Comparison of the effects of shortening rest intervals on the quality of cardiopulmonary resuscitation, physiological parameters, and hemodynamic parameters in well-trained rescuers

Randomized simulation study

Dong Hun Kim, PhD, Sang-Min Lee, PhD, Gyun Moo Kim, MD, PhD, Kyung Woo Lee, MD, PhD, Seung Hyun Ko, MD, Ye Jin Oh, MS, Young Woo Seo, MD, Suk Hee Lee, MD, Tae Chang Jang, MD, PhD.

Abstract

Background: Cardiopulmonary resuscitation (CPR) performance depends on individual ability and training. Well-trained or professional rescuers can maintain high-quality CPR for longer than laypeople. This study aimed to examine the effects of reducing resting intervals on CPR performance, physiological parameters, and hemodynamic parameters during prolonged CPR in well-trained providers.

Methods: The study enrolled 90 volunteers from the paramedic students of our institution. They were randomly divided into 3 groups: 2 minutes, 1 minute 45 seconds, and 1 minute 30 seconds rest groups. Each participant performed 5 cycles of chest compression only CPR (2 min/cycle) with different resting intervals according to grouping. CPR quality, physiological variations, and hemodynamic variations were measured for each cycle and compared across the groups.

Results: Of the 90 volunteers, 79 well-trained providers were finally included. The variation of the average chest compression depth across the 5 cycles showed significant differences between the 3 groups: from cycle 1 to 2: 1.2 (3.1) mm, −0.8 (2.0) mm, and −2.0 (3.0) mm in the 2 minutes, 1 minute 45 seconds, and 1 minute 30 seconds groups, respectively (P < .001); from cycle 1 to 3: 0.0 (3.0) mm, −0.7 (3.2) mm, and −2.6 (3.9) mm, respectively (P = .030). However, all 3 groups maintained the recommended rate and chest compression depth for all 5 cycles. Physiological and hemodynamic parameters showed no significant differences between the groups.

Conclusions: Well-trained providers were able to maintain high-quality CPR despite reducing rest intervals. Adjusting the rest interval may help maintain overall CPR quality in special situations or where layperson rescuers are involved.

Abbreviations: AHA = American Heart Association, COCPR = chest compression only cardiopulmonary resuscitation, CPR = cardiopulmonary resuscitation, HR = heart rate.

Keywords: cardiopulmonary resuscitation, emergency medical services, emergency medical technicians, fatigue, students

1. Introduction

High-quality chest compressions during cardiopulmonary resuscitation (CPR) are crucial to improve the survival rate of cardiac arrest patients.[1,2] The 2015 Guidelines for CPR recommend a compression depth of 5 to 6 cm at a rate of 100 to 120 compressions/min.[3] However, continuously maintaining high-quality chest compressions causes accumulated fatigue, which then deteriorates the quality of compressions; therefore, the guidelines recommend switching with another rescuer, if possible, every 2 minutes.[4] During prolonged CPR, fatigue has a decisive impact on continuing high-quality CPR, and fatigue levels differ between individuals. Recent guidelines also classify instruction methods according to the extent of the rescuer's training. Chest compression only CPR (COCPR) is recommended for laypeople with no experience in CPR and conventional CPR (including ventilation and chest compressions) for healthcare providers.[5,6] Individual CPR performance may vary according to the rescuer's physical condition, training level, and experience. Fatigue during CPR may also differ according to the level of training or proficiency. The CPR quality delivered by laypeople deteriorated over time.[7] By contrast, well-trained
healthcare professionals and emergency medical providers were able to maintain high-quality CPR for 10 minutes.[8]

Cardiac arrest is unpredictable and can occur in many situations. If CPR is performed by a layperson without any CPR experience or a rescuer who cannot maintain high-quality CPR due to fatigue, high-quality CPR cannot be guaranteed with prolonged duration. High-quality CPR can only be maintained when well-trained rescuers perform high-quality chest compressions for 2 minutes, rest for a short interval, and switch with another rescuer before CPR quality declines.

