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DOI:

10.4103/2452-2473.313333

Effect of smartphone applications on cardiopulmonary resuscitation quality metrics in a mannequin study: A randomized trial

Hüseyin Sevil¹, Volga Bastan¹, Esma Gültürk², Imad El Majzoub³, Erkan Göksu^{1*}

¹Department of Emergency Medicine, Akdeniz University School of Medicine, ²Akdeniz University, Vocational School of Health Services, Akdeniz University, Antalya, Turkey, ³Department of Emergency Medicine, American University of Beirut Medical Center, Beirut, Lebanon

*Corresponding author

Abstract:

OBJECTIVE: The aim of this randomized, cross-over trial is to reveal the effect of smartphone cardio-pulmonary resuscitation (CPR) feedback applications (App) on a group of lay rescuers' chest compression-only CPR quality metrics. Quality metrics is measured initially and after 3 months.

METHODS: A floor-based Resusci Anne mannequin (Laerdal Medical, Stavanger, Norway) was used. Three scenarios (CPR with device App-on [scenario-a], CPR with device App-off [scenario-b], and hands-only CPR [scenario-c]) were randomly allocated to all participants. All the participants performed 2 min of hands only-CPR for each scenario. Data of mean chest compression rate, mean chest compression depth, and recoil were recorded and compared for each scenario.

RESULTS: One hundred and thirty-seven first-year students from the Vocational School of Health Services in Turkey participated in this study to mimic lay rescuers. Difference in the initial mean rate of chest compressions was statistically significant when CPR was performed with device App-on (scenario-a) compared to scenarios b and c ($P < 0.001$, $P < 0.001$). Furthermore, difference in the mean chest compression rate at the 3rd month was statistically significant among the scenarios when CPR was performed with device App-on (scenario-a) ($P = 0.002$, $P = 0.001$). The difference in initial and 3rd month mean compression depth and the percentage of recoil was not statistically significant among the scenarios.

CONCLUSION: This study shows that the mean chest compression rate and percentage of compressions with adequate rate improved with smartphone App-on, and these results were persistent up to 3 months.

Keywords:

Cardiopulmonary resuscitation, emergency medicine, feedback device, quality metrics

Submitted: 03-07-2020

Revised: 26-08-2020

Accepted: 24-09-2020

Published: 09-04-2021

ORCID:

HS: 0000-0002-2618-8318

VB: 0000-0003-3102-1579

EG: 0000-0001-5884-7018

IE: 0000-0001-7736-0985

EG: 0000-0002-6164-3849

Address for correspondence:

Dr. Erkan Göksu,
Department of Emergency
Medicine, Akdeniz
University School of
Medicine, Antalya, Turkey.
E-mail: erkangoksu@
akdeniz.edu.tr

Introduction

According to 2016 unpublished data from resuscitation outcomes consortium investigators, the incidence of out-of-hospital cardiac arrest (OHCA) assessed by emergency medical services (EMS) was

reported to be 110.8/100,000 in the US population.^[1] The survival to hospital discharge after EMS-treated cardiac arrest was found to be 11.4%.^[1] However, these numbers are obtained from the developed countries. We expect global percentages to be significantly lower.

Both the European and the American guidelines emphasize the importance of

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How to cite this article: Sevil H, Bastan V, Gültürk E, El Majzoub I, Göksu E. Effect of smartphone applications on cardiopulmonary resuscitation quality metrics in a mannequin study: A randomized trial. Turk J Emerg Med 2021;21:56-61.

Box-ED Section:**What is known about the topic?**

Cardio-pulmonary resuscitation (CPR) feedback devices provide information on chest compression rate, depth, and recoil. Their use by medical professionals is limited.

What did this study ask?

This study aims to evaluate the use of a CPR feedback application (App) downloaded on a mobile phone by lay rescuers.

What did this study find?

The mean chest compression rate and percentage of compressions with adequate rate improved, and this was persistent up to 3 months with the use of smartphone Apps.

Why does this study matter to clinicians?

