Submitted: 07 May, 2021 Accepted: 31 May, 2021 Published: 08 March, 2022 DOI:10.22514/sv.2021.119

Open Access
Signa Vitae

ORIGINAL RESEARCH

The immediate effect of deliberate practice and real-time feedback on high-quality CPR training in intern doctors, acute care providers, and lay rescuers

Serpil Yaylaci[1,*], Kamil Kayayurt[1], Hasan Aldinc[1], Cem Gun[1], Alphan Sekuri[2]

[1]Department of Emergency Medicine, Acibadem Mehmet Ali Aydinlar University, School of Medicine, 34684 Istanbul, Turkey
[2]Acibadem Mehmet Ali Aydinlar University, School of Medicine, 34684 Istanbul, Turkey

***Correspondence**
serpilyaylaci@hotmail.com;
serpil.yaylaci@acibadem.edu.tr
(Serpil Yaylaci)

Abstract

The quality of cardiopulmonary resuscitation (CPR) is the main determinant of survival in cardiac arrest, so high-quality CPR (HQ-CPR) from bystanders is essential. The best instructional model for HQ-CPR performed by bystanders remains under investigation, and an instructional model's effect on various learner types is unknown. This study examined the immediate effect of a brief, blended instructional design that combines deliberate practice (DP) with real-time feedback (RTF) on the booster training of intern doctors (IDs) and acute care providers (ACPs) as well as on the skills acquisition training of lay rescuers (LRs). This cohort crossover study was conducted in a university-affiliated hospital in January 2020. Just-in-time training on HQ-CPR that featured a popular song was provided to IDs (n = 24), ACPs (n = 29), LRs (n = 25); groups performed one-minute cardiac compressions twice, without RTF and with verbal coaching, followed by debriefing, and then with only RTF. The impact of RTF on depth, rate, compression quality (CQ), and recoil was assessed. RTF significantly improved depth, rate, CQ, and recoil ($p < 0.001$). Among the LRs, the depth was 0.2 millimeters below the lower cutoff. Without RTF, the previously trained IDs and ACPs tended to perform inadequately faster and deeper compressions, while the untrained LRs performed slower, shallow compressions. DP combined with RTF yielded a significant immediate effect on the HQ- CPR training outcomes of all learner types.

Keywords

Audio feedback; Cardiopulmonary resuscitation; Deliberate practice; Public participation; Visual feedback

1. Introduction

High-quality cardiopulmonary resuscitation (HQ-CPR) is a shared instructional objective of training in basic life support (BLS) and advanced life support (ALS) for lay rescuers (LRs) and health care providers. People are increasingly being trained, experiencing efficient educational approaches, and developing collective knowledge and experience of life support and technological integration in resuscitation. Despite significant improvements, survival from out-of-hospital cardiac arrest (OHCA) has remained unchanged since 2012 [1], and LRs may fail to reach the desired CPR standards [2, 3]. CPR by health care providers on OHCA patients leads to higher survival rates than that of LRs, albeit not as high as CPR performed on patients with in-hospital cardiac arrest (IHCA) [4–8]. While IHCA outcomes are improving, those of OHCA are not [9, 10]. Even though resuscitation training is widespread, learners do not adequately acquire and retain resuscitation knowledge and skills [5–8, 11], resulting in suboptimal learning outcomes with standards not achieved in real life [12, 13].

Educational efficacy is an essential component in improving survival [14], but the best instructional approach remains under investigation [9]. The effects of different learner types on the educational efficacy of the HQ-CPR training require further exploration. Studying these effects could facilitate the current improvement and simplification of resuscitation education. Research on the best instructional approach suggests that incorporating deliberate practice (DP) and real-time feedback (RTF) into the design improves skill acquisition and retention [15–17]. In DP, a discrete goal is set, immediate feedback is given after performance, and abundant time is provided to improve performance.

In patients with OHCA, advising LRs to perform hands-only CPR resulted in a 12% increase in LR-initiated CPR, and such CPR has improved survival by 6% [18], yet only 34.4% of adults receive LR-initiated CPR before paramedics arrive [19]. Therefore, easy-to-teach and easy-to-learn approaches are required in training [20].

The effects of different learner types on the educational efficacy of the HQ-CPR training require further exploration.

FIGURE 1. ZOLL R Series® Monitor Defibrillator with audial and visual feedback feature.

Studying these effects could facilitate the current improvement and simplification of resuscitation education.