Therefore, we altered the 2-minute compression, 2-minute rest rule, which has hitherto been considered unchangeable, by shortening the resting interval for well-trained rescuers to 1 minute 45 seconds and 1 minute 30 seconds. The aim of study was to examine the effects of reducing resting intervals during prolonged CPR in well-trained providers. We measured subjective fatigue and objective physiological and hemodynamic variations over 5 cycles of CPR to measure changes in CPR quality with the new shortened resting intervals.

2. Subjects and methods

2.1. Study design

In this prospective randomized simulation study, paramedic students who underwent clinical practicing at our emergency medical center from June 2018 to February 2019 were recruited. Participants were divided into 3 groups; 2 minutes, 1 minute 45 seconds, and 1 minute 30 seconds rest groups. Each participant performed 5 cycles of COCPR (2 min/cycle) on a simulation mannequin. Participants allocated to the 2 minutes, 1 minute 45 seconds, and 1 minute 30 seconds rest groups were given 2 minutes, 1 minute 45 seconds, and 1 minute 30 seconds of rest, respectively, between each cycle. We evaluated CPR parameters during compressions, and physiologic parameters and hemodynamic parameters before compressions and immediate after compressions during each rest time. All the volunteers who enrolled for the study provided informed consent, and the study was approved by our institutional board (CR-18-090).

2.2. Participants and randomization

Inclusion criteria were paramedic students who had CPR training and practice. The 90 participants voluntarily applied to the study, were stratified by sex, and then randomly assigned to 3 groups by simple block randomization. Two participants did not attend the evaluation; thus, 88 participants were evaluated for 5 cycles of COCPR. Well-trained rescuers were classified by the total score computed based on depth, rate, and hand position of chest compressions from the simulation mannequin. After excluding 9 participants who failed to meet the cut-off value of 80 in cycle 1, data from 79 participants were included in the study (Fig. 1).

2.3. Variables and outcomes

General characteristics of participants including age, height, weight, sex, school year, number of CPR trainings, and number of practices were surveyed using a questionnaire. Subjective...
fatigue was measured using a 10-point Likert scale. CPR parameters were measured using a simulation mannequin, Resusci Anne QPCR/SimPad PLUS with SkillReporter (Laerdal Medicals; Stavanger, Norway): total score, chest compression rate, chest compression depth, and chest recoil. Physiological parameters like systolic blood pressure, heart rate (HR), and respiratory rate were measured using conventional instruments. Hemodynamic parameters were measured using a noninvasive electrical cardiometry device, ICON Cardiotronic, (Osypka Medical GmbH; Berlin, Germany) which measured stroke volume and cardiac output (L/min) before compressions, immediately after compressions, and during rest in each cycle. Cardiac output as measured by ICON strongly correlates with that measured using transoesophageal echocardiography; electrical cardiometry can also continuously monitor and quantify hemodynamic parameters.\(^{[9,10]}\)

The primary outcome was the variation of average chest compression depth according to cycles, and the secondary outcomes were the average chest compression rate, HR, and cardiac output according to cycles.

2.4. Sample size calculation

The primary endpoint was set as chest compression depth according to time. The difference in compression depth (5 mm) and standard deviation (4.5 mm) in the 2 minutes rest group were taken as reference values from Wang et al.\(^{[11]}\) In the 1 minute 45 seconds rest group and 1 minute 30 seconds rest group, the difference in chest compression depth was assumed to be 7 mm, 9 mm, and standard deviation (4.5 mm) was assumed to be the same. With an alpha of 0.05 and power 0.80, 27 participants were required for each group. Assuming a 5% study withdrawal rate, we calculated that 29 participants were required for each group; therefore, the target sample size was 87.

