



Evaluation of the effect of shift cycle time on chest compression quality during cardiopulmonary resuscitation

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ABSTRACT

Objective: Considering the potential role of shift cycle time on chest compression quality during cardiopulmonary resuscitation (CPR) and the available contradictory results in this regard, the present study aimed at evaluating the effect of 1-min versus 2-min shift cycle time on the quality of CPR. **Materials and Methods:** In this randomized crossover study, 80 rescuers performed CPR on a manikin in two scenarios with a rotation of 1 and 2-min cycles. The quality of CPR was evaluated and compared based on the information obtained regarding the chest compression depth, recoil, and rate of chest compression. In addition, rescuer fatigue was recorded in 1-min versus 2-min shift cycles. **Results:** In the 1-min group, the number of chest compressions per minute, complete recoil, and good rate with the mean of 114.89 ± 3.62 , 54.34 ± 3.86 , and 76.06 ± 8.00 were significantly higher than those of the 2-min group with the mean of 113.78 ± 4.94 , 53.49 ± 5.27 , and 73.98 ± 7.87 ($P < 0.05$), respectively. In addition, the quality of CPR provided by males was significantly higher than females in both groups. The score of rescuer fatigue was higher in the 2-min group as compared with the 1-min group ($P < 0.001$). **Conclusion:** According to the results of the present study, the difference in the quality of CPR in terms of the number of chest compressions, complete recoil, and good rate was higher in the 1-min group as compared with the 2-min group. In addition, the quality of CPR in terms of chest compression depth and number in both 1-and 2-min rotation cycles was higher for male rescuers than females. Furthermore, rescuer fatigue was higher in the 2-min group as compared with the 1-min group. The mentioned finding may be a factor in reducing, albeit slightly, the quality of CPR in the group with a longer time.

KEYWORDS: Chest compression, Compression depth, Recoil, Resuscitation quality

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INTRODUCTION

Cardiopulmonary resuscitation (CPR) as a general skill can be considered as one of the paramount innovations in the history of medicine and a rapid and immediate intervention in preventing death in a person that has suddenly experienced cardiorespiratory arrest [1]. The purpose of resuscitation is the restoration of major organs such as heart and lungs as well as the ability of patients to survive [2]. About half a million heart arrests occur annually in the United States. 290,000 and 210,000 of the mentioned arrests are in- and out-of-hospital arrests. The mortality rate of the out-of-hospital resuscitation was approximately 90% [3].

Despite the fact that more than 50 years have passed since the invention of CPR, the survival rate is still low. Various studies have revealed that the quality of CPR can be affected by several factors. Using the adequate rate to apply compression to the chest, the chest compression depth, allowing the

chest to return to its normal position, and minimizing the interruptions in applying compression to the chest can increase the chances of resuscitation. In fact, it can be stated that cerebral and coronary perfusion pressures are imperative and determining factors in the success of resuscitation; therefore, the quality of CPR is considered significant. In addition, the rescuer fatigue when applying rapid compression to the chest can have a negative effect on CPR. Previous studies have indicated that rescuer fatigue may occur within one (initial) minute of resuscitation and thus reduce the effectiveness of chest compression [4-6]. Accordingly, the rapid decrease in the effectiveness of CPR within the 1st min means that constant shift of the rescuers can be a good way to reduce the

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interruption of resuscitation and increase the quality of cardiac compression [7].

In this regard, some previous studies have shown that changing the shift cycle from 2 to 1 min can improve the quality of chest compressions regardless of the rescuer strength. Hence, it would be advantageous for both rescuers to decrease the existing shift cycle suggested in the pertinent guidelines [8-10].

Although many studies have not found significant differences in the quality of CPR, the compression depth, the chest compression rate, and the mean number of effective chest compressions in the 1st min as compared with the 2nd min by reducing the compression rotation cycle time [11-13], it is evident that increasing the duration of CPR and rescuer strength as well as the rescuer sex may have a significant effect on the quality of CPR and its ultimate outcome [7,13]. Consequently, it seems that further studies with the consideration of rescuer conditions can be of great necessity in selecting the appropriate cycle in CPR. Therefore, the present study aimed at evaluating the effect of chest compression shift cycle time on the quality of CPR on a human manikin.

MATERIALS AND METHODS

The present study was a randomized crossover study. According to the objective of this study that was evaluation of the effect of chest compression shift cycle time on the quality of CPR on a human manikin, the study population involved all 400 rescuers in the skill lab of Al-Zahra hospital in Isfahan during 2018–2019. In this study, according to the Cochran's sample size formula at a 95% confidence interval level and considering the $P = 0.5$, the margin of error equal to 0.05, and the population size of rescuers ($n = 400$), the sample size of rescuers was considered to be 80.