The smartphone Apps may reduce no-flow time and increase CPR quality in patients with cardiac arrest.

high-quality chest compressions with adequate rate, depth, and recoil in addition to quick defibrillation of shockable rhythms in improving patient outcomes.^[2,3] A high-quality cardio-pulmonary resuscitation (CPR) should begin within 10 s of a determined cardiac arrest, at a rate of 100–120 compressions/minute and a depth of at least 2 inches allowing complete recoil of chest after each compression.^[4]

Resuscitation of OHCA patients is time-sensitive. This is especially important given the fact that homes were found to be the most common location of OHCA (70%).^[5] Moreover, in communities with weak EMS support, the load of resuscitation is usually thrown on untrained bystanders or lay rescuers. This comes to stress the usefulness of feedback devices/applications (Apps) in ensuring high-quality chest compressions. Although devices that provide feedback on chest compression rate, depth and recoil have been proven to be of limited value for medical professionals, it seems they are extremely valuable for lay rescuers. This includes basic life support (BLS)-certified individuals, because it was shown that the retained CPR skills decline after a period of time.^[6] Still, several studies have shown that feedback devices are of no benefit in terms of return of spontaneous circulation (ROSC).^[7]

According to global statistics from 2016, 1495.36 million units of smartphones were sold all around the world.^[8] Several smartphone Apps have been developed to assess the users' chest compression quality, including rate, depth, and recoil. Such Apps may be downloaded, free

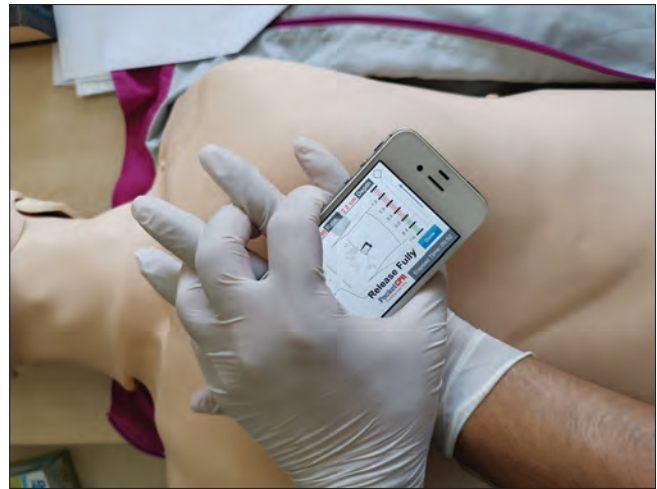


Figure 1: The proper hand position with the smartphone during cardio-pulmonary resuscitation

of charge, from either "Google Play Store" or "Apple Store."

In this study, we aim to explore the initial and 3rd month effect of smartphone CPR Apps on the quality of chest compression-only CPR by lay rescuers.

Methods

This is a randomized, crossover trial performed in the emergency department (ED) of a tertiary care facility with an annual influx of 90,000 patients. The ethical committee of Akdeniz University approved the study, and verbal consent was obtained from the participants (# 43024083-100-29051-109), (Akdeniz University, Clinical Research Ethical Committee, Date: 17.02.2017, Approval number: 70904504/45).

One-hundred thirty-seven first year students from Vocational School of Health Services participated in this study. These participants were chosen to mimic lay rescuers. Students who had previous BLS education or had BLS experience of any form were excluded from the study because participants should not have any knowledge about CPR.

A mobile phone (Apple iPhone 4S) and a downloaded CPR feedback App (Pocket-CPR-Zoll Medical Corporation, Chelmsford, MA) were employed in this study. Pocket-CPR is an App that can be downloaded to mobile phones, and this App was designed to guide the provider's chest compressions (rate, depth, and recoil) in a real-time fashion through both visual instructions (on the screen of the phone) and auditory feedback. All participants received a 30-min didactic session on chest compression-only CPR, in addition to a demonstration on how to hold the mobile phone and monitor the chest compression rate, depth, and recoil [Figure 1]. In addition, participants were given

30 min to get acquainted with the App and learn the proper way of handling the mobile phone (i.e., proper position).

