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Influence of rescuer strength and shift cycle time on chest compression quality

HYUNJONG KIM[1], JE SUNG YOU[2], SUNG PHIL CHUNG[2]

1 Department of Emergency Medicine, Inje University Ilsan Paik Hospital, Gyeonggido, Korea
2 Department of Emergency Medicine, Yonsei University College of Medicine, Seoul, Korea

Corresponding author
Sung Phil Chung
Department of Emergency Medicine
Gangnam Severance Hospital, Yonsei University College of Medicine
211 Eonju-ro, Gangnam-gu, Seoul, Korea 06273
Phone: +82-2-2019-3030
Fax: +82-2-2019-4820
E-mail: emstar@yuhs.ac

ABSTRACT

Introduction. Previous studies have suggested that differences in rescuer strength and compression shift cycle are strongly associated with the quality of chest compression. We hypothesised that changing the shift cycle from two minutes to one would have a positive effect on the quality of chest compression in two-rescuer cardiopulmonary resuscitation (CPR), regardless of rescuer strength.
Methods.Thirty-nine senior medical students participated in this prospective, simulation-based, crossover study. After evaluation of muscle strength using a handgrip dynamometer, each participant was required to perform two sets of compressions separated by a 15-minute rest. Participants started with either four cycles of chest compressions for one minute followed by a one-minute rest (1-MCS), or with two cycles of chest compressions for two minutes followed by a two-minute rest (2-MCS). After a 15-minute break, participants switched groups and performed the other set of compressions. Mean compression depth (MCD), mean adequate compression (MAC), and adequate compression ratio (ACR) per minute were measured for each group. Subjective fatigue was reported after the completion of each set of compression cycles. Results. Rescuer strength was strongly correlated with MCD ($p < 0.01$), MAC ratio ($p < 0.01$), and ACR ($p < 0.01$), and cycle group was correlated with MCD ($p < 0.01$) and ACR ($p = 0.03$). Subjective fatigue with 1-MCS was lower than with 2-MCS, regardless of rescuer strength.
Conclusion. We found that the quality of chest compressions could be improved by changing the shift cycle from two minutes to one, regardless of rescuer strength. Therefore, reducing the existing shift cycle recommended in guidelines for two rescuers could be beneficial.

Key words: CPR, fatigue, hand strength

INTRODUCTION

Chest compression is one of the most important components of cardiopulmonary resuscitation (CPR). Recent (2015) guidelines from the American Heart Association (AHA) and the European Resuscitation Council (ERC) recommend ‘fast, hard and undisrupted high-quality chest compressions,’ as have previous guidelines. (1,2) Some research has indicated that the quality of chest compression is reduced by rescuer fatigue, especially induced by delivering compressions for more than one minute. Because such fatigue may compromise performance before the rescuer is aware of its presence, shifting chest compression between rescuers before the onset of conscious fatigue has been recommended. Thus, current guidelines for two-rescuer CPR encourage compression shifts that cycle every two minutes. (3-6)
It is possible that ‘impoverishment by rescuer fatigue’ could be induced before the end of the recommended cycle, particularly given the emphasis on hard and fast compressions. Rates of decline in exercise performance are related to personal fitness, a relationship that would also be expected to affect the quality of chest compressions. Some researchers have suggested a relationship between fitness factors and CPR performance, with strength being the most prominent. (7-9) Nevertheless, it is difficult to recommend a muscle-strengthening program as an essential method for improving CPR performance, due to many limitations, including a shortage of lead-time.
Given this background, we hypothesised that chest compression quality could be maintained, and CPR quality improved, by reducing the chest compression shift cycle from two minutes to one, regardless of rescuer strength.

METHOD

Study Subjects

We designed a prospective, randomised, crossover study. This study was conducted with the approval of the institutional review board of the participating hospital. All participants were voluntarily recruited from senior-grade medical students who had completed a one-day course in basic life support within three months, and who had had no actual CPR experience during their clerkship. The study protocol was introduced to all participants, and all gave informed consent before the study. We excluded students with physical problems that made chest compression and strength testing difficult. Students could be excluded of their own volition, even if previously involved.

