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Different Resting Methods in Improving Laypersons Hands-Only Cardiopulmonary Resuscitation Quality and Reducing Fatigue: A Randomized Crossover Study



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Abstract

Objective: To determine the effects of different resting methods with various rest-start points or rest-compression ratios on improving cardiopulmonary resuscitation (CPR) quality and reducing fatigue during continuous chest compressions (CCC) in 10-min hands-only CPR scenario.

Methods: This prospective crossover study was conducted in 30 laypersons aged 18-65. Trained participants were randomized to follow different orders to perform following hands-only CPR methods: (1) CCC, 10-min CCC; (2) 4+6, 4-min CCC + 6-min of 10-s pause after 60-s compressions; (3) 2+8 (10/60), 2-min CCC + 8-min of 10-s pause after 60-s compressions; (4) 5/30, 2-min CCC + 8-min of 5-s pause after 30-s compressions; (5) 3/15, 2-min CCC + 8-min of 3-s pause after 15-s compressions. CPR quality (depth, rate, hands-on duration, chest compression fraction (CCF)) and participants' fatigue indicators (heart rate, blood pressure, rating of perceived exertion (RPE)) were compared among methods of different rest-start points and different rest-compression ratios with CCC.

Results: Twenty-eight participants completed all methods. All resting methods reduced the trend of declining compression depth and the trend of increasing RPE while maintaining CCF of more than 86%. In methods with different rest-start points, the 2+8 method showed no difference in overall CPR quality or fatigue, but better CPR quality of every minute than 4+6 method. In methods with different rest-compression ratios, the 3/15 method showed the best CPR quality and the highest heart rate increment.

Conclusion: During prolonged hands-only CPR, appropriate transient rests were associated with higher CPR quality and lower subjectively perceived fatigue in laypersons.

Keywords: Hands-only CPR, Laypeople, Rest, Rescuer fatigue, High-quality CPR

Introduction

Cardiopulmonary resuscitation (CPR) increases survival following out-of-hospital cardiac arrest (OHCA) by providing adequate blood

flow to minimize myocardial and brain injury¹⁻³. Compared to conventional CPR technique engaging mouth-to-mouth contact between rescuers and patients, hands-only CPR, namely continuous chest compressions (CCC) without ventilations, has been proven to be

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as effective as conventional CPR in improving patients' outcomes^{4–6}, and more accepted by laypersons^{7–9}. Given the potential benefits, current guidelines of the International Liaison Committee on Resuscitation (ILCOR), American Heart Association (AHA), and European Resuscitation Council (ERC) recommended hands-only CPR for untrained lay rescuers or for those who are unable to perform rescue breaths^{1–3}.

Hands-only CPR is simple to perform, but high-quality resuscitation is still not easy to achieve. High-quality hands-only CPR refers to compressions with adequate rate, adequate depth, avoidance of leaning and minimized hands-off time^{10,11}. However, it has been demonstrated that the quality of CPR, especially compression depth declined greatly during the first few minutes mainly due to rescuer fatigue^{12–14}. Consistent with others, our previous study also displayed that in trained laypersons, the proportion of compression depth of 5–6 cm dropped dramatically from 25% to nearly 0% after 2 mins hands-only CPR¹⁵.

Guidelines recommend rescuers rotate every 2 mins to maintain high-quality CPR^{2,3}, but this role change strategy is not feasible for single rescuer, especially for lay bystanders. As confirmed by previous studies, more than 60%–70% of OHCA occur at home where in most cases the spouse of the patient is the only bystander at scene, and that EMS response time generally ranges from 5 to 10 mins (16 mins in China)^{16–18}. To help single rescuer recover from fatigue and improve CPR quality, “a 10-second rest after 100 chest compressions” protocol was developed in emergency medical trainees¹⁹. Based on that, the 2016 Singapore guideline recommended that “if tired after 100 compressions, take up to 10 seconds of rest”²⁰. Yet there is lack of specific resting methods for laypersons, and limited evidence to prove their associations with fatigue and CPR quality.

In order to identify appropriate resting methods during hands-only CPR for laypersons, we proposed four rest methods with different rest-start points and rest-compression ratios, and compared their CPR quality as well as fatigue during the CCC in a 10-min scenario.

Method

Study design

This prospective randomized crossover study was conducted in a “WeCan CPR” training center in Shanghai, China²¹. The study protocol was approved by the Joint Research Ethics Board of the Shanghai Jiao Tong University Schools of Public Health and Nursing (SJUPN-201914).

Study population

Participants were recruited from trainees aged 18–65 of the “WeCan CPR” training program from November 2018 to May 2019. The WeCan CPR course is a video-based, one-hour training program targeted for potential bystanders. At the end of the course, participants were asked to perform 1-min hands-only CPR on Resusci Anne manikin (Laerdal Medical, Stravanger, Norway) without any feedback. Those who reached $\geq 75\%$ of score was invited to join this study. They were told to perform five different types of hands-only CPR for 10 minutes each time with at least twelve hours' rest between two tests. Physicians, nurses, other healthcare professionals, and those with physical discomfort or disability were excluded. Subjects were voluntary to participate and could quit at any time. All of them have provided written informed consent.