The inclusion criteria for rescuers were their willingness to participate in the study as well as their successful completion of BLS and ATLS courses. In case of their non-cooperation in this project, they were excluded from the study.

After the approval of the proposal by ethic committee of Isfahan University of Medical Sciences (ethical code: IR. MUI. MED. REC.1397.214, on 13 October 2018) and obtainment of the informed written consent from the participants, 80 selected rescuers were included in the study.

At the beginning of the study, the rescuers' demographic characteristics including their age, sex, and body mass index (BMI) were recorded.

All rescuers were randomly selected and organized into pairs to perform chest compressions. All CPR rescuers participated in both 1-min and 1-min scenarios. In the 1-and 2-min scenarios, rescuers rotated every 1 and 2 min, respectively. In the 1-min scenario, the chest compression was performed for 10 min in 10 1-min cycles. In the 2-min scenario, the chest compression was performed for 10 min in 5 2-min cycles. After 30 min of rest, participants changed their groups and performed the next series of chest compressions. It

should be noted that chest compressions were interrupted only every 2 min for 10s to simulate pulse and breathe check.

To perform CPR, a suitable manikin (Laerdal Resusci-Anne model, Laerdal Medical, Norway) was placed on the ground, and a CPR meter placed on the manikin's sternum was used to measure the generated compression depth. The display screen of the device provides information about the recoil, the compression depth, and the rate of chest compression. In addition, the device stores the mean chest compression rate at the adequate depth, the mean chest compression depth, and the percentage of chest compressions with the adequate rate.

Target values of CPR for this device are chest compression depth of 50–60 mm and chest compression rate of 100–120 times/min \pm 3/min. Good rate was defined as 100–120 chest compressions per minute. Complete chest recoil was defined as a release force of <2.5 kg. In addition, an adequate depth was regarded as a depth of more than 50 mm. Good chest compression was considered as a combination of chest compressions with adequate rate, adequate depth, and complete release (based on the ranges specified in the device) [13].

It is worth mentioning that in order not to inform the rescuer of the information provided by the CPR meter display screen, the display screen was covered with a label, and rescuers were requested to perform chest compressions according to the recommendations of the latest CPR guidelines.

Moreover, it should be noted that the rescuer fatigue score immediately after completing each series of chest compression cycles was evaluated and recorded by a Visual Analogue Scale (VAS) scale, so that based on rescuers' self-scoring from 0 (no fatigue) to 10 (extreme fatigue) [5].

Finally, the collected data were entered into SPSS (version 25; SPSS Inc., Chicago, Ill., USA) The data were represented as means \pm standard deviation or n (%). At the level of inferential statistics, considering the results of Kolmogorov–Smirnov test that indicated the normal distribution of data, independent samples t -tests and paired-samples t -tests were used. The significance level of <0.05 was considered in all analyses.

RESULTS

In the present study, out of 80 rescuers, 43 (53.8%) and 37 (46.2%) were male and female, respectively, with a mean age of 25.91 ± 1.57 years and a BMI of 22.63 ± 1.94 kg/m² [Table 1].

The number of chest compressions per minute in the 2-min group with the mean of 113.78 ± 4.94 was

Table 1: Demographics of participants

Characteristics	<i>n</i> (%) or Mean \pm SD
Sex	
Male	43 (53.8)
Female	37 (46.2)
Age (year)	25.91 \pm 1.57
BMI (kg/m ²)	22.62 \pm 1.94

SD: Standard deviation, BMI: Body mass index

significantly lower than that of the 1-min group with the mean of 114.89 ± 3.62 ($P < 0.001$). In addition, although the chest compression depth, adequate depth percentage, and good compression percentage in the 2-min group were lower than those of the 1-min group, this difference was not significant ($P > 0.05$). Moreover, complete recoil and good rate in the 1-min group with the means of 54.34 ± 3.86 and 76.06 ± 8.00 were significantly higher than those of the 2-min group with the means of 53.49 ± 5.27 and 73.98 ± 7.87 , respectively ($P < 0.001$) [Table 2].

In addition, it was revealed that in both 1-and 2-min groups, the number of chest compressions/minute, the mean chest compression depth, and the complete recoil provided by male rescuers were significantly higher than female rescuers ($P < 0.05$); however, the percentage of adequate depth was not different between male and female rescuers in neither of the groups ($P > 0.05$) [Table 3].

Moreover, the rate of rescuer fatigue in the 2-min group was higher than that of the 1-min group ($P < 0.001$). Furthermore, the fatigue score of female rescuers was higher than that of male rescuers in the 2-min group (male: 5.93 ± 1.12 vs. female: 6.51 ± 1.51 ; $P = 0.024$); however, fatigue score of male rescuers was higher than that of female rescuers in the 1-min group (male: 4.28 ± 0.83 vs. female: 3.59 ± 0.93 ; $P = 0.001$) [Figure 1].