Moreover, a floor-based Resusci Anne mannequin, from Laerdal Medical, Stavanger, Norway, was used. The skill reporter device of Resusci Anne mannequin was used to record the compression rate, compression with adequate rate, compression depth, and recoil. Resusci Anne is a CPR training mannequin used since 1960 to train more than 500 million people.^[9]

Three scenarios were randomly allocated to all participants: CPR with device-App on (scenario-a), CPR with device App off (scenario-b), and hands-only CPR (scenario-c). CPR with device App off scenario (scenario-b) was used to assess if chest compression was affected while holding the phone. Each participant randomly performed all three scenarios. Since we have three scenarios and six possible sequences, we used the randomized block design. The order of the scenarios performed was allocated by a researcher who did not have a role in the enrollment process using the block method. All the participants randomly performed 2 min of BLS for each scenario. Then, the scenarios were allocated randomly again after 3 months for each participant. The randomization sequence was repeated exactly the same way in the 3rd month. Data of mean chest compression rate, compressions with adequate rate (%), mean chest compression depth, and recoil were recorded for each scenario with the skill reporter of the mannequin. A 10-min rest was given for each participant before moving to the next scenario.

Statistical analysis

The study data were analyzed using the SPSS software version 16.0 for Windows (SPSS Inc., Chicago, IL, USA). Demographic and baseline characteristics were summarized as a mean \pm standard deviation for continuous variables and as a percentage of the group for categorical variables. Nonnormally distributed data are presented as medians (interquartile range). The normality analysis was performed with the Kolmogorov–Smirnov test.

Since we have randomized participants into three independent groups (scenario a-c) and data were not normally distributed, changes in mean chest compression rate, compressions with adequate rate (%), mean chest compression depth, and recoil (%) were analyzed using Kruskal–Wallis with Bonferroni correction ($P < 0.017$).

Furthermore, the paired sample *t*-test was used to compare the measurements at two time points (initial assessment and 3rd month assessment). $P < 0.05$ was accepted as statistically significant.

In addition, a sample size of 137 participants was calculated to detect a chest compression depth of 5 mm with a two-sided alpha value of 0.05 and a statistical power of 0.9.

Results

The mean age of the participants was 21 ± 6 years old, of which 43.1% were males. The mean height and weight of participants was 169 ± 7.5 and 64.3 ± 10.9 , respectively. The mean BMI was 22 ± 2.7 .

Mean chest compression rate

Initial mean chest compression rate/min in scenarios a, b, and c was 108 ± 5.9 , 112 ± 9.2 , and 112 ± 9.5 , respectively. The difference in the initial mean chest compression rate and the percentage of compressions with adequate rate was statistically significant when CPR is performed with device App-on (scenario-a) compared to scenarios b and c ($P < 0.001$) [Table 1]. However, the initial mean compression rate and the percentage of compressions with adequate rate were not affected by whether CPR was performed with the App off or by hands-only ($P = 0.42$ and 0.78 , respectively). Similar trends in statistical significance were seen upon reassessment after 3 months ($P < 0.001$) [Table 1].

Comparison of initial and 3rd month mean chest compression rate was statistically significant in all scenarios. Comparison of initial and 3rd month percentage of compressions with adequate rate was only statistically significant in CPR with smartphone App-off [Table 2].

Mean chest compression depth

Initial mean chest compression depth and in scenarios a, b, c was 48 ± 8.6 , 47.5 ± 8.7 , and 47.8 ± 9 , respectively. Third month chest compression depth was 51.3 ± 8.8 , 52 ± 9 , and 51.3 ± 9.6 , respectively. Initial and 3rd month mean compression depth was not statistically significant among the scenarios ($P = 0.68$ and 0.91 , respectively) [Table 1]. Comparison of initial and 3rd month mean compression depth was statistically significant in all scenarios ($P < 0.001$) [Table 2].

Recoil

There was no statistically significant difference among the scenarios regarding the percentage of recoil in both the initial assessment and the 3rd month assessment ($P = 0.34$ and 0.86 , respectively) [Table 1]. When initial and 3rd month recoil percentages were compared, none of the scenarios were statistically significant [Table 2].

