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CPR Feedback/Prompt Device Improves the Quality of Hands-only CPR Performed in Manikin by Laypersons Following the 2015 AHA Guidelines

Yuanshan Liu[a,d,1], Zitong Huang[a,d,1], Heng Li[d,e], Guanghui Zheng[a,e], Qin Ling[a,b], Wanchun Tang[a,b,c], Zhengfei Yang[a,b,d]

[a] *Sun Yat-sen Memorial Hospital, Sun Yat-sen University, Guangzhou, China*

[b]*Weil Institute of Emergency and Critical Care Medicine, School of Medicine, Virginia Commonwealth University, Richmond, VA, USA.*

[c]*Department of Emergency Medicine, Virginia Commonwealth University, Richmond, VA, USA.*

[d]*Institute of Cardiopulmonary Cerebral Resuscitation, Sun Yat-sen University, Guangzhou, China.*

[e]*Department of Emergency Medicine, Taiping People's Hospital, Medical School of Jinan University, Guangzhou, China.*

The work was performed at Tang Wanchun Laboratories of Emergency & Critical Care Medicine, Guangzhou, China.

Zitong Huang and Yuanshan Liu contributed equally to this work.

Address for correspondence:

Zhengfei Yang, M.D., Ph.D.

Sun Yat-sen Memorial Hospital, Sun Yat-sen University,

107 Yan Jiang Xi Road, Guangzhou 510120, China.

Tel: +86-20-81332084

Fax: +86-20-81332410

Email: yangzhengfei@vip.163.com

and

Wanchun Tang, MD

Sun Yat-sen Memorial Hospital, Sun Yat-sen University,

107 Yan Jiang Xi Road, Guangzhou 510120, China.

Tel: +86-20-81332084

Fax: +86-20-81332410

Email: wanchun.tang@vcuheath.org

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ABSTRACT

Purpose: We investigated the effects of a cardiopulmonary resuscitation (CPR) feedback/prompt device on the quality of chest compression (CC) during hands-only CPR following the 2015 AHA guidelines.

Methods: A total of 124 laypersons were randomly assigned into three groups. The first (n=42) followed the 2010 guidelines, the second (n=42) followed the 2015 guidelines with no feedback/prompt device, the third (n=40) followed the 2015 guidelines with a feedback/prompt device (2015F). Participants underwent manual CPR training and took a written basic life support examination, then required to perform two minutes of hands-only CPR monitored by a CPR feedback/prompt device. The quality of CPR was quantified as the percentage of correct CCs (mean CC depth and rate, complete recoil and chest compression fraction (CCF)) per 20 seconds, as recorded by the CPR feedback/prompt device.

Results: Significantly higher correct ratios of CC, CC depth, and rate were achieved in the 2010 group in each minute vs. the 2015 group. The greater mean CC depth and rate were observed in the 2015F group vs. the 2015 group. The correct ratio of CC was significantly higher in the 2015F group vs. the 2015 group. CCF was also significantly higher in the 2015F group vs. the 2015 group in the last 20 seconds of CPR.

Conclusions: It is difficult for a large percentage of laypersons to achieve the targets of CC depth and rate following the 2015 AHA guidelines. CPR feedback/prompt devices significantly improve the quality of hands-only CPR performance by laypersons following the standards of the 2015 AHA guidelines.

Key Words: CPR Feedback/Prompt Device; CPR Quality; Hands-only CPR; Manikin

1. Introduction:

High-quality CPR improves the outcome and survival of out-hospital cardiac arrest (OHCA) because of its contribution to blood flow, oxygen and energy delivery, defibrillation success and return of spontaneous circulation (ROSC) [1,2]. Recently, the new AHA 2015 guidelines emphasized the importance of high-quality CPR and upgraded the requirements of both CC depth (from at least 50mm to 50-60mm) and compression rate (from at least 100/min to 100-120/min)[3], since complications were found in recommended compression depth and rate in the 2010 AHA guidelines (AHA 2010). Some studies showed that it was difficult for laypersons or rescuers to achieve both CC rate and depth specified in AHA 2010 in the CPR manikin training, particularly lightweight rescuers [4,5]. The rescuers had difficulty in meeting the guidelines due to increased fatigue [6]. Moreover, a recent study found that maximum survival was observed in the CC depth of 40.3 to 55.3 mm, suggesting the AHA 2010 target might be too high [7].

