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An Appropriate Compression Pace is Important for Securing the Quality of Hands-only CPR – A manikin study

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ABSTRACT

It is important to implement good quality chest compressions for cardiopulmonary resuscitation (CPR). This manikin study examined the effects of different compression rates on chest compression depth variables using a metronome sound guide. Fifty sixth-year dentistry students participated in the study. Each participant performed CPR at 3 different compression rates, 110, 100, and 90 compressions per min (pace-110-g, pace-100-g, and pace-90-g) for 2 consecutive one-minute sets with a ten-second break between the sets. The percentage of compressions deeper than 5 cm at pace-110-g decreased significantly from 22.1 ± 4.7% in the first set to 16.7 ± 4.4%* in the second set (*$p<0.05$ vs. the first set). However, no significant differences were observed between the first and second sets at pace-100-g and pace-90-g. The results obtained for pace-110-g were compared in detail by gender. In the male group, the percentage of compressions deeper than 5 cm was 43.5 ± 7.5% in the first set, and this decreased significantly to 34.6 ± 7.6%* in the second set (*$p<0.001$ vs. the first set). However, the percentage of compressions deeper than 5 cm in the female group was 2.3 ± 1.6%* in the first set and 0.2 ± 0.2%* in the second set (*$p<0.05$ vs. male). Our study demonstrated that the compression pace of 110 compressions per min was inadequate to provide chest compressions of an appropriate depth, which decreased rapidly. Therefore, limiting the rate of compressions to within a certain number per min may contribute to minimizing deteriorations in compression depth in hands-only CPR.

Key words: *Hands-only CPR, Chest compression, Compression pace*

High quality chest compressions with an appropriate compression pace may facilitate the successful return of spontaneous circulation (ROSC)[7,12]. A previous study investigating the rate of chest compressions demonstrated that optimal blood flow could be obtained by maintaining chest compressions at a rate of at least 100 per min[9]. Accordingly, a rate of chest compressions faster than 100 per min was recommended by the American Heart Association (AHA) 2010 Guidelines (G2010)[3]. However, the rate of chest compressions is often much lower during training and actual CPR attempts[1,15,18]. An improved survival rate was reported in a clinical study of out- of-hospital cardiac arrest when chest compressions were implemented at a mean chest compression rate of above 110 per min[4]. Faster chest compression rates also improved ROSC and 24h survival rates after ventricular fibrillation in an animal study[8]. Thus, the implementation of a good quality chest compression pace to obtain ROSC is important.

In a previous study, males performed chest compression of greater quality compared with female participants[16]. Therefore, chest compression rate

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and depth are compared here according to gender.

The recommended chest compression rate has increased in recent years with every amendment to the AHA guidelines. In the AHA Guidelines 2010, the recommended rate of chest compressions is at least 100/min, while it was stated as “about 100/min” in the 2005 recommendation[5]. However, the European Resuscitation Council Guidelines 2010 recommended an upper compression rate of 120/min[10].

An appropriate compression pace is important to ensure the quality of chest compressions. Recent findings have revealed that a reduction in compression quality was more evident in chest-compression-only CPR than in standard CPR after 90 sec[14], although this effect may not be significant for ROSC. In the present study, we measured the chest compression depth of different compression rate variables using a metronome sound guide when compression-only CPR was performed on a manikin by rescuers according to the G2010.

MATERIALS AND METHODS

Participants, ethical considerations, and study design

Fifty sixth-year dentistry students agreed to participate in this study, which was approved by the Ethics Committee of Hiroshima University Graduate School of Medicine. All procedures were conducted according to the Declaration of Helsinki.

The participants in this study were students in the same school year who had received the same CPR training at Dental School. Participants were instructed to perform chest compressions according to the G2010 (compression depth >5 cm) prior to the experiment.

Each participant performed CPR at 3 different compression rates using a metronome sound guide with at least a 30-min rest between each 2-min set of compressions. An electronic metronome with an audible beeping tone was used to guide participants on the chest compression rate. 110, 100, and 90 compressions per min (pace-110, pace-100, and pace-90) were performed on the chest of a manikin at the sternum level (ALS Skillmeter, Laerdal Medical, Norway) for 2 consecutive one-minute sets with a ten-second break between the sets. Data were collected in a separate room without a clock, and oral announcements were made during the experiment. In previous studies, it was reported that applying a backboard significantly increased chest compression depth during cardiopulmonary resuscitation of a manikin. Therefore, our study subjects were asked to perform chest compressions on the hard floor.

Measurement & Statistical quality of chest compressions

We counted the number of chest compressions and those with an appropriate depth during each min of the CPR period in a manikin equipped with a ALS Skillmeter & Heartsim 4000 (Laerdal Medical, Stavanger, Norway). An appropriate depth was defined as 5 cm or more by the G2010.