2.5. Statistical methods

Demographic data were analyzed using descriptive statistics. Quantitative data were presented as means and standard deviations, while qualitative data were presented as frequencies and percentages. To test the homogeneity of the demographic characteristics between the groups, quantitative data were tested using either a parametric (1-way ANOVA) or a nonparametric (Kruskal–Willis) test depending on the normality of the data, while qualitative data were tested using the Chi-square test. To compare the quality of chest compression across the groups, the rate and depth of chest compressions were measured. For each of these measures, the differences in the values between cycles 1 and 2, cycles 1 and 3, cycles 1 and 4, and cycles 1 and 5 were computed. These differences were analyzed with either a parametric (1-way ANOVA) or nonparametric (Kruskal–Willis) test depending on the normality of the data. If the differences were statistically significant, Scheffe test was performed for post-hoc analysis. Variations in fatigue, physiological parameters, and hemodynamic parameters for all 5 cycles were analyzed using repeated measures 2-way ANOVA to determine differences between time points, between groups, and between group and time point interactions. All statistical analyses were performed using SPSS v. 19.0 (IBM Corp, Armonk, NY) using 2-tailed tests. \(P\)-values <.05 were deemed to be statistically significant.

3. Results

3.1. General characteristics of participants

No differences were found between rest groups for age, weight, and number of CPR trainings or practices. There were also no statistically significant differences between the groups in height, body mass index, sex, school year, number of practices, and confidence levels. All values are tabulated in Table 1.

3.2. Comparing CPR quality between groups across 5 cycles

Average chest compression depth was \(\geq 53.9\) (6.8) mm for all 5 cycles in all 3 groups (all groups maintained the recommended depth of 5–6 cm throughout all cycles). Comparing cycle 2 to cycle 1, chest compression depth increased by 1.2 (3.1) mm, decreased by 0.8 (2.0) mm, and decreased by 2.0 (3.0) mm in the 2 minutes, 1 minute 45 seconds, and 1 minute 30 seconds rest groups, respectively, with statistically significant differences between the groups \(\left(< .001\right)\). Comparing cycle 3 to cycle 1, depth decreased by 0.0 (3.8) mm, 0.7 (3.2) mm, and 2.6 (3.9) mm, respectively, with statistically significant differences between the

### Table 1

**General characteristics of participants.**

| Characteristic  | 2 min     | 1 min 45 s | 1 min 30 s | \(P\)-value |
|----------------|-----------|------------|------------|-------------|
| Age            | 22.3 (1.6) | 21.2 (1.7) | 22.0 (2.8) | .167        |
| Height (cm)    | 171 (7.5)  | 168.2 (7.5)| 171.5 (8.1)| .260        |
| Weight (kg)    | 67.4 (14.4)| 63.6 (9.5) | 69.5 (13.6)| .245        |
| BMI            | 22.9 (3.4) | 22.4 (2.3) | 23.5 (3.8) | .456        |
| Number of trainings | 19.7 (23.5) | 15.6 (14.7) | 17.6 (13.9) | .716        |
| Number of practices | 71.3 (84.0) | 45.9 (61.0) | 66.8 (65.6) | .399        |
| Sex            |           |            |            |             |
| Male           | 16 (61.5)  | 14 (56.0)  | 17 (60.7)  | .910        |
| Female         | 10 (38.5)  | 11 (44.0)  | 11 (39.3)  |             |
| School year    |           |            |            |             |
| 2              | 19 (73.1)  | 21 (84.0)  | 21 (75.0)  | .122        |
| 3              | 7 (26.9)   | 2 (8.0)    | 7 (25.0)   |             |
| 4              | 0 (0.0)    | 2 (8.0)    | 0 (0.0)    |             |

BM = body mass index.
groups ($P = .030$). Considering that there were no statistically significant differences when comparing cycle 4 and 5 ($P = .093$ and .059 respectively) to cycle 1, it is speculated that rescuers exhibited a temporary decrease in compression depth in earlier cycles due to fatigue caused by the shorter rest interval. However, these differences disappeared in further cycles of CPR; suggesting that they became accustomed to the fatigue and kept pace over time (Fig. 2).

Compression rate (compressions/min) tended to increase further into the cycles in each group, but all groups maintained the recommended rate of 100 to 120 compressions/min till cycle 5. Compared to cycle 1, there were no statistically significant differences between the groups in cycle 2, 3, 4, and 5 ($P = .422, .655, .788,$ and .797 respectively) (Fig. 3). All values are tabulated in Table 2.

