Cardiopulmonary Resuscitation Support Application on a Smartphone
– Randomized Controlled Trial –

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Background: This simulation trial aimed to compare the quality of cardiopulmonary resuscitation (CPR) with and without the newly-developed CPR support application on smartphones.

Methods and Results: In this trial, participants were randomly assigned to either the CPR support application group or the control group, stratified by sex and previous CPR training. Participants’ CPR skills were evaluated by a 2-min case-based scenario test using the Leardal Resusci Anne PC Skillreporting Manikin System®. The outcome measures were the proportion of chest compressions performed in each group and the number of total chest compressions and appropriate chest compressions performed during the 2-min test period. A total of 84 participants were enrolled and completed the protocol. All participants in the CPR support application group performed chest compressions, compared with only 31 (75.6%) in the control group (P<0.001). Among participants who performed chest compressions during the 2-min test period, the number of total chest compressions was significantly higher in the CPR support application group than in the control group (211.6±29.5 vs. 77.0±43.3, P<0.001). The number of appropriate chest compressions tended to be greater in the CPR support application group than in the control group, although it was statistically insignificant (30.3±57.3 vs. 17.2±28.7, P=0.246).

Conclusions: In this cohort of laypersons, the newly-developed CPR support application for smartphones contributed to increasing the implementation rate and the number of total chest compressions performed and may assist in improving the survival rate for out-of-hospital cardiac arrests (UMIN000004740).

Key Words: Automated external defibrillator; Cardiopulmonary resuscitation; Randomized controlled trial; Smartphones

Sudden cardiac arrest is a leading cause of death in the industrialized world,1–4 and approximately 70,000 cardiac events occur every year in Japan alone.5 However, survival after an out-of-hospital cardiac arrest is still <10%.5–8 Although bystander cardiopulmonary resuscitation (CPR) plays an important key role in the “chain of survival”,1–4 most cardiac arrest victims do not, unfortunately, receive bystander CPR.6–10 To further increase the proportion of bystander CPR, the dissemination of CPR training is essential, but it is difficult for the general public to acquire and retain CPR skills.1–4

Editorial p ????

The 2010 CPR guidelines suggest that the use of CPR prompt/feedback devices improves skill acquisition and retention by both the general public and healthcare professionals in
CPR training courses and in the clinical setting. Recently, some reports showed that CPR support systems with CPR-guided metronomes and voicemail from mobile phones served to improve CPR quality, and that smartphones with an acceleration sensor as the CPR feedback device were more effective for improving the compression rhythm.

The dissemination of smartphones and tablet devices has been greatly increasing, and their potential use as current CPR prompt/feedback devices might be very important for lay-rescuers. Hence, we developed a smartphone application for the general public to assist with CPR. The aim of this simulation trial was to compare the quality of CPR with and without the newly-developed CPR support application on a smartphone.

**Methods**

**Study Design**
This study, designed as an open, prospective, individual randomized controlled trial, was carried out in 2011 from January to March.

**CPR Support Application on a Smartphone**
We developed an application with animation explaining emergency medical services activation, hand position during chest compression, compression depth, and chest compression rate according to metronome-like sounds on a smartphone. This tutorial application was based on the 2010 CPR guidelines, and can be used to easily learn and remember CPR visually (Figure 1). The metronome rhythm was 110 beats/min in accordance with the 2010 CPR guideline’s recommendation.

The dissemination of smartphones and tablet devices has been greatly increasing, and their potential use as current CPR prompt/feedback devices might be very important for lay-rescuers. Hence, we developed a smartphone application for the general public to assist with CPR. The aim of this simulation trial was to compare the quality of CPR with and without the newly-developed CPR support application on a smartphone.

**Study Participants**
Participants aged ≥18 years were recruited via local billboards and internet advertisements, as well as by word of mouth from current participants. Certified medical professionals such as medical doctors, nurses, pharmacists, nutritionists, medical technicians, radiographers, occupational therapists, physical therapists, medical engineers, paramedics, and students majoring in these medical services were excluded.