DISCUSSION

According to the results of the present study, although chest compression depth, percentage of adequate depth, and

Table 2: Comparison of quality parameters between the groups

Variables	2 min group	1 min group	P
Numbers of chest compressions/min	113.76±4.94	114.89±3.62	<0.001
Chest compression depth/mm	55.55±7.13	56.56±6.40	0.343
The percentage of good rate	73.98±7.87	76.06±8.00	0.040
The percentage of adequate chest compression depth	58.49±17.09	60.24±14.24	0.523
The percentage of good compression	59.34±17.74	64.01±21.31	0.137
The percentage of complete recoil	53.49±5.27	54.34±3.86	0.001

Table 3: Comparison of quality metrics according to sex

Variables	Male	Female	P
Numbers of chest compressions/min	115.79±3.26	113.84±3.77	0.015
Chest compression depth/mm	58.40±5.64	54.43±6.64	0.005
1 min group			
Adequate chest compression depth (%)	59.84±11.69	60.70±16.89	0.788
Complete recoil (%)	54.98±3.46	52.59±4.21	0.006
Numbers of chest compressions/min	115.30±4.26	111.97±5.12	0.002
Chest compression depth/mm	56.98±6.86	53.89±7.18	0.043
2 min group			
Adequate chest compression depth (%)	59.53±18.45	57.27±15.52	0.558
Complete recoil (%)	54.00±4.93	51.89±4.04	0.042

percentage of good compression in the 2-min group were less than those of the 1-min group, this difference was not statistically significant ($P > 0.05$). In contrast, the number of chest compressions, percentage of good rate, and complete recoil in the 1-min group were significantly higher than those of the 2-min group ($P < 0.05$). In this regard, a study has indicated that the percentage of good compression after 3 min of resuscitation has decreased from 93% to 39% [14]. In fact, this result suggests that increasing the CPR cycle time can reduce its quality.

Sugerman *et al.* have reported that the chest compression depth during cardiac resuscitation of hospitalized patients has significantly decreased 90 s after the start of CPR [7].

Badaki-Makun *et al.* have confirmed that 10 min of continuous chest compression on a child or adult manikin reduced the chest compression depth and increased the chest compression rate. The mentioned researchers provided evidence that the application of 1-and 1-min shift cycles in children also requires the rotation of rescuers every 2 min as is the case with adults [9].

Kim *et al.* also showed that the quality of chest compression can be increased by changing the cycle length from 2 to 1 min [8]. Therefore, reducing the shift cycle in guidelines regarding the use of two rescuers can be beneficial.

In contrast, Kılıç *et al.* did not find any significant difference between the 1-and 2-min groups in terms of the following items: the numbers of chest compressions, the percentage of good rate, the percentage of adequate depth, the percentage of good compression, and the complete recoil. The obtained findings in some items were in contrast to the findings of our study as reducing the shift cycle length could increase the number of chest compressions, percentage of good rate, and complete recoil in our study [13].

In addition, another prospective crossover study compared the quality of CPR in the 1st and 2nd min between the two groups and revealed that the mean chest compression rate per minute (121 vs. 124), the percentage of adequate

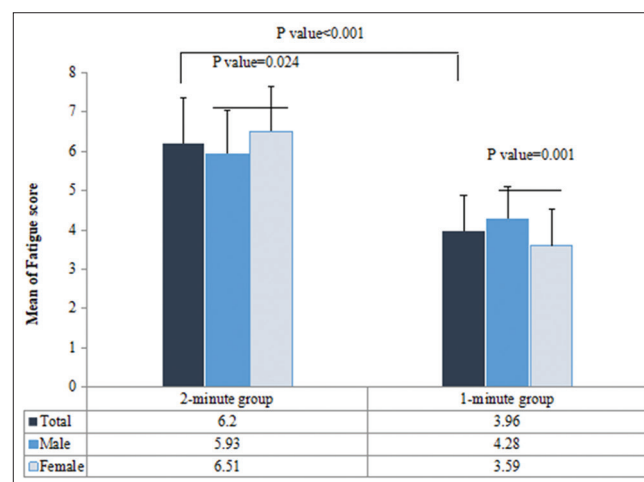


Figure 1: Comparison of the mean rescuer fatigue according to sex in each group

compression depth (76% vs. 54%), the chest compression depth (53 vs. 47 mm), and the repetition of error-free chest compression (42% vs. 47%) were significantly different between the 1-and 2-min groups [10]. The results of Mander and Geijssel study on a human manikin indicated that the mean number of effective chest compression in the 1st min as compared with the 2nd min was not significantly different [15]. The findings of our study revealed that although the chest compression depth and the percentage of adequate compression depth in the 1-min group were higher than those of the 2-min group, this difference was not statistically significant, and only a significant difference was found in terms of the good rate and the number of chest compressions.