Data were compared between groups using the Student’s t-test and repeated measures two-way analysis of variance (ANOVA). Values are shown as the mean ± the standard error (SEM). Analyses were performed using Stat View™ (SAS Institute, San Francisco, USA). Results were considered significant when p was less than 0.05.

RESULTS

The number of participants in each pace group (pace-110, pace-100, and pace-90) was 50. Table 1 shows the height, weight, completion of an AHA BLS provider course, and age of the participants (Table 1).

The average number of chest compressions was measured at each pace. The average numbers of chest compressions in the first and second sets were 109.2 ± 1.4 and 109.2 ± 1.6 compressions per min, respectively, in the pace-110 group, 99.9 ± 1.3 and 99.5 ± 1.2 in the pace-100 group, and 89.7 ± 1.1 and 89.7 ± 1.1 in the pace-90 group. No significant difference was observed in the average number of compressions between the first and second set at each pace.

Table 1. Baseline characteristics of male and female participants

	Male(n=25)	Female(n=25)
Height (mean, cm)	**170.3±5.5**	**158.3±4.6***
Weight (mean, kg)	**64.9±9.6**	**49.4±5.4***
Age (mean)	**25±1.9**	**26.1±3.9**
AHA BLS course experience	**1**	**2**
CPR experience	**0**	**0**

Values are shown as the mean ± S.E.M.
*p<0.0001 (non-Paired t-test: vs Male)
AHA BLS course: American Heart Association Provider course.
CPR: Cardiopulmonary Resuscitation.

Figure 1 shows time-course changes in the number of chest compressions performed by male and female participants at each pace. The number of compressions performed in the second set was significantly higher in males than in females in the pace-110 group (109.7 ± 0.3 vs. 108.8 ± 0.3*, *p<0.05, respectively). The number of females able to maintain a rate faster than 110 per min was significantly lower in the second set than in the first set (Fig. 1). A slight decrease in the number of compressions performed during the whole 2-min study period was observed only in females in the pace-110 group.

Figure 2 shows the percentage of compressions performed by male and female participants that reached 5 cm or deeper in the first and second sets of each pace. Compressions performed by male and female participants in the pace-110 group were compared in detail. In males, the percentage of compressions deeper than 5 cm of 43.5 ± 7.5% in the first set was significantly higher than that of 34.6 ± 7.6%* in the second set (*p<0.001 vs. the first set). However, in females, the percentages of compressions deeper than 5 cm in the first set and second set were 2.3 ± 1.6%* and 0.2 ± 0.2%* (*p<0.05 vs. male). On the other hand, pace 90 and pace 100 were not decreased in the second set (Fig. 2).

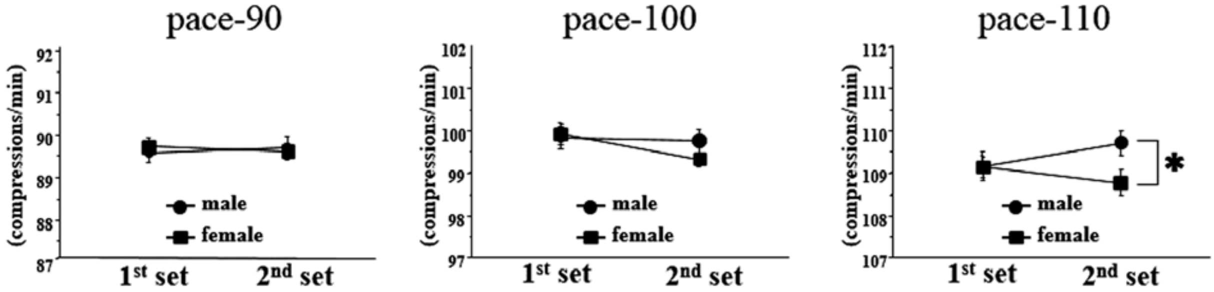

Fig. 1. Time-course changes in the number of chest compressions performed by male and female participants in each group.

Values are shown as the mean ± S.E.M.
*p<0.05 (two-way ANOVA: between both groups)

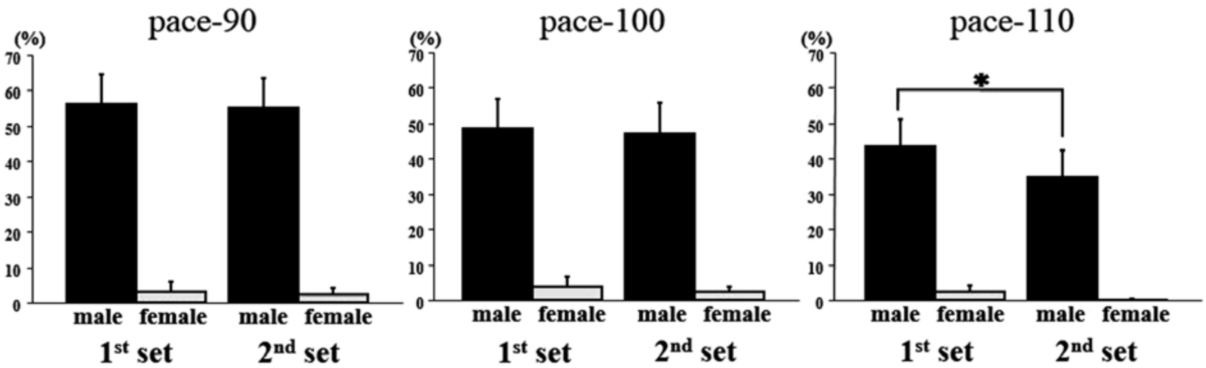

Fig. 2. The percentage of compressions performed by male and female participants that reached 5 cm or deeper in the first and second sets in each group.

