BMJ Open

Opening a new era for high-quality CPR training with real-time feedback device called QCPR Classroom: A cluster randomized control trial

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-026140
Article Type:	Research
Date Submitted by the Author:	25-Aug-2018
Complete List of Authors:	Tanaka, Shota; Kokushikan University, Research Institute of Disaster Management and EMS, Tsukigase, Kyoko; Kokushikan University, Research Institute of Disaster Management and EMS, Hara, Takahiro; Kokushikan University, Graduate School of EMS System Sagisaka, Ryo; Kokushikan University, Graduate School of EMS System Myklebust, Helge; Laerdal Medical Cooperation Birkenes, Tonje; Laerdal Medical Cooperation Takahashi, Hiroyuki; Kokushikan University, Research Institute of Disaster Management and EMS, Iwata, Ayana; Kokushikan University, Research Institute of Disaster Management and EMS, Kidokoro, Yutaro; Kokushikan University, Research Institute of Disaster Management and EMS, Yamada, Momoyo; Kokushikan University, Research Institute of Disaster Management and EMS, Ueta, Hiroki; Meiji University of Integrative Medicine, Faculty of Emergency Medical Science Takyu, Hiroshi; Kokushikan University, Graduate School of EMS System Tanaka, Hideharu; Kokushikan University, Graduate School of EMS System; Kokushikan University, Research Institute of Disaster Management and EMS,
Keywords:	bystander, cardiac arrest, CPR training, resuscitation, Mass CPR training

Title: Opening a new era for high-quality CPR training with real-time feedback device called QCPR Classroom: A cluster randomized control trial

Shota Tanaka [1)], Kyoko Tsukigase [1)], Takahiro Hara [2)], Ryo Sagisaka [2)], Helge Myklebust [3)], Tonje S. Birkenes [3)], Hiroyuki Takahashi [1) 4)], Ayana Iwata [1)], Yutaro Kidokoro [1)], Momoyo Yamada [1)], Hiroki Ueta [5)], Hiroshi Takyu [2)], Hideharu Tanaka [1) 2)]

1) Research Institute of Disaster Management and EMS, Kokushikan University
2) Graduate School of EMS System, Kokushikan University
3) Laerdal Medical, Stavanger, Norway
4) Department of Sports Medicine, Kokushikan University, Japan
5) Faculty of Emergency Medical Science, Meiji University of Integrative Medicine

Correspondence author: SHOTA TANAKA
Kokushikan University, 7-3-1, Nagayama, Tama City, Tokyo, JAPAN
E-mail: tanakamedical24@gmail.com
TEL/FAX: +81-42-339-7197

Keywords: cardiac arrest, bystander, CPR training, resuscitation, Mass CPR training

Word Count: 3637

Abstract

Objectives "Quality Cardiopulmonary Resuscitation (QCPR)-Classroom" device has recently introduced to provide a higher quality of CPR training. The aim of this study was to examine whether QCPR-Classroom training can lead to higher chest compression quality than ordinary CPR training.

Setting Layperson CPR training

Design A cluster randomized control trial was conducted to compare standard CPR training (control) and QCPR-Classroom (intervention) groups.

Participants A total of 642 people were recruited from among CPR trainees.

Interventions CPR performance data in both groups was blindly captured on instrumented Little Anne prototypes for one minute pre- and post-training.

Primary and secondary outcome measures The primary outcome was compression depth (mm), rate (compressions per minute [cpm]), ≧90% adequate depth (%), and recoil (%). The scores from the survey were considered as a secondary outcome.

Results There were 259 people in the control group and 238 people in the QCPR-Classroom group who were eligible for analysis. After training, the mean compression depth and rate were 56.1±9.8mm and 119.2±7.3 compressions per minute (cpm) in the control group and 59.5±7.9mm and 116.8±5.5cpm in the QCPR-Classroom group, respectively. The QCPR-Classroom group showed a significantly higher rate of achieving ≧90% adequate depth than the control group (*p*=0.001). The difference between pre- and post-training of achieving ≧90% recoil was 1.5% in the control group (95% CI, -6.9-1.0; pre 40.2% vs. post 41.7%; *p*=0.72) and 27.7% in the QCPR-Classroom group (95% CI, 19.0-36.0; pre 44.5% vs.

post 72.3%; $p<0.0001$). The sound from a metronome set at 110 beats per minute had a positive influence on the CPR performance.

Conclusion Regardless of the lack of the subjective assessment by instructors, the QCPR-Classroom concept helped students achieve high-quality CPR training, especially for proper compression depth and full recoil. As an advantage of QCPR-Classroom, good educational achievement with fewer instructors can be seen.

Article Summary

The paper describes the use a novel "QCPR classroom" technique to educate laypeople in CPR. A large classroom in which learners could see their CPR performance both on a mannequin and on a big screen at the front of the class was used. Students were randomized into a control group and a QCPR classroom group. They were assessed on their ability to perform 1 minute of chest compression-only CPR. The QCPR group had a higher rate of achieving > 90% depth than the control group and a higher rate of achieving >90% recoil. However, there was no difference in average depth or rate between the two groups. The American Heart Association recommends use of audiovisual feedback device during CPR education. Benefits of audiovisual feedback devices are well accepted and agreed. QCPR classroom concept is a fancy new idea for mass-CPR training.

Strengths and limitations of this study

- Benefit of mass CPR training over QCPR Classroom, an audiovisual feedback device, is good educational achievement with fewer instructors.
- Arranging objective real-time feedback on big screen in front of everyone to visible to both instructor and students made significantly improve CPR quality.
- No retention measurement was taken and the measurements were all students together

Introduction

The burden of cardiovascular diseases and the increasing cases of out-of-hospital cardiac arrest (OHCA) remain a global concern [1]. Performing bystander cardiopulmonary resuscitation (CPR) is one factor that can increase the survival rate of OHCA [2-7]. The survival rate may be directly linked to the number of bystanders trained in CPR [2]. The Global Resuscitation Alliance (GRA) was recently established to improve OHCA survival, and high-performance CPR was highlighted: a push depth of 5-6 cm, rate of 100-120 compressions per minute (cpm), full recoil, and minimized fraction time (less than 10 seconds) [8]. In the GRA consensus, mandatory School and Community CPR was listed as one of the 10 steps to increase OHCA survival [8]. This type of CPR training is the best way to increase the number of people trained in CPR in a short time, but the quality assurance is questionable. On Aug 15, 2017, the American Heart Association (AHA) announced that AHA instructors will be required to use a feedback device during AHA CPR training [9].

Healthcare professionals were found to perform incomplete compression recoil in 46% of all cases and in 23.4% of cases involving paediatric patients [10-11]. However, performing full recoil is emphasized in the GRA consensus, along with the use of a feedback device during CPR training [8]. Incomplete recoil leads to insufficient time for blood to fill into the heart, which eventually leads to less blood flow to the brain [12]. Coronary and cerebral perfusion pressure can deteriorate due to incomplete decompression [13]. Full recoil is one of the most important concepts for ensuring high-quality CPR [8,14-15]. However, teaching the concept of recoil has been difficult for non-healthcare professionals, for which little is known about what the best teaching method is. Key points during CPR training are teaching to compress the chest 5 cm deep and allowing for full chest recoil, but these two components are hard to achieve during training without a feedback device.

We are currently facing a period of transition to a new style of CPR training. Many companies have introduced feedback devices, and research supports their effectiveness [16-25]. However, most of them cannot monitor recoil, or they are unavailable for CPR training that targets a large population. According to previous studies, the CPRcard (Laerdal Medical, Stavanger, Norway) could be a promising device to ensure CPR quality during large-scale CPR training [23-26]. Laerdal Medical (Stavanger, Norway) also recently launched the "QCPR Classroom" concept, which provides real-time visual feedback for a greater number of participants at once. The effectiveness of the QCPR Classroom device was recently demonstrated by Kong et al. [27]. The purpose of this study is to examine the effectiveness of CPR skills delivered by QCPR Classroom training in comparison to ordinary CPR training. The hypothesis of the study was that QCPR Classroom would generate higher achievement in CPR skill regardless of instructors' teaching skill. We aimed to determine whether QCPR Classroom could be the best practical model for CPR training.

Methods

The study was approved by the Institutional Review Board at Kokushikan University. A cluster randomized controlled trial (cRCT) was used [17,28], and oral informed consent was obtained from all participants prior to the CPR training and study enrolment.

Patient and Public Involvement

Patients and/or public were not involved this study. Study population were focused on CPR trainees.

Study population

A total of 642 people were recruited from among CPR trainees who were enrolled in the Heart Saver Japan CPR training, which was held between March and September 2017. The inclusion criteria was age over 15 years. The exclusion criterion was the presence of upper extremity injury within the past 6 months, working as a healthcare professional who is regularly involved in resuscitation, such as Emergency Medical Technicians (EMTs), paramedics, and emergency room physician or nurses. Previous CPR training status and quantity and timing of previous trainings were not used as inclusion or exclusion criteria.

Measurements

Participants enrolled in the CPR+automated external defibrillator (AED) training. The primary outcome was compression depth (mm), compression rate (compressions per minute [cpm]), adequate depth (%), and adequate recoil (%). These measurements were blindly measured both pre- and post-training for one minute. The scores from the survey conducted after the training were considered as a secondary outcome. For data analysis, we used a cutoff of 90 % compliance with depth > 5 cm.

Study procedure

We randomly selected which CPR training would be given (ordinary or QCPR Classroom). Four lead instructors who have worked as healthcare professionals and have had over 5 years of experience in teaching CPR were selected from the Heart Saver Japan organization. All of them are well experienced in teaching CPR and have trained over 5,000 people. The data collection took place during the Heart Saver Japan CPR+AED training sessions. Statistician generated a randomization list and each session was randomly assigned to the intervention. A total of 18 CPR training sessions were studied, with 9 ordinary CPR training (control group) and 9 QCPR Classroom sessions (Figure 1).

In the control group, participants received only subjective feedback from the instructor. In the QCPR Classroom group, participants received subjective and objective feedback from the instructor based on real-time feedback through the mannequin, and participants were able to correct themselves from feedback displayed on the screen of the device (Figure 2).

To measure the effect of CPR training, one minute of chest compression was measured without any feedback given as a pre-test. Similarly to the pre-test, one minute of chest compression was also measured after the training as a post-test. Although one minute of measurement may not be sufficient duration for CPR performance in real life, we focused on the initial CPR performance by a single rescuer situation. A survey and baseline characteristics, such as weight, height, and CPR training experience (Table 1), were also collected after the post-training measurement. A metronome was set at 110 beats per minute (bpm) and used for every instance of hands-on practice during the QCPR Classroom session, but no metronome was used during the ordinary CPR training.

Table 1. Demographic Characteristics

	Control (n = 259)	QCPR Classroom (n = 238)	*p* value
Age, mean±SD	22.4 ± 9.0	19.4 ± 5.6	<.0001 *
median (IQR)	19 (17-23.5)	17 (16-21)	<.0001 *
Male, (%)	130 (50.2)	101 (42.4)	0.08
height, mean	164.5 ± 14.3	164.2 ± 8.2	0.47
weight, mean	57.9 ± 12.1	56.0 ± 9.6	0.06
BMI, mean	21.1 ± 3.1	20.7 ± 2.6	0.07
CPR training, (%)	203 (78.4)	170 (71.4)	0.07
CPR training within 1 year, (%)	89 (41.2)	63 (36.4)	0.34

CPR: cardiopulmonary resuscitation; SD: standard deviation; IQR; interquartile range; BMI: body mass index

* p < .05 significant

Instrumentation

Compression data was captured using the Laerdal QCPR Classroom mannequin system (Laerdal Medical, Stavanger, Norway), as shown in Figure 2. This prototype system for community CPR training provides real-time visual feedback from 42 mannequins, where icons representing CPR performance from each mannequin are visualized on an iPad tablet. We mirrored the iPad screen on a laptop using the application Reflector 2 (Squirrels®, North Canton, OH, United States) in order to present real-time feedback on a large screen at the front of the classroom (Figure 3). QCPR Classroom uses Laerdal Little Anne mannequins, and each one is instrumented with an optical compression sensor and microcontroller. The microcontroller analyses the signal from the compression sensor and calculates the number of compressions, compression depth, rate, and incomplete release. A compression score is calculated using the rate, depth, and release. Each sensor was checked for depth accuracy using a calibrated compression machine with ±15% considered as acceptable error.

The microcontroller also compares the compression performance with guidelines from the 2015 AHA requirements. Deviations from the guidelines are reported as “too shallow”, “incomplete release”, “too fast”, or “too slow”, and deviation in each factor is presented as yellow icons on the tablet. If the compression performance is good, a green “Everything OK” icon is presented. Data from the tablet is sent to a Microsoft Azure cloud service and made available as downloadable *.csv* files, which include the following parameters from each mannequin and CPR session: the number of compressions, average compression rate, average compression depth, number of compressions with adequate depth, number of compressions with acceptable release, compression score, time, and location of use.

Statistical analysis

The rate and depth measurements are shown as the mean and standard deviation. Normal distributions and homogeneity of variance were confirmed by a Q-Q plot. The difference between pre- and post-training measurements within the groups were analysed using a paired t-test and McNemar test. Group comparison for both pre- and post-training was conducted using Welch’s t-test and the chi-square test. For the analysis, the rates of achievement of ≧90% adequate depth and recoil were calculated as percentages and considered as indexes of high competency. Analysing the percentage variables to compare the numerical value using a parametric test, such as a t-test, would neglect the upper limit of 100 %, so we set a criterion of ≧90% for their high-quality performance. The differences and 95% confidence intervals are shown in tables. The medians and interquartile ranges are presented for ordinal data. We compared the groups using the Wilcoxon single-rank test for continuous variables. The data was analysed using JMP (V.11.2.0, the SAS Institute Inc.), and p-values less than 0.05 were considered as significant.

Results

Demographic characteristics

A total of 642 people participated in this study. As shown in Figure 1, 145 participants were excluded due to incomplete data (n = 135), age under 15 years (n = 8), and paramedics (n = 2). Significant age difference between the groups was found (22.4±9.0 vs. 19.4±5.6; *p*=<.0001). After the CPR training, 497 participants were eligible for analysis, with 259 people in the control group and 238 people in the QCPR Classroom group. The demographic characteristics are shown in Table 1.