In one nursing education and training programs, Tripp and Tollefson altered the conventional options into the complex options and found that more complex items were more difficult for learners to achieve [8]. The AHA 2015 guidelines have added even more requirements compared to AHA 2010, and these may further increase the difficulty for layperson rescuers to learn and provide high-quality CPR and may also be another reason for decreasing the quality of CC during CPR. A number of studies proved that the use of CPR feedback/prompt devices during real-time CPR or training could improve the performance of CPR, including the CC depth and rate [9,10].

In this study, we sought to investigate the quality of CC during hands-only CPR when CPR was performed according to the AHA 2010 or AHA 2015 guidelines. Rescuers were randomly assigned to perform CPR on the manikin model according to the AHA 2010 or AHA 2015 guidelines. LinkCPR is the CPR feedback/prompt device used for monitoring the quality of CPR in the procedure. We hypothesize that the new requirements of CC depth and rate from the AHA 2015 guidelines will decrease the CPR quality, and this could be improved by using a CPR feedback/prompt device.

2. Methods

2.1. Study design and participants

This study was a prospective, randomized and controlled study. Hands-only CPR was performed based on AHA 2010 or AHA 2015 guidelines. Our aim was to assess the CPR quality and improvement under the 2015 AHA CPR guidelines by using the CPR feedback/prompt device. The study was implemented in Tang Wanchun laboratories of emergency & critical care medicine, Guangzhou, China and approved by the Institutional Review Board of Sun Yat-sen Memorial Hospital.

Total of 140 laypersons who had no experience with basic life support training or real CPR were invited to participate in this study. The participants were assigned randomly to perform CPR on manikins based on AHA 2010 or AHA 2015 guidelines. After they received manual CPR training by AHA instructors using AHA 2010 or AHA 2015 guidelines, and took a theoretical basic life support examination, the participants were required to perform two minutes of hands-only CPR. They did not know the goal of the study or which guideline was taught during the trial.

2.2. Study protocol

After the training course and theoretical examination, the qualified participants continued to the formal trial. The participants were assigned randomly into three groups to perform two minutes of hands-only CPR on manikins: the 2010 group (participants were required to perform hands-only CPR based on AHA 2010 guidelines without a CPR feedback/prompt device), the 2015 group (participants were required to perform hands-only CPR based on AHA 2015 guidelines without a CPR feedback/prompt device) and the 2015F group (participants were required to perform hands-only CPR based on AHA 2015 guidelines with a CPR feedback/prompt device). The CPR quality measurements included CC depth, rate, complete chest recoil and CCF, which were monitored and recorded by the CPR feedback/prompt device. The participants in the 2015F group were required to perform hands-only CPR based on AHA 2015 guidelines, and their performances were corrected by instructors when they missed their targets as notified by the CPR feedback/prompt device. The participants in the 2010 and 2015 groups did not have help from a CPR feedback/prompt device. All the participants were barred from communicating with each other during the entire trial. A flowchart of the study is shown in Figure 1.

2.3. CPR feedback device

LinkCPR (SunLife, China) is a newly designed feedback/prompt device that can provide the real-time CC depth, rate, chest recoil and CCF feedback and data review in both real CPR and CPR training. LinkCPR collects acceleration data from acceleration censor and calculates the depth and rate of compression on its own algorithm. The accuracy of depth measurement is ±2mm, and rate measure is ±1 times/min. On the other hand, it uses dual acceleration compensation technology which can accurately measure the CC depth whether patients are laying on a soft or hard surface.