*p<0.001 (Paired t-test: between both groups)

DISCUSSION

Chest compressions are the most important treatment affecting the ROSC of cardiac arrest. The G2010 for CPR recommended that untrained bystanders should perform chest-compression-only CPR with an emphasis on "push hard and fast" (a chest compression depth of >5 cm at a rate of >100 compressions per min). A faster chest compression rate was shown to improve immediate and 24h survival rates following ventricular fibrillation arrest in an animal study[8]. Clinical studies have also reported improvements in survival due to a faster compression rate[2]. However, faster compression rates induce rescuer fatigue, which, in turn, decreases the quality of CPR. Therefore, limiting the rate of compressions to within a certain number per min minimizes deteriorations in the depth of compressions. The influence of the chest compression rate on the depth of compressions performed by a single rescuer has yet to be determined.

Our study showed that a chest compression pace of 90-110 per min for 2 min on a manikin whilst maintaining the chest compression depth recommended by the G2010 was not feasible. The main drawback to a faster compression rate was a significant decrease in the depth of compressions performed by both male and female participants. However, no significant decrease was observed in the depth of chest compressions performed over 2 min in the pace-100 and pace-90 groups, and the chest compression depth was maintained to an acceptable level according to the G2005.

Furthermore, the female group showed a significant decrease in the number of chest compressions during pace-110 between the first set and second set. These findings suggest that maintaining the quality of chest compressions, i.e., appropriate p, in accordance with the G2010, may be difficult to achieve for females.

Recent studies on adult CPR have suggested that the rates of defibrillation success and ROSC may be improved by performing chest compressions to a depth deeper than 5 cm[8)]. In addition, even deeper compressions were shown to lead to a higher survival rate in dogs[6)]. Therefore, the G2010 recommends that at least 100 chest compressions deeper than 5 cm per min should be maintained during CPR[9)]. However, a clinical study of in-hospital cardiac arrest revealed that sternal and rib fractures are frequent complications of chest compressions performed at an exact and ideal depth of chest compressions[11)]. These findings suggest that maintaining the quality of chest compressions, i.e., appropriate depth, in accordance with the G2010 may exceed the recommendation for chest compression.

On the other hand, the compression rate and total number of compressions are important for maintaining the quality of CPR[2)]. The results of the present study showed that the chest compression rate did not decrease over time in the 3 groups. However, the total number of compressions performed was markedly higher and the number of compressions performed at the proper depth was markedly lower in the pace-110 group than in other groups. These results indicated that participants were unable to maintain the quality of chest compressions at a pace of 110 per min.

As seen in other studies, when rescuers were provided with a rest period during continuous-chest-compression (CCC) CPR (for example, a 10-s rest after 100 chest compressions), the mean chest compression depth and percentage of adequate compressions were higher than those during CCC without rest[13)]. Chika and coauthors reported that CPR quality during CCC-CPR with rest decreased after 1 min compared with conventional CPR[14)]. Our study protocol may also be different from actual continuous chest-compression CPR, which is performed without intervals for artificial respiration.

There are several limitations to this study. First, the number of participants was small. Second, we used a manikin equipped with an ALS Skillmeter (Laerdal Medical, Stavanger, Norway) that requires a force of more than 45 kg to generate a compression deeper than 51 mm. This is the average force required to perform chest compression by a lay person[17)]. As a result, patient outcomes from different chest compression paces were not measured. We were unable to confirm how much force is required to perform a chest compression by a real lay person. Patient outcomes from different chest compression paces were also not measured. Third, we could not measure the average depth for chest compressions because the numerical count system of HeartSim 4000 (Laerdal Medical, Stavanger, Norway) was used in this study. Finally, we did not compare the quality of chest compressions with those performed during conventional CPR.

CONCLUSIONS

The present study compared the quality of chest compressions performed at three different paces by dentistry students. The depth of chest compressions at a rate of 110 compressions per minute was inadequate and decreased more rapidly over the 2-min test period. Female students were unable to deliver chest compressions deeper than 5 cm from the first set. We consider pace-100 to be a reasonable limit for the rate of compressions performed per min in order to minimize deteriorations in compression depth in chest-compressions-only CPR for dentistry students.

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