**Randomization**
We held a prior explanatory meeting to obtain informed consent from the participants. The App Store is a service for the iPhone, iPod Touch, and iPad created by Apple Inc, which allows its users to browse and download applications from the iTunes Store that are developed with the iPhone SDK.
Outcome Measures
The outcome measures were the proportion of chest compressions performed in each group and the total number and appropriateness of the chest compressions performed during the 2-min test period based on the 2010 CPR guidelines. Other outcome measures included the proportions calling 119 and requesting an AED, the number of chest compressions with an appropriate depth (≥5 cm), the number of chest compressions with correct hand position, compression depth, time to first resuscitation (the shorter time of initiation of chest compression or ventilation), time to first compression, and time without chest compression.

Statistical Analysis
The sample size was calculated based on the number of appropriate chest compressions performed for 2 min in previous studies. The mean number of appropriate chest compressions performed for 2 min was approximately 48, and the CPR support device using voicemail improved CPR quality by approximately 30%. Based on these results, we estimated that a user of the CPR support application would perform 64 chest compressions, and a control group member would perform 48 chest compressions. Based on 0.8 power to detect a significant difference (P=0.05, two-sided), 40 participants were required for each study group. To compensate for possible absences, we planned to enroll 45 participants per group. Baseline characteristics and outcomes were compared between groups using an unpaired t-test for numerical variables and chi-square test for categorical variables. Data are presented as mean±standard deviation. In addition, we divided the subjects into 2 groups: trained and untrained CPR groups (according to a previous study). All of the tests were 2-tailed and P<0.05 was considered statistically significant. All statistical analyses were performed using SPSS statistical package version 18.0J (SPSS, Inc, Chicago, IL, USA).

Ethical Considerations
All procedures were conducted according to the Declaration of Helsinki. Participants gave written informed consent prior

Interventions
On the trial day, participants assigned to the CPR support application group carefully familiarized themselves with application on a smartphone for 10 min immediately before the trial. After that, they were encouraged to use the application during the CPR skills test. The control group members attended the CPR skills test without the CPR support application. The trial was carried out person by person, and each examinee was unaware of the performance of the others. After the trial, the control group members were also instructed on how to use the CPR support application. All participants received a gift card of 3,000 yen as a token of thanks for their participation.

Data Collection
The CPR skills of each participant were evaluated using a case-based scenario at Kyoto University. In this test, each participant was called into the testing room individually and provided with the following scenario: You are in a department store. Suddenly, a man collapses in front of you saying “I feel sick”. I (the instructor) am a passing salesclerk. Please do whatever you can do with this manikin in front of you as if it is the collapsed man. After the presentation, we evaluated the participant’s CPR skills (including calling for 119 (the emergency call number in Japan) and using an automated external defibrillator (AED)) for 2 min using the LearnResusci Anne PC Skillreporting Manikin System® (Laerdal Medical, Stavanger, Norway). The instructor did not do anything other than receive the call for 119 and provide an AED when the participant requested it.

Figure 2. Participant flow in a study of a newly-developed cardiopulmonary resuscitation (CPR) support application on smartphones.
to participation. This study was approved by the Ethics Committee of Kyoto University Graduate School of Medicine, and was registered in the UMIN Clinical Trials Registry (UMIN000004740).

Results

A total of 103 participants applied, but 16 did not attend the pre-trial explanatory meeting and so we did not obtain their informed consent. The remaining 87 were randomly assigned to either the CPR support application group (44) or the control group (43); 1 participant from the CPR support application group and 2 from the control group did not attend the trial, leaving 43 in the CPR support application group and 41 in the control group who completed the study protocol (Figure 2).

Baseline characteristics of the participants are shown in Table 1. The mean age was 21 years in both groups, and there were no significant differences between the groups in sex ratio, previous CPR training, experience of sudden cardiac arrest, family history of sudden cardiac death, or having a smartphone.