### 3.3. Comparing fatigue, physiologic parameters, and hemodynamic parameters between groups across 5 cycles

Subjective fatigue tended to increase further into the cycles. Overall, it increased from 3.8 (2.2) to 5.8 (1.9); patterns of increase were similar for all groups, with no statistically significant differences between them ($P = .897$).

Comparing physiological parameters, HRs at baseline and during cycles 1, 2, 3, 4, and 5 were $86.9 (14.1), 129.4 (20.3), 134.2 (22.0), 133.5 (19.1), 135.4 (21.0),$ and $133.9 (25.2)$ beats/min, respectively, for the 2 minutes rest group; $86.5 (9.7), 131.0 (17.8), 133.4 (15.2), 133.2 (14.9), 133.9 (15.6),$ and $132.2 (16.6)$ beats/min, respectively, in the 1 minute 45 seconds rest group; and $89.7 (14.0), 126.3 (18.4), 131.3 (19.3), 131.8 (20.8), 128.7 (22.8),$ and $126.3 (23.2)$ beats/min, respectively, in the 1 minute 30 seconds rest group. The stable HR at baseline rapidly rose after cycle 1, with no marked changes through cycles 2 to 5. Although there were statistically significant differences across time points ($<0.01$), there were no statistically significant differences between groups ($P = .370$) and time and group interaction ($P = .755$).

Systolic blood pressure, stable at baseline, rapidly rose after cycle 1, with no marked changes through cycles 2 to 5. Although there were significant differences across time points ($P < .001$), there were no significant differences between groups ($P = .944$). Although respiratory rates showed significant differences across time points ($P < .001$), there were no significant differences between groups.

Comparing hemodynamic parameters using ICON CardioTronic: cardiac output at baseline and in cycles 1, 2, 3, 4, and 5 were $6.3 (1.5), 9.9 (2.3), 9.9 (2.4), 9.9 (3.0),$ and $10.1 (2.8),$ and 9.2...
Table 2
Comparison of CPR performance of the 3 resting interval groups.

|                  | 2min* | 1 min 45s* | 1 min 30s* | P-value |
|------------------|-------|------------|------------|---------|
| Compression depth|       |            |            |         |
| 1st              | 56.0 (4.7) | 56.5 (4.0) | 57.0 (4.1) |         |
| 2nd              | 57.2 (3.8) | 55.7 (4.1) | 55.0 (5.7) |         |
| 3rd              | 56.0 (4.8) | 55.8 (5.3) | 54.4 (5.9) |         |
| 4th              | 55.7 (5.0) | 55.6 (4.6) | 54.3 (6.3) |         |
| 5th              | 55.7 (5.0) | 55.1 (5.4) | 53.9 (6.8) |         |
| Change from 1st time |     |            |            |         |
| 2nd              | 1.2 (3.1)  | -0.8 (2.0) | -2.0 (3.0) | <.001a,b,c |
| 3rd              | 0.0 (3.8)  | -0.7 (3.2) | -2.6 (3.9) | .030a,b,c |
| 4th              | -0.3 (4.5) | -0.3 (3.2) | -2.7 (4.4) | .093    |
| 5th              | -0.3 (4.6) | -1.4 (3.5) | -3.1 (4.6) | .059    |
| Compression rate/min |     |            |            |         |
| 1st              | 107.8 (8.5) | 108.8 (7.9) | 107.7 (8.8) |         |
| 2nd              | 108.7 (10.0) | 110.7 (9.2) | 108.5 (10.7) |         |
| 3rd              | 110.6 (9.7) | 112.1 (9.0) | 109.9 (10.4) |         |
| 4th              | 111.9 (10.3) | 113.3 (9.0) | 111.3 (11.1) |         |
| 5th              | 112.5 (10.1) | 114.6 (9.7) | 113.0 (11.4) |         |
| Change from 1st time |     |            |            |         |
| 2nd              | 0.8 (2.9)  | 1.9 (3.4)  | 0.8 (3.6)  | .422    |
| 3rd              | 2.8 (3.4)  | 3.3 (4.0)  | 2.3 (5.0)  | .655    |
| 4th              | 4.1 (4.9)  | 4.5 (4.8)  | 3.6 (5.0)  | .788    |
| 5th              | 4.7 (5.2)  | 5.8 (5.4)  | 5.3 (6.8)  | .797    |