Study protocol

Thirty participants were randomly assigned to five groups and allocated to start five methods (CCC and four resting methods) in different orders (See flow gram in Fig. 1). The crossover study design was used, considering large inter-individual differences in chest compression quality^{22,23}, and different orders set to avoid possible effect of test order on participant's performance. Between each test, participants rested for more than 12 hours. Before test process, participants were all trained to use the rating of perceived exertion (RPE) scale with range of 6–20 to express their subjectively perceived fatigue²⁴.

For each test, participants were asked to perform 10-min hands-only CPR on a ResusciAnne QCPR manikin (Laerdal Medical, Norway) without any kind of feedback on compression depth or rate. Two researchers conducted the tests: one monitored the time and informed participants to stop or start compression, while another asked and recorded participant's self-reported RPE scale every minute. Before and immediately after each test, participant's heart rate and blood pressure were measured using a smart wristband (Huawei band 4, HUAWEI, Shenzhen, China) and an upper arm type blood pressure monitor (Omron HEM-7133, OMRON, Kyoto, Japan), respectively.

Design of resting methods

We proposed four resting methods, namely 4+6 (4-min CCC + 6-min of 10-s pause after 60-s compressions), 2+8 or 10/60 (2-min CCC + 8-min of 10-s pause after 60-s compressions), 5/30 (2-min CCC + 8-min of 5-s pause after 30-s compressions), and 3/15 (2-min CCC + 8-min of 3-s pause after 15-s compressions).

To determine the appropriate time to start rest, we proposed 2+8 and 4+6 method. Firstly, we chose the 2nd minute as one option of start point because it was recommended by guidelines that rescuers change over about every 2 mins^{2,3}. In addition, we found in our unpublished research that in laypersons, the proportion of compressions with depth of ≥ 45.6 mm could maintain $>60\%$ at the first 2 mins. This depth criteria of 45.6 mm was originated from a study where Stiell et.al found that compression depths between 40 and 55 mm (peak at 45.6 mm) were associated with the highest survival²⁵. Secondly, we chose the 4th minute as another start point according to our previous findings that the proportion of compressions with depth of ≥ 40 mm could maintain $>60\%$ for more than 4 mins¹⁵. This depth criteria of 40 mm was derived from resuscitation guidelines in Asia: considering that the body size of rescuers is generally lighter, the recommended compression depth was “approximately 5 cm” by Resuscitation Council of Asia (RCA) and Korea^{26,27}, and more specifically, “depth of 4–6 cm” in Singapore²⁶.

To determine a more specific rest-compression ratio, we proposed three methods (10/60, 5/30, 3/15). Compared to 10-s break after 200 chest compressions and CCC, a 10-s pause after 100 chest compressions was shown to increase CPR quality¹⁹. In this study, we firstly modified “100 compressions” into “60 s” based on average compression rate of $100^{-1}/\text{min}$. We assumed that if put into practice, it's more convenient for dispatchers to count time than counting compressions. Then we proposed three methods with different ratio but the same amount of rest and compression time (10/60, 5/30, 2/15). Lastly, considering that a 2-s rest was not practical, we modified the 2/15 method into 3/15.

The “2-min CCC + 8-min of 10-s pause after 60-s compressions” was used both in the comparison of different rest-start points (as 2