This study aimed to investigate and compare the immediate effects of a brief, blended instructional design combining DP with RTF on the booster training of intern doctors (IDs) and acute care providers (ACPs) as well as the HQ-CPR skills acquisition training of LRs who might potentially provide BLS in cases of OHCA. A second aim of the study was to investigate the generalizability of RTF intervention in various learner types in HQ-CPR training.

2. Methods

2.1 Study design

This cohort crossover study was conducted in a university-affiliated tertiary hospital's emergency department in January 2020. The ethical approval of this study was authorized by the Acibadem Mehmet Ali Aydinlar University Medical Research Assessment Committee (ATADEK) with the decision number 2019-20/36 on the 19th of December 2019.

2.2 Participants

The participants were at least 18 years old and provided informed consent. They included:

24 IDs in their emergency medicine internship (All of the interns currently in their emergency medicine rotation at the time of the study conduct);

29 ACPs working in the hospital's emergency department (Nurses and paramedics currently employed in the emergency department at the time of the study conduct);

25 LRs who were randomly chosen by the hospital's human resources department.

The IDs and ACPs had received their most recent BLS training one year earlier as a part of their ALS training. The LRs had no prior BLS training. RTF was introduced for the first time to all the groups.

2.3 Study intervention

A 30-minute tutorial explaining HQ-CPR was given separately to each group. All the groups watched a video and a device demonstration about HQ-CPR practice. The participants were given individual hands-on time with the RTF function of the ZOLL R Series® Monitor Defibrillator (ZOLL Medical Corporation, Chelmsford, MA, USA) (Fig. 1) and the Laerdal® Mini Anne torso mannequin (Laerdal Medical AS, Stavanger, Norway). They were shown a YouTube video posted by the American Heart Association (AHA) to promote hands-only CPR, which featured the song "Stayin' Alive" by the Bee Gees (The Bee Gees, "Stayin' Alive"; *Saturday Night Fever*, *The Original Movie Soundtrack*; Polygram International Music, 1977).

Fig. 2 shows the flow of the study. The defibrillator's electrodes with built-in accelerometers captured the rate and depth of each compression and recoil, and the defibrillator's monitor provided audial and visual RTF. Both trials were recorded by the defibrillator. The trainer who was providing

