuer resuscitations. Also, this study showed that although the rate of chest compression had a downward trend in the two scenarios, non-professional rescuers maintained 100 to 120 chest compressions for 16 minutes in the 1-minute scenario.

Conflict of interest

The authors of this paper declare no competing interests. Each author of this paper has completed the ICMJE conflict of interest statement.

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