Primary outcome

All chest compression parameters at pre-training and post-training are shown in Table 2. After the training, the mean compression depth of each student was 56.1±9.8 mm in the control group and 59.5±7.9 mm in the QCPR Classroom group. Significantly more participants in the QCPR Classroom group achieved ≧90% of the adequate depth compared to the control group (*p* = 0.001; Table 3). In the QCPR Classroom group, there was an improvement of 39.1% (95% CI, 5.1-21.0) in achieving ≧90% of the adequate depth (37.8% at pre-training vs. 76.9% at post-training). In the control group, the improvement was 29.7% (95% CI, 21.3-37.7) in achieving ≧90% of the adequate depth (34.0% at pre-training and 63.7% at post-training; $p < 0.0001$; Table 2).

Both groups demonstrated average compression rates of 100-120 cpm (Table 2). A statistically significant difference was found between groups in terms of recoil ($p < 0.0001$; Table 2). The control group demonstrated a 1.5% (95% CI, -6.9-1.0) increase in the percentage of achieving ≧90% recoil (40.2% pre-training vs. 41.7% post-training; $p = 0.72$). The QCPR Classroom group demonstrated a 27.7% (95% CI, 19.0-36.0) increase in the percentage of achieving ≧90% recoil (44.5% pre-training vs. 72.3% post-training; $p <$ 0.0001; Table 2).

Table 2. Comparison in CPR performance competency between pre- and post-training in each groups

	Control (n = 259)				QCPR Classroom (n = 238)			
	Pre-training	Post-training	*p* value	Difference (95% CI)	Pre-training	Post-training	*p* value	Difference (95% CI)
rate (cpm) +	121.4 ±15.5	119.2 ± 7.3	0.02 *	-2.3 (-4.2 − -0.3)	115.7 ± 19.0	116.8 ± 5.5	0.39	1.1 (-1.4 − 3.6)
depth (mm) +	51.4±11.6	56.1 ±9.8	<0.0001 *	4.6 (3.5 − 5.8)	48.2 ± 14.7	59.5 ± 7.9	<0.0001 *	11.3 (9.8 − 12.8)
adequate depth ≥ 90% ++	88 (34.0)	165 (63.7)	<0.0001 *	29.7 (21.3 − 37.7)	90 (37.8)	183 (76.9)	<0.0001 *	39.1 (30.6 − 46.9)
recoil ≥ 90% ++	104 (40.2)	108 (41.7)	0.72	1.5 (-6.9 − 1.0)	106 (44.5)	172 (72.3)	<0.0001 *	27.7 (19.0 − 36.0)

paired-t test and McNemar test; CPR: cardiopulmonary resuscitation; CI: confidence interval

+ Mean and standard deviation for rate nad depth measurement

[++] Numbers (percentage) for ≥ 90% of the adequate depth and recoil achieved

* p < .05 significant

1

Table 3. The difference of CPR perofrmance competency between the control group and QCPR Classroom group at pre- and post-training

	Control (n = 259)	QCPR Classroom (n = 238)	*p* value	Difference (95% CI)
Pre-training test				
rate (cpm) [+]	121.4 ±15.5	115.7 ± 19.0	<0.001 *	-5.7 (-8.7 — -2.6)
depth (mm) [+]	51.4±11.6	48.2 ± 14.7	0.008 *	-3.2 (-5.5 — -0.85)
adequate depth ≥ 90% [++]	88 (34.0)	90 (37.8)	0.37	3.8 (-4.6 — 12.2)
recoil ≥ 90% [++]	104 (40.2)	106 (44.5)	0.32	4.4 (-4.3 — 13.1)
Post-training test				
rate (cpm) [+]	119.2 ± 7.3	116.8 ± 5.5	<0.001 *	-2.3 (-3.5 — -1.2)
depth (mm) [+]	56.1 ±9.8	59.5 ± 7.9	<0.001 *	3.5 (1.9 — 5.1)
adequate depth ≥ 90% [++]	165 (63.7)	183 (76.9)	0.001 *	13.2 (5.1 — 21.0)
recoil ≥ 90% [++]	108 (41.7)	172 (72.3)	<0.001 *	30.6 (22.1 — 38.6)

Welch's t test and Chi-Square test; CPR: cardiopulmonary resuscitation; CI: confidence interval

[+] Mean and standard deviation for rate nad depth measurement

[++] Numbers (percentage) for ≥ 90% of the adequate depth and recoil achieved

* p < .05 significant

Secondary outcome

The survey asked about participants' confidence levels before and after training regarding three parameters (rate, depth, and recoil) using the following question: "On a scale of 1-10, with 1 being not confident and 10 being very confident, how much confidence do you have to perform chest compressions?" The confidence level toward CPR performance was not different between the two groups. The question "how easy to understand the instructor?" was asked to address the ease of understanding. In terms of rate, the QCPR Classroom training group (10.0[9.0-10.0]) showed higher scores, compared to the control group (10.0[8.5-10.0]; *p*=0.01; Table 4).

Table 4. Survey ragarding participants' confidence levels before and after training regarding three parameters (rate, depth, and recoil)

Question	Control (n = 259)	QCPR Classroom (n = 238)	*p* value
How much confidence do you have to perform chest compressions before training?			
rate	5.0 (3.0-8.0)	5.0 (3.0-7.0)	0.33
depth	5.0 (3.0-7.5)	5.0 (3.0-7.0)	0.27
recoil	5.0 (3.0-7.0)	5.0 (3.0-7.0)	0.37
How much confidence do you have to perform chest compressions after training?			
rate	8.0 (7.0-9.0)	8.0 (7.0-9.0)	0.98
depth	8.0 (7.0-9.0)	8.0 (7.0-9.0)	0.96
recoil	8.0 (7.0-9.0)	8.0 (7.0-9.0)	0.76
How easy to understand the feedback from instructor?			
rate	10.0 (8.5-10.0)	10.0 (9.0-10.0)	0.01*

depth	10.0 (8.0-10.0)	10.0 (9.0-10.0)	0.08
recoil	10.0 (8.0-10.0)	10.0 (9.0-10.0)	0.12

Wilcoxon test, Median (IQR)

Survey were rated "On a scale of 1-10, with 1 being not confident and 10 being very confident, how easy was it to understand the instructor?"

Discussion

The 2015 AHA Guidelines recommend the implementation of audio-visual feedback during CPR training, and previous studies indicate that it significantly increases CPR quality [16-25]. CPR quality was significantly higher in the QCPR Classroom group than in the control group. There was a significant increase in achieving ≧90% adequate depth and recoil in the QCPR Classroom training group (27.7% increase in recoil and 39.1% increase in adequate depth). However, there was only a 1.5% increase in adequate recoil and a 29.7% increase in adequate depth in the control group. Skorning et al. found 27.9% higher achievement of correct compression depth with a feedback device compared to results obtained without one [20]. Various types of mannequins have been used for CPR training, but the quality of CPR training is dependent on the instructor, and little is known about the training quality. The GRA has highlighted the importance of high-performance CPR, and knowledge in the general population is needed.

Significant age difference was found, but the previous studies indicated that chest compression delivered by the 13-14 year olds group was similar to what the adult performed and the researchers concluded the performance was depended on weight, age [29], as well as height, BMI, and sex [30]. In our study, the median and IQR for each group was 19(17-23) and 17(16-21), so there is no height and weight difference between two groups and both groups included over 15 years old, so we considered that the age difference was clinically negligible to perform adequate CPR performance.

In our study, 72.3% of the participants in the QCPR Classroom group achieved ≧90% adequate recoil in post-training. Healthcare professionals were previously found to perform incomplete chest recoil in 46% of cases [10]. Teaching the concept of recoil is not easy, and we found that only 1.5% of participants achieved ≧90% adequate recoil in the control group. Contri et al. stated that instruction about recoil must be modified according to the participants' physical characteristics [30]. However, during ordinary community CPR training, the instructor cannot spend much time on each individual and find out who needs to correct their performance.

This was the study to examine the effect of using "QCPR Classroom" training. As Kong et al. concluded, overall CPR quality was improved through QCPR-Classroom based training [27]. The QCPR Classroom group showed significant improvement in CPR skills between post-training and pre-training, which demonstrates the advantages of the concept. The control group also demonstrated significant improvements between post-training and pre-training for rate, depth, and ≧90% adequate depth (Table 2). As shown in Table 3, the QCPR Classroom group was 13.2% higher on ≧90% adequate depth than those in the control group (p=0.001). The QCPR Classroom group was 30.6% higher on ≧90% adequate recoil than those in the control group (p=<0.001). Higher adequate depth and recoil are the significant advantages of the QCPR Classroom. This real-time visual in-action feedback system has been provided a significant impact on CPR performance throughout the CPR practice. The purpose of QCPR Classroom is to make it easy to objectively measure and improve CPR performance in community CPR classes. In a large classroom, learners could see their CPR performance on a big screen at the front of the class. Kong et al. randomized the groups and the instructor only visible the feedback icon on iPad [27]. Students only received objective feedback directly from instructor. Our study randomized the groups and both students and instructor were visible the feedback icon on iPad by arranging on big screen in front of the classroom.

While there is sufficient evidence supporting the benefits of CPR feedback devices during training, this novel "QCPR Classroom" is a unique real-time feedback system that 42 mannequins provide feedback at the same time in the large group training setting, including the quality of recoil. Only one study has examined how "QCPR Classroom" training affects CPR performance improvement of laypeople in the large group setting [27]. One of advantages of QCPR Classroom was to be able to provide student feedback. This is able to make that good educational achievement with fewer instructors. Our model can be given students to have real-time feedback by themselves. Providing high quality CPR training with the lead-instructor:manikin:students ratio of 1:42:84 can be possible.

CPR training has been studied for decades by observing participants and comparing their performance to guidelines. The findings show that training does not provide sufficient practice [31,32], it does not include DA-CPR [33], participants lack preparedness for real situations [32,34-35], and objective student feedback and assessment are not performed [36]. In 1991, Kaye et al. reported that instructors made CPR courses by themselves and included only 10 minutes of practical training [31]. The instructors also performed subjective assessments of the students to let the students pass the course, even though the students would not have passed according to objective measurements or evaluation by researchers [31].

The need for standardized training, more relevant training, and objective assessment has been known since the early 1990s, but most training teaches laypeople to perform CPR alone without dispatcher assistance, and they practice CPR without feedback or performance assessment. We generally do not know what quality of CPR participants will perform during training, but we know that good-quality bystander CPR has positively reflected in survival [37-40]. It is possible to make training for laypeople more relevant and effective by focusing on the most important learning objectives, prioritizing practical training, training people to work in teams with dispatchers, using objective feedback to stimulate good performance, and documenting the results for quality improvement and cultivating a culture of excellence. QCPR Classroom can provide objective feedback on the quality and quantity of CPR.

Abella et al. suggested the use of feedback in a hospital setting [16], and Hostler et al. suggested the use of feedback devices in the EMS field [17]. Tanaka et al. also suggested the implementation of feedback devices in athletic training [41]. It is also highly recommended for even healthcare professionals to use such a device. Laypeople who may encounter situations of cardiac arrest rarely would need to use a feedback device in order to deliver high-quality CPR, which may be directly linked to the chances for survival. An AED with a feedback device is the best method for citizens to deliver higher-quality CPR. We believe that the combination of training with QCPR Classroom and performing CPR with a feedback device in the field would have a positive impact on survival rates.

The AHA recently announced that the use of a feedback device would be mandated in CPR training by January 2019 [9]. Many companies have launched various types of feedback devices [16-25]. In our examination of effectiveness of the QCPR Classroom training, the CPR performance was significantly increased, especially in recoil and adequate depth.

In our opinion, recoil is the most difficult part for participants to perform within such a short time, especially for those who are training in CPR for the first time. The confidence level that learners had toward recoil was 8.0/10.0 in our study, which is the same as for depth and rate in both groups. The hands are off the sternum when teaching full recoil, and incomplete release would occur if the recoil concept was not mentioned. In our opinion, instructors prioritize teaching the concepts of depth and rate rather than recoil because feedback on recoil cannot be given as subjectively. In ordinary CPR training, we assume that the main focus of participants tends to be compressing harder; therefore, participants easily forget recoil and neglect to perform it. Our results showed a significantly increase in adequate depth and no change in recoil in ordinary CPR training, which supports our hypothesis. QCPR Classroom significantly improved the recoil performance, although it did not influence the confidence level.

The definition of high-quality CPR highlights the importance of depth, rate, and recoil. Performing good chest compression with these three factors leads to favourable outcomes. However, CPR instructors must understand the difficulty of achieving appropriate depth, rate, and recoil [42]. Moreover, recent guidelines increasingly emphasize the necessity of high-quality CPR performance by not only EMTs or first responders, but also citizens [42]. School training in CPR is the most certain method of implementing high-quality CPR training in the general population. However, school teachers are not professional CPR instructors or trained in teaching CPR, so there is no guarantee of the teaching quality. QCPR Classroom can deliver sufficient feedback even when school teachers do not have CPR instruction skills. Future studies should examine the effect of QCPR Classroom training conducted by school teachers who have no background in CPR instruction.

With the highlighted importance of objective feedback during CPR training, we hope this pilot study on QCPR Classroom training could be considered as a model for future CPR training. The role of instructors is to emphasize the importance of bystander CPR and Public Access Defibrillation. Therefore, instead of focusing too much on the recoil or another part of high-quality CPR, the importance of immediate initiation of CPR without hesitating should be highlighted during the training. It is still very important to determine how to design these environments and prioritize emergency action plans, such as contacting EMS personnel and summoning other people.

Study limitations

Our study has several limitations. First, the mannequin's chest is not as hard as the human body, so it is not the same in real life. Second, this study was conducted using CPR training that targeted a large amount of lay people, who all performed CPR together. Since chest compression was tested in this environment, the rate measurement may have been influenced by other participants. The metronome was used in the QCPR Classroom group only, but no metronome was used in the control group. Third, the instructors' knowledge may have been questionable since the instructors were learning about the device as the training proceeded. Finally, the study was only measured short-term improvement, not the retention.