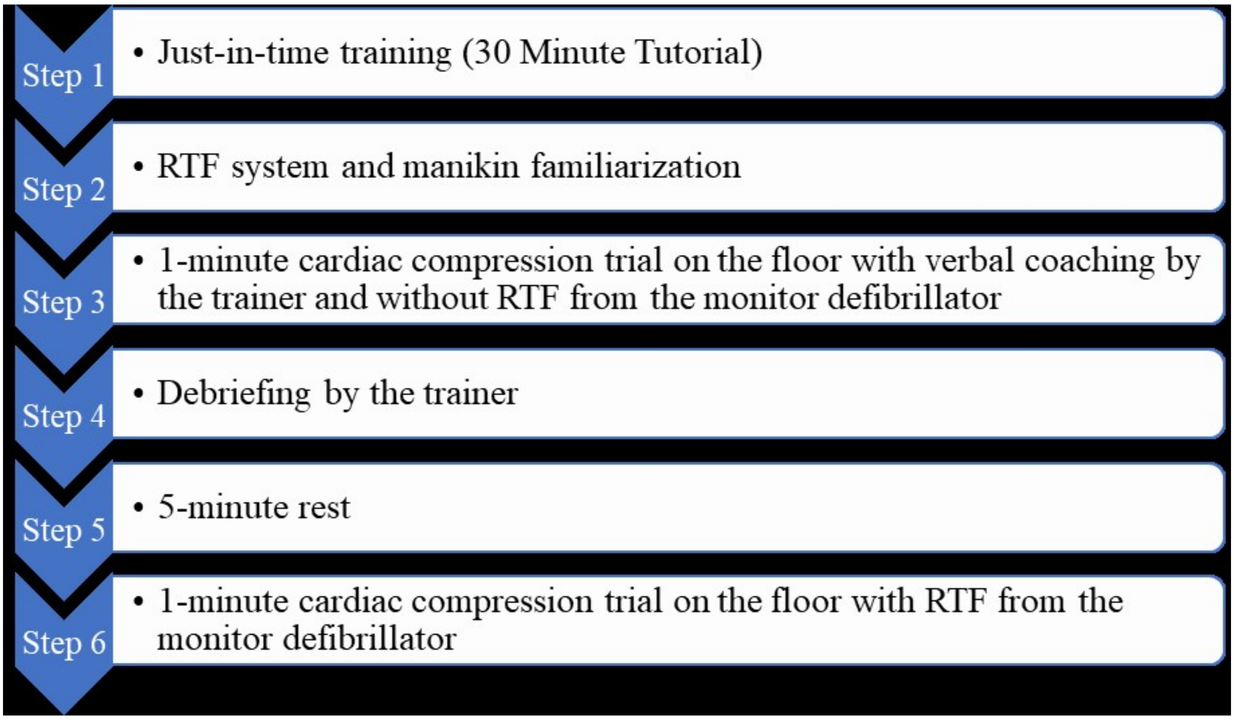

FIGURE 2. Deliberate practice flow. (RTF: real-time feedback).

verbal coaching during the first trial was able to see only the live recording of visual RTF and the audial RTF function of the device was disabled. The participants were blinded to all RTF from the defibrillator and receiving verbal coaching from only the trainer. The verbal coaching comprised of brief orders such as "Faster", "Slower", "Shallower", and "Deeper".

2.4 Outcome measures

The primary outcomes were defined as the differences in the means of four parameters: depth, rate, compression quality (CQ), and recoil according to the feedback status. The secondary outcomes were defined as the differences between the groups in the mean pairwise comparisons of the measurements according to the feedback status.

A compression rate of 100 to 120 per minute and compressions with a depth of 5 to 6 cm were considered effective. CQ (the percentage of adequate compressions on the mannequin) is a quantitative parameter that is calculated by measuring both the depth and the rate of compressions over the period. A CQ below 60% indicated that the compressions did not reach the correct depth and rate, while a CQ of 60% or above was considered an acceptable standard. Recoil was measured as the mean release velocity in millimeters per second (mm/s). A mean release velocity below 300 mm/s was considered a poor release, one between 300 and 400 mm/s a moderate release, and one above 400 mm/s a full release. A mean release velocity of 300 mm/s and above was considered an effective recoil.

2.5 Statistical analysis

The study had between 71.4%–100% power to produce a significant difference with n = 78 participants in terms of depth–non-feedback, CQ–feedback, and recoil–feedback, with a 5% type 1 error according to a post hoc power analysis.

The descriptive statistics were presented using mean, standard deviation, median, minimum, and maximum scale variables. The comparison of more than two normally distributed independent groups such as the IDs, ACPs, and LRs was performed with a one-way analysis of variance (ANOVA). Nonparametric statistical methods were used for values with skewed distribution.

Kruskal-Wallis test was used to compare more than two nonparametric distributed independent groups such as the learner types. Mann-Whitney U test was used to compare two nonparametric distributed independent groups as a post-hoc test of the Kruskal Wallis test. Tukey test was used to compare two normally distributed independent groups as a post-hoc test of one-way ANOVA. Fisher's exact test was used for the categorical variables.

The comparison of two normally distributed dependent groups such as non-feedback and feedback was performed using paired samples t test, and nonparametric statistical methods were used for values with skewed distribution. Wilcoxon signed-rank test was used to compare two nonparametric distributed dependent groups regarding feedback status. Statistical significance was accepted when the two-sided p-value was lower than 0.05.

The statistical analysis was performed using MedCalc Statistical Software version 12.7.7 (MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2013).

3. Results

Of the 78 participants, 43 were female (55.1%) and 35 male (44.9%). Twenty-four of the participants were IDs (30.8%), 29 ACPs (37.2%), and 25 LRs (32%). The mean age of the participants was 26.1 ± 4.9, and the median age was 24 (min: 20; max: 43).

TABLE 1. Comparison of the measurements of the groups according to the feedback status.