Although we cannot assure that the results would be identical in real situations under the best possible conditions, the quality of CPR has decreased by increasing the CPR time per cycle according to the results of this study. In this regard, many other studies have revealed that the quality of CPR decreases significantly after the 1st min of CPR. In fact, the main factor in this respect is the fatigue of the rescuer and the decrease of their strength in achieving sufficient depth. Therefore, although factors such as gender, BMI, and strength of the rescuer cannot be controlled, shortening the rotation time of each CPR cycle can help restore the relative strength of the rescuer in performing CPR more accurately and completely [6].

Furthermore, evaluation of the quality of CPR according to the rescuer sex revealed that the number of chest compressions per minute, the mean compression depth, and the complete recoil in male rescuers were significantly higher than female rescuers ($P < 0.05$). In fact, it can be stated that male rescuers' strength was higher than female rescuers' strength in delivering a higher quality CPR in both 1-and 2-min rotation cycles.

Consistent with the findings of the present study, a good number of studies have pointed to differences in the quality of CPR provided by rescuers with a different sex. The percentage of adequate chest compressions, the recoil percentage, and the mean compression depth were higher in male rescuers as compared with female rescuers [13,15]. In addition, Kim *et al.* revealed that rescuer strength was strongly associated with the mean compression depth [8]. Moreover, Ock *et al.*'s study reported that reductions in chest compression quality were lower among rescuers of greater strength [16].

In this regard, it can be mentioned that a reduction rate in the performance is associated with the rescuers' fitness, so that it can be expected to affect the quality of chest compression. This effect can be attributed to rescuer fatigue.

The results of the present study revealed that by shortening the rotational cycle of CPR, a significant reduction was observed in rescuer fatigue, which was higher in female rescuers than male rescuers. Therefore, as fatigue can directly and negatively affect the quality of CPR including the number of chest compressions and the adequate compression depth, it seems that using shorter cycles is more advantageous due to less rescuer fatigue.

In this respect, some studies have shown that the quality of CPR decreases with rescuer fatigue, especially when the resuscitation lasts more than 1 min because this fatigue can affect the performance of rescuers before they realize the fatigue. Therefore, it is recommended to rescuers to interchangeably perform chest compressions before they feel fatigue. As a result, current guidelines for two-rescuer CPR recommend the rescuer rotations to be performed every 2 min [5,14,17,18] before the rescuers feel fatigue or even before the end of the recommended cycle as it is possible that the quality of the rescuer performance reduces. This reduction especially occurs when chest compression is performed quickly. Therefore, as stated earlier, the rescuers' physical strength can affect the quality of CPR as well as the rate, number, and depth of adequate compressions.

Some researchers have suggested an association between the quality of CPR and rescuer fitness factors, which can have the greatest impact on the rescuer strength [16,19,20]. However, it is challenging to recommend a program to strengthen the rescuers' muscle as an indispensable method to improve CPR performance because there are many limitations including a shortage of lead-time.

Therefore, due to the physical conditions and rescuers' stress during resuscitation operations, which are inevitable and uncontrollable, some researchers have recently focused on changing the rotation cycle time in CPR, using feedback devices [21,22], and addressing the effect of one-handed chest compression [23] on the quality of CPR.

Among the limitations of this study, the use of manikin can be mentioned. In spite of the possibility of standardizing the parameters with the design of the present study, the real-life experiences seem to be different.

Second, the time needed for rotating the rescuers was not recorded in the 1-min scenario. Although a 2.8 s delay was indicated in another study, its hemodynamic effects on humans were not addressed in the present study. However, as a strong point of the study, the resuscitation time lasting 10 min can be referred to. The mentioned time was longer than that of some previous studies in this respect. Furthermore, a consideration of rescuer fatigue and sex that affect the resuscitation quality can be considered as another strong point of the study.

CONCLUSION

According to the results of the present study, the difference in the quality of CPR in terms of the number of chest compressions, complete recoil, and good rate was significant between the 1-and 2-min groups. The mentioned items were significantly higher in the 1-min group as compared with the 2-min group. In addition, male rescuers in both cycles (1 and 2 min) had a higher number of compressions, compression depth, and good rate than female rescuers. Moreover, the rescuer fatigue was higher in the 2-min group as compared with the 1-min group, which may be a factor in reducing, albeit slightly, the quality of resuscitation in the group with a longer time.

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Conflicts of interest

There are no conflicts of interest.

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