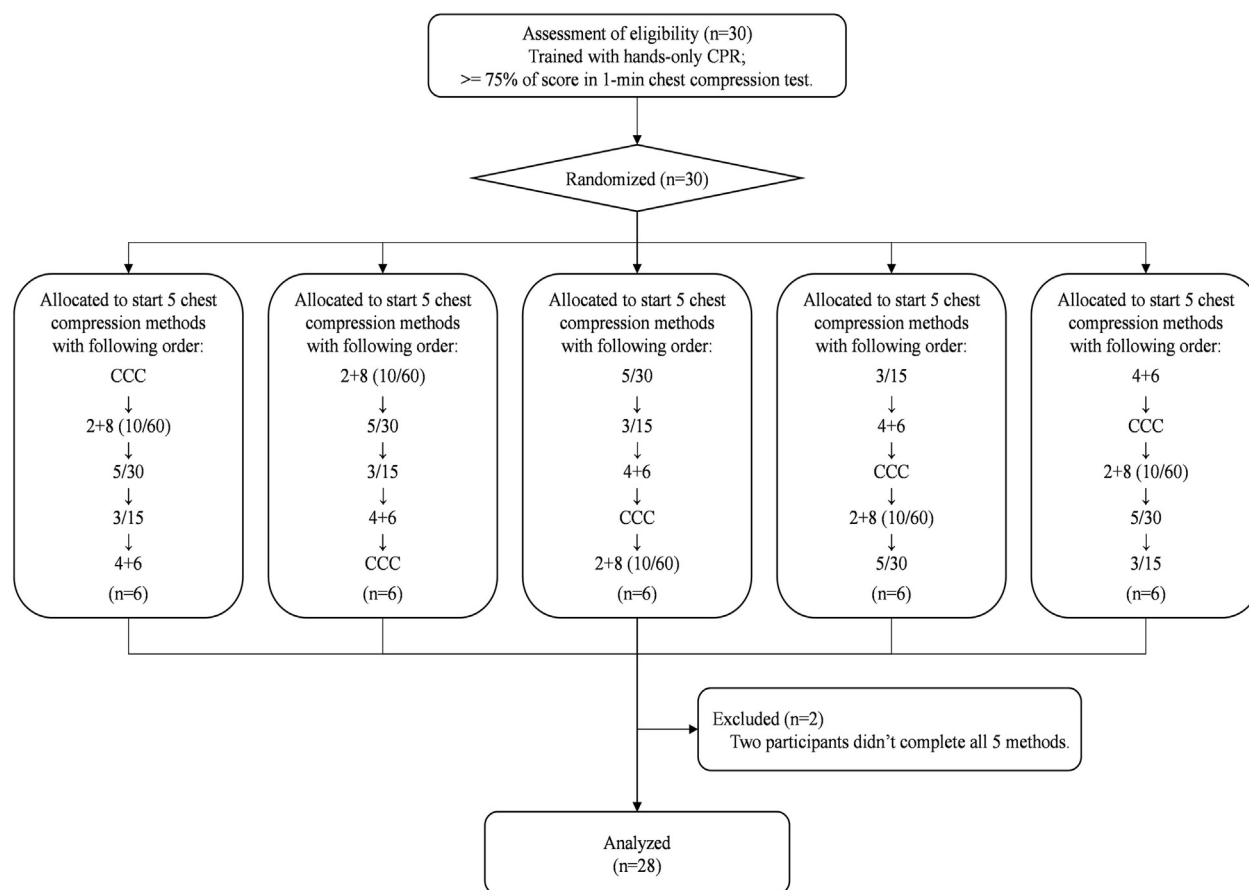


Fig. 1 – Flow diagram of the study. CCC, 10-min CCC; 4+6, 4-min CCC + 6-min of 10-s pause after 60-s compressions; 2+8 (10/60), 2-min CCC + 8-min of 10-s pause after 60-s compressions; 5/30, 2-min CCC + 8-min of 5-s pause after 30-s compressions; 3/15, 2-min CCC + 8-min of 3-s pause after 15-s compressions; CPR, cardiopulmonary resuscitation.

+8) and the comparison of different rest-compression ratios (as 10/60).

Data collection and outcome measures

Participants' gender and age was recorded. CPR quality indicators, including compression number, depth, rate, proportion of adequate rate, leaning depth, number and duration of hands-off ≥ 1.5 s, as well as chest compression fraction (CCF, percent of time that compressions are performed in 10 min) was recorded by SimPad PLUS (Laerdal Medical, Stravanger, Norway) and extracted using Skill Reporter Extractor software (Laerdal Medical, Stravanger, Norway). Based on the depth of each compression, we calculated the proportion of compressions with depth of ≥ 50 mm, of ≥ 45.6 mm, and of ≥ 40 mm for overall and every minutes.

Participants' fatigue was objectively evaluated by changes in heart rate, systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse pressure (PP, the pressure difference between SBP and DBP). Their subjective fatigue was determined by self-reported RPE scale for every minute during chest compressions.

The primary outcome was average chest compression depth. Secondary outcomes included other CPR quality indicators and participants' fatigue indicators.

Sample size estimation

Sample size was calculated based on pilot test from November 2018 to January 2019 where 10 participants completed all five methods. A 5% change of the proportion of compressions with depth of ≥ 50 mm was considered to be relevant. With a 90% power at the two-sided significance level of 5%, the minimum numbers of participants required were 18 (different rest-compression ratios) and 22 (different rest-start points), respectively. Considering the possibility for participants not completing all methods, we assumed a 20% increase in the sample size. The final sample size was decided to be 26 for each method. Those 10 participants in the pilot period were included in the final analysis as the protocol was the same.

Statistical analysis

Statistical analysis was performed using SPSS 22.0 (SPSS, Inc., Chicago, IL, USA). Data were presented as frequencies with percentages for categorical variables, and means \pm standard deviation or median (interquartile range, IQR) for continuous variables. Normal distribution was confirmed using Kolmogorov-Smirnov test. Differences between method were compared using paired sample *t* test or repeated measures ANOVA analysis for continuous variables with normal distribution, and Friedman test for variables with nonparamet-

ric distribution. Paired sample *t* test or Wilcoxon signed ranks test was performed to compare CPR quality between 2 consecutive minutes. All *P*-values were two-tailed, *P*<0.05 was regarded as significant.

Results

Demographic characteristics

Thirty participants were enrolled, and two of them were excluded because of incomplete test process (Fig. 1). Of 28 participants analyzed, 19 (67.9%) were female, mean age was 38.5 ± 14.7 (range 20-57) years, and average weight was 61.1 ± 14.7 (range 47.8 - 72.4) kg.

CPR quality and rescuer fatigue by different rest-start points

As shown in Table 1, in methods with different rest-start points but the same rest-compression ratio, there was no significant difference in all CPR quality indicators except for total number of compressions. The total CCFs of 4+6, 2+8 and CCC methods were 91.6%, 89.6% and 100%, respectively. The hands-off duration for each rest was of no difference between 4+6 method and 2+8 method (9.9 ± 0.5 s vs. 9.5 ± 0.7 s, *P*=0.045), but the former one showed less total hands-off time (50.5 ± 2.1 s vs. 62.2 ± 5.9 s, *P*<0.001) and higher

CCF ($91.6 \pm 0.4\%$ vs. $89.6 \pm 1.0\%$, *P*<0.001) because of fewer number of rests (5.0 ± 0.2 vs. 6.6 ± 0.7 , *P*<0.001). There was no significant difference among all method in any physiological indicators before or after 10-min test.