Measurements	Non-feedback	Feedback	*p*
	Mean (SD)	Mean (SD)	
	Med (Min–Max)	Med (Min–Max)	
Depth			
Intern doctors	8.01 (1.13) 8 (5–10)	5.45 (0.39) 5.35 (4.9–6.8)	$<0.001^d$
Acute care providers	6.33 (0.95) 6.3 (4.7–8.6)	5.46 (0.45) 5.6 (4.3–6.2)	$<0.001^c$
Lay rescuers	4.17 (0.94) 4.2 (2.5–5.8)	4.98 (0.64) 4.9 (3.9–6)	$<0.001^c$
p	$<0.001^b$	0.007^a	
Rate			
Intern doctors	117 (8) 119 (100–132)	111 (5) 112 (101–118)	0.001^c
Acute care providers	121 (11) 123 (100–150)	113 (7) 112 (99–128)	$<0.001^c$
Lay rescuers	100 (19) 92 (70–136)	114 (8) 113 (99–137)	$<0.001^c$
p	$<0.001^b$	0.236^b	
Compression quality			
Intern doctors	1 (3.23) 0 (0–14)	65 (23) 71 (0–91)	$<0.001^d$
Acute care providers	13 (23) 0 (0–79)	56 (29) 60 (0–98)	$<0.001^d$
Lay rescuers	1.48 (5.46) 0 (0–27)	29 (32) 17 (0–100)	$<0.001^d$
p	0.003^a	$<0.001^a$	
Recoil			
Intern doctors	395.5 (70.36) 409 (221–523)	498 (96.65) 500.5 (312–523)	$<0.001^c$
Acute care providers	383.86 (54.27) 383 (274–485)	453.93 (74.56) 453 (303–590)	$<0.001^c$
Lay rescuers	246.16 (65.39) 222 (165–396)	356.12 (53.43) 364 (245–443)	$<0.001^c$
p	$<0.001^a$	$<0.001^b$	

(SD: Standard Deviation, Med: Median, Min: Minimum, Max: Maximum) ^{a}Kruskal-Wallis test, ^{b}One-Way ANOVA, ^{c}Paired Samples t test, ^{d}Wilcoxon test.

Table 1 shows the cardiac compression performances of the groups in terms of all parameters without and with RTF. There was a significant difference between the non-feedback and RTF measurements in all parameters. The averages of rate and depth with non-feedback measurements were higher than with RTF for the IDs and ACPs. Recoil and CQ were higher with RTF than with non-feedback measurements in the IDs, ACPs, and LRs (paired samples *t*-test, Wilcoxon test: $p < 0.05$) (**Supplementary Figs. 1,2,3,4**).

The post hoc pairwise comparisons in Table 2 show a significant difference between the IDs and the ACPs for depth and CQ in non-feedback measurements. The average of the IDs was higher than that of the ACPs for depth and lower for CQ. There was a significant difference between the IDs and the LRs for rate (non-feedback), depth (non-feedback and RTF), CQ (RTF), and recoil (non-feedback and RTF). The average of the IDs was higher than that of the LRs in all parameters. A significant difference was found between the ACPs and the LRs for rate (non-feedback), depth (non-feedback and RTF), CQ (non-feedback and RTF), and recoil (non-feedback and

TABLE 2. Post-hoc Pairwise comparisons of the measurements according to the feedback status.

Measurements	Intern doctors vs. acute care providers	Intern doctors vs. lay rescuers	Acute care providers vs. lay rescuers
Depth			
Non-feedback[b]	<0.001	<0.001	<0.001
Feedback[a]	0.662	0.009	0.005
Rate			
Non-feedback[b]	0.448	<0.001	<0.001
Compression quality			
Non-feedback[a]	0.005	0.755	0.009
Feedback[a]	0.186	<0.001	0.002
Recoil			
Non-feedback[a]	0.396	<0.001	<0.001
Feedback[b]	0.099	<0.001	<0.001

[a]*Mann-Whitney U test,* [b]*Tukey test.*

TABLE 3. Comparisons of the compression quality of the groups according to the feedback status.

Feedback status	≥60	<60	*p*
	n (%)	n (%)	
Non-feedback			
Intern doctors	0 (0.0)	24 (100.0)	
Acute care providers	3 (10.3)	26 (89.7)	0.105
Lay rescuers	0 (0.0)	25 (100.0)	
Feedback			
Intern doctors	16 (66.7)	8 (33.3)	
Acute care providers	15 (51.7)	14 (48.3)	0.001
Lay rescuers	4 (16.0)	21 (84.0)	

(n: Number) Fisher's Exact test.

TABLE 4. Comparisons of the recoil of the groups according to the feedback status.

Feedback status	≥300	<300	*p*
	n (%)	n (%)	
Non-feedback			
Intern doctors	21 (87.5)	3 (12.5)	
Acute care providers	26 (89.7)	3 (10.3)	<0.001
Lay rescuers	6 (24.0)	19 (76.0)	
Feedback			
Intern doctors	24 (100)	0 (0.0)	
Acute care providers	29 (100)	0 (0.0)	0.005
Lay rescuers	20 (80.0)	5 (20.0)	

(n: number) Fisher's Exact test.

RTF). The average of the ACPs was higher than that of the LRs in all parameters (Mann-Whitney U test, Tukey test: $p < 0.016$, Bonferroni correction).