2.4. Measurements

The following parameters of CC quality were assessed: (1) Demographic information of every participant, including age, gender, height, weight, heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP) and calculated body mass index (BMI); (2) Mean CC rate and depth which were recorded and calculated by a CPR feedback/prompt device every 20 seconds during two minutes of CPR attempts; (3) The numbers of chest compressions and complete recoils; (4) The correct numbers for depth, rate and complete recoils; and (5) CCF as calculated by the CPR feedback/prompt device during two minutes of CPR attempts. In the 2010 group, the appropriate CC depth was defined as at least 50mm, and CC rate was defined as at least 100/min; in the 2015 and 2015F groups, the appropriate CC depth was defined as 50-60 mm, and CC rate was defined as 100-120/min.

2.5. Statistical Analysis

All the statistical analyses were performed using SPSS 20.0 for Windows software (IBM SPSS, Armonk, NY). Quantitative data were presented as mean ± standard deviation (SD) variation. Continuous variables were compared with parametric Student's t test or the Mann-Whitney U test for nonparametric data. Normal distribution was confirmed with the Kolmogorov-Smirnov test. Comparisons between time-based measurements within each group were performed with repeated measures analysis. The chi-square test was used for the comparison of categorical variables such as the proportion of gender. A value of $p<0.05$ was considered significant.

3. Results

After the training course and theoretical examination, 10 participants were excluded because they failed to pass the examination and 6 participants temporarily exited the formal study for personal reasons. Consequently, 124 participants were eventually arranged into the formal trial. The 2010 and 2015 groups each included 42 participants, while the 2015F group included 40 participants.

3.1. Baseline characteristics

The baseline characteristics of the three groups were similar (Table 1), including gender, age, height, weight and body mass index, and there were no significant differences between physical signs such as heart rate and blood pressure.

3.2. CC quality comparison between AHA 2010 and AHA 2015

It is well known that appropriate CC depth and rate are two of the most significant components in high-quality CPR in the both AHA 2010 and AHA 2015 guidelines [3,11]. In the study, we found during two minutes of hands-only CPR, much deeper mean compression depth was observed in the 2015 group, especially in the second minute (Mean CC depth in 1min vs 2010 group 51mm to 49mm, p=0.297; in 2min vs 2010 group 49mm to 44mm, p=0.001). On the contrary, mean compression rate in the 2010 group was significantly greater (Mean CC rate in 1min vs 2015 group 118/min to 112/min, p=0.015; in 2min vs 2015 group 112/min to 109/min, p=0.02). In addition, we compared the correct ratio of CC, CC depth and rate between the 2010 group and 2015 groups. Significantly higher correct ratios were achieved in the 2010 group in each minute (Correct ratio for CC in 1min vs 2015 group 54.9% to 29.6%, $p<0.001$; in 2min vs 2015 group 53.6% to 25.6%, $p<0.001$). There were no significant differences between the time in each group (All the data in 1 min vs 2 min, $p>0.05$). A description of detailed data is presented in Table 2.