CPR = cardiopulmonary resuscitation.
* P-value < .05.
a: 2-minute compression and 2-minute rest group.
b: 2-minute compression and 1 minute 45 seconds rest group.
c: 2-minute compression and 1 minute 30 seconds rest group.
Comparison of fatigue, physiological parameters, and hemodynamic parameters of the 3 resting interval groups.

|                         | Baseline | 1st | 2nd | 3rd | 4th | 5th | Time | Group | T&G |
|-------------------------|----------|-----|-----|-----|-----|-----|------|-------|------|
| Heart rate (bpm)        |          |     |     |     |     |     |      |       |      |
| 2 min                   | 86.9 (17.5) | 129.4 (20.3) | 134.2 (22.0) | 133.5 (19.1) | 135.4 (21.0) | 133.9 (25.2) | <0.001 * | 0.370 | 0.755 |
| 1 min 45 s              | 86.5 (9.7) | 131.0 (17.8) | 133.4 (15.2) | 133.2 (14.9) | 133.9 (15.6) | 132.2 (16.6) |          |       |      |
| 1 min 30 s              | 89.7 (14.0) | 126.5 (18.4) | 131.3 (19.3) | 131.8 (20.8) | 128.7 (22.8) | 126.3 (23.2) |          |       |      |
| SBP (mm Hg)             |          |     |     |     |     |     |      |       |      |
| 2 min rest              | 127.2 (14.3) | 140.3 (21.2) | 144.6 (21.4) | 144.5 (18.4) | 144.1 (14.2) | 145.4 (15.9) | <0.001 * | 0.944 | 0.872 |
| 1 min 45 s              | 125.8 (13.3) | 143.9 (22.1) | 144.0 (18.8) | 144.4 (20.2) | 134.7 (17.9) | 146.1 (17.3) |          |       |      |
| 1 min 30 s              | 130.7 (15.7) | 143.4 (14.1) | 144.3 (15.5) | 146.0 (14.9) | 147.2 (15.9) | 144.5 (15.4) |          |       |      |
| RR/min                  |          |     |     |     |     |     |      |       |      |
| 2 min                   | 15.4 (4.1) | 22.7 (5.9) | 22.5 (6.9) | 22.3 (6.2) | 21.8 (6.6) | 20.8 (6.8) | <0.001 * | 0.894 | 0.594 |
| 1 min 45 s              | 14.9 (2.6) | 21.6 (6.7) | 21.8 (6.8) | 23.0 (7.2) | 23.2 (6.7) | 21.9 (6.6) |          |       |      |
| 1 min 30 s              | 15.6 (3.6) | 22.8 (6.3) | 22.5 (6.0) | 22.9 (6.2) | 22.5 (6.6) | 23.5 (6.5) |          |       |      |
| Fatigue                 |          |     |     |     |     |     |      |       |      |
| 2 min                   | 3.8 (2.2) | 4.7 (1.8) | 5.2 (1.4) | 5.5 (1.7) | 5.5 (2.3) |          | <0.001 * | 0.897 | 0.477 |
| 1 min 45 s              | 4.2 (2.2) | 4.8 (1.9) | 5.3 (2.0) | 5.5 (1.8) | 5.8 (1.9) |          |          |       |      |
| 1 min 30 s              | 3.9 (1.9) | 4.6 (1.8) | 5.1 (1.8) | 5.4 (1.9) | 5.7 (2.3) |          |          |       |      |
| Cardiac output (L/min)  |          |     |     |     |     |     |      |       |      |
| 2 min                   | 6.3 (1.5) | 9.9 (2.3) | 9.9 (2.4) | 9.9 (3.0) | 10.1 (2.8) | 9.2 (2.0) | <0.001 * | 0.615 | 0.993 |
| 1 min 45 s              | 6.2 (1.2) | 10.4 (2.3) | 9.0 (1.7) | 9.4 (1.6) | 10.0 (1.9) | 9.5 (2.2) |          |       |      |
| 1 min 30 s              | 6.5 (1.2) | 9.7 (1.5) | 10.1 (1.9) | 10.0 (2.5) | 9.5 (2.8) | 9.2 (2.2) |          |       |      |
| Stroke volume (mL)      |          |     |     |     |     |     |      |       |      |
| 2 min                   | 72.5 (12.3) | 77.0 (17.1) | 74.4 (16.6) | 74.8 (20.6) | 76.2 (22.9) | 69.9 (16.5) | <0.001 * | 0.799 | 0.851 |
| 1 min 45 s              | 71.1 (13.3) | 79.2 (14.5) | 74.4 (13.9) | 71.0 (11.3) | 75.2 (12.1) | 72.1 (13.8) |          |       |      |
| 1 min 30 s              | 72.5 (7.6) | 78.2 (14.3) | 78.0 (14.7) | 76.5 (18.3) | 75.0 (18.3) | 73.6 (14.5) |          |       |      |