Changes of chest compression quality over 10 mins were shown in Fig. 2-1. The median chest compression depth and percentage of adequate depth declined significantly over time in CCC method. This trend of declining chest compression depth was slowed down after the 2nd minute in 2+8 method, while in 4+6 method, though not statistically significant, compression depth was improved after the 5th minute. The leaning depth was greater in CCC method than in 4+6 and 2+8 method from the 5th minute.

As presented in Fig. 3-2, the RPE scale in all methods increased significantly over time. Since the 7th minutes, participants' subjectively perceived fatigue was the severest in CCC method than 4+6 and 2+8 method.

CPR quality and rescuer fatigue by different rest-compression ratios

In methods with same rest-start point but different rest/compression ratios, no significant difference was observed in leaning depth, compression rate, or proportion of compressions with adequate rate. The 3/15 method showed the deepest compression depth 47.5 (39.5, 52.2) mm, and the highest proportion of compression with depth of ≥ 50 mm 19.7 (0.5, 65.4) % compared with 10/60, 5/30 and CCC

Table 1 – CPR quality and rescuer fatigue by different rest-start points

Variable	CCC method	4+6 method	2+8 method	<i>P</i> -value
Overall CPR quality				
Chest compression depth (mm) ^a	41.3 (36.4, 48.9)	41.6 (37.4, 48.2)	44.4 (36.1, 50.5)	0.20
Compressions with depth ≥ 50 mm (%) ^a	2.8 (0.2, 18.6)	4.3 (0, 21.0)	6.0 (0.1, 38.5)	0.06
Compressions with depth ≥ 45.6 mm (%) ^a	22.0 (5.7, 66.6)	29.6 (3.8, 68.9)	42.2 (2.2, 92.3)	0.15
Compressions with depth ≥ 40 mm (%) ^a	64.2 (27.2, 93.8)	64.3 (32.1, 95.1)	88.6 (28.1, 99.4)	0.31
Leaning depth (mm) ^a	3.0 (1.7, 3.8)	2.3 (1.6, 2.8)	2.0 (1.8, 2.8)	0.31
Number of chest compressions ^b	1103.1 \pm 50.9	1005.6 \pm 27.9	994.2 \pm 29.5	<0.001
Chest compression rate (min ⁻¹) ^b	111.0 \pm 5.3	110.1 \pm 3.3	111.1 \pm 3.1	0.42
Compressions with rate of 100-120 min ⁻¹ (%) ^b	90.4 \pm 15.6	93.7 \pm 9.3	94.8 \pm 6.1	0.25
Total CCF (%) ^c	100 \pm 0.1	91.6 \pm 0.4	89.6 \pm 1.0	<0.001
Hands-off duration for each rest (s) ^c	0.1 \pm 0.3	9.9 \pm 0.5	9.5 \pm 0.7	0.045
Number of rests ^c	0.1 \pm 0.3	5.0 \pm 0.2	6.6 \pm 0.7	<0.001
Total hands-off duration (s) ^c	0.2 \pm 0.7	50.5 \pm 2.1	62.2 \pm 5.9	<0.001
Participants' physiological measures of fatigue^a				
Heart rate at baseline (min ⁻¹)	78 (70, 82)	74 (70, 82)	75 (72, 79)	0.67
Heart rate at 10th min (min ⁻¹)	92 (87, 97)	92 (85, 98)	94 (87, 102)	0.59
Heart rate increment (min ⁻¹)	14 (11, 17)	16 (9, 24)	18 (11, 24)	0.82
SBP at baseline (mmHg)	110 (106, 121)	113 (107, 120)	112 (108, 121)	0.92
SBP at 10th min (mmHg)	121 (114, 132)	121 (115, 128)	126 (117, 131)	0.70
SBP increment (mmHg)	9 (2, 13)	9 (3, 13)	8 (2, 19)	0.55
DBP at baseline (mmHg)	77 (71, 84)	75 (70, 80)	76 (70, 83)	0.87
DBP at 10th min (mmHg)	79 (70, 84)	78 (73, 82)	78 (72, 85)	0.72
DBP increment (mmHg)	3 (-4, 5)	1.5 (-5, 9)	2 (-3, 6)	0.88
Pulse pressure at baseline (mmHg)	36 (31, 41)	38 (31, 43)	37 (29, 45)	0.74
Pulse pressure at 10th min (mmHg)	45 (39, 52)	40 (39, 49)	45 (38, 52)	0.41
Pulse pressure increment (mmHg)	9 (3, 15)	7 (1, 11)	8 (2, 15)	0.25

CCC, 10-min CCC; 4+6, 4-min CCC + 6-min of 10-s pause after 60-s compressions; 2+8 (10/60), 2-min CCC + 8-min of 10-s pause after 60-s compressions; 5/30, 2-min CCC + 8-min of 5-s pause after 30-s compressions; 3/15, 2-min CCC + 8-min of 3-s pause after 15-s compressions; CPR, cardiopulmonary resuscitation; CCF, chest compression fraction; SBP, systolic blood pressure; DBP, diastolic blood pressure.