3.3. Chest compression with the CPR feedback/prompt device help

According to AHA 2015 guidelines, high-quality CC (included appropriate depth, rate and complete chest recoil) and CCF are the major factors of the high-quality CPR [3]. Overall, the mean CC depth of the 2015F group was significantly deeper (Mean CC depth in 20s vs 2015 group 55mm to 52mm, p=0.008; in 40s vs 2015 group 56mm to 51mm, p=0.001; in 60s vs 2015 group 56mm to 51mm, p=0.002; in 80s vs 2015 group 56mm to 50mm, $p<0.001$; in 100s vs 2015 group 56mm to 49mm, $p<0.001$; in 120s vs 2015 group 55mm to 48mm, $p<0.001$) and stably maintained between 50-60 mm, while the mean CC depth of the 2015 group was in a downward trend throughout the entire CPR performance (p=0.005), and less than the requirements of AHA 2015 guidelines after 80 seconds during the two minutes of CPR (Fig.2A). Moreover, the mean CC rate of the 2015F group was significantly lower (Mean CC rate in 20s vs 2015 group 105/min to 113/min, p=0.002; in 40s vs 2015 group 104/min to 111/min, p=0.004; in 60s vs 2015 group 104/min to 110/min, p=0.008; in 80s vs 2015 group 104/min to 108/min, p=0.009; in 100s vs 2015 group 103/min to 109/min, p=0.009; in 120s vs 2015 group 104/min to 109/min, p=0.009), however, the mean CC rate for every 20 seconds of the 2015F group was more constant and accurate, maintaining 100-110/min. By contrast, although the mean CC rate for every 20 seconds of the 2015 group was also between 100-120/min, it significantly declined during the entire two minutes of CPR ($p<0.001$) (Fig.2B).

When considering the CC depth, both rate and complete recoil were major factors to perform high-quality CPR[12], in this trial, with the help of a CPR feedback/prompt device, the correct ratio of chest compression in the 2015F group was maintained close to 90% and significantly higher (Correct ratio of CC in 20s vs 2015 group 87.7% to 31.1%, p<0.001; in 40s vs 2015 group 87.6% to 33.7%, p<0.001; in 60s vs 2015 group 88.1% to 32.8%, p<0.001; in 80s vs 2015 group 85.9% to 33.9%, p<0.001; in 100s vs 2015 group 87.4% to 29.7%, p<0.001; in 120s vs 2015 group 88.2% to 27.5%, p<0.001) (Fig.2C).

Through analysis of the CCF which was recorded by the CPR feedback/prompt device during the entire CPR performance in this study, there were no significant differences in the CCF of the two groups. However, with the compression time prolonged, the CCF of the 2015F group was significantly higher (CCF in 20s vs 2015 group 99.8% to 99.4%, p=0.195; in 40s vs 2015 group 99.4% to 98.4%, p=0.136; in 60s vs 2015 group 98.1% to 97.9%, p=0.844; in 80s vs 2015 group 97.2% to 97.1%, p=0.92; in 100s vs 2015 group 97.3% to 96.1%, p=0.329, in 120s vs 2015 group 98.3% to 95.9%, p=0.026) in the last 20 seconds (Fig.2D).

4. Discussion

Our present study demonstrated that the AHA 2010 guidelines lead the participants to push faster, and the detailed data showed that the compression rate of the 2010 group was faster than that of the 2015 group, whereas the compression depth of the 2010 group decayed over time. It was more difficult for the 2010 group to achieve the targets of the AHA 2015 guidelines. Furthermore, in the comparison of the 2015 group and 2015F groups, several findings were acquired: (1) The mean CC depth and rate were maintained in target of AHA 2015 guidelines during the two minutes of hands-only CPR performance with the use of CPR feedback/prompt device; (2) The correct ratio of chest compression was improved by using the CPR feedback/prompt device; (3) The CCF declined in the final approximately 20 seconds during the two minutes of hands-only CPR performance without help of a CPR feedback/prompt device.