Table 3 shows the significant differences between the groups' CQ in RTF measurements. Those with a CQ of more than 60% were more likely to be IDs and ACPs, while those with a CQ lower than 60% were more likely to be LRs (Fisher's exact test: $p < 0.05$).

Table 4 gives the comparisons of recoil measurements as mean release velocity (mm/s). There was a significant difference between the groups in terms of recoil in the non-feedback and RTF measurements. Those with a recoil of more than 300 mm/s were more likely to be IDs and ACPs, while those with a recoil of less than 300 mm/s were more likely to be LRs (Fisher's exact test: $p < 0.05$).

4. Discussion

Interventions to enhance CPR training and performance have been sought for many years. The current study evaluated the immediate effect of DP interventions, such as just-in-time training (JIT), verbal coaching, and RTF. Feedback was shown to be effective and is mandated by the AHA and recommended by the European Resuscitation Council in CPR training [10, 21]. A systematic review has highlighted the need for instructor-led CPR training with real-time or delayed feedback [22]. A systematic review of the literature has considered the effect of RTF on only single learner types in CPR training studies [15], but, to our knowledge, there has been no prior interventional study with a triple comparison of different learner types (IDs, ACPs, and LRs) without and with RTF.

The results indicate that RTF helped all the groups to improve in all parameters. In terms of depth, deeper than adequate compressing IDs and ACPs improved and were in the reference interval, but LRs fell short minimally even with RTF, with an average of 4.98 centimeters. In terms of rate, all the groups achieved the expected interval with RTF. The improved statistics in each of these parameters before and after RTF show its positive impact on CQ. Measurement of CPR quality is needed to achieve HQ-CPR, even among health care providers.

The one possible downside may be the inadequate improvement in the CQ of the LRs. Although RTF significantly improved the CQ of IDs and ACPs above the threshold, the LRs did not demonstrate a satisfactory improvement. Achieving adequate improvement in CQ may require further and repetitive training for a group whose experience is limited to two minutes; the optimal CQ may be harder to achieve because the quality is evaluated by a combination of rate and the depth of each compression. It has been suggested that provider fatigue begins at between 90 seconds and three minutes [23].

The untrained LRs demonstrated an improvement with the RTF in terms of rate and depth compared to their compressions without feedback. The most prominent improvement was in the rate. Considering the brief period of training and that this was their first time doing cardiac compressions, achieving compression depth only 0.2 millimeters below the lower cutoff and improving their CQ from scratch seems promising. A longer period of training and refresher trainings at intervals would make achieving these thresholds possible.

Only the LRs had slow recoil without feedback, and all the groups had release velocities higher than 300 mm/s with RTF. The IDs and ACPs were found to be fully releasing, and the LRs were found to be moderately releasing. Release velocity is independently associated with improved survival and a favorable neurological outcome at hospital discharge after adult OHCA [24]. It is noteworthy that RTF improved all the groups' release velocities.

All the participants received a lecture on the determinants of HQ-CPR. A comparison of JIT versus RTF has found that both of them improved CPR performance similarly [11]. The performance in the non-feedback group may be falsely high because of the didactic education provided, and the real-world effect of RTF may be greater than identified in the current study.

The skills related to CPR may decay over time. The IDs and ACPs had received their most recent CPR training a year earlier and struggled to achieve optimal results without RTF. Their performances improved in all aspects with the help of RTF, which improves their psychomotor skills and provides objective insights for these two groups that frequently perform CPR in IHCAs. RTF on the compression, depth, and recoil of CPR yields a 25% increase in survival from IHCA at hospital discharge [25]. RTF has not been shown to have a significant effect on the neurological outcome in IHCA and OHCA [26], but a trial on the effect of RTF and debriefing on the one-month survival and neurological survival of OHCA patients is currently being conducted [27]. Refresher trainings with RTF or delayed feedback is recommended every three to six months for laypeople, which could also be implemented with health care professionals [22]. Studies comparing booster trainings with RTF (at one, three, and six months) with six-minute monthly boosters have demonstrated greater improvement in compression in the six-minute monthly group [28, 29]. In the current study, the two-minute instructional design, which combined various educational modalities (such as JIT, DP with RTF, verbal coaching, debriefing, and a popular song) could be considered to be acquisition training for the LRs and booster training for IDs and ACPs.