Conclusion

The use of a novel “QCPR Classroom” technique to educate a large group of laypeople with real-time visual CPR feedback has been described. We assessed the impact of real-time visual feedback in the context of classroom-based CPR training on CPR quality pre and post-training. The QCPR group had a higher rate of achieving ≧90% adequate depth than the control group and a higher rate of achieving ≧90% adequate recoil. The two groups presented within the suggested range in average depth or rate. From the results, “QCPR Classroom” training could provide significantly higher quality CPR training than ordinary training with subjective assessment by instructors, especially in recoil. The metronome seemed to be offering benefits to the QCPR Classroom group performance. During in-action CPR practice, displaying all student’s feedback on the big screen significantly provided accurate real-time visual feedback to achieve two important components together: compressing the chest with the depth over 5 cm and minimizing the incomplete release the chest. Teaching CPR to larger group laypeople with a real-time feedback system, a novel “QCPR Classroom” could be a great model for the next generation of CPR training.

Acknowledgments

The authors wish to thank all staff members at the Research Institute of Disaster Management and EMS at Kokushikan University for their assistance in this study. The authors also thank Laerdal Medical for their assistance in using QCPR Classroom.

Author Contributions

All authors were involved in the study design. ST carried out all the studies, participated in the sequence alignment, and drafted the manuscript. ST, KT, TH, and HT contributed to the study implementation. HM and TB developed the concept and contributed to technological support. ST, KT, TH, HT, AI, HU, YK, MY and HT were involved in the data collection. RS conducted statistical analysis. ST, RS, and HT performed data analysis. HM and TB revised the manuscript. HT also revised and approved the final manuscript. All authors read and approved the final submission.

Funding

None

Conflict of Interests

Tonje Søraas Birkenes and Helge Myklebust are employees of Laerdal Medical. They contributed the QCPR Classroom prototype, study design, and critical revision of the manuscript, but had no role in data collection, analysis of the results, or decision to publish.

Ethical Approval

The study was approved by the Institutional Review Board at Kokushikan University, Japan.

Data statement

All relevant data are within the paper and its Supporting Information files.

Figure legends

Figure 1. Flow chart of the study

Figure 2. Image of QCPR Classroom feedback system

Figure 3. Image of actual display on the front screen

References

1. Mozaffarian D, Benjamin EJ, Go AS, et al. Heart disease and stroke statistics–2016 update: a report from the American Heart Association. Circulation. 2015;133:e38-e360.
2. Hasselqvist-Ax I, Riva G, Herlitz J, Rosenqvist M, Hollenberg J, Nordberg P, Ringh M, Jonsson M, Axelsson C, Lindqvist J, Karlsson T, Svensson L. Early cardiopulmonary resuscitation in out-of-hospital cardiac arrest. N Engl J Med. 2015;372:2307-2315.
3. Wissenberg M, Lippert FK, Folke F, Weeke P, Hansen CM, Christensen EF, Jans H, Hansen PA, Lang-Jensen T, Olesen JB, Lindhardsen J, Fosbol EL, Nielsen SL, Gislason GH, Kober L, Torp-Pedersen C. Association of national initiatives to improve cardiac arrest management with rates of bystander intervention and patient survival after out-of-hospital cardiac arrest. JAMA. 2013;310:1377-1384.
4. Hansen CM, Kragholm K, Pearson DA, et al. Association of bystander and first-responder intervention with survival after out-of-hospital cardiac arrest in North Carolina, 2010–2013. JAMA. 2015;314:255-264.
5. Iwami T, Kawamura T, Hiraide A, et al. Effectiveness of bystander-initiated cardiac-only resuscitation for patients with out-of-hospital cardiac arrest. Circulation. 2007;116:2900-2907.
6. Takahashi H, Sagisaka R, Natsume Y, Tanaka S, Takyu H, Tanaka H. Does Dispatcher-Assisted CPR generate the same outcomes as spontaneously delivered Bystander CPR in Japan? Am J Emerg Med. (In Press).
7. Nakahara S, Tomio J, Ichikawa M, Nakamura F, Nishida M, Takahashi H, Morimura N, Sakamoto T. Association of bystander interventions with neurologically intact survival

among patients with bystander-witnessed out-of-hospital cardiac arrest in Japan. JAMA. 2015;314:247-54.

8. Global Resuscitation Alliance. Improving Survival from Out-of-Hospital Cardiac Arrest: A Call to Establish a Global Resuscitation Alliance. (Accessed 2 December 2017, at http://www.laerdalevents.com/gra/wp-content/pdf/call_to_establish.pdf)

9. American Heart Association. AHA requirement on Use of feedback devices in adult CPR training courses. (Accessed 1 September 2017, at http://ahainstructornetwork.americanheart.org/idc/groups/ahaecc-public/@wcm/@ecc/documents/downloadable/ucm_495639.pdf.)

10. Aufderheide TP, Pirrallo RG, Yannopoulos D, et al. Incomplete chest wall decompression: a clinical evaluation of CPR performance by EMS personnel and assessment of alternative manual chest compression-decompression techniques. Resuscitation. 2005;64:353-362.

11. Sutton RM, Niles D, Nysaether J, et al. Quantitative Analysis of CPR Quality During In-Hospital Resuscitation of Older Children and Adolescents. Pediatrics. 2009;124(2):494-9.

12. American Heart Association. Highlights of the 2015 American Heart Association guidelines update for CPR and ECC. Texas, American Heart Association, 2015. (Accessed 1 September 2017, at https://eccguidelines.heart.org/wp-content/uploads/2015/10/2015-AHA-Guidelines-Highlights-English.pdf)

13. Yannopoulos S, McKnite S, Aufderheide TP, Sigurdsson G, Pirrallo RG, Benditt D, Lurie KG. Effect of incomplete chest wall decompression during cardiopulmonary resuscitation

on coronary and cerebral perfusion pressures in a porcine model of cardiac arrest. Resuscitation. 2005;64:363-72.

14. Neumar RW, Shuster M, Callaway CW, et al. 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care, Part 1: Executive Summary. Circulation. 2015;132:S315–67.

15. Perkins GD, Handley AJ, Koster RW, et al. European Resuscitation Council Guidelines for Resuscitation 2015 Section 2. Adult basic life support and automated external defibrillation. Resuscitation. 2015;95:81-99.

16. Abella BS, Edelson DP, Kim S, et al. CPR quality improvement during in-hospital cardiac arrest using a real-time audiovisual feedback system. Resuscitation. 2007;73(1):54–61.

17. Hostler D, Everson-Stewart S, Rea TD, et al; Effect of real-time feedback during cardiopulmonary resuscitation outside hospital: prospective, cluster-randomised trial. BMJ 2011;342(d512):1-10.

18. Buleon C, Delaunay J, Parienti J.-J., Halbout L., Arrot X, Gerard J.-L., Hanouz J.-L. Impact of a feedback device on chest compression quality during extended manikin CPR: a randomized crossover study. Am J Emerg Med. 2016;34:1754-1760.

19. Bobrow BJ, Vadeboncoeur TF, Stolz U, et al. The influence of scenario-based training and real-time audiovisual feedback on out-of-hospital cardiopulmonary resuscitation quality and survival from out-of-hospital cardiac arrest. Ann Emrg Med. 2013;62(1):47-56.

20. Skorning M, Beckers SK, Brokmann JC, et al. New visual feedback device improves performance of chest compressions by professionals in simulated cardiac arrest. Resusciation. 2010;81:53-58.

21. Buleon C, Parienti J-J, Halbout L, et al. Improvement in chest compression quality using a feedback device (CPRmeter): a stimulation randomized crossover study. Am J Emerg Med. 2013;31:1457-1461.

22. Kramer-Johansen J, Myklebust H, Wik L, et al. Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: a prospective interventional study. Resuscitation. 2006;71:283-292.

23. Cheng A, Brown LL, Duff JP, et al.; International Network for Simulation-Based Pediatric Innovation, Research, & Education (INSPIRE) CPR Investigators. Improving cardiopulmonary resuscitation with a CPR feedback device and refresher simulations (CPR CARES Study): a randomized clinical trial. JAMA Pediatr. 2015; 169:137-44.

24. Cheng A, Overly F, Kessler D, et al.; International Network for Simulation-Based Pediatric Innovation, Research, & Education (INSPIRE) CPR Investigators. Perception of CPR quality: Influence of CPR feedback, Just-in-Time CPR training and provider role. Resuscitation 2015;87:44-50.

25. White AE, Ng HX, Ng WY, Ng EKX, Fook-Chong S, Kua PHJ, Ong MEH. Measuring the effectiveness of a novel CPRcard^{TM} feedback device during stimulated chest compressions by non-healthcare workers. Singapore Med J 2017:58:438-445.

26. Tanaka S, White AE, Sagisaka R, et al. Comparison of quality of chest compressions during training of laypersons using Push Heart and Little Anne manikins using blinded CPRcards. Int Emerg Med. 2017;10(1):20.

27. Kong SY, Shin SD, Song KJ, et al. Effect of instructor's real-time feedback using QCPR-classroom device during layperson cardiopulmonary resuscitation (CPR) training

on quality of CPR Performances: A prospective cluster-randomised trial. BMJ Open. 2018;8:doi:10.1136/bmjopen-2018-EMS.25.

28. Hernández-Padilla JM, Suthers F, Granero-Molina J, Fernández-Sola C. Effects of two retraining strategies on nursing students' acquisition and retention of BLS/AED skills: A cluster randomised trial. Resuscitation. 2015;93:27-34.

29. Jones I, Whitefield R, Colquhoun M, Chamberlain D, Vetter N, Newcombe R, et al. At what age can schoolchildren provide effective chest compressions? AN observational study from the Heartstart UK schools training programme. BMJ. 2007;334:1201.

30. Contri E, Cornara S, Somaschini A, et al.Complete chest recoil during laypersons' CPR: Is it a matter of weight? Am J Emerg Med. 2017;35:1266-1268.

31. Kaye W, Rallis SF, Mancini ME, et al. The problem of poor retention of cardiopulmonary resuscitation skills may lie with the instructor, not the learner or the curriculum. Resuscitation. 1991;21:67-87.

32. Parnell MM, Larsen PD. Poor quality teaching in lay person CPR courses. Resuscitation. 2007;73:271-278.

33. Wagner P, Lingemann C, Arntz HR, Breckwoldt J. Official lay basic life support courses in Germany: is delivered content up to date with the guidelines? An observational study. Emerg Med J. 2015;32(7):547-52.

34. Møller TP, Hansen CM, Fjordholt M, Pedersen BD, Østergaard D, Lippert FK. Debriefing bystanders of out-of-hospital cardiac arrest is valuable. Resuscitation. 2014;85:1504-1511.

35. Hirose T, Iwami T, Ogura H, et al. Effectiveness of a simplified cardiopulmonary resuscitation training program for the non-medical staff of a university hospital. Scand J Trauma Resusc Emerg Med. 2014;22(31):1-7.

36. Lynch B, Einspruch EL, Nichol G, Aufderheide TP. Assessment of BLS skills: optimizing use of instructor and manikin measures. Resuscitation. 2008;76:233-243.

37. Wik L, Steen PA, Bircher NG. Quality of bystander cardiopulmonary resuscitation influences outcome after prehospital cardiac arrest. Resuscitation. 1994;28:195-203.

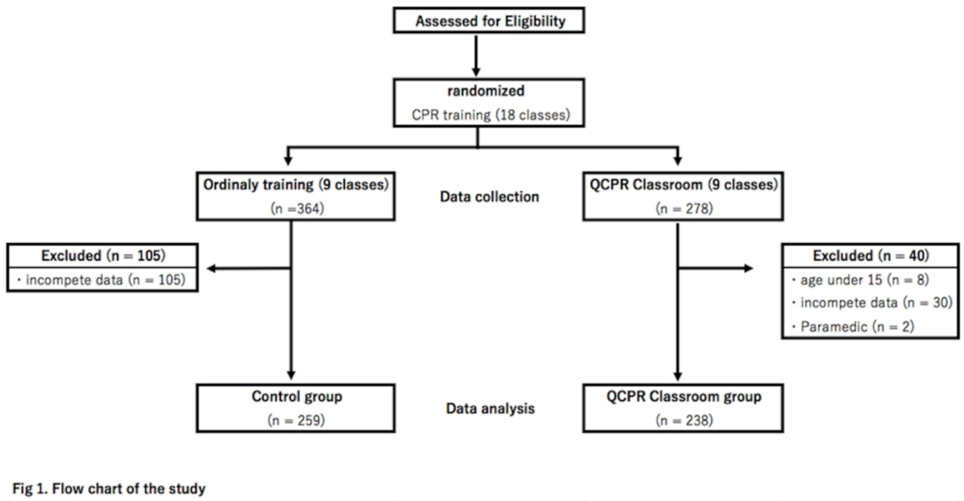
38. Van Hoeyweghen RJ, Bossaert LL, Mullie A, et al. Quality and efficiency of bystander CPR. Resuscitation. 1993;26:47-52. Emerg Med J. 2014;0:1-6.

39. Gallagher EJ, Lombardi G, Gennis P. Effectiveness of bystander cardiopulmonary resuscitation and survival following out-of-hospital cardiac arrest. JAMA. 1995;274:1992-1925.

40. Takei Y, Nishi T, Matsubara H, Hashimoto M, Inaba H. Factors associated with quality of bystander CPR: the presence of multiple rescuers and bystander-initiated CPR without instruction. Resuscitation. 2014;85:492-498.

41. Tanaka S, Rodrigues W, Sotir S, Sagisaka R, Tanaka H. CPR Performance in the Presence of Audiovisual Feedback or Football Shoulder Pads. BMJ Open Sport Exerc Med. 2017;3(1):e000208.

42. Japan Resuscitation Council. Chapter 8 ETI: Education, Implementation, and Teams. (Accessed 2 December 2017, at http://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/b7b5b647189bc07f38f6fecf014cf5d9.pdf).



Flow chart of the study

Fig 2. Image of QCPR Classroom feedback system

Image of QCPR Classroom feedback system

Fig 3. Image of actual display on the front screen

Image of actual display on the front screen

Reporting checklist for qualitative study.

Based on the SRQR guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the SRQR reporting guidelines, and cite them as:

O'Brien BC, Harris IB, Beckman TJ, Reed DA, Cook DA. Standards for reporting qualitative research: a synthesis of recommendations. Acad Med. 2014;89(9):1245-1251.