^a Values are shown as median (interquartile range). Differences between "CCC", "4+6" and "2+8" method were compared with Friedman test.

^b Values are shown as mean \pm standard deviation. Differences between "CCC", "4+6" and "2+8" method were compared with repeated measures ANOVA analysis.

^c Values are shown as mean \pm standard deviation. Differences between "4+6" and "2+8" method were compared with paired sample *t* test.

method. The total CCFs of 10/60, 5/30, 3/15 methods were 89.6%, 88.7%, and 86.3%, respectively. The 3/15 method had the longest total hands-off time (82.5 ± 5.8 s) and lowest CCF (86.3 ± 1.0 %). There was no significant difference among all methods in any physiological indicators before or after 10-min test except for heart rate, where the increment of heart rate in 3/15 method was remarkably higher than that of other methods (Table 2).

Fig. 2-2 showed that, the trend of descending compression depth of CCC was slowed down after the 2nd minute in 10/60, 5/30 and 3/15 method. The quality of compression depth was the highest in 3/15 method, followed by the 10/60 and 5/30 method. All those three methods were superior to CCC in avoiding leaning from the 4th minute.

Regarding RPE (Fig. 3-2), from the 6th minute, the median RPE scale was always the highest in CCC than in 10/60, 5/30, 3/15 method.

Discussion

In this crossover study where laypersons performed 10-mins hands-only CPR with different rest methods, methods with rests after 2 minutes (no matter the rest/ compression ratio) could achieve significantly higher-quality CPR and lower subjectively perceived fatigue than CCC. This study showed that, the compression depth significantly decreased over time in CCC methods, and all resting methods

we proposed could result in better compression depth and lower subjectively perceived fatigue while maintaining high CCF.

It's essential for rescuers to minimize interruptions in CPR to maximize the amount of blood flow, and a higher CCF is predictive of survival following OHCA^{28,29}. Guidelines recommended that pauses should be minimized and CCF >60% was reasonable¹⁻³. In this study, with each rest of 3 to 10 s, the overall CCFs of all rest methods were above 86%. To maximize the time with CCC, 2 methods of different start points (4+6 and 2+8) was developed. Though the 2+8 method showed lower CCF because its spontaneously greater number of rests, it was not associated with lower overall quality or more fatigue compare with 4+6 and CCC method. In fact, the earlier to start rest, the better CPR quality of every minute could be achieved.

It was shown that a 10-s pause after 100 chest compressions could increase hands-only CPR quality¹⁹, and this protocol was suggested by the Singapore guideline²⁰. To determine a more specific rest/compression ratio, we proposed three methods, and found that 3/15 was superior to others in chest compression quality. It was reasonable that the highest CPR quality occurred in 3/15 method because it contained the longest overall hands-off time: participants performed the least number of compressions, had longer time to rest, which might help them recover from fatigue. Beyond our hypothesis, the 3/15 method didn't show the least level of fatigue, however, it showed the greatest heart rate increment, and a comparatively large scale of RPE. In fact, 3 seconds was barely enough for a

Table 2 – CPR quality and rescuer fatigue by different rest-compression ratios.