A modified version of this study design could be used to educate a broader population. Concordant with the results, significant improvement has been demonstrated with RTF compared to instructor-led feedback only [30]. Adding the educational models with RTF to CPR training could be proposed to authorities to involve more laypeople in performing bystander CPR.

The current study demonstrates the positive impact of RTF on cardiac compression regardless of prior training. This shows that RTF is useful not only in training but may also be beneficial in real life. A depth estimation algorithm for smartwatches with built-in accelerometers has been developed that may evolve into wearable RTF devices in the near future [31], so the widespread use of smartphones and smartwatches could facilitate the improvement of CPR quality with RTF. Using applications and social media, these devices could also support CPR learning. Technological learning modalities could make the learner independent of an instructor and of a specific time and location [20], and self-directed training is recommended for LRs if instructor-led training is not available [32–35]. Gamified learning environments (such as virtual and augmented reality) and tablet apps simulating monitors might engage more and different types of learners. These enhance retention and assist in the competency assessment of CPR [20].

The integration of RTF into automated external defibrillators (AEDs) in public areas could be considered, as an increased efficacy of bystander compressions has been demonstrated in a simulation model using an RTF-integrated AED [36]. RTF might also be integrated into the defibrillators on crash carts. The current study suggests that health care providers may also struggle in delivering efficient compressions, so the guidance from RTF devices implemented in defibrillators could improve CQ and, therefore, the outcomes of IHCAs and OHCAs.

5. Limitations

As this was a mannequin study, it has limitations in terms of generalizing the results to real life. One evident limitation is the sample size. Real-life factors that might affect the impact of RTF on CPR performance, such as the resuscitation environment and provider stress or motivation, could not be evaluated. Recognition of CPR need and activation of the emergency medical services were not evaluated. The use of two one-minute compressions in training limits the assessment of the impact of RTF on HQ-CPR. The participants were not allowed to repeat their practice until they achieved the target performance level. The standardized order of non-feedback CPR before RTF CPR may also have obscured some real effects of the RTF due to the practice effect. It was not possible to isolate the improvement resulting from an individual component in the blended instructional design. Another limitation of this study is that a one-time training event was conducted without further evaluation of the retention of knowledge.

6. Conclusions

This study demonstrated that a blended instructional design combining DP with RTF enhances the booster training of IDs and ACPs as well as the skills acquisition training of LRs, who are potential BLS providers in cases of OHCA. The previously trained IDs and ACPs tended to perform inadequately faster and deeper compressions, and the untrained LRs performed slower, shallow compressions without RTF. DP with RTF provided an immediate significant effect on the HQ-CPR training outcomes in all parameters for all learner types. The blended instructional design could be used as a transitional approach to self-directed learning in HQ-CPR training.

AUTHOR CONTRIBUTIONS

SY created the methodology, conceptualized, and supervised the study. KK provided resources and visualization. HA took part in investigation. HA and CG provided data curation. CG administered the project. AS wrote the original draft. SY and AS reviewed and edited the original draft.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The ethical approval of this study was authorized by the Acibadem Mehmet Ali Aydinlar University Medical Research Assessment Committee (ATADEK) with the decision number 2019-20/36 on the 19th of December 2019.

ACKNOWLEDGMENT

We would like to thank Mr. Anas Mansi and Mr. Cem Esinoğlu from ZOLL Clinical Support Department for their logistic and educational collaboration and Erol Barbur, MD for his helpful comments on the manuscript and contributions.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.signavitae.com/mre-signavitae/article/1410493869458374656/attachment/Supplementary%20materials.rar.

DATA AVAILABILITY STATEMENT

The data from this study is available on reasonable request from the corresponding author.

REFERENCES

[1] Virani SS, Alonso A, Benjamin EJ, Bittencourt MS, Callaway CW, Carson AP, *et al*. Heart disease and stroke statistics—2020 update: A report from the American Heart Association. Circulation. 2020; 141: e139–e596.

[2] Nishi T, Takei Y, Kamikura T, Ohta K, Hashimoto M, Inaba H. Improper bystander-performed basic life support in cardiac arrests managed with public automated external defibrillators. The American Journal of Emergency Medicine. 2015; 33: 43–49.

[3] Gyllenborg T, Granfeldt A, Lippert F, Riddervold IS, Folke F. Quality of bystander cardiopulmonary resuscitation during real-life out-of-hospital cardiac arrest. Resuscitation. 2017; 120: 63–70.

[4] Nord A, Svensson L, Karlsson T, Claesson A, Herlitz J, Nilsson L. Increased survival from out-of-hospital cardiac arrest when off duty medically educated personnel perform CPR compared with laymen. Resuscitation. 2017; 120: 88–94.