When the AHA 2010 guidelines updated the requirements, the CC depth and rate were increased without upper limit. "Push as fast and hard as you can" was suddenly recommended as the new standard of CPR performance. Initially, several studies demonstrated that outcomes and survivals of OHCA were associated with the CC depth and rate. Animal studies performed by Feneley et al indicated that the hemodynamic and survival benefited of the significantly higher mean aortic and coronary perfusion pressures attained with high-rate compression [13]. Several animal and clinical studies emphasized that high-impulse CPR was vital and necessary for rescuers to perform effective rate (100-120/min) and depth (≥ 50 mm) CPR with complete sternal recoil. High-impulse CPR with its high-velocity short duration compression phase and longer duration decompression phase (or duty cycle adequately < 50%) not only produces superior hemodynamics but also apparently produces substantial compression-induced ventilation. A longer decompression phase maximizes sternal recoil, thereby increasing venous return, coronary and cerebral perfusion, and inspiratory volume[14-20]. In the clinic, Kramerjohansen et al showed that increased compression depth was associated with increased short-term survival[21]. Recently, another two human studies and meta-analyses also demonstrated that the emphasis of high-quality CPR improved the survival outcomes of cardiac arrest patients [22,23]. On the contrary, an increase in incomplete recoil was observed due to the increasing compression rate [24]. Two recent studies revealed the excessive compression rate lead to a shallower CC depth [25,26]. In addition, a number of studies had demonstrated that the rescuers' fatigue reduced the correct ratio of high quality CPR performance, especially female or lightweight rescuers [4,5,27-29]. Several studies also revealed it was difficult for rescuers to achieve the standard of high quality CPR performance. Yang et al demonstrated that rescuers had difficulty meeting the requirements of the AHA 2010 guidelines due to the potential factors of increased physical exertion and rescuer fatigue [6]. Another clinical study of Sutton et al proved that achieving 2010 targets for rate and depth was difficult due to the increasing requirements of CC depth, rate and CCF in the 2010 guidelines[30]. In 2015, due to a series of problems documented including physical exertion, rescuer fatigue, and the difficulties reaching the 2010 targets, the AHA 2015 guidelines established the new upper limit determining a CC rate of 120/min and depth of 60mm. To our knowledge, this is the first study to investigate the correct ratio of high quality CPR following the publication of the AHA 2015 guidelines. In the present study, the data showed a relatively large percentage of participants easily performed over the limits of AHA 2015 and had difficulty achieving the target CC depth and rate of the AHA 2015 guidelines. This difficulty was the main reason for the decrease in the correct ratio of CC.

In order to solve the insufficient-quality CPR performances in 2015 group, the participants in 2015F group were required to perform CPR with the help of a CPR feedback/prompt device. When their CC depth, rate and chest recoil were not in target, they were reminded and corrected by the device. Moreover, due to fatigue and physical exertion, the CC depth, rate, chest recoil and CCF decayed with prolonged time performing CPR. When the CPR feedback/prompt device reminded and corrected them, the participants easily maintained their quality of CPR in the target range. Mounting evidence is consistent with the findings we presented. In a manikin study, Pederty et al demonstrated that with the use of audiovisual feedback, the CC depth, rate, gender, age and adherence were improved [31]. The ICPR feedback device was studied by Semeraro et al, and was observed to significantly improve the performance of chest compressions [32]. In addition, Lyngeraa et al also investigated two minutes of continuous CPR with the help of a feedback device, and the results were consistent with our study that the quality of CPR was maintained during two minutes of CPR with the use of a feedback device [33]. Another three recent studies acquired similar conclusions that feedback devices significantly help improve CPR performance, including aiding rescuers with low body weight [23,34,35]. Chest compression fraction was emphasized in AHA 2015 guidelines as one of the main components in high quality CPR [3]. Christenson et al proved that CCF was related to the survival of out-of-hospital cardiac arrest victims, particularly the ventricular fibrillation [36]. Hellevuo et al reported the CCF was improved during the entire CPR performance by using feedback devices [37]. Our study came to a similar conclusion, however, we observed that CCF was improved by a CPR feedback/prompt device solely in the last 20 seconds. Participants' fatigue in the 2015 group without an alert by the CPR feedback/prompt device may be the reason. Since significant improvements of CPR performance were observed in the present study, a CPR feedback/prompt device is clearly beneficial for in-hospital and out-of-hospital use to improve the CPR performance of the rescuers.

5. Limitations

The primary limitation of present study was that the volunteers who participated in this trial were fairly young; the average age was 21 years old. Middle and older aged people were not included. Secondly, we did not investigate the differences between male and female, and it may be likely that the female participants would more easily fatigue during the two minutes of CPR performance. Third, several factors such as ventilation and wrong hand placement were not assessed. These three limitations might influence the quality of CPR. Finally, this study excluded professional medical rescuers, and there may be different results in real-time CPR.