Variable	CCC method	10/60 method	5/30 method	3/15 method	P-value
Overall CPR quality					
Chest compression depth (mm) ^a	41.3 (36.4, 48.9)	44.4 (36.1, 50.5)	44.9 (34.1, 51.3)	47.5 (39.5, 52.2)	0.047
Compressions with depth \geq 50 mm (%) ^a	2.8 (0.2, 18.6)	6.0 (0.1, 38.5)	5.3 (0, 57.9)	19.7 (0.5, 65.4)	0.036
Compressions with depth \geq 45.6 mm (%) ^a	22.0 (5.7, 66.6)	42.2 (2.2, 92.3)	39.8 (10.1, 87.4)	67.2 (11.4, 94.3)	0.19
Compressions with depth \geq 40 mm (%) ^a	64.2 (27.2, 93.8)	88.6 (28.1, 99.4)	82.4 (19.1, 99.0)	90.4 (43.2, 98.8)	0.51
Leaning depth (mm) ^a	3.0 (1.7, 3.8)	2.0 (1.8, 2.8)	1.8 (1.4, 2.6)	2.2 (1.5, 2.9)	0.23
Number of chest compressions ^b	1103.1 \pm 50.9	994.2 \pm 29.5	977.6 \pm 52.2	962.4 \pm 26.6	<0.001
Chest compression rate (min ⁻¹) ^b	111.0 \pm 5.3	111.1 \pm 3.1	110.6 \pm 4.7	111.3 \pm 2.8	0.73
Compressions with rate of 100-120 min ⁻¹ (%) ^b	90.4 \pm 15.6	94.8 \pm 6.1	90.3 \pm 14.0	92.3 \pm 4.5	0.42
Total CCF (%) ^b	100 \pm 0.1	89.6 \pm 1.0	88.7 \pm 0.8	86.3 \pm 1.0	<0.001
Hands-off duration for each rest (s) ^b	0.1 \pm 0.3	9.5 \pm 0.7	5.2 \pm 0.3	3.1 \pm 0.3	<0.001
Number of rests ^b	0.1 \pm 0.3	6.6 \pm 0.7	13.2 \pm 0.7	26.0 \pm 0.8	<0.001
Total hands-off duration (s) ^b	0.2 \pm 0.7	62.2 \pm 5.9	68.1 \pm 4.5	82.5 \pm 5.8	<0.001
Participants' physiological measures of fatigue ^a					
Heart rate at baseline (min ⁻¹)	78 (70, 82)	75 (72, 79)	75 (70, 80)	75 (69, 82)	0.67
Heart rate at 10th min (min ⁻¹)	92 (87, 97)	94 (87, 102)	93 (85, 107)	99 (92, 110)	0.59
Heart rate increment (min ⁻¹)	14 (11, 17)	18 (11, 24)	13 (10, 26)	20 (14, 33)	0.82
SBP at baseline (mmHg)	110 (106, 121)	112 (108, 121)	115 (106, 126)	112 (107, 120)	0.92
SBP at 10th min (mmHg)	121 (114, 132)	126 (117, 131)	125 (119, 135)	120 (113, 130)	0.70
SBP increment (mmHg)	9 (2, 13)	8 (2, 19)	12 (6, 15)	8 (1, 15)	0.55
DBP at baseline (mmHg)	77 (71, 84)	76 (70, 83)	75 (67, 80)	75 (70, 78)	0.87
DBP at 10th min (mmHg)	79 (70, 84)	78 (72, 85)	78 (72, 84)	79 (73, 82)	0.72
DBP increment (mmHg)	3 (-4, 5)	2 (-3, 6)	2 (-1, 8)	3 (-1, 6)	0.88
Pulse pressure at baseline (mmHg)	36 (31, 41)	37 (29, 45)	39 (33, 50)	40 (33, 45)	0.74
Pulse pressure at 10th min (mmHg)	45 (39, 52)	45 (38, 52)	48 (43, 55)	45 (37, 51)	0.41
Pulse pressure increment (mmHg)	9 (3, 15)	8 (2, 15)	10 (1, 13)	5 (-2, 12)	0.25

CCC, 10-min CCC; 4+6, 4-min CCC + 6-min of 10-s pause after 60-s compressions; 2+8 (10/60), 2-min CCC + 8-min of 10-s pause after 60-s compressions; 5/30, 2-min CCC + 8-min of 5-s pause after 30-s compressions; 3/15, 2-min CCC + 8-min of 3-s pause after 15-s compressions; CPR, cardiopulmonary resuscitation; CCF, chest compression fraction; SBP, systolic blood pressure; DBP, diastolic blood pressure.

^a Values are shown as median (interquartile range). Differences between "CCC", "10/60", "5/30" and "3/15" method were compared with Friedman test.

^b Values are shown as mean \pm standard deviation. Differences between "CCC", "10/60", "5/30" and "3/15" method were compared with repeated measures ANOVA analysis.