[5] Hunt EA, Duval-Arnould JM, Chime NO, Jones K, Rosen M, Hollingsworth M, *et al*. Integration of in-hospital cardiac arrest contextual curriculum into a basic life support course: a randomized, controlled simulation study. Resuscitation. 2017; 114: 127–132.

[6] Wayne DB, Siddall VJ, Butter J, Fudala MJ, Wade LD, Feinglass J, *et al*. A longitudinal study of internal medicine residents' retention of advanced cardiac life support skills. Academic Medicine. 2006; 81: S9–S12.

[7] Nichol G, Thomas E, Callaway CW, Hedges J, Powell JL, Aufderheide TP, *et al*. Regional variation in out-of-hospital cardiac arrest incidence and outcome. Journal of the American Medical Association. 2008; 300: 1423-1431.

[8] Abella BS, Sandbo N, Vassilatos P, Alvarado JP, O'Hearn N, Wigder HN, *et al*. Chest compression rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest. Circulation. 2005; 111: 428–434.

[9] Merchant RM, Topjian AA, Panchal AR, Cheng A, Aziz K, Berg KM, *et al*. Part 1: Executive Summary: 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2020; 142: S337–S357.

[10] Perkins GD, Graesner JT, Semeraro F, Olasveengen T, Soar J, Lott C, *et al*. European Resuscitation Council Guidelines 2021: Executive summary. Resuscitation. 2021; 161: 1–60.

[11] Cheng A, Overly F, Kessler D, Nadkarni VM, Lin Y, Doan Q, *et al*. Perception of CPR quality: Influence of CPR feedback, Just-in-Time CPR training and provider role. Resuscitation. 2015; 87: 44–50.

[12] Bhanji F, Mancini ME, Sinz E, Rodgers DL, McNeil MA, Hoadley TA, *et al*. Part 16: education, implementation, and teams: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010; 122: S920–S933.

[13] Bhanji F, Donoghue AJ, Wolff MS, Flores GE, Halamek LP, Berman JM, *et al*. Part 14: Education: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2015; 132: S561–S573.

[14] Søreide E, Morrison L, Hillman K, Monsieurs K, Sunde K, Zideman D, *et al*. The formula for survival in resuscitation. Resuscitation. 2014; 84: 1487–1493.

[15] Yeung J, Meeks R, Edelson D, Gao F, Soar J, Perkins GD. The use of CPR feedbackprompt devices during training and CPR performance: a systematic review. Resuscitation. 2009; 80: 743–751.

[16] Cheng A, Magid DJ, Auerbach M, Bhanji F, Bigham BL, Blewer AL, *et al*. Part 6: Resuscitation Education Science: 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2020; 142: S551–S579.

[17] Cheng A, Nadkarni VM, Mancini MB, Hunt EA, Sinz EH, Merchant RM, *et al*. Resuscitation Education Science: Educational Strategies to Improve Outcomes from Cardiac Arrest: a Scientific Statement from the American Heart Association. Circulation. 2018; 138: e82–e122.

[18] Bobrow BJ, Spaite DW, Berg RA, Stolz U, Sanders AB, Kern KB, *et al*. Chest compression-only CPR by lay rescuers and survival from out-of-hospital cardiac arrest. Journal of the American Medical Association. 2010; 304: 1447–1454.

[19] Girotra S, van Diepen S, Nallamothu BK, Carrel M, Vellano K, Anderson ML, *et al*. Regional Variation in out-of-Hospital Cardiac Arrest Survival in the United States. Circulation. 2016; 133: 2159–2168.

[20] Greif R, Lockey A, Breckwoldt J, Carmona F, Conaghan P, Kuzovlev A, *et al*. European Resuscitation Council Guidelines 2021: Education for resuscitation. Resuscitation. 2021; 161: 388–407.

[21] American Heart Association. Requirement on Use of Feedback Devices in Adult CPR Training Courses. 2017. Available at: http://ahainstructornetwork.americanheart.org/idc/groups/ahaecc-public/@wcm/@ecc/documents/downloadable/ucm_495639.pdf (Accessed: 24 June 2021).

[22] Riggs M, Franklin R, Saylany L. Associations between cardiopulmonary resuscitation (CPR) knowledge, self-efficacy, training history and willingness to perform CPR and CPR psychomotor skills: a systematic review. Resuscitation. 2019; 138: 259–272.