Discussion

In this mannequin study, chest compression-only CPR

Table 1: Initial and third month assessment of collected data

Measurement	Scenario			P*
	CPR with smartphone App-on ^a	CPR with smartphone App-off ^b	Hands-only CPR ^c	
Initial assessment				
Mean chest compression rate/min (SD)	108±5.9	112±9.2	112±9.5	a,b P<0.001 a,c P<0.001 b,c P=0.42
Compressions with adequate rate (%)	86±20	68±31	68±33	a,b P<0.001 a,c P<0.001 b,c P=0.78
Mean compression depth (mm)	48±8.6	47.5±8.7	47.8±9	P=0.68
Recoil (%)	83±26	87±22	84±24	P=0.34
Third month assessment				
Mean chest compression rate/min (SD)	107±5.9	110±8.6	109±8.1	a,b P=0.002 a,c P=0.001 b,c P=0.96
Compressions with adequate rate (%)	87 ±19.6	77±27	75±28	a,b P<0.001 a,c P<0.001 b,c P=0.36
Mean compression depth (mm)	51.3±8.8	52±9	51.3±9.6	P=0.91
Recoil (%)	84.8±34	84.4±26	86.2±25	P=0.86

*P<0.017 was accepted as statistically significant. SD=Standard deviation, CPR=Cardio-pulmonary resuscitation

Table 2: Comparison of initial and 3rd month assessments

Measurement	Scenario		
	CPR with smartphone App-on	CPR with smartphone App-off	Hands-only CPR
Mean chest compression rate/min (SD)	0.007	0.028	0.009
Compressions with adequate rate (%)	0.083	0.004	0.13
Mean compression depth (mm)	<0.001	<0.001	<0.001
Recoil (%)	<0.11	0.41	0.25

SD=Standard deviation, CPR=Cardio-pulmonary resuscitation

was studied in three different scenarios (mobile phone App-on, mobile phone App-off, and hands-only CPR). In our study, mean chest compression rate and percentage of compressions with adequate rate with smartphone when the App-on was significantly different than App-off and hands-only CPR at both the initial and 3rd month assessment.

In a prospective, randomized, crossover study, a mobile phone App (iCPR) with an armband was assessed.^[10] In line with our study, this study demonstrated that iCPR improved the quality of chest compression in terms of rate, although they have found a statistically significant difference in favor of chest compressions rate with iCPR. The mean compression rate was 101 ± 2.8 with iCPR and 107.8 ± 20.5 when it is performed without iCPR. The clinical significance of this finding is questionable likewise to our study but the percentage of compressions with adequate rate in our study is significantly higher in App-on scenario (86 ± 20) when compared with scenarios b (68 ± 31) and c (68 ± 33). We believe that this finding emphasizes the chest compression rate when App-on (scenario-a) was clinically significant. Moreover,

also participants of their study were doctors, nurses, and laypeople. Heterogeneity of the study population may be a confounder while interpreting the results. In their study, authors noted that the duration between the performances may cause “carry-over effect.” The carry-over effect or learning bias can be decreased by appropriate “wash-out” period. In order to minimize these effects, we used randomization and 10 min of wash-out period between the scenarios. We also repeated the scenarios 3 months after the initial assessment.^[10]

In their randomized, cross-over study, Truszcwski *et al.* compared four different methods/devices (TrueCPR, CPR-Ezy, smartphone-ICPR and standard CPR) and in the study of Sakai *et al.*, they used a self-developed smartphone App on laypeople with and without previous CPR training.^[11,12] In the study of Truszcwski *et al.*, the mean chest compression rate of the control group was faster, and in the study of Sakai *et al.*, the mean chest compression rate of the control group was slower. However, the mean compression rates of smartphone groups in all the studies published between 2010 and 2019 were within the limit of guideline recommendations.^[10,11,13-17]

In the prospective, single-blinded, randomized, controlled mannequin trial of Chan *et al.*, 50 participants were randomized to either “Pocket CPR®” or control group. The mean compression depth of the Pocket CPR® group was statistically significant; however, the mean compression rate of the Pocket CPR® group was significantly slower. Participants of this study were experienced providers, and most of them stated that holding the iPhone was difficult. However, in our study, compression rates and depths were not different whether participants held the phone or not (scenarios b and c) indicating that holding may be difficult, but it seems that it is not affecting the rate or depth of compressions.^[13]

The depth of chest compressions reported in the studies of Park *et al.*, Sakai *et al.*, and Semeraro *et al.* did not find any statistically significant difference between smartphones and control groups.^[10,12,15] Moreover, only 2 of 8 studies, by Zapletal *et al.* and Chan *et al.*, the mean compression depth was compatible with the current guidelines.^[13,17]