6. Conclusions

It is difficult for a large percentage of laypersons to achieve the targets of CC depth and rate following the 2015 AHA guidelines. A CPR feedback/prompt device significantly improves the quality of hands-only CPR performance by laypersons following the standards of the 2015 AHA guidelines.

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Figure Legends

Figure 1. Flow diagram of the study

Figure 2. Quality comparison of CPR between both groups with or without feedback device when following 2015 AHA guidelines. (A) Comparison of mean chest compression depth per 20 seconds between both groups with or without feedback device when following 2015 AHA guidelines. Significant downward trend was observed following the prolonged time ($p=0.005$) (B) Comparison of mean chest compression rate per 20 seconds between both groups with or without feedback device when following 2015 AHA guideline. Significant downward trend was observed following the prolonged time ($p<0.001$) (C) Comparison of correct ratio of chest compression per 20 seconds between both groups with or without feedback device when following 2015 AHA guidelines. No significant trend was observed following the prolonged time ($p=0.627$) (D) Comparison of ratio of chest compression fraction per 20 seconds between both groups with or without feedback device when following 2015 AHA guidelines. Significant downward trend was observed following the prolonged time ($p<0.001$) $^{*}p<0.01$ vs. 2015 group, $^{\#}$ $p<0.05$ vs. 2015 group.

Table 1

Baseline characteristics

	2010 group (n=42)	2015 group (n=42)	2015F group (n=40)	p-Value
Gender (female), n (%)	21（50）	23(54.8)	23 (57.5)	0.788
Age, year	21±1	21±1	21±1	0.948
Height, cm	166.6±7.4	166.0±7.3	166.1±7.5	0.922
Weight, kg	57.7±10	57.8±9	57.7±8.9	0.999
BMI[a], kg/m^2	20.7±2.9	20.9±2.5	20.8±2.4	0.944
HR[b], beats/min	70.8±6.3	71.1±6.7	70.9±6.7	0.971
SBP[c], mmHg	112.6±10.0	113.5±9.9	113.5±9.6	0.892
DBP[d], mmHg	70.8±5.2	69.6±4.0	69.7±3.8	0.371

BMI, Body mass index: weight (kg)/height (m)2, HR, Heart rate, SBP, Systolic blood pressure, DBP, Diastolic blood pressure. 2010 Group, hands-only CPR without feedback device when following 2010 AHA guidelines; 2015 Group, hands-only CPR without feedback device when following 2015 AHA guidelines; 2015F Group, hands-only CPR with feedback device when following 2015 AHA guidelines.

Values are presented as mean±SD.

Table 2

Mean chest compression depth and mean chest compression rate. Correct ratio for CC, CC depth and rate.

	2010 group	2015 group	2015F group
Mean chest compression depth			
1 min (mm)	49±7	51±8	56±3**
2 min (mm)	44±8	49±8##	56±3**
Mean chest compression rate			
1 min (/min)	118±13	112±15#	104±5**
2 min (/min)	115±14	109±13#	104±4*
Correct ratio for CC depth			
1 min (%)	63.1±33.1	37.6±25.8##	89.1±8.8**
2 min (%)	64.2±32.2	35.8±27.5##	88.4±8.4**
Correct ratio for CC rate			
1 min (%)	83.5±17.7	61.9±30.1##	86.5±9.7**
2 min (%)	76.4±24.3	58.9±32.6##	85.9±9.0**
Correct ratio for CC			
1 min (%)	54.9±31.0	29.6±18.6##	87.8±9.2**
2 min (%)	53.6±31.9	25.6±17.5##	87.1±8.7**

CC, chest compressions. 2010 Group, hands-only CPR without feedback device when following 2010 AHA guidelines; 2015 Group, hands-only CPR without feedback device when following 2015 AHA guidelines; 2015F Group, hands-only CPR with feedback device when following 2015 AHA guidelines. There were no significant differences between the time in each group (All the data in 1min vs 2min, p>0.05). Values are presented as mean±SD.