[23] Sugerman NT, Edelson DP, Leary M, Weidman EK, Herzberg DL, Vanden Hoek TL, *et al*. Rescuer fatigue during actual in-hospital cardiopulmonary resuscitation with audiovisual feedback: a prospective multicenter study. Resuscitation. 2009; 80: 981–984.

[24] Kovacs A, Vadeboncoeur TF, Stolz U, Spaite DW, Irisawa T, Silver A, *et al*. Chest compression release velocity: Association with survival and favorable neurologic outcome after out-of-hospital cardiac arrest. Resuscitation. 2015; 92: 107–114.

[25] Goharani R, Vahedian-Azimi A, Farzanegan B, Bashar FR, Hajiesmaeili M, Shojaei S, *et al*. Real-time compression feedback for patients with in-hospital cardiac arrest: a multi-center randomized controlled clinical trial. Journal of Intensive Care. 2019; 7: 5.

[26] Wang S, Su C, Fan H, Hou W, Chen Y. Effects of real-time feedback on cardiopulmonary resuscitation quality on outcomes in adult patients with cardiac arrest: a systematic review and meta-analysis. Resuscitation. 2020; 155: 82–90.

[27] Hirakawa A, Hatakeyama T, Kobayashi D, Nishiyama C, Kada A, Kiguchi T, *et al*. Real-time feedback, debriefing, and retraining system of cardiopulmonary resuscitation for out-of-hospital cardiac arrests: a study protocol for a cluster parallel-group randomized controlled trial. Trials. 2018; 19: 510.

[28] Kardong-Edgren S, Oermann MH, Odom-Maryon T. Findings from a nursing student CPR study: implications for staff development educators. Journal for Nurses in Staff Development. 2012; 28: 9–15.

[29] Oermann MH, Kardong-Edgren SE, Odom-Maryon T. Effects of monthly practice on nursing students' CPR psychomotor skill performance. Resuscitation. 2011; 82: 447–453.

[30] Tanaka S, Tsukigase K, Hara T, Sagisaka R, Myklebust H, Birkenes TS, *et al*. Effect of real-time visual feedback device 'Quality Cardiopulmonary Resuscitation (QCPR) Classroom' with a metronome sound on layperson CPR training in Japan: a cluster randomized control trial. BMJ Open. 2019; 9: e026140.

[31] Lu T, Chen Y, Ho T, Chang Y, Lee Y, Wang Y, *et al*. A novel depth estimation algorithm of chest compression for feedback of high-quality cardiopulmonary resuscitation based on a smartwatch. Journal of Biomedical Informatics. 2018; 87: 60–65.

[32] Roppolo LP, Pepe PE, Campbell L, Ohman K, Kulkarni H, Miller R, *et al*. Prospective, randomized trial of the effectiveness and retention of 30-min layperson training for cardiopulmonary resuscitation and automated external defibrillators: the American Airlines Study. Resuscitation. 2007; 74: 276–285.

[33] Saraç L, Ok A. The effects of different instructional methods on students' acquisition and retention of cardiopulmonary resuscitation skills. Resuscitation. 2010; 81: 555–561.

[34] Bobrow BJ, Vadeboncoeur TF, Spaite DW, Potts J, Denninghoff K, Chikani V, *et al*. The effectiveness of ultrabrief and brief educational videos for training lay responders in hands-only cardiopulmonary resuscitation: implications for the future of citizen cardiopulmonary resuscitation training. Circulation. Cardiovascular Quality and Outcomes. 2011; 4: 220–226.

[35] Chung CH, Siu AYC, Po LLK, Lam CY, Wong PCY. Comparing the effectiveness of video self-instruction versus traditional classroom instruction targeted at cardiopulmonary resuscitation skills for laypersons: a prospective randomised controlled trial. Hong Kong Medical Journal. 2010; 16: 165–170.

[36] Kim CH, Kim TH, Shin SD, Song KJ, Ro YS, Ahn KO, *et al*. The effect of automatic external defibrillator with a real-time feedback on quality of bystander cardiopulmonary resuscitation: a before-and-after simulation study. Health & Social Care in the Community. 2019; 27: e744–e751.

How to cite this article: Serpil Yaylaci, Kamil Kayayurt, Hasan Aldinc, Cem Gun, Alphan Sekuri. The immediate effect of deliberate practice and real-time feedback on high-quality CPR training in intern doctors, acute care providers, and lay rescuers. Signa Vitae. 2022; 18(2): 48-55. doi:10.22514/sv.2021.119.