		Reporting Item	Page Number
	#1	Concise description of the nature and topic of the study identifying the study as qualitative or indicating the approach (e.g. ethnography, grounded theory) or data collection methods (e.g. interview, focus group) is recommended	1
	#2	Summary of the key elements of the study using the abstract format of the intended publication; typically includes background, purpose, methods, results and conclusions	2-3
Problem formulation	#3	Description and signifcance of the problem / phenomenon studied: review of relevant theory and empirical work; problem statement	5-6
Purpose or research question	#4	Purpose of the study and specific objectives or questions	6
Qualitative approach and research paradigm	#5	Qualitative approach (e.g. ethnography, grounded theory, case study, phenomenolgy, narrative research) and	7

		guiding theory if appropriate; identifying the research paradigm (e.g. postpositivist, constructivist / interpretivist) is also recommended; rationale. The rationale should briefly discuss the justification for choosing that theory, approach, method or technique rather than other options available; the assumptions and limitations implicit in those choices and how those choices influence study conclusions and transferability. As appropriate the rationale for several items might be discussed together.	
Researcher characteristics and reflexivity	#6	Researchers' characteristics that may influence the research, including personal attributes, qualifications / experience, relationship with participants, assumptions and / or presuppositions; potential or actual interaction between researchers' characteristics and the research questions, approach, methods, results and / or transferability	7
Context	#7	Setting / site and salient contextual factors; rationale	8
Sampling strategy	#8	How and why research participants, documents, or events were selected; criteria for deciding when no further sampling was necessary (e.g. sampling saturation); rationale	n/a
Ethical issues pertaining to human subjects	#9	Documentation of approval by an appropriate ethics review board and participant consent, or explanation for lack thereof; other confidentiality and data security issues	7
Data collection methods	#10	Types of data collected; details of data collection procedures including (as appropriate) start and stop dates of data collection and analysis, iterative process, triangulation of sources / methods, and modification of procedures in response to evolving study findings; rationale	7-8
Data collection instruments and technologies	#11	Description of instruments (e.g. interview guides, questionnaires) and devices (e.g. audio recorders) used for data collection; if / how the instruments(s) changed over the course of the study	9-10
Units of study	#12	Number and relevant characteristics of participants, documents, or events included in the study; level of	8

		participation (could be reported in results)	
Data processing	#13	Methods for processing data prior to and during analysis, including transcription, data entry, data management and security, verification of data integrity, data coding, and anonymisation / deidentification of excerpts	9-10
Data analysis	#14	Process by which inferences, themes, etc. were identified and developed, including the researchers involved in data analysis; usually references a specific paradigm or approach; rationale	10
Techniques to enhance trustworthiness	#15	Techniques to enhance trustworthiness and credibility of data analysis (e.g. member checking, audit trail, triangulation); rationale	10-11
Syntheses and interpretation	#16	Main findings (e.g. interpretations, inferences, and themes); might include development of a theory or model, or integration with prior research or theory	11-14
Links to empirical data	#17	Evidence (e.g. quotes, field notes, text excerpts, photographs) to substantiate analytic findings	n/a
Intergration with prior work, implications, transferability and contribution(s) to the field	#18	Short summary of main findings; explanation of how findings and conclusions connect to, support, elaborate on, or challenge conclusions of earlier scholarship; discussion of scope of application / generalizability; identification of unique contributions(s) to scholarship in a discipline or field	15-20
Limitations	#19	Trustworthiness and limitations of findings	20
Conflicts of interest	#20	Potential sources of influence of perceived influence on study conduct and conclusions; how these were managed	22
Funding	#21	Sources of funding and other support; role of funders in data collection, interpretation and reporting	22

BMJ Open

Effect of real-time visual device QCPR Classroom with a metronome sound in a layperson CPR training: A cluster randomized control trial

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-026140.R1
Article Type:	Research
Date Submitted by the Author:	09-Feb-2019
Complete List of Authors:	Tanaka, Shota; Kokushikan University, Research Institute of Disaster Management and EMS, Tsukigase, Kyoko; Kokushikan University, Research Institute of Disaster Management and EMS, Hara, Takahiro; Kokushikan University, Graduate School of EMS System Sagisaka, Ryo; Kokushikan University, Graduate School of EMS System Myklebust, Helge; Laerdal Medical Cooperation Birkenes, Tonje; Laerdal Medical Cooperation Takahashi, Hiroyuki; Kokushikan University, Research Institute of Disaster Management and EMS, Iwata, Ayana; Kokushikan University, Research Institute of Disaster Management and EMS, Kidokoro, Yutaro; Kokushikan University, Research Institute of Disaster Management and EMS, Yamada, Momoyo; Kokushikan University, Research Institute of Disaster Management and EMS, Ueta, Hiroki; Meiji University of Integrative Medicine, Faculty of Emergency Medical Science Takyu, Hiroshi; Kokushikan University, Graduate School of EMS System Tanaka, Hideharu; Kokushikan University, Graduate School of EMS System; Kokushikan University, Research Institute of Disaster Management and EMS,
Primary Subject Heading:	Medical education and training
Secondary Subject Heading:	Emergency medicine, Medical education and training
Keywords:	bystander, cardiac arrest, CPR training, resuscitation, Mass CPR training

Title: Effect of real-time visual device QCPR Classroom with a metronome sound in a layperson CPR training: A cluster randomized control trial

Shota Tanaka [1)], Kyoko Tsukigase [1)], Takahiro Hara [2)], Ryo Sagisaka [2)], Helge Myklebust [3)], Tonje S. Birkenes [3)], Hiroyuki Takahashi [1) 4)], Ayana Iwata [1)], Yutaro Kidokoro [1)], Momoyo Yamada [1)], Hiroki Ueta [5)], Hiroshi Takyu [2)], Hideharu Tanaka [1) 2)]

1) Research Institute of Disaster Management and EMS, Kokushikan University
2) Graduate School of EMS System, Kokushikan University
3) Laerdal Medical, Stavanger, Norway
4) Department of Sports Medicine, Kokushikan University, Japan
5) Faculty of Emergency Medical Science, Meiji University of Integrative Medicine

Correspondence author: SHOTA TANAKA

Kokushikan University, 7-3-1, Nagayama, Tama City, Tokyo, JAPAN

E-mail: tanakamedical24@gmail.com

TEL/FAX: +81-42-339-7197

Keywords: cardiac arrest, bystander, CPR training, resuscitation, Mass CPR training

Word Count: 4133

Abstract

Objectives "Quality Cardiopulmonary Resuscitation (QCPR)-Classroom" device has recently introduced to provide a higher quality of CPR training. The aim of this study was to examine whether novel QCPR-Classroom training can lead to higher chest compression quality than standard CPR training.

Setting Layperson CPR training

Design A cluster randomized control trial was conducted to compare standard CPR training (control) and QCPR-Classroom (intervention) groups.

Participants A total of 642 people age over 15 years were recruited from among CPR trainees.

Interventions CPR performance data in both groups was registered without any feedback on instrumented Little Anne prototypes for one minute pre- and post-training.

Primary and secondary outcome measures The primary outcome was compression depth (mm), rate (compressions per minute [cpm]), percentage of adequate depth (%), and recoil (%). The scores from the survey were considered as a secondary outcome. The survey included about the participants' confidence level about the rate, depth, and recoil on pre- and post-training, as well as the ease of understanding feedback from instructor.

Results There were 259 people in the control group and 238 people in the QCPR-Classroom group who were eligible for analysis. After training, the mean compression depth and rate were 56.1±9.8mm and 119.2±7.3 cpm in the control group and 59.5±7.9mm and 116.8±5.5cpm in the QCPR-Classroom group, respectively. The QCPR-Classroom group showed a significantly higher percentage of adequate depth than the control group (p=0.001). The difference between pre- and post-training of adequate recoil was 2.7% in the control

group (95% CI, -1.7-7.1; pre 64.2±36.5% vs. post 66.9±34.6%; p=0.23) and 22.6% in the QCPR-Classroom group (95% CI, 17.8-27.3; pre 64.8±37.5% vs. post 87.4±22.9%; p<0.0001). The sound from a metronome set at 110 beats per minute had a positive influence on the CPR performance.

Conclusion The QCPR-Classroom concept helped students achieve high-quality CPR training, especially for proper compression depth and full recoil. To reach a good educational achievement, a novel QCPR Classroom with a metronome sound is a recommended CPR training model.

Article Summary

The paper describes the use a novel "QCPR classroom" technique with a metronome sound to educate laypeople in CPR. A large classroom in which learners could see their CPR performance on a big screen at the front of the class was used. Students were randomized into a control group and a QCPR classroom group. They were assessed on their ability to perform 1 minute of chest compression-only CPR. Post training results showed that the QCPR group had 13.6% better adequate depth and 20.5% better adequate recoil than the control group. However, there was no difference in average depth or rate between the two groups. The American Heart Association recommends use of audiovisual feedback device during CPR education. Benefits of visual feedback devices are well accepted and agreed. QCPR classroom concept is a fancy new idea for mass-CPR training.

Strengths and limitations of this study

- One of the advantages of CPR training carried by QCPR Classroom concept is a good educational achievement with fewer instructors.

- Arranging objective real-time feedback on big screen in front of everyone to visible to both instructor and students made significantly improve CPR quality.

- No retention measurement was taken and the measurements were all students together

Introduction

The burden of cardiovascular diseases and the increasing cases of out-of-hospital cardiac arrest (OHCA) remain a global concern [1]. Performing bystander cardiopulmonary resuscitation (CPR) is one factor that can increase the survival rate of OHCA [2-7]. The survival rate may be directly linked to the number of bystanders trained in CPR [2]. As a complement to the 2015 American Heart Association (AHA) and Japan Resuscitation Council (JRC) Guideline, the Global Resuscitation Alliance (GRA) was recently established to improve OHCA survival, and high-performance CPR was highlighted: a push depth of 5-6 cm, rate of 100-120 compressions per minute (cpm), full recoil, and minimizing interruptions for chest compressions (less than 10 seconds) [8-10]. In the GRA consensus, mandatory School and Community CPR was listed as one of the 10 steps to increase OHCA survival [8].

Healthcare professionals were found to perform incomplete compression recoil in 46% of all cases and in 23.4% of cases involving paediatric patients [11-12]. However, performing full recoil is emphasized in the GRA consensus, along with the use of a feedback device during CPR training [10]. Incomplete recoil leads to insufficient time for blood to fill into the heart, which eventually leads to less blood flow to the brain [8]. Coronary and cerebral perfusion pressure can deteriorate due to incomplete decompression [13]. Full recoil is one of the most important concepts for ensuring high-quality CPR [10,14,15]. Key points during CPR training are teaching to compress the chest 5 cm deep and allowing for full chest recoil, but these two components are hard to achieve during training without a feedback device.

We are currently facing a period of transition to CPR training with a feedback device, as various feedback devices were introduced, and research supported their effectiveness [16-28]. However, they are unavailable for CPR training that targets a large population. Laerdal Medical (Stavanger, Norway) launched the "QCPR Classroom" concept, which provides real-time visual feedback for a greater number of participants at once. The effectiveness of the QCPR Classroom device was recently demonstrated by Kong et al. [29]. The purpose of this study is to examine the effectiveness of CPR skills delivered by QCPR Classroom feedback in training in compared to standard CPR training. The hypothesis of the study was that QCPR Classroom would generate higher achievement in CPR skill regardless of instructors' teaching skill. We aimed to determine whether QCPR Classroom could be the best practical model for CPR training.

Methods

Study population and design

Prior to the CPR training and study enrolment, oral informed consent was obtained from all participants. The study was approved by the Institutional Review Board at Kokushikan University. Sample size calculation was based on adequate depth from our pilot trial that we compared the effect of the QCPR Classroom. We calculated sample size of 232, with 90% power to detect a percentage of adequate compression depth between two groups (α= 0.05). To reach a power of 90%, 41 was needed per group in parallel, and design effect was 5.66. 15% was detected as a deficit due to a mechanical issue, so 272 per group was calculated as a sample size. A total of 642 people were recruited from among CPR trainees who were enrolled in the Heart Saver Japan CPR training, which was held between March and September 2017. The inclusion criteria was age over 15 years. The exclusion criteria was the presence of upper extremity injury within the past 6 months, working as a healthcare professional who is regularly involved in resuscitation, such as Emergency Medical Technicians (EMTs), paramedics, and emergency room physician or nurses. Previous CPR training status and quantity and timing of previous trainings were not used as inclusion or exclusion criteria.

Measurements

Participants enrolled in the CPR+automated external defibrillator (AED) training. The primary outcome was compression depth (mm), compression rate (compressions per minute [cpm]), adequate depth (%), and adequate recoil (%). These measurements were carried out without any feedback for the trainees on both pre- and post-training for one minute on the basis that the bystander should change every one minute during chest compression-only CPR [30]. The scores from a survey conducted after the training were considered as a secondary outcome. The survey included about the participants' confidence level about the rate, depth, and recoil on pre- and post-training, as well as the ease of understanding feedback from instructor. The survey was rated *"On a scale of 1-10, with 1 being very difficult and 10 being very easy, how do you rate the ease of understanding the feedback from instructor."* and *"On a scale of 1-10, with 1 being not confident and 10 being very confident, how much confidence do you have to perform chest compression before and after training."* The survey is able to be accessed in Appendix.

Study procedure

A cluster randomized controlled trial (cRCT) was used (allocation ratio 1:1). A researcher (R.S) generated a randomization list and block-two randomized was performed. R.S. was not involved in the data collection and worked on statistics independently. Each session was randomly assigned to the intervention (standard or QCPR Classroom). Four lead instructors who have worked as healthcare professionals and have had over 5 years of experience in teaching CPR were selected from the Heart Saver Japan organization. The data collection took place during the Heart Saver Japan CPR+AED training sessions. The training focused on Basic Life Support, including CPR skills and AED according to the JRC 2015 Guideline. Students were not medical personnel, so we instructed compression-only CPR. No pre-assignment or e-learning was given. The training was started with a power point presentation-based instructor-led lecture followed by psychomotor practice. Psychomotor practice focused on chest-compression CPR. The sequence of the psychomotor practice is as follows: 1) Keys of compression: depth, rate, recoil, 2) single rescuer chest compression-only CPR, 3) two bystander chest compression-only CPR, focusing on minimizing interruptions, 4) check respiration, 5) scene safety, check consciousness, and call for help 6) the use of AED, 7) practice from" scene safety" to "resume chest compression after giving a shock", 8) scenario-based training. A total of 18 CPR training sessions were studied, with 9 standard CPR training (control group) and 9 QCPR Classroom sessions (Figure 1).

In the QCPR Classroom group, participants received subjective and objective feedback from the instructor based on real-time feedback through the manikin, and participants were able to correct themselves from feedback displayed on the screen of the device (Figure 2). The control group was given only instructor's subjective feedback, so metronome sound was not used, which hand clap was allowed to give based on instructor's experience. As the AHA made the statement, audio-visual feedback is mandated to use [31]. QCPR Classroom only provides visual feedback, so we used sound as an auditory aid for instruction in the QCPR Classroom group.