Study protocol

This study was conducted from April to August of 2012 in a tertiary university hospital in the Republic of Korea. Participant gender, age, and weight data were collected, and body mass index (BMI) was calculated. Muscle strength was evaluated by testing handgrip strength before conducting chest compressions. Chest compression quality was evaluated using a manikin, with participants in a kneeling position. Each participant was required to perform either four cycles of chest compressions for one minute followed by a one-minute rest (1-MCG, one-minute shift cycle group), or two cycles of chest compressions for two minutes followed by a two-minute rest (2-MCG, two-minute shift cycle group). After taking a rest for 15 minutes, each participant performed the compression cycle set used by the other group. Which cycle method was conducted first was allocated based on a random number generator. Subjective fatigue was reported after the completion of both cycle tests and a rest period of ten minutes (figure 1).

Data collection

The primary measures of this study are the ratio of adequate chest compression and chest compression depth. Adequate chest compression was defined by a depth between 50 to 60 mm. Hand strength testing was carried out using a handgrip dynamometer, with participants in a sitting position, with the elbow flexed to 90 degrees. Each was asked to perform a maximal contraction for 5 seconds. The sum of the results from right and left hands was recorded. A Resusci Anne Manikin® with PC skill reporting system® (Laerdal Medical, Stavanger, Norway) was used to evaluate the performance of chest compression. Mean compression depth (MCD), mean adequate compression (MAC), and adequate compression ratio per minute (ACR) were obtained for each group. We fixed the compression rate to 120 times per minute, using a metronome, to evaluate the quality of chest compression only by depth. A zero to one-hundred-point visual analogue scale (VAS) was used to record subjective fatigue.

Statistical analysis

A linear mixed model was used to analyse data from this crossover design study. Four fixed effects were considered for this analysis, based on the following: sequence, group, period, and strength. The first was the sequence effect, referring to which group (1-MCG or 2-MCG) performed first. The second was the group effect that indicated differences between the two groups. The third was the period effect that considered differences at each minute over time. The fourth was the strength effect, the influence of rescuer strength. The data were analysed using SAS 9.2 (SAS Institute Inc., Cary, NC, USA) and presented as means and 95% confidence intervals. A two-sided p-value of less than 0.05 was considered statistically significant.

RESULTS

General characteristics

A total of thirty-nine senior medical students participated in this study. The age of the participants was 25.08±1.58 years for both genders. Nineteen participants (48.7%) were assigned to first conduct chest compressions for one minute followed by a one-minute rest (1-MCG) (figure 1). Height, weight, BMI, and strength data were collected (table 1).

Mean compression depth (MCD), mean adequate compression (MAC) ratio, and subjective fatigue are shown in table 2.

MCD and the MAC ratio over four minutes were compared between groups. The results were not influenced by a sequence effect ($p = 0.24$, $p = 0.64$, respectively). MCD was deeper with 1-MCG (50.67±5.33mm) than with 2-MCG (49.44±5.86mm) and positively correlated with group ($p < 0.01$) and with strength ($p < 0.01$) (figure 2). The MAC ratio was less related to the group effect ($p = 0.07$) but was positively associated with strength ($p < 0.01$), meaning that stronger participants had higher MAC ratios, regardless of group. Subjective fatigue was not statistically correlated with strength or sequence but showed some evidence of a group effect, so that subjective fatigue was lower with 1-MCG (72.10±12.07) than with 2-MCG (80.18±11.97), regardless of rescuer strength.

Compression rate and adequate compression ratio at every minute (ACR) (figures 3,4; table 3).

Chest compression rate per minute was affected only by period ($p < 0.01$). ACR was statistically correlated with strength ($p < 0.01$), period ($p < 0.01$), and group ($p < 0.03$).

DISCUSSION

The quality of chest compression is among the most important factors that influence the prognosis of cardiac arrest patients. Therefore, new guidelines, announced in 2015, emphasise uninterrupted, fast, and hard chest compressions, at a rate of 100 to 120 times a minute, to a depth of 5 to 6 cm in adult patients. (1,2) However such efforts toward high-quality chest compression have the potential to increase the rate of rescuer fatigue due to increased workload.

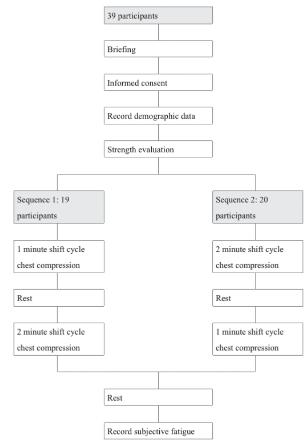

Figure 1. Flow chart of the research protocol.