2-1. Comprasion by different rest-start points

2-2. Comprasion by different rest-compression ratios

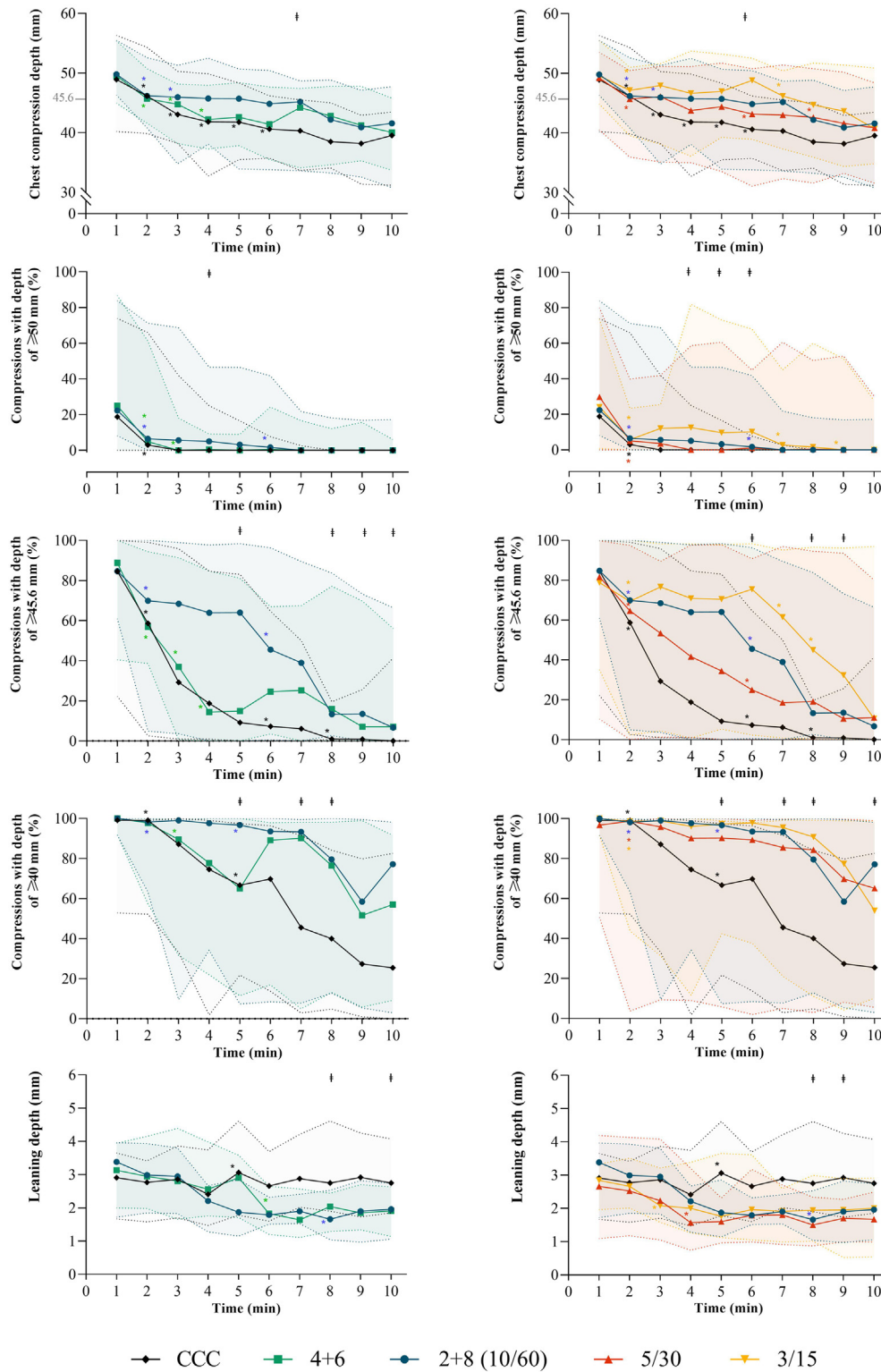
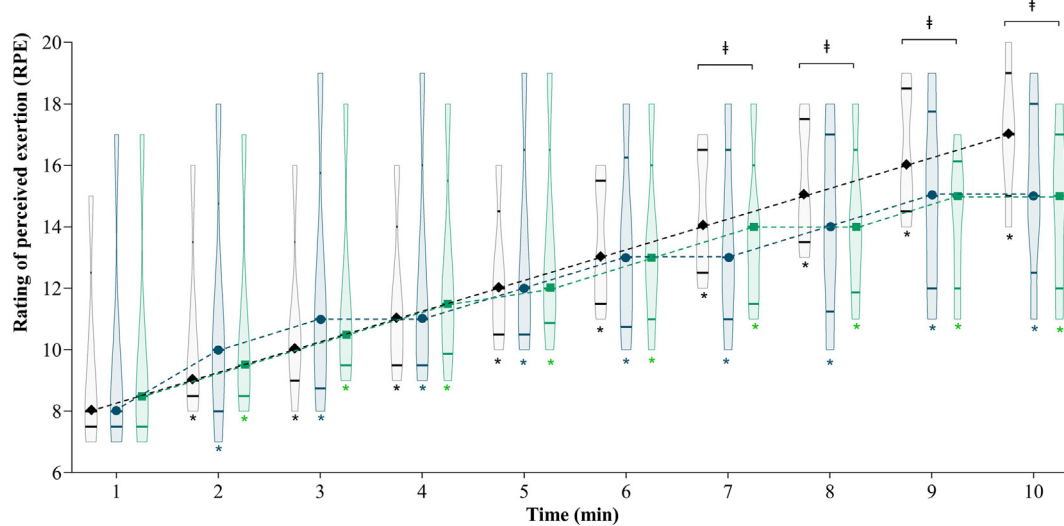


Fig. 2 – Comparison of chest compression depth, percentage of adequate compression depth, and leaning depth over 10 minutes in different methods. (n = 28) Values are shown as median and interquartile range. CCC, 10-min CCC; 4+6, 4-min CCC + 6-min of 10-s pause after 60-s compressions; 2+8 (10/60), 2-min CCC + 8-min of 10-s pause after 60-s compressions; 5/30, 2-min CCC + 8-min of 5-s pause after 30-s compressions; 3/15, 2-min CCC + 8-min of 3-s pause after 15-s compressions. Significant difference between different method (P<0.05, Friedman test); * Significant difference between the marked minute with its previous minute (P<0.05, Wilcoxon signed ranks test).