To measure the effect of CPR training, one minute of chest compression was measured without any feedback given as a pre-test. Similarly to the pre-test, one minute of chest compression was also measured after the training as a post-test. Although one minute of measurement may not be sufficient duration for CPR performance in real life, we focused on the initial CPR performance by a single rescuer situation. A survey and baseline characteristics, such as weight, height, and CPR training experience (Table 1), were also collected after the post-training measurement. The metronome was set at 110 beats per minute (bpm) and used for every instance of hands-on practice during the QCPR Classroom session, but no metronome was used during the standard CPR training.

Table 1. Demographic Characteristics

	Control (n = 259)	QCPR Classroom (n = 238)	*p* value
Age, mean±SD	22.4 ± 9.0	19.4 ± 5.6	<.0001 *
median (IQR)	19 (17-23.5)	17 (16-21)	<.0001 *
Male, (%)	130 (50.2)	101 (42.4)	0.08
height, mean	164.5 ± 14.3	164.2 ± 8.2	0.47
weight, mean	57.9 ± 12.1	56.0 ± 9.6	0.06
BMI, mean	21.1 ± 3.1	20.7 ± 2.6	0.07
CPR training, (%)	203 (78.4)	170 (71.4)	0.07
CPR training within 1 year, (%)	89 (41.2)	63 (36.4)	0.34

CPR: cardiopulmonary resuscitation; SD: standard deviation; IQR; interquartile range; BMI: body mass index

* p < .05 significant

Instrumentation

Compression data was registered using the Laerdal QCPR Classroom manikin system (Laerdal Medical, Stavanger, Norway), as shown in Figure 2. This prototype system for community CPR training provides real-time visual feedback from 42 manikins, where icons representing CPR performance from each manikin are visualized on an iPad tablet. We mirrored the iPad screen on a laptop using the application Reflector 2 (Squirrels®, North Canton, OH, United States) in order to present real-time feedback on a large screen at the front of the classroom (Figure 3). QCPR Classroom uses Laerdal Little Anne manikin, and each one is instrumented with an optical compression sensor and microcontroller. The microcontroller analyses the signal from the compression sensor and calculates the number of compressions, compression depth, rate, and incomplete release. A compression score is calculated using the rate, depth, and release. Each sensor was checked for depth accuracy using a calibrated compression machine with ±15% considered as acceptable error.

The microcontroller also compares the compression performance with guidelines from the 2015 AHA requirements. Deviations from the guidelines are reported as "too shallow", "incomplete release", "too fast", or "too slow", and deviation in each factor is presented as yellow icons on the tablet. If the compression performance is good, a green "Everything OK" icon is presented. Data from the tablet is sent to a Microsoft Azure cloud service and made available as downloadable *.csv* files, which include the following parameters from each manikin and CPR session: the number of compressions, average compression rate, average compression depth, number of compressions with adequate depth, number of compressions with acceptable release, compression score, time, and location of use. The control group also used the same Laerdal Little Anne manikins. However, we did not use a screen to show students an objective feedback. During the training in the control group, lead-instructor were not allowed to access iPad, so they only gave subjective feedback to the students.

Statistical analysis

The rate and depth measurements are shown as the mean and standard deviation. Normal distributions and homogeneity of variance were confirmed by a Q-Q plot. The differences and 95% confidence intervals are shown in tables. The adequate depth and recoil were calculated as percentages. Analysing the percentage variables to compare the numerical value using a parametric test, such as a t-test. The difference between pre- and post-training measurements within the groups were analysed using a paired t-test and McNemar test. Group comparison for both pre- and post-training was conducted using Welch's t-test and the chi-square test. The medians and interquartile ranges are presented for ordinal data. We compared the groups using the Wilcoxon single-rank test. The data was analysed using JMP (V.11.2.0, the SAS Institute Inc.), and *p*-values less than 0.05 were considered as significant.

Results

Demographic characteristics

A total of 642 people participated in this study. As shown in Figure 1, 145 participants were excluded due to incomplete data (n = 135), age under 15 years (n = 8), and paramedics (n = 2). Significant age difference between the groups was found (22.4±9.0 vs. 19.4±5.6; *p*=<.0001). A statistical difference in age among individuals in clusters, yet the standard deviation and IRQ ranges overlap. The age variation was not clinically significant due to overlap of precision measured. After the CPR training, 497 participants were eligible for analysis, with 259 people in the control group and 238 people in the QCPR Classroom group. The demographic characteristics are shown in Table 1.

Primary outcome

All chest compression parameters at pre-training and post-training are shown in Table 2. After the training, the mean compression depth of each student was 56.1±9.8 mm in the control group and 59.5±7.9 mm in the QCPR Classroom group. Significantly more participants in the QCPR Classroom group achieved higher adequate depth compared to the control group ($p < 0.001$; Table 3). In the QCPR Classroom group, there was an improvement of 39.0% (95% CI, 33.8-44.2) in the percentage of the adequate depth (48.3±44.2% at pre-training vs. 87.3±24.8% at post-training). In the control group, the improvement was 20.0% (95% CI, 15.4-24.7) in the percentage of the adequate depth (53.6±38.9% at pre-training vs. 73.7±37.3% at post-training; $p < 0.0001$; Table 2).

Both groups demonstrated average compression rates of 100-120 cpm (Table 2). A statistically significant difference was found between groups in terms of recoil ($p < 0.001$; Table 3). The control group demonstrated a 2.7% (95% CI, -1.7—7.1) increase in the percentage of recoil (64.2±36.5% pre-training vs. 66.9±34.6% post-training; $p = 0.23$). The QCPR Classroom group demonstrated a 22.6% (95% CI, 17.8—27.3) increase in the percentage of recoil (64.8±37.5% pre-training vs. 87.4±22.9% post-training; $p < 0.0001$; Table 2).

Table 2. Comparison in CPR performance competency between pre- and post-training in each groups

	Control (n = 259)				QCPR Classroom (n = 238)			
	Pre-training	Post-training	*p* value	Difference (95% CI)	Pre-training	Post-training	*p* value	Difference (95% CI)
rate (cpm) +	121.4 ±15.5	119.2 ±7.3	0.02 *	-2.3 (-4.2 - -0.3)	115.7 ± 19.0	116.8 ± 5.5	0.39	1.1 (-1.4 - 3.6)
depth (mm) +	51.4 ±11.6	56.1 ±9.8	<0.0001 *	4.6 (3.5 - 5.8)	48.2 ± 14.7	59.5 ± 7.9	<0.0001 *	11.3 (9.8 - 12.8)
adequate depth (%) ++	53.6 ±38.9	73.7 ±37.3	<0.0001 *	20.0 (15.4 — 24.7)	48.3 ± 44.2	87.3 ± 24.8	<0.0001 *	39.0 (33.8 — 44.2)

adequate recoil (%) ++	64.2 ±36.5	66.9 ±34.6	0.23	2.7 (-1.7 — 7.1)	64.8 ± 37.5	87.4 ±22.9	<0.0001 *	22.6 (17.8 — 27.3)

paired-t test and McNemar test; CPR: cardiopulmonary resuscitation; CI: confidence interval

+ Mean and standard deviation for rate and depth measurement

++ Numbers (percentage) for the adequate depth and recoil

* p < .05 significant

Table 3. The difference of CPR performance competency between the control group and QCPR Classroom group at pre- and post-training

	Control (n = 259)	QCPR Classroom (n = 238)	*p* value	Difference (95% CI)
Pre-training test				
rate (cpm) +	121.4 ±15.5	115.7 ± 19.0	<0.001 *	-5.7 (-8.7 - -2.6)
depth (mm) +	51.4±11.6	48.2 ± 14.7	0.008 *	-3.2 (-5.5 - -0.85)
adequate depth (%) ++	53.6 ±38.9	48.3 ± 44.2	0.15	-5.3 (-12.7 — 2.0)

adequate recoil (%) ++	64.2 ±36.5	64.8 ± 37.5	0.84	3.3 (-5.9 – 7.2)
Post-training test				
rate (cpm) +	119.2 ± 7.3	116.8 ± 5.5	<0.001 *	-2.3 (-3.5 - -1.2)
depth (mm) +	56.1 ±9.8	59.5 ± 7.9	<0.001 *	3.5 (1.9 - 5.1)
adequate depth (%) ++	73.7 ±37.3	87.3 ± 24.8	<0.001 *	13.6 (8.0 – 19.2)
adequate recoil (%) ++	66.9 ±34.6	87.4 ±22.9	<0.001 *	20.5 (15.3 – 25.7)

Welch's t test and Chi-Square test; CPR: cardiopulmonary resuscitation; CI: confidence interval

+ Mean and standard deviation for rate and depth measurement

++ Numbers (percentage) for the adequate depth and recoil

* p < .05 significant

Secondary outcome

The survey included about participants' confidence levels before and after training regarding three parameters (rate, depth, and recoil) using the following question: "*On a scale of 1-10, with 1 being not confident and 10 being very confident, how much confidence do you have to perform chest compressions?*" The confidence level toward CPR performance was not different between the two groups. The question "*how do you rate the ease of understanding the feedback from instructor?*" was asked to address the ease of understanding. A significance difference was seen regarding the rate feedback from instructor, which the QCPR Classroom training group (10.0[9.0-10.0]) showed higher scores, compared to the control group (10.0[8.5-10.0]; *p*=0.01; Table 4).

Table 4. Survey regarding the ease of understanding the feedback from instructor and confidence levels before and after training on three parameters (rate, depth, and recoil)

Question	Control (n = 259)	QCPR Classroom (n = 238)	*p* value
*** How much confidence do you have to perform chest compressions before training?**			
rate	5.0 (3.0-8.0)	5.0 (3.0-7.0)	0.33
depth	5.0 (3.0-7.5)	5.0 (3.0-7.0)	0.27
recoil	5.0 (3.0-7.0)	5.0 (3.0-7.0)	0.37
*** How much confidence do you have to perform chest compressions after training?**			
rate	8.0 (7.0-9.0)	8.0 (7.0-9.0)	0.98
depth	8.0 (7.0-9.0)	8.0 (7.0-9.0)	0.96
recoil	8.0 (7.0-9.0)	8.0 (7.0-9.0)	0.76
**** How do you rate the ease of understanding the feedback from instructor?**			
rate	10.0 (8.5-10.0)	10.0 (9.0-10.0)	0.01*
depth	10.0 (8.0-10.0)	10.0 (9.0-10.0)	0.08
recoil	10.0 (8.0-10.0)	10.0 (9.0-10.0)	0.12

Wilcoxon test, Median (IQR)

* The survey was rated on "*On a scale 1 to 10, with 1 being not confident and 10 being very confident, how much confidence do you have to perform chest compression before and after training?*"

** The survey was rated on "*On a scale 1 to 10, with 1 being very difficult and 10 being very easy, how do you rate the ease of understanding the feedback from instructor?*"

Discussion

The 2015 AHA Guidelines recommend and the AHA announced in 2017 that use of audio-visual feedback would be mandated in all CPR training [8,14,31], and previous studies indicate that the use of feedback for CPR performance significantly improve CPR quality [16-28]. CPR quality was significantly better in the QCPR Classroom group than in the control group. There was a significant increase in the percentage of adequate depth and recoil in the QCPR Classroom training group (39.0% increase in adequate depth and 22.6% increase in recoil). However, there was 20.0% increase in adequate depth and 2.7% increase in adequate recoil in the control group. Skorning et al. found 73.1 % of participant who used a feedback device achieved correct depth and 45.2% of participant who did not use a feedback device achieved correct depth [20]. Cartigiani et al. tested a QCPR Skillreporter feedback model where school children were allowed to practice two-minute compression only sessions CPR while receiving real time feedback on a computer screen, aiming at a 60% overall compression score [32]. Following the practice, the students received overall performance feedback from the computer. This model used equipment designed for smaller groups. While QCPR Classroom can handle 42 mannikins simultaneously and feedback is given on only one parameter at the time, Cartigiani et al. used a system that can handle 6 mannikins simultaneously which give feedback on depth, rate and leaning simultaneously [32]. From our study, the compression depth was 59.5±7.9 mm in the QCPR Classroom group and 56.1±9.8 mm in the control group on post-training. The number of subjects who compressed greater than 60mm is 105 in the QCPR Classroom and 90 in the control group. None of the subjects in the QCPR Classroom group performed below 50mm on post-test, however, 64 subjects in the control group still did not reach 50mm on post-test.

Various types of manikins have been used for CPR training, but the quality of CPR training is dependent on the instructor, and little is known about the training quality. The GRA has highlighted the importance of high-performance CPR, and knowledge in the general population is needed. Significant age difference was found, but the previous studies indicated that chest compression delivered by the 13-14 year olds group was similar to what the adult performed and the researchers concluded the performance was depended on weight, age [33], as well as height, BMI, and sex [34]. In our study, the median and IQR for each group was 19(17-23) and 17(16-21), so there is no height and weight difference between two groups and both groups included over 15 years old, so we considered that the age difference was clinically negligible to perform adequate CPR performance.

Healthcare professionals were previously found to perform incomplete chest recoil in 46% of cases [11]. Teaching the concept of recoil is not easy, as we found that only 2.7% increase in the control group. Contri et al. stated that instruction about recoil must be modified according to the participants' physical characteristics [34]. However, during standard community CPR training, the instructor cannot spend much time on each individual and find out who needs to correct their performance.

This novel "QCPR Classroom" is a unique real-time visual in-action feedback system has been provided a significant impact on CPR performance that 42 manikins provide feedback at the same time in the large group training setting. As Kong et al. concluded, overall CPR quality was improved through QCPR-Classroom based training [29]. The QCPR Classroom group showed significant improvement in CPR skills between post-training and pre-training, especially in the percentage of adequate depth and recoil. The purpose of QCPR Classroom is to make it easy to objectively measure and improve CPR performance in community CPR classes. In a large classroom, learners could see their CPR performance on a big screen at the front of the class. Kong et al. randomized the groups and the instructor only visible the feedback icon on iPad and has examined how "QCPR Classroom" training affects CPR performance improvement of laypeople in the large group setting [29]. Students only received objective feedback directly from instructor. Our study randomized the groups and both students and instructor were visible the feedback icon on iPad by arranging on big screen in front of the classroom, which would be given students to have real-time feedback by themselves. Providing high quality CPR training with the lead-instructor:manikin:students ratio of 1:42:84 can be possible. This is able to make that good educational achievement with fewer instructors.