CPR skills in the CPR support application group and control group are shown in Table 2. The proportion of those who called 119 and requested an AED was significantly greater in the CPR support application group than in the control group (67.4% vs. 46.3%, P=0.041, and 60.5% vs. 22.0%, P<0.001, respectively). All participants in the CPR support application group performed chest compressions, compared with only 31 (75.6%) in the control group (P<0.001). Among participants who performed chest compressions during the 2-min test period, the number of total chest compressions was significantly higher in the CPR support application group than in the control group (211.6±29.5 vs. 77.0±43.3, P<0.001). Consequently, the mean time without chest compressions was significantly shorter in the CPR support application group than in the control group (4.4±11.7 s vs. 63.8±23.1 s, P<0.001). The number of appropriate chest compressions tended to be greater in the CPR support application group than in the control group, although it was statistically insignificant (30.3±57.3 vs. 17.2±28.7, P=0.246). The number of chest compressions with correct hand position were significantly higher in the CPR support application group than in the control group (109.0±92.9 vs. 42.6±35.5, P<0.001), and the number of chest compressions with appropriate depth tended to be higher in the CPR support application group than in the control group, although it was statistically insignificant (65.7±73.4 vs. 41.0±48.7, P=0.095). The mean time to first chest compression or first ventilation was significantly longer in the CPR support application group than in the control group (37.1±17.9 s vs. 37.1±17.9 s, P<0.001).
The CPR skills in the groups with and without previous CPR training are shown in Table 3. Among the CPR-trained participants, all performed chest compressions in the CPR support application group, against 20 (80%) in the control group (P=0.020). Among the CPR-trained group, the number of appropriate chest compressions tended to be approximately 2-fold greater in the CPR support application group than in the control group, although it was statistically insignificant (39.5±64.4 vs. 17.4±31.0, P=0.163). In the CPR support application group, both the proportion requesting an AED and the activation of EMS were higher and the interruption time was shorter in the CPR support application group than in control group. Previous reports showed that voicemail and video delivered by cellular phones improved the quality of CPR,12,21 but the issue of what type of delivery device would be most effective is still controversial. We consider that smartphones are widely available in the industrialized world, and that CPR application will play a key role in the public acquiring and retaining CPR skills.22

This study also evaluated CPR quality in terms of hand position and compression depth based on the 2010 CPR guidelines,1–4 but the number of appropriate chest compressions was insufficient regardless of whether or not the CPR support application was used. This result suggests that it is difficult for the general public to perform high-quality CPR, especially in actual emergency settings.1–4 To increase the quality of the CPR performed by bystanders, it is most important for the general public to receive CPR training.23

In addition, the time to first CPR was longer in the CPR support group than in the control group. This result was consistent with previous reports; it took longer to start CPR by the prompt/feedback device users because of the device’s boot time.12,21,24 Further efforts to improve the application are indispensable for its utility and effectiveness.

In the subgroup analysis, the number of appropriate chest compressions was insufficient in both groups, irrespective of previous CPR training. However, the number of appropriate chest compressions among those in the CPR-trained group tended to be higher in the CPR support application group than in the control group, suggesting that the CPR support application might have produced a retention effect for those who had received previous CPR training. Participants in this study were using our application for the first time, so greater familiarity with this application might be effective in the general public acquiring the skills to perform high-quality CPR.

The number of smartphones is increasing year-by-year, reaching approximately 10 million units in Japan.24 Therefore, smartphones and tablet devices will become key instruments in resuscitation education, as well as at the actual emergency.
scene. The dissemination of the CPR support application to these devices might improve the general public’s understanding of the importance of CPR and using an AED, and lead to an increase in the proportion of bystander CPR.

**Study Limitations**

The resuscitation skills were evaluated by a case-based scenario test, and so resuscitation performance in a real emergency setting where lay-rescuers might easily panic was unknown. Moreover, appropriate resuscitation skills on a manikin might not necessarily lead to better clinical outcomes. Thus, we consider that further improvements of this application are warranted to make it an even better CPR support device that can be used in the actual resuscitation scenes. In addition, our results might not be fully generalized because many of the study participants were young adults. Therefore, validation for the middle-aged is also needed.

**Conclusions**

A newly-developed CPR support application on smartphones contributed to increasing the implementation rate and the number of chest compressions among a cohort of the general public. Further improvement of this application is needed for its effective use in resuscitation education and at the actual emergency scene.

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