3-1. Comparison by different rest-start points



3-2. Comparison by different rest-compression ratios

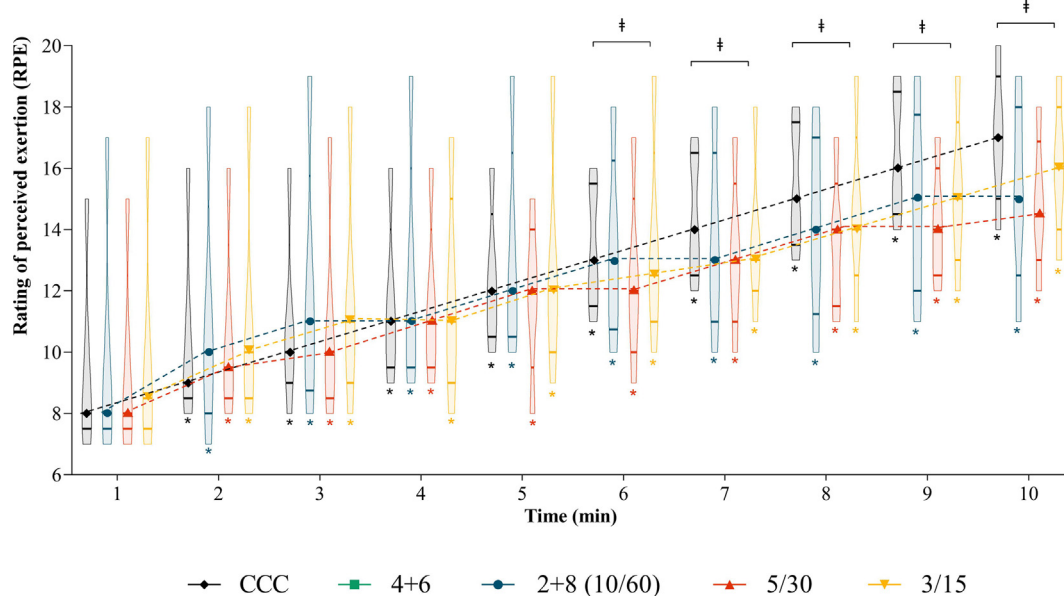


Fig. 3 – Comparison of rating of perceived exertion (RPE) over 10 minutes in different methods. (n = 28) Violin plot showing the medians, interquartile range, and min-max values. CCC, 10-min CCC; 4+6, 4-min CCC + 6-min of 10-s pause after 60-s compressions; 2+8 (10/60), 2-min CCC + 8-min of 10-s pause after 60-s compressions; 5/30, 2-min CCC + 8-min of 5-s pause after 30-s compressions; 3/15, 2-min CCC + 8-min of 3-s pause after 15-s compressions. Significant difference between different method (P<0.05, Friedman test); * Significant difference between the marked minute with its previous minute (P<0.05, Wilcoxon signed ranks test).

rest. When given 10 seconds, participants could sit down and relax their shoulders; a 5-s rest allowed them to swing their arms back and force; but in 3 second, it was even hard for them to leave their hands from the manikin. In this sense, rescuer fatigue may not be the determinant of CPR quality. With appropriate intentional methods, it's possible to achieve high-quality CPR even with a considerable level of fatigue, and methods involving short time sprinting of chest compressions with short rests (e. g. 3 s rest after 15 chest compressions) may be more effective than long time chest compressions with long rests.

Varies approaches to reducing rescuer fatigue and improving CPR quality have been investigated. Rotation of rescuers was considered reasonable³⁰ and was recommended by current guidelines to change over about every 2 minutes^{2,3}. While Bjørshol et al. suggested that instead of changing rescuers frequently, more attention should be paid on inter-individual differences in CPR quality²³. Wang et al. demonstrated that placing the dominant hand against the sternum could improve chest compression quality significantly³¹. Trenkamp et al. reported that heel compressions helped bystanders to provide effective CCC for 10 mins³². Novel CPR feedback devices

and smartphone Apps have also been reported to reduce rescuer fatigue during long-time CCC^{33–35}. But all those mentioned were not appropriate for single lay rescuer at home. Although dispatchers' continuous instructions of "push harder" and encouragement during T-CPR may help^{36,37}, it's hard to prevent the CPR quality from declining over time. Thus, providing proper rest after specific period of CCC is an alternative way to maintain considerable high-quality CPR in prolonged resuscitation. From a practical point of view, it's feasible to train laypersons with CCC with rests, or to instruct rescuers to perform so during T-CPR. Additional research is needed to test its effect in real-life resuscitation with wider population.

Despite great improvement after using these rest methods, the chest compression depth was still dismal considering that the proportion of compression depth of ≥ 5 cm was less than 20%, and in most cases, nearly 0% from the 2nd minute. This could add to a study from Japan that compression depth of ≥ 5 cm was hard to achieve in a substantial proportion of Asian rescuers because of their light body weight²². Moreover, participants were able to compress ≥ 4 cm for quite a long time, which supported that recommended compression depth of 4–6 cm, rather than 5–6 cm was more appropriate in Asian^{20,26}.

Several limitations should be noted. Firstly, the compression quality on manikin may not reflect to that in real life, or correlate with what is clinically effective. Rescuer attitude during a simulated situation may be different from that during an actual cardiac arrest. Secondly, the carry-over effect and learning effect could not be excluded over repeated measures. Nevertheless, we selected qualified trained laypersons, and randomized participants to perform five methods in different orders to avoid learning effect and inter-individual differences. Third, female participants accounted for 67.9%, and age range was 20–57 years, which might not represent all bystanders in real life. Finally, as the average EMS response time are generally more than 10 mins¹⁷, it is impossible to predict the results after 10 mins based on current findings.

Conclusions

In this study, 10-min chest compressions incorporated with transitional rests were associated with higher-quality hands-only CPR and lower subjectively perceived fatigue among laypersons. Earlier rest-start point was associated with better quality of every minute. Methods involving short time sprinting of compressions with short rests (e. g. 3-s rest after 15-s compressions) might be more appropriate than long time compressions with long rests. Further studies are needed to confirm their effectiveness in real-life resuscitation with varied situations in wider population.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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