CPR training has been studied for decades by observing participants and comparing their performance to guidelines. The findings show that training does not provide sufficient practice [35,36], it does not include DA-CPR [37], participants lack preparedness for real situations [36,38,39], and objective student feedback and assessment are not performed [40]. In 1991, Kaye et al. reported that instructors made CPR courses by themselves and included only 10 minutes of practical training [35]. The instructors also performed subjective assessments of the students to let the students pass the course, even though the students would not have passed according to objective measurements or evaluation by researchers [35].

The need for standardized training, more relevant training, and objective assessment has been known since the early 1990s, but most training teaches laypeople to perform CPR alone without dispatcher assistance, and they practice CPR without feedback or performance assessment. We generally do not know what quality of CPR participants will perform during resuscitation, but we know that good-quality bystander CPR has positively reflected in survival [41-44]. It is possible to make training for laypeople more relevant and effective by focusing on the most important learning objectives, prioritizing practical training, training people to work in teams with dispatchers, using objective feedback to stimulate good performance, and documenting the results for quality improvement and cultivating a culture of excellence. QCPR Classroom can provide objective feedback on the quality and quantity of CPR.

The use of feedback in a hospital setting was suggested [16], as well as in the EMS field [17]. Tanaka et al. also suggested the implementation of feedback devices in athletic training [45]. The use such a device is also highly recommended for even healthcare professionals to use such a device. Laypeople who may encounter situations of cardiac arrest rarely would need to use a feedback device in order to deliver high-quality CPR, which may be directly linked to the chances for survival. An AED with a feedback device is the best method for citizens to deliver higher-quality CPR. We believe that the combination of training with QCPR Classroom and performing CPR with a feedback device in the field would have a positive impact on survival rates.

In our opinion, recoil is the most difficult part for participants to perform within such a short time, especially for those who are training in CPR for the first time. The confidence level that learners had toward recoil was 8.0/10.0 in our study, which is the same as for depth and rate in both groups. The hands are off the sternum when teaching full recoil, and incomplete release would occur if the recoil concept was not mentioned. In our opinion, instructors prioritize teaching the concepts of depth and rate rather than recoil because feedback on recoil cannot be given as subjectively. In standard CPR training, we assume that the main focus of participants tends to be compressing harder; therefore, participants easily forget recoil and neglect to perform it. Our results showed a significantly increase in adequate depth and no change in recoil in standard CPR training, which supports our hypothesis. QCPR Classroom significantly improved the recoil performance, although it did not influence the confidence level.

The definition of high-quality CPR highlights the importance of depth, rate, and recoil. Performing good chest compression with these three factors leads to favourable outcomes. However, CPR instructors must understand the difficulty of achieving appropriate depth, rate, and recoil [46]. Moreover, recent guidelines increasingly emphasize the necessity of high-quality CPR performance by not only EMTs or first responders, but also citizens [46].

With the highlighted importance of objective feedback during CPR training, we hope this pilot study on QCPR Classroom training could be considered as a model for future CPR training. The role of instructors is to emphasize the importance of bystander CPR and Public Access Defibrillation. Therefore, instead of focusing too much on the recoil or another part of high-quality CPR, the importance of immediate initiation of CPR without hesitating should be highlighted during the training. It is still very important to determine how to design these environments and prioritize emergency action plans, such as contacting EMS personnel and summoning other people.

Study limitations

In this study, strength was Arranging objective real-time feedback on big screen in front of everyone to visible to both instructor and students made significantly improve CPR quality. Our study has several limitations. First, the manikins' chest is not as hard as the human body, so it is not the same in real life. Second, this study was conducted using CPR training that targeted a large amount of lay people, who all performed CPR together. Since chest compression was tested in this environment, the rate measurement may have been influenced by other participants. The metronome was used in the QCPR Classroom group only, but no metronome was used in the control group. Third, the instructors' knowledge may have been questionable since the instructors were learning about the device as the training proceeded. Fourth, the survey has been collected post-course including questions about how the participants felt about their confidence prior to the training which may add a large element of recall bias. Fifth, the potential lack of generalizability since the quality of instructors and the standards of training may vary compared to other settings. Sixth, loss of participants due to lack of data. This was occurred because of mechanical issue and CPR skill data was not well registered on cloud. Finally, the study was only measured short-term improvement, not the retention.

Conclusion

The use of a novel "QCPR Classroom" prototype to educate a large group of laypeople with real-time visual CPR feedback has been described and the effectiveness of training was assessed. The QCPR Classroom training achieved a higher percentage of adequate depth and recoil than the standard training with subjective assessment by instructors group and a higher percentage of adequate recoil. During in-action "QCPR Classroom" training with a metronome sound, displaying all student's feedback on the big screen significantly provided accurate real-time visual feedback to achieve two important components together: compressing the chest with the depth over 5 cm and minimizing the incomplete release the chest. Teaching CPR to larger group laypeople with a real-time feedback system, a novel QCPR Classroom with a metronome sound is a recommended CPR training model.

Acknowledgments

The authors wish to thank all staff members at the Research Institute of Disaster Management and EMS at Kokushikan University for their assistance in this study. The authors also thank Laerdal Medical for their assistance in using QCPR Classroom.

Author Contributions

ST carried out all the studies, participated in the sequence alignment, and drafted the manuscript. ST, KT, TH, RS, HM, TB, HTaky, and HTana were involved in the study design. ST, KT, TH, and HTana contributed to the study implementation. HM and TB developed the concept and contributed to technological support. ST, KT, TH, HTaka, AI, HU, YK, MY and HTana were involved in the data collection. RS conducted statistical analysis. ST, RS, and HTana performed data analysis. HTaky, HM, and TB contributed critical revisions to the manuscript. HTana also revised and approved the final manuscript. All authors read and approved the final submission.

Funding

None

Conflict of Interests

Tonje Søraas Birkenes and Helge Myklebust are employees of Laerdal Medical. They contributed the QCPR Classroom prototype, study design, and critical revision of the manuscript, but had no role in data collection, analysis of the results, or decision to publish. Other authors did not receive any payment, gift or anything from Laerdal Medical.

Ethical Approval

The study was approved by the Institutional Review Board at Kokushikan University, Japan under the registration number 16-RI002 on February 23rd, 2017.

Data Availability Statement

All relevant data are within the paper and its data are available from corresponding author, ST, upon request.

Figure legends

Figure 1. Flow chart of the study

Figure 2. Image of QCPR Classroom feedback system

Figure 3. Image of actual display on the front screen

References

1. Mozaffarian D, Benjamin EJ, Go AS, et al. Heart disease and stroke statistics–2016 update: a report from the American Heart Association. Circulation. 2015;133:e38-e360.
2. Hasselqvist-Ax I, Riva G, Herlitz J, Rosenqvist M, Hollenberg J, Nordberg P, Ringh M, Jonsson M, Axelsson C, Lindqvist J, Karlsson T, Svensson L. Early cardiopulmonary resuscitation in out-of-hospital cardiac arrest. N Engl J Med. 2015;372:2307-2315.
3. Wissenberg M, Lippert FK, Folke F, Weeke P, Hansen CM, Christensen EF, Jans H, Hansen PA, Lang-Jensen T, Olesen JB, Lindhardsen J, Fosbol EL, Nielsen SL, Gislason GH, Kober L, Torp-Pedersen C. Association of national initiatives to improve cardiac arrest management with rates of bystander intervention and patient survival after out-of-hospital cardiac arrest. JAMA. 2013;310:1377-1384.
4. Hansen CM, Kragholm K, Pearson DA, et al. Association of bystander and first-responder intervention with survival after out-of-hospital cardiac arrest in North Carolina, 2010–2013. JAMA. 2015;314:255-264.
5. Iwami T, Kawamura T, Hiraide A, et al. Effectiveness of bystander-initiated cardiac-only resuscitation for patients with out-of-hospital cardiac arrest. Circulation. 2007;116:2900-2907.
6. Takahashi H, Sagisaka R, Natsume Y, Tanaka S, Takyu H, Tanaka H. Does Dispatcher-Assisted CPR generate the same outcomes as spontaneously delivered Bystander CPR in Japan? Am J Emerg Med. 2018;36(3):384-391.
7. Nakahara S, Tomio J, Ichikawa M, Nakamura F, Nishida M, Takahashi H, Morimura N, Sakamoto T. Association of bystander interventions with neurologically intact survival

among patients with bystander-witnessed out-of-hospital cardiac arrest in Japan. JAMA. 2015;314:247-54.

8. American Heart Association. Highlights of the 2015 American Heart Association guidelines update for CPR and ECC. Texas, American Heart Association, 2015. (Accessed 1 September 2017, at https://eccguidelines.heart.org/wp-content/uploads/2015/10/2015-AHA-Guidelines-Highlights-English.pdf)

9. Japan Resuscitation Council. Chapter 1 BLS: Basic Life Support. (Accessed 3 February 2019, at https://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/1327fc7d4e9a5dcd73732eb04c159a7b.pdf).

10. Global Resuscitation Alliance. Improving Survival from Out-of-Hospital Cardiac Arrest: A Call to Establish a Global Resuscitation Alliance. (Accessed 2 December 2017, at http://www.laerdalevents.com/gra/wp-content/pdf/call_to_establish.pdf)

11. Aufderheide TP, Pirrallo RG, Yannopoulos D, et al. Incomplete chest wall decompression: a clinical evaluation of CPR performance by EMS personnel and assessment of alternative manual chest compression-decompression techniques. Resuscitation. 2005;64:353-362.

12. Sutton RM, Niles D, Nysaether J, et al. Quantitative Analysis of CPR Quality During In-Hospital Resuscitation of Older Children and Adolescents. Pediatrics. 2009;124(2):494-9.

13. Yannopoulos S, McKnite S, Aufderheide TP, Sigurdsson G, Pirrallo RG, Benditt D, Lurie KG. Effect of incomplete chest wall decompression during cardiopulmonary resuscitation on coronary and cerebral perfusion pressures in a porcine model of cardiac arrest. Resuscitation. 2005;64:363-72.

14. Neumar RW, Shuster M, Callaway CW, et al. 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care, Part 1: Executive Summary. Circulation. 2015;132:S315–67.

15. Perkins GD, Handley AJ, Koster RW, et al. European Resuscitation Council Guidelines for Resuscitation 2015 Section 2. Adult basic life support and automated external defibrillation. Resuscitation. 2015;95:81-99.

16. Abella BS, Edelson DP, Kim S, et al. CPR quality improvement during in-hospital cardiac arrest using a real-time audiovisual feedback system. Resuscitation. 2007;73(1):54–61.

17. Hostler D, Everson-Stewart S, Rea TD, et al; Effect of real-time feedback during cardiopulmonary resuscitation outside hospital: prospective, cluster-randomised trial. BMJ 2011;342(d512):1-10.

18. Buleon C, Delaunay J, Parienti J.-J., Halbout L., Arrot X, Gerard J.-L., Hanouz J.-L. Impact of a feedback device on chest compression quality during extended manikin CPR: a randomized crossover study. Am J Emerg Med. 2016;34:1754-1760.

19. Bobrow BJ, Vadeboncoeur TF, Stolz U, et al. The influence of scenario-based training and real-time audiovisual feedback on out-of-hospital cardiopulmonary resuscitation quality and survival from out-of-hospital cardiac arrest. Ann Emrg Med. 2013;62(1):47-56.

20. Skorning M, Beckers SK, Brokmann JC, et al. New visual feedback device improves performance of chest compressions by professionals in simulated cardiac arrest. Resusciation. 2010;81:53-58.

21. Buleon C, Parienti J-J, Halbout L, et al. Improvement in chest compression quality using a feedback device (CPRmeter): a stimulation randomized crossover study. Am J Emerg Med. 2013;31:1457-1461.

22. Kramer-Johansen J, Myklebust H, Wik L, et al. Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: a prospective interventional study. Resuscitation. 2006;71:283-292.

23. Cheng A, Brown LL, Duff JP, et al.; International Network for Simulation-Based Pediatric Innovation, Research, & Education (INSPIRE) CPR Investigators. Improving cardiopulmonary resuscitation with a CPR feedback device and refresher simulations (CPR CARES Study): a randomized clinical trial. JAMA Pediatr. 2015; 169:137-44.

24. Cheng A, Overly F, Kessler D, et al.; International Network for Simulation-Based Pediatric Innovation, Research, & Education (INSPIRE) CPR Investigators. Perception of CPR quality: Influence of CPR feedback, Just-in-Time CPR training and provider role. Resuscitation 2015;87:44-50.

25. White AE, Ng HX, Ng WY, Ng EKX, Fook-Chong S, Kua PHJ, Ong MEH. Measuring the effectiveness of a novel CPRcard™ feedback device during stimulated chest compressions by non-healthcare workers. Singapore Med J 2017;58:438-445.

26. Tanaka S, White AE, Sagisaka R, et al. Comparison of quality of chest compressions during training of laypersons using Push Heart and Little Anne manikins using blinded CPRcards. Int Emerg Med. 2017;10(1):20.

27. Baldi E, Cornara S, Contri E, et al. Real-time visual feedback during training improves layperson's CPR quality: a randomized controlled manikin study. CJEM. 2017;19(6):480-487.

28. Yeung J, Meeks R, Edelson D, Gao F, Soar J, Perkins G. The use of CPR feedback/prompt devices during training and CPR performance: A systematic review. Resuscitation. 2009;80:743-751.

29. Kong SY, Shin SD, Song KJ, et al. Effect of instructor's real-time feedback using QCPR-classroom device during layperson cardiopulmonary resuscitation (CPR) training on quality of CPR Performances: A prospective cluster-randomised trial. BMJ Open. 2018;8:doi:10.1136/bmjopen-2018-EMS.25.

30. Nishiyama C, Iwami T, Kawamura T, Ando M, Yonemoto N, Hiraide A, Nonogi H. Quality of chest compressions during continuous CPR; comparison between chest compression-only CPR and conventional CPR. Resuscitation. 2010;81:1152-1155.

31. American Heart Association. AHA requirement on Use of feedback devices in adult CPR training courses. (Accessed 1 September 2017, at http://ahainstructornetwork.americanheart.org/idc/groups/ahaecc-public/@wcm/@ecc/documents/downloadable/ucm_495639.pdf.).