RR = respiration rate, SBP = systolic blood pressure, T&G = time and group interaction.

* P-value < .05.

Table 3

In this study, the rest interval between 2-minute cycles of COCPR was shortened to 1 minute 45 seconds and 1 minute 30 seconds, and CPR quality was compared to CPR quality with conventional rest intervals of 2 minutes. The results showed that all 3 groups maintained the recommended rate and depth of chest compressions throughout the 5 cycles. Comparing the average compression depth in cycles 2, 3, 4, and 5 to cycle 1 values, there were no significant differences between the 2 minutes rest group and 1 minute 45 seconds rest group. The 1 minute 30 seconds rest group showed significantly reduced depth in cycles 2 and 3 compared to the other groups, but this difference disappeared further into the cycles, suggesting that this group temporarily demonstrated lower CPR quality in earlier cycles due to the short rest interval following cycle 1, but was able to achieve and maintain high-quality CPR comparable to the other groups in subsequent cycles. Bjorshol et al[6] studied professional emergency medical technicians who performed CPR for 10 minutes and were able to maintain the American Heart Association (AHA) recommended rate and depth of chest compressions throughout. Hong et al[12] studied 20 healthcare providers who performed conventional CPR including ventilation for 10 minutes and were able to maintain recommended chest compression depths throughout. Although our study evaluated paramedic students, they had undergone an average of 15.6 CPR trainings and practiced CPR 45.9 times on average; their curriculum included adequate training in basic CPR. Moreover, only include well-trained rescuers were included in this study. Compared to untrained laypeople, well-trained rescuers can perform CPR using strategies like applying body weight and effectively distributing their strength to continuously provide high-quality CPR. The variation of subjective fatigue was not substantial, with a minimum average of 3.8 in earlier cycles to a maximum average of 5.8 after cycle 5; it did not significantly differ between groups. Continuous performing high-quality CPR induces fatigue, which directly degrades CPR quality. Therefore, fatigue has been extensively studied. Among early fatigue studies, Ochoa et al[13] reported that rescuers who performed 5 minutes of CPR showed reduced chest compression quality starting at 1 minute into CPR. Ashton et al[14] had rescuers perform 3-minute cycles of compressions interspersed with 30 seconds rest intervals; compression quality began to deteriorate 1 minute later. This quick onset of fatigue seemed to be influenced by participants’ age, fitness, and extent of CPR training. According to Wik et al,[15] many prehospital CPR cases received chest compressions with inadequate depth and prolonged pauses between cycles. Furthermore, 37% of in-hospital CPR cases involved low chest compression depths and 24% had pauses between cycles.[16] These results showed that, historically, CPR quality has been low for both in-hospital and prehospital cardiac arrests. Accordingly, AHA Guidelines for CPR began to emphasize high-quality compressions, and continuously recommend the “push hard,
push fast” strategy with a compression depth of 5 to 6 cm at a rate of 100 to 120 compressions/min.1,3,17) Studies published after this emphasis on high-quality CPR demonstrated that chest compression quality was maintained despite prolonged CPR.12,16,19) As the outcomes of CPR simulation studies may vary depending on participants’ proficiency, time of research, and research methodology, study designs need to be examined carefully.