*p<0.05 vs 2015 group, **p<0.01 vs 2015 group, [#]p<0.05 vs 2010 group, [##]p<0.01 vs 2010 group

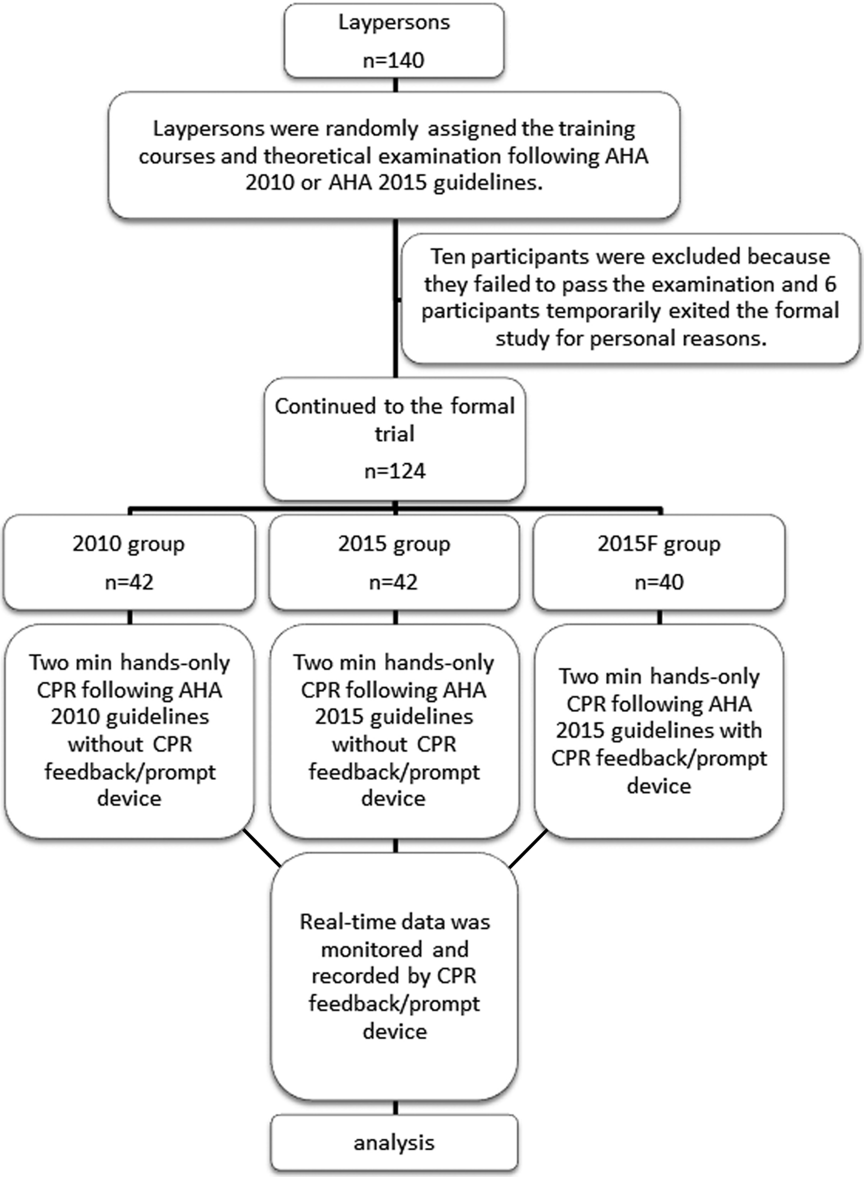
Laypersons
n=140
Laypersons were randomly assigned the training courses and theoretical examination following AHA 2010 or AHA 2015 guidelines.
Ten participants were excluded because they failed to pass the examination and 6 participants temporarily exited the formal study for personal reasons.
Continued to the formal trial
n=124
2010 group
n=42
2015 group
n=42
2015F group
n=40
Two min hands-only CPR following AHA 2010 guidelines without CPR feedback/prompt device
Two min hands-only CPR following AHA 2015 guidelines without CPR feedback/prompt device
Two min hands-only CPR following AHA 2015 guidelines with CPR feedback/prompt device
Real-time data was monitored and recorded by CPR feedback/prompt device
analysis