32. Cortegiani A, Russotto V, Montalto F, Iozzo P, Meschis R, Pugliesi M, et al. (2017) Use of a Real-Time Training Software (Laerdal QCPR®) Compared to Instructor-Based Feedback for High-Quality Chest Compressions Acquisition in Secondary School Students: A Randomized Trial. PLoS ONE 12(1): e0169591.

33. Jones I, Whitefield R, Colquhoun M, Chamberlain D, Vetter N, Newcombe R, et al. At what age can schoolchildren provide effective chest compressions? AN observational study from the Heartstart UK schools training programme. BMJ. 2007;334:1201.

34. Contri E, Cornara S, Somaschini A, et al.Complete chest recoil during laypersons' CPR: Is it a matter of weight? Am J Emerg Med. 2017;35:1266-1268.

35. Kaye W, Rallis SF, Mancini ME, et al. The problem of poor retention of cardiopulmonary resuscitation skills may lie with the instructor, not the learner or the curriculum. Resuscitation. 1991;21:67-87.

36. Parnell MM, Larsen PD. Poor quality teaching in lay person CPR courses. Resuscitation. 2007;73:271-278.

37. Wagner P, Lingemann C, Arntz HR, Breckwoldt J. Official lay basic life support courses in Germany: is delivered content up to date with the guidelines? An observational study. Emerg Med J. 2015;32(7):547-52.

38. Møller TP, Hansen CM, Fjordholt M, Pedersen BD, Østergaard D, Lippert FK. Debriefing bystanders of out-of-hospital cardiac arrest is valuable. Resuscitation. 2014;85:1504-1511.

39. Hirose T, Iwami T, Ogura H, et al. Effectiveness of a simplified cardiopulmonary resuscitation training program for the non-medical staff of a university hospital. Scand J Trauma Resusc Emerg Med. 2014;22(31):1-7.

40. Lynch B, Einspruch EL, Nichol G, Aufderheide TP. Assessment of BLS skills: optimizing use of instructor and manikin measures. Resuscitation. 2008;76:233-243.

41. Wik L, Steen PA, Bircher NG. Quality of bystander cardiopulmonary resuscitation influences outcome after prehospital cardiac arrest. Resuscitation. 1994;28:195-203.

42. Van Hoeyweghen RJ, Bossaert LL, Mullie A, et al. Quality and efficiency of bystander CPR. Resuscitation. 1993;26:47-52. Emerg Med J. 2014;0:1-6.

43. Gallagher EJ, Lombardi G, Gennis P. Effectiveness of bystander cardiopulmonary resuscitation and survival following out-of-hospital cardiac arrest. JAMA. 1995;274:1992-1925.

44. Takei Y, Nishi T, Matsubara H, Hashimoto M, Inaba H. Factors associated with quality of bystander CPR: the presence of multiple rescuers and bystander-initiated CPR without instruction. Resuscitation. 2014;85:492-498.

45. Tanaka S, Rodrigues W, Sotir S, Sagisaka R, Tanaka H. CPR Performance in the Presence of Audiovisual Feedback or Football Shoulder Pads. BMJ Open Sport Exerc Med. 2017;3(1):e000208.

46. Japan Resuscitation Council. Chapter 8 ETI: Education, Implementation, and Teams. (Accessed 2 December 2017, at http://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/b7b5b647189bc07f38f6fecf014cf5d9.pdf).

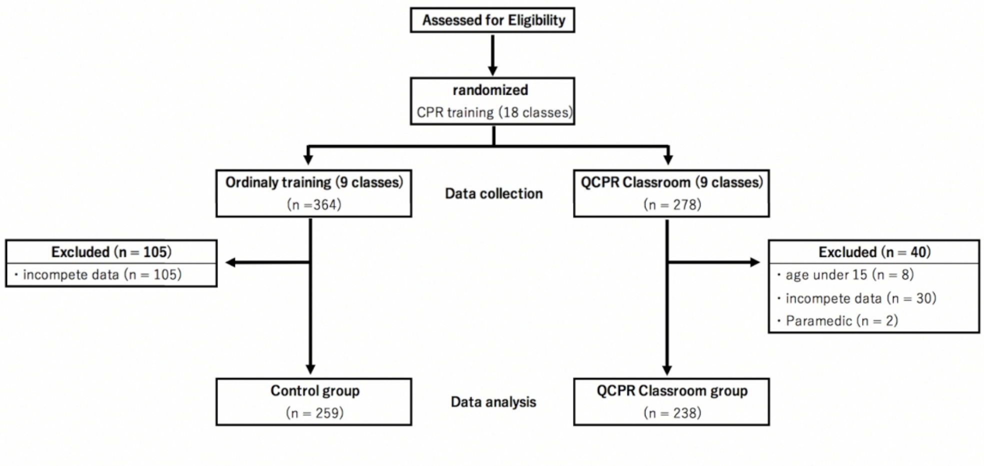


Fig 1. Flow chart of the study

Flow chart of the study

Fig 2. Image of QCPR Classroom feedback system

Image of QCPR Classroom feedback system

Fig 3. Image of actual display on the front screen

Image of actual display on the front screen

Date: ____/_____/_____

Research Institute of Disaster Management and EMS,
Kokushikan University

Survey

We conduct this survey for those who had a CPR training. Thank you for your cooperation to take part in this survey. The result will only use for a research purpose and will be kept in the strictest confidentiality. Please make a circle (o) or fill in the blank.

1. Number of mannikin:__________ **2. Sex: male / female**

3. Age: __________ years old **height: __________ cm** **weight: __________ kg**

4. Have you ever taken CPR training course? Yes / No

5. if "Yes" on question 4, did you take within a year? Yes / No

Question 6: On a scale 1 to 10, with 1 being very difficult and 10 being very easy, …

6. How do you rate the ease of understanding the feedback from instructor?

(1) rate	(1 = very difficult)	1	2	3	4	5	6	7	8	9	10	(10 = very easy)
(2) depth	(1 = very difficult)	1	2	3	4	5	6	7	8	9	10	(10 = very easy)
(3) recoil	(1 = very difficult)	1	2	3	4	5	6	7	8	9	10	(10 = very easy)

Question 7 & 8: On a scale 1 to 10, with 1 being not confident and 10 being very confident, …

7. How much confidence do you have to perform chest compression before training?

(1) rate	(1 = not confident)	1	2	3	4	5	6	7	8	9	10	(10 = very confident)
(2) depth	(1 = not confident)	1	2	3	4	5	6	7	8	9	10	(10 = very confident)
(3) recoil	(1 = not confident)	1	2	3	4	5	6	7	8	9	10	(10 = very confident)

8. How much confidence do you have to perform chest compression after training?

(1) rate	(1 = not confident)	1	2	3	4	5	6	7	8	9	10	(10 = very confident)
(2) depth	(1 = not confident)	1	2	3	4	5	6	7	8	9	10	(10 = very confident)
(3) recoil	(1 = not confident)	1	2	3	4	5	6	7	8	9	10	(10 = very confident)

9. Please feel free to comments

Table 1: CONSORT 2010 checklist of information to include when reporting a cluster randomised trial

Section/Topic	Item No	Standard Checklist item	Extension for cluster designs	Page No *
Title and abstract				
	1a	Identification as a randomised trial in the title	Identification as a cluster randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)[1,2]	See table 2	2
Introduction				
Background and objectives	2a	Scientific background and explanation of rationale	Rationale for using a cluster design	5-6
	2b	Specific objectives or hypotheses	Whether objectives pertain to the the cluster level, the individual participant level or both	6
Methods				
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	Definition of cluster and description of how the design features apply to the clusters	8
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons		**n/a**
Participants	4a	Eligibility criteria for participants	Eligibility criteria for clusters	7
	4b	Settings and locations where the data were collected		**7**
Interventions	5	The interventions for each group with sufficient details to allow replication, including how	Whether interventions pertain to the cluster level, the individual participant level or both	7-8

		and when they were actually administered		
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	Whether outcome measures pertain to the cluster level, the individual participant level or both	7-8
	6b	Any changes to trial outcomes after the trial commenced, with reasons		**n/a**
Sample size	7a	How sample size was determined	Method of calculation, number of clusters(s) (and whether equal or unequal cluster sizes are assumed), cluster size, a coefficient of intracluster correlation (ICC or *k*), and an indication of its uncertainty	7
	7b	When applicable, explanation of any interim analyses and stopping guidelines		**n/a**
Randomisation:				
Sequence generation	8a	Method used to generate the random allocation sequence		**8**
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	Details of stratification or matching if used	8
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	Specification that allocation was based on clusters rather than individuals and whether allocation concealment (if any) was at the cluster level, the individual participant level or both	n/a
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who	Replace by 10a, 10b and 10c	8

		assigned participants to interventions		
	10a		Who generated the random allocation sequence, who enrolled clusters, and who assigned clusters to interventions	8
	10b		Mechanism by which individual participants were included in clusters for the purposes of the trial (such as complete enumeration, random sampling)	8
	10c		From whom consent was sought (representatives of the cluster, or individual cluster members, or both), and whether consent was sought before or after randomisation	7
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	**participants**	**7-8**
	11b	If relevant, description of the similarity of interventions		**n/a**
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	How clustering was taken into account	11-12
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses		**n/a**
Results				

Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	For each group, the numbers of clusters that were randomly assigned, received intended treatment, and were analysed for the primary outcome	12, Fig 1
	13b	For each group, losses and exclusions after randomisation, together with reasons	For each group, losses and exclusions for both clusters and individual cluster members	12, Fig 1
Recruitment	14a	Dates defining the periods of recruitment and follow-up		**7**
	14b	Why the trial ended or was stopped		**n/a**
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Baseline characteristics for the individual and cluster levels as applicable for each group	10, Table 1
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	For each group, number of clusters included in each analysis	12
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	Results at the individual or cluster level as applicable and a coefficient of intracluster correlation (ICC or k) for each primary outcome	12-16
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended		**n/a**
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing		**n/a**

		pre-specified from exploratory		
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms[3])		**n/a**
Discussion				
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses		**21-22**
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	Generalisability to clusters and/or individual participants (as relevant)	16-21
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence		**n/a**
Other information				
Registration	23	Registration number and name of trial registry		**n/a**
Protocol	24	Where the full trial protocol can be accessed, if available		**n/a**
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders		**23**

** Note: page numbers optional depending on journal requirements*

[1] Hopewell S, Clarke M, Moher D, Wager E, Middleton P, Altman DG, et al. CONSORT for reporting randomised trials in journal and conference abstracts. *Lancet* 2008, 371:281-283

[2] Hopewell S, Clarke M, Moher D, Wager E, Middleton P, Altman DG at al (2008) CONSORT for reporting randomized controlled trials in journal and conference abstracts: explanation and elaboration. *PLoS Med* 5(1): e20

[3] Ioannidis JP, Evans SJ, Gotzsche PC, O'Neill RT, Altman DG, Schulz K, Moher D. Better reporting of harms in randomized trials: an extension of the CONSORT statement. *Ann Intern Med* 2004; 141(10):781-788.

BMJ Open

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

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-026140.R2
Article Type:	Research
Date Submitted by the Author:	01-Mar-2019
Complete List of Authors:	Tanaka, Shota; Kokushikan University, Research Institute of Disaster Management and EMS, Tsukigase, Kyoko; Kokushikan University, Research Institute of Disaster Management and EMS, Hara, Takahiro; Kokushikan University, Graduate School of EMS System Sagisaka, Ryo; Kokushikan University, Graduate School of EMS System Myklebust, Helge; Laerdal Medical Cooperation Birkenes, Tonje; Laerdal Medical Cooperation Takahashi, Hiroyuki; Kokushikan University, Research Institute of Disaster Management and EMS, Iwata, Ayana; Kokushikan University, Research Institute of Disaster Management and EMS, Kidokoro, Yutaro; Kokushikan University, Research Institute of Disaster Management and EMS, Yamada, Momoyo; Kokushikan University, Research Institute of Disaster Management and EMS, Ueta, Hiroki; Meiji University of Integrative Medicine, Faculty of Emergency Medical Science Takyu, Hiroshi; Kokushikan University, Graduate School of EMS System Tanaka, Hideharu; Kokushikan University, Graduate School of EMS System; Kokushikan University, Research Institute of Disaster Management and EMS,
Primary Subject Heading:	Medical education and training
Secondary Subject Heading:	Emergency medicine, Medical education and training
Keywords:	bystander, cardiac arrest, CPR training, resuscitation, Mass CPR training

SCHOLARONE™
Manuscripts

Title: 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

Shota Tanaka [1)], Kyoko Tsukigase [1)], Takahiro Hara [2)], Ryo Sagisaka [2)], Helge Myklebust [3)], Tonje S. Birkenes [3)], Hiroyuki Takahashi [1) 4)], Ayana Iwata [1)], Yutaro Kidokoro [1)], Momoyo Yamada [1)], Hiroki Ueta [5)], Hiroshi Takyu [2)], Hideharu Tanaka [1) 2)]

1) Research Institute of Disaster Management and EMS, Kokushikan University
2) Graduate School of EMS System, Kokushikan University
3) Laerdal Medical, Stavanger, Norway
4) Department of Sports Medicine, Kokushikan University, Japan
5) Faculty of Emergency Medical Science, Meiji University of Integrative Medicine

Correspondence author: SHOTA TANAKA

Kokushikan University, 7-3-1, Nagayama, Tama City, Tokyo, JAPAN

E-mail: tanakamedical24@gmail.com

TEL/FAX: +81-42-339-7197

Keywords: cardiac arrest, bystander, CPR training, resuscitation, Mass CPR training

Word Count: 4223

Abstract

Objectives "Quality Cardiopulmonary Resuscitation (QCPR)-Classroom" was recently introduced to provide higher-quality CPR training. This study aimed to examine whether novel QCPR-Classroom training can lead to higher chest-compression quality than standard CPR training.

Design A cluster randomized controlled trial was conducted to compare standard CPR training (control) and QCPR-Classroom (intervention).

Setting Layperson CPR training in Japan

Participants Six hundred forty-two people aged over 15 years were recruited from among CPR trainees.

Interventions CPR performance data were registered without feedback on instrumented Little Anne prototypes for one minute pre- and post-training. A large classroom was used in which QCPR-Classroom participants could see their CPR performance on a big screen at the front; the control group only received instructor's subjective feedback.