In a randomized controlled study by Lee *et al.*, the effectiveness of a smartwatch-based feedback App that gives feedback on the quality of chest compression was assessed. The display of the smartwatch showed three different colors as visual feedback to guide chest compression depth and regular vibrations for chest compression rate. In this study, the differences in both the rate of chest compressions and the proportion of correct chest decompression detected with and without the use of the smartwatch-based App were not statistically significant. However, chest compressions were significantly deeper with the use of the smartwatch-based feedback App.^[18] On the contrary, in our study, the mean compression depth was not statistically significant among the scenarios.

In another randomized, parallel controlled study by Ahn *et al.*, 40 senior medical students participated in a mannequin study, where a smartwatch-based feedback App was used. The App gives visual feedback for chest compression depth and vibration for chest compression rate. In this study, the proportion of accurate chest compression depth in the intervention group was significantly higher than that of the control group. The mean compression depth and the proportion of complete chest compression, however, did not differ significantly between the two groups. The results regarding mean compression depth and the proportion of complete chest compression are in line with our findings.^[6] In another randomized study, 21 medical students who had taken a BLS course within 3 months of enrollment were included. In this study, Pocket CPR® was used. Chest compression rate and depth were not statistically significant different between the groups. The proportion of adequate

compression depth was 38.1% with smartphone and 22.2% without the smartphone. In this study, the values displayed by the smartphone in the provider’s hands tend to be higher than the one recorded in skill meter software.^[15] This might be the reason that in our study not to find a statistically significant difference regarding chest compression depth.

In general studies recruited healthcare professionals or certificated laypersons,^[10-14] only few of them recruited medical students without previous experience or education of BLS.^[15-17] We believe that homogeneous participants may give accurate results.

There are several studies comparing different feedback devices.^[6,10] However, the problem that arises with such feedback devices is their lack of availability among lay rescuers. Supplying lay rescuers with feedback devices, as we do for automated external defibrillators, could be a possible solution. However, for logistic reasons, this is not an option in the near future. Accordingly, feedback Apps that can be readily available on devices we use on daily basis, such as smartphones or smartwatches, could be another plausible solution.

Furthermore, it is a known fact that skills and knowledge relating to bystander CPR decay rapidly after initial training.^[19] We believe that our study with its randomized design and number of participants strongly support the previous studies, but unique feature of this study is retention of chest compression only CPR skills up to 3 months when participants used smartphone App.

Further studies that compare programs that evaluate CPR quality metrics and visual and verbal feedback devices are needed.

Limitations

This study has several limitations. First, this is a mannequin study, and this may not reflect real life situations, where stress and safety must be considered. Second, all participants were young healthy attendees from the Vocational School of Health Services and were familiar with the use of smartphones and their exposure to CPR is likely to have been more than the general public.

In addition, the smartphone used in this study is relatively small in size; therefore, different results might be observed with the use of different types of smartphones. The wash out period of 10 min may be too short to eliminate carry-over effect.

Conclusion

This study shows that smartphone Apps might enhance

the rate and increase the percentage of compressions with adequate rate in potential lay rescuers. This might have a positive impact on the quality of the CPR performed by lay rescuers that need guidance to perform this maneuver correctly. Smartphone Apps are the most feasible solution out there for lay rescuers. This study showed that the rate and percentage of compressions with adequate rate was greater when using the smartphone App. Furthermore, this study showed that lay rescuers can keep up their skills up to 3 months with this App.

Perhaps, we need more studies to be able to tackle the effect of such Apps on ROSC after performing CPR by lay rescuers.

Author contributions statement

H. Sevil and E. Goksu designed the study, prepared the manuscript.

V. Bastan and E. Gulturk helped in recruitment process.

I El Majzoub review the manuscript language.

Consent to participate

Consent was obtained from all participants.

Ethical approval

Akdeniz University, Clinical Research Ethical Committee, Date: 17.02.2017, Approval number: 70904504/45.

Financial support and sponsorship

The medical devices used in the study were supported by Akdeniz University Research Project Unit.

Conflicts of interest

None Declared.

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