Real-time feedback devices have increasingly been utilized in prehospital, in-hospital CPR, and during education sessions to improve CPR quality.20,21) Mptots et al.18) asked female university students to perform CPR for 30 minutes using a feedback device; excepting those that dropped out, participants maintained an effective chest compression rate >70% of the 30 minutes. Abelairas-Gomez C et al.19) compared 5 cycles of 2-minute CPR cycles using a feedback device to measure muscle fatigue; they found that participants maintained high-quality CPR throughout all cycles, excepting those whose CPR quality was <70%. In conclusion, simulation training utilizing real-time feedback devices enhances overall CPR quality and enables rescuers to maintain high-quality CPR for longer durations. Furthermore, these devices help untrained laypeople maintain high-quality CPR. By preventing the deterioration of CPR quality over prolonged durations, these devices enable an objective comparison of fatigue and physiological variations over time, compensating for individual differences in CPR quality. Though this study did not use a feedback device, participants were able to maintain high-quality chest compression over prolonged periods; this was probably because all participants were well-trained rescuers, familiar with and proficient in CPR. Subsequent studies could utilize feedback devices to expand the scope of the study population to include untrained laypeople.

The current study showed that stable HR before chest compressions rapidly rises after cycle 1 and is maintained consistently through cycles 2 to 5, with no significant differences between groups. Hong et al.12) measured maximum and minimum HR as physiological parameters and reported that HR rapidly rose early on in CPR but plateaued over time—correlating well with our results. Cardiac output measured using ICON Cardioptotic also increased early in the CPR but plateaued further into the cycles. Subjective fatigue did not significantly differ between the 3 groups despite the varied rest times. This suggests that rescuers were able to perform high-quality CPR for a prolonged period because their physiological and hemodynamic parameters were maintained after initial elevation and subjective fatigue varied only slightly through the later cycles as a result of rapid body adjustment.

This study has a few limitations. First, the study population consisted of young college students, therefore, results cannot be generalized. Second, due to lack of objective criteria for trained rescuers, we determined this based on values measured by a specific device, so it cannot be applied generally. Third, although we measured hemodynamic parameters immediately after chest compression using ICON Cardioptotic, there was a time delay in achieving reliable results from this equipment due to generating electrocardiogram and electrical velocimetry. Fourth, because of the varying rest intervals, it is difficult to apply the results to a CPR situation involving an automated external defibrillator, as it analyses rhythms in 2-minute intervals. Despite these limitations, this study is significant in that it attempted to alter the rest interval, which has hitherto been considered unchangeable, in a prolonged CPR scenario involving 5 cycles of COCPR performed by trained rescuers. Further, we evaluated CPR quality, physiological changes, and hemodynamic changes across the 5 cycles for all 3 variations of rest intervals.

5. Conclusions

Well-trained rescuers were able to maintain high-quality CPR as recommended by AHA guidelines despite slightly shortened rest intervals. The shortened rest intervals of well-trained rescuers could provide a shortened shift to untrained rescuers. Adjusting the rest intervals according to the rescuer’s proficiency may help maintain the overall quality of CPR, especially in special situations or if CPR is performed by an untrained rescuer.

Author contributions

Conceptualization: Tae Chang Jang, Sang-Min Lee, Seung Hyun Ko, Ye Jin Oh.

Data curation: Dong Hun Kim, Ye Jin Oh.

Formal analysis: Dong Hun Kim, Tae Chang Jang.

Investigation: Dong Hun Kim, Tae Chang Jang, Gyun Moo Kim, Ye Jin Oh, Suk Hee Lee.

Methodology: Dong Hun Kim, Tae Chang Jang, Kyung Woo Lee.

Resources: Gyun Moo Kim, Kyung Woo Lee, Seung Hyun Ko, Suk Hee Lee.

Supervision: Tae Chang Jang.

Writing – original draft: Dong Hun Kim.

Writing – review and editing: Tae Chang Jang, Young Woo Seo.

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