Primary and secondary outcome measures The primary outcomes were compression depth (mm), rate (compressions per minute [cpm]), percentage of adequate depth (%), and recoil (%). Survey scores were a secondary outcome. The survey included participants' confidence regarding CPR parameters and ease of understanding instructor feedback.

Results In total, 259 and 238 people in the control and QCPR-Classroom groups, respectively, were eligible for analysis. After training, the mean compression depth and rate were 56.1 ± 9.8 mm and 119.2 ± 7.3 cpm in the control group and 59.5 ± 7.9 mm and 116.8 ± 5.5 cpm in the QCPR-Classroom group. The QCPR-Classroom group showed significantly more adequate depth than the control group (p = 0.001). There were 39.0% (95% CI, 33.8–

44.2; $p < 0.0001$) and 20.0% improvements (95% CI, 15.4–24.7; $p < 0.0001$) in the QCPR-Classroom and control groups, respectively. The difference in adequate recoil between pre- and post-training was 2.7% (95% CI, −1.7–7.1; pre 64.2 ± 36.5% vs. post 66.9 ± 34.6%; $p = 0.23$) and 22.6% in the control and QCPR-Classroom groups (95% CI, 17.8–27.3; pre 64.8 ± 37.5% vs. post 87.4 ± 22.9%; $p < 0.0001$), respectively.

Conclusions QCPR-Classroom helped students achieve high-quality CPR training, especially for proper compression depth and full recoil. For good educational achievement, a novel QCPR-Classroom with a metronome sound is recommended.

Strengths and limitations of this study

- One of the advantages of CPR training using the QCPR-Classroom concept is good educational achievement with fewer instructors.
- Arranging objective real-time feedback on a big screen in front of everyone, visible to both instructor and students, significantly improved CPR quality.
- The QCPR-Classroom group had 13.6% better adequate depth and 20.5% better adequate recoil than the control group.
- No retention measurement was taken, and the measurements were of all students together.
- This was manikin-based training, so it was not the same as in real life since the chest was not as hard as the human body.

INTRODUCTION

The burden of cardiovascular diseases and the increasing number of out-of-hospital cardiac arrest (OHCA) cases remain a global concern.[1] Performing bystander cardiopulmonary resuscitation (CPR) is one factor that can increase the survival rate of OHCA.[2–7] The survival rate may be directly linked to the number of bystanders trained in CPR.[2] As a complement to the 2015 American Heart Association (AHA) and Japan Resuscitation Council Guideline, the Global Resuscitation Alliance (GRA) was recently established to improve OHCA survival, and high-performance CPR was highlighted: a push depth of 5–6 cm, rate of 100–120 compressions per minute (cpm), full recoil, and minimizing interruptions for chest compressions (less than 10 seconds).[8–10] In the GRA consensus, mandatory School and Community CPR was listed as one of the 10 steps to increase OHCA survival.[8]

Healthcare professionals were found to perform incomplete compression recoil in 46% of all cases and in 23.4% of cases involving pediatric patients.[11–12] Incomplete recoil leads to less blood flow to the brain,[8] which causes coronary and cerebral perfusion pressure to deteriorate.[13] Full recoil is one of the most important concepts for ensuring high-quality CPR.[10,14,15] Teaching individuals to compress the chest 5 cm deep and allow for full chest recoil is difficult during training without a feedback device.

We are currently facing a period of transition to CPR training with a feedback device as various feedback devices have been introduced, and research has supported their effectiveness.[16–28] However, they are unavailable for CPR training targeting a large population. Laerdal Medical (Stavanger, Norway) launched the “QCPR Classroom” concept, which provides real-time visual feedback for a greater number of participants at once. The effectiveness of the QCPR-Classroom device was recently demonstrated by Kong et al.[29] This study aims to examine the effectiveness of CPR skills delivered with QCPR-Classroom feedback compared to standard CPR training. The hypothesis was that QCPR Classroom would generate higher achievement in CPR skill regardless of instructors' teaching skill. We aimed to determine whether QCPR Classroom could be the best practical model for CPR training.

METHODS

Patient and public involvement

Patients and/or the public were not involved in this study. The study population was focused on CPR trainees.

Study population and design

Prior to CPR training and study enrollment, oral informed consent was obtained from all participants. The study was approved by the Institutional Review Board at Kokushikan University. Sample size calculation was based on adequate depth from our pilot trial in which we examined the effect of the QCPR Classroom. We calculated a sample size of 232 with 90% power to detect a percentage of adequate compression depth between two groups ($\alpha = 0.05$). To reach a power of 90%, 41 participants were needed per group in parallel, and the design effect was 5.66; 15% was detected as a deficit due to a mechanical issue, so 272 per group was calculated as a sample size. A total of 642 people were recruited from among CPR trainees enrolled in the Heart Saver Japan CPR training, which was held between March and September 2017. The inclusion criterion was age over 15 years. The exclusion criteria were the presence of upper extremity injury within the past 6 months and working as a healthcare professional regularly involved in resuscitation, such as Emergency Medical Technicians, paramedics, and emergency room physicians or nurses. Previous CPR training status and quantity and timing of previous trainings were not used as inclusion or exclusion criteria.

Measurements

The primary outcome was compression depth (mm), compression rate (cpm), adequate depth (%), and adequate recoil (%). These measurements were obtained both pre- and immediately post-training. No feedback was provided to the participants. The measurement duration was one minute as the bystander should change every minute during chest compression-only CPR.[30] This was because the quality of chest compression-only CPR was demonstrated to decrease due to fatigue, and this can alter the results. The scores from a survey conducted after the training were considered a secondary outcome. The survey included the participants' confidence about the rate, depth, and recoil pre- and post-training as well as the ease of understanding feedback from the instructor. The survey is available in the Appendix.

Study procedure

A cluster randomized controlled trial was used (allocation ratio 1:1). A researcher (R.S) generated a randomization list, and block-two randomization was performed. R.S. was not involved in the data collection and worked on statistics independently. Each session was randomly assigned to the intervention (standard or QCPR Classroom). Four lead instructors who had worked as healthcare professionals and had over five years of experience teaching CPR were selected from the Heart Saver Japan organization. Data were collected during the Heart Saver Japan CPR + Automated External Defibrillator (AED) training sessions. The training focused on Basic Life Support, including CPR skills and AED, according to the Japan Resuscitation Council 2015 Guideline. Students were not medical personnel, so we instructed compression-only CPR. No pre-assignment or e-learning was given. The training started with a PowerPoint presentation-based instructor-led lecture followed by psychomotor practice. Psychomotor practice focused on chest-compression CPR. The sequence of the psychomotor practice is as follows: 1) Keys of compression: depth, rate, recoil; 2) single-rescuer chest compression-only CPR; 3) two-bystander chest compression-only CPR focusing on minimizing interruptions; 4) check respiration; 5) scene safety, check consciousness, and call for help; 6) use of AED; 7) practice from "scene safety" to "resume chest compression after giving a shock"; and 8) scenario-based training. A total of 18 CPR training sessions were studied with 9 standard CPR training (control group) and 9 QCPR-Classroom sessions (Figure 1).

In the QCPR-Classroom group, participants received subjective and objective feedback from the instructor based on real-time feedback through the manikin, and participants were able to correct themselves based on feedback displayed on the screen of the device (Figure 2). The control group received instructor's subjective feedback, so a hand clap was used based on the instructor's experience instead of using a metronome sound. As the AHA stated, audio-visual feedback is mandated for use.[31] QCPR Classroom only provides visual feedback, so we used sound as an auditory aid for instruction in the QCPR-Classroom group.

To measure the effect of CPR training, one minute of chest compression was measured without any feedback given as a pre-test. Similarly, one minute of chest compression was also measured after the training as a post-test. Although one minute of measurement may not be sufficient for CPR performance in real life, we focused on the initial CPR performance in a single-rescuer situation. A survey and baseline characteristics, such as weight, height, and CPR training experience (Table 1), were also collected after the post-training measurement. The metronome was set at 110 beats per minute and used for every instance of hands-on practice during the QCPR-Classroom session, but no metronome was used during the standard CPR training.

Table 1. Demographic Characteristics

	Control (n = 259)	QCPR Classroom (n = 238)	*p* value
Age, mean±SD	22.4 ± 9.0	19.4 ± 5.6	<.0001 *
median (IQR)	19 (17-23.5)	17 (16-21)	<.0001 *
Male, (%)	130 (50.2)	101 (42.4)	0.08
height, mean	164.5 ± 14.3	164.2 ± 8.2	0.47
weight, mean	57.9 ± 12.1	56.0 ± 9.6	0.06
BMI, mean	21.1 ± 3.1	20.7 ± 2.6	0.07
CPR training, (%)	203 (78.4)	170 (71.4)	0.07
CPR training within 1 year, (%)	89 (41.2)	63 (36.4)	0.34

CPR: cardiopulmonary resuscitation; SD: standard deviation; IQR; interquartile range; BMI: body mass index

* p < .05 significant

Instrumentation

Compression data were registered using the Laerdal QCPR-Classroom manikin system (Laerdal Medical, Stavanger, Norway), as shown in Figure 2. This prototype system for community CPR training provides real-time visual feedback from 42 manikins while icons representing CPR performance from each manikin are visualized on an iPad tablet. We mirrored the iPad screen on a laptop using the application Reflector 2 (Squirrels®, North Canton, OH, United States) to present real-time feedback on a large screen at the front of the classroom (Figure 3). QCPR Classroom uses Laerdal Little Anne manikins, and each is instrumented with an optical compression sensor and microcontroller. The microcontroller analyses the signal from the compression sensor and calculates the number, depth, and rate of compressions and incomplete release. A compression score is calculated using the rate, depth, and release. Each sensor was checked for depth accuracy using a calibrated compression machine with ±15% considered to indicate acceptable error.

The microcontroller also compares the compression performance with guidelines from the 2015 AHA requirements. Deviations from the guidelines are reported as "too shallow," "incomplete release," "too fast," or "too slow," and deviation in each factor is presented as yellow icons on the tablet. If the compression performance is good, a green "Everything OK" icon is presented. Data from the tablet is sent to a Microsoft Azure cloud service and made available as downloadable *.csv* files, which include the following parameters from each manikin and CPR session: the number of compressions, average compression rate, average compression depth, number of compressions with adequate depth, number of compressions with acceptable release, compression score, time, and location of use. The control group also used the same Laerdal Little Anne manikins. However, we did not use a screen to show students objective feedback. During the training in the control group, lead-instructors were not allowed to access iPad, so they only gave subjective feedback to the students.

Statistical analysis

The rate and depth measurements are shown as the mean and standard deviation. Normal distributions and homogeneity of variance were confirmed by a Q-Q plot. The differences and 95% confidence intervals are shown in tables. The adequate depth and recoil were calculated as percentages. The difference between pre- and post-training measurements within the groups were analyzed using a paired t-test and McNemar test. Group comparison for both pre- and post-training was conducted using Welch's t-test and chi-square test. The medians and interquartile ranges are presented for ordinal data. We compared the groups using the Wilcoxon single-rank test. The data were analyzed using JMP (V.11.2.0, the SAS Institute Inc.), and *p*-values less than 0.05 were considered significant.

RESULTS

Demographic characteristics

A total of 642 people participated in this study. As shown in Figure 1, 145 participants were excluded due to incomplete data (n = 135), age under 15 years (n = 8), and being paramedics (n = 2). Significant age difference between the groups was found ($p \leq .0001$). A statistical difference was found in age among individuals in clusters, but the standard deviation and interquartile range overlapped. The age variation was not clinically significant due to overlap of precision measured. After the CPR training, 497 participants were eligible for analysis with 259 in the control group and 238 in the QCPR-Classroom group. The demographic characteristics are shown in Table 1.

Primary outcome

All chest-compression parameters at pre- and post-training are shown in Table 2. After the training, the mean compression depth of each student was 56.1 ± 9.8 mm in the control group and 59.5 ± 7.9 mm in the QCPR-Classroom group. Significantly more participants in the QCPR-Classroom group achieved higher adequate depth compared to the control group ($p < 0.001$; Table 3). In the QCPR-Classroom group, there was an improvement of 39.0% (95% CI, 33.8–44.2) in the percentage of adequate depth. In the control group, the improvement was 20.0% (95% CI, 15.4–24.7; $p < 0.0001$; Table 2).

Both groups demonstrated average compression rates of 100–120 cpm (Table 2). A statistically significant difference was found between groups in terms of recoil ($p < 0.001$; Table 3). The control group demonstrated a 2.7% (95% CI, −1.7–7.1) increase in the percentage of recoil ($p = 0.23$). The QCPR-Classroom group demonstrated a 22.6% (95% CI, 17.8–27.3) increase in the percentage of recoil ($p < 0.0001$; Table 2).

Table 2. Comparison in CPR performance competency between pre- and post-training in each groups

	Control (n = 259)				QCPR Classroom (n = 238)			
	Pre-training	Post-training	*p* value	Difference (95% CI)	Pre-training	Post-training	*p* value	Difference (95% CI)
rate (cpm) $^{+}$	121.4 ±15.5	119.2 ±7.3	0.02 *	-2.3 (-4.2 – -0.3)	115.7 ± 19.0	116.8 ± 5.5	0.39	1.1 (-1.4 – 3.6)
depth (mm) $^{+}$	51.4 ±11.6	56.1 ±9.8	<0.0001 *	4.6 (3.5 – 5.8)	48.2 ± 14.7	59.5 ± 7.9	<0.0001 *	11.3 (9.8 – 12.8)
adequate depth (%) $^{++}$	53.6 ±38.9	73.7 ±37.3	<0.0001 *	20.0 (15.4 – 24.7)	48.3 ± 44.2	87.3 ± 24.8	<0.0001 *	39.0 (33.8 – 44.2)
adequate recoil (%) $^{++}$	64.2 ±36.5	66.9 ±34.6	0.23	2.7 (-1.7 – 7.1)	64.8 ± 37.5	87.4 ±22.9	<0.0001 *	22.6 (17.8 – 27.3)

paired-t test and McNemar test; CPR: cardiopulmonary resuscitation; CI: confidence interval

+ Mean and standard deviation for rate and depth measurement

++ Numbers (percentage) for the adequate depth and recoil

* p < .05 significant

Table 3. The difference of CPR performance competency between the control group and QCPR Classroom group at pre- and post-training

	Control (n = 259)	QCPR Classroom (n = 238)	*p* value	Difference (95% CI)
Pre-training test				
rate (cpm) +	121.4 ±15.5	115.7 