Many researchers have suggested that physical fatigue during chest compression decreases the quality of CPR. Ochoa et al. showed that the quality of chest compression in a manikin study started to fall off after one minute, regardless of sex, height, race, or weight. (6) Ashton et al., in their study showing changes in quality during three minutes of continuous chest compression, indicated that regular rest should be taken by the rescuer, prior to the perception of fatigue. (3)

Recent guidelines have recommended that providers of chest compression should alternate every two minutes where more than two rescuers can deliver CPR. But a reduction in chest compression time may be worth considering, given the potential for the increased workload needed to deliver high-quality chest compression, inducing rescuer fatigue.

Because fatigue could negatively influence the quality of chest compression, many researchers have been interested in fitness factors associated with rescuer fatigue. Hansen et al. showed that ventilation threshold and strength were positively correlated with the quality of chest compression. (7) Ock et al. found that reductions in chest-compression quality were lower among rescuers of greater strength. (8)

The positive correlation found between strength and the quality of chest compression has led to recommendations of fitness programs to improve rescuer strength. Nevertheless, it is difficult to recommend such a fitness program as a standard protocol for maintaining high-quality chest compression, not only because improving strength cannot be achieved in a short pe-

Table 1. General characteristics of study participants (n = 39).

	Total (n = 39)		Male (n = 26)		Female (n = 13)		p-valuea
Age (y)	25.08	±1.58	25.12	±1.72	25.00	±1.29	0.830
Height (m)	1.70	±0.08	1.74	±0.05	1.61	±0.05	<0.01*
Weight(kg)	61.33	±10.71	66.85	±8.28	50.30	±4.82	<0.01*
BMI(kg/m2)	21.18	±2.42	22.11	±2.30	19.32	±1.35	<0.01*
Muscle strength(kg)	72.31	±19.42	84.28	±10.13	48.37	±7.03	<0.01*

Values are mean±standard deviation
BMI, body mass index; n, number of subjects
aStatistical significance was tested by an independent t-test.
*Statistically significant p value was marked.

Table 2. Comparison of chest compression quality between the 2 min. shift cycle group and 1 min. shift cycle group.

Variables	2-MCG (95% CI)	1-MCG (95% CI)	p-value of each effect		
			Sequence	Group	Strength
Mean compression depth (mm)	49.44±5.86	50.67±5.33	0.21	<0.01*	<0.01*
Mean adequate compression ratio (%)	67.56±35.29	70.43±35.85	0.64	0.07	<0.01*
Subjective fatigue	80.18±11.97	72.10±12.07	0.41	<0.01*	0.82

min., minute; CI, confidence interval; 2-MCG, 2-minute shift cycle group; 1-MCG, 1-minute shift cycle group
All values are estimated mean±standard deviation, with the exception of the p-values.
*Statistically significant p value was marked.

Table 3. Comparison of chest compression quality between 2 min. shift cycle group and 1 min. shift cycle group at each period.

Variables	Group	Period (minute)				p-value of each effect			
		1	2	3	4	Sequence	Period	Group	Strength
Compression rate at every period (rate min−1)	2-MCG	120±3.08	119.51±3.74	118.9±2.99	119±4.15	0.23	<0.01*	0.84	0.96
	1-MCG	120.62±7.87	118.87±2.55	119.08±3.19	118.67±3.75				
Adequate compression ratio at every period (%)	2-MCG	81.39±31.97	60.61±40.35	73.53±34.69	54.45±42.71	0.64	<0.01*	0.03*	<0.01*
	1-MCG	76.34±33.60	71.59±36.39	70.09±37.20	63.69±41.62				

CI, confidence interval; 1-MCG, 1-minute shift cycle group; 2-MCG, 2-minute shift cycle group.
All values are estimated mean±standard deviation, except the p-values.
*Statistically significant p value was marked.

riod of time but also given individual differences in rescuer fitness.

Our study started from three key assumptions. First, that the emphasis on high-quality chest compression could increase rescuer fatigue. Second, that increased fatigue could reduce the quality of chest compression during the recommended compression shift cycle length of two minutes. Finally, that strength is an important factor in maintaining chest compression quality, but one that is hard to improve. We hypothesised that adequate chest compression quality could be maintained by changing the compression shift cycle, regardless of rescuer physical strength.