Figure 1

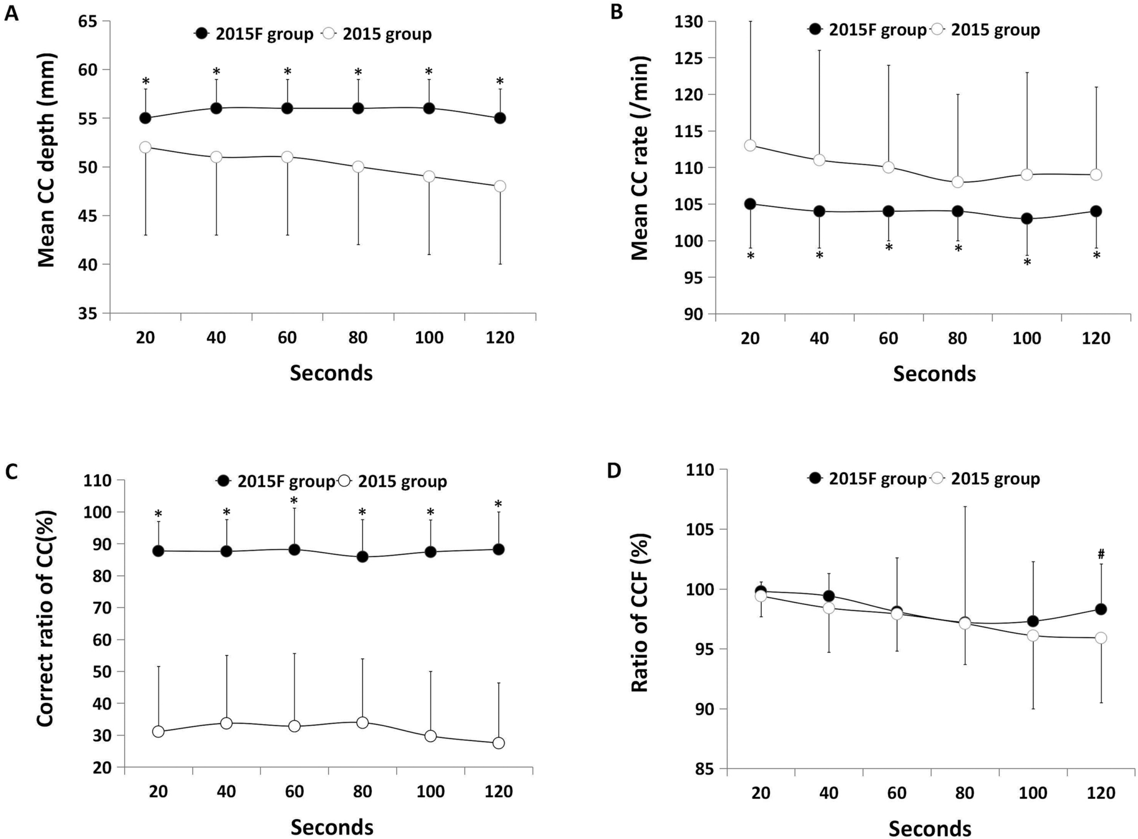
A
Mean CC depth (mm)
2015F group
2015 group
Seconds
B
Mean CC rate (/min)
2015F group
2015 group
Seconds
C
Correct ratio of CC(%)
2015F group
2015 group
Seconds
D
Ratio of CCF (%)
2015F group
2015 group
Seconds

Figure 2