In this study, the compression rate was fixed at 120 times per minute, so that decreases in chest compression quality could be expressed as changes in chest compression depth. As we intended, there were no differences in the chest compression rate between the two groups (1-MCG vs. 2-MCG) (figure 3). We measured the handgrip strength of participants, which has been shown to be well correlated with overall strength, and has been used in other investigations. (10-12)

Group effect and strength had a statistically significant impact on MCD, and strength contributed significantly to MAC. Thus, as suggested in previous studies, MCD and MAC were greater for the stronger participants. Furthermore, the group effect meant that the shorter shift cycle (1-minute vs. 2-minute) was correlated with better MCD. This suggests the possibility for improvement in chest compression quality by changing shift cycle (table 2). Group effect was not associated with positive changes in MAC, but had some impact on ACR (table 3, figure 4). This indicates that changing the shift cycle had an influence on chest compression quality over the four-minute time interval. Subjective fatigue was also lower with 1-MCG, regardless of participant strength. We thought subjective fatigue might be recognized above a certain degree of fatigue threshold, and a two-minute chest compression might be above the threshold, otherwise, one-minute compression might not. So, the differences in subjective fatigue could be explained, even though the same total compression time

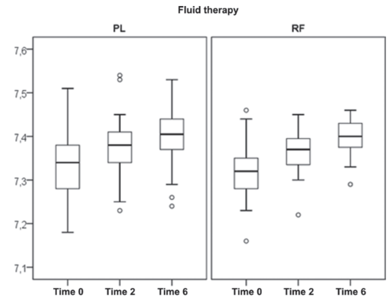

Figure 2. Correlation between strength and mean compression depth.
Positive correlation is seen. Spearman's rho in the 2-MCG is 0.80 (p <0.01), and in the 1-MCG is 0.82 (p <0.01).
1-MCG, 1 minute shift cycle group;
2-MCG, 2 minute shift cycle group.

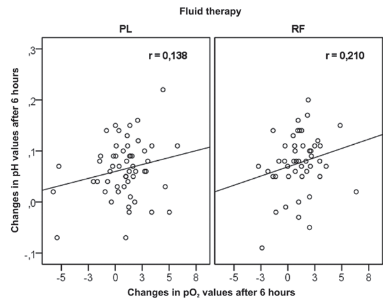

Figure 3. Compression rate at every period in each group.

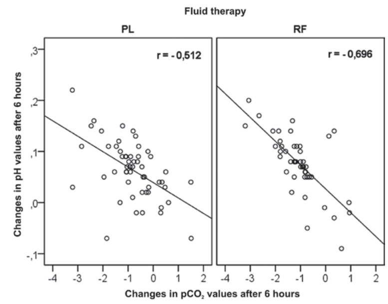

Figure 4. Adequate compression ratio at every period for each group.

(four minutes) was given to both groups. Our results are in line with those of previous studies that have emphasised the importance of rescuer strength in chest compression. Furthermore, they suggest the possibility that chest compression quality could be maintained by changing the compression shift cycle, regardless of rescuer strength. Changing the chest compression shift cycle from two minutes to one minute should reduce subjective fatigue and maintain chest compression quality, in situations with two (or more) CPR rescuers.

There were several limitations to this study. First, the total chest compression time was just four minutes. This time is too short to reflect all CPR procedures, where the duration may be longer than four minutes. Second, this was a continuous chest compression study. In a two-rescuer basic life-support situation, the ventilation that would be carried out by the other rescuer may affect the opportunity for rest during CPR. This study may be more relevant after the placement of advanced airway devices, as continuous chest compression is still recommended by guidelines under those conditions. Third, reducing the compression shift time may increase the frequency of rescuer shifts, which could interrupt the continuity of chest compression. Thus, in actual practice, changing shift times may be best considered by expert resuscitation teams that can minimise interruption time. Further study should be conducted to evaluate any increased shift frequency effect. Fourth, we used a kneeling position and a metronome, which have been introduced as factors that facilitate chest compression in some studies. (13,14) In future work, the effects of metronome use and participant position should be considered. Finally, our sample is relatively small and therefore limits the strength of our findings.

CONCLUSION

With the emphasis in recent guidelines on fast and hard chest compressions, we suggest that the quality of compressions could be more easily maintained by reducing the compression shift time from two minutes to one minute, regardless of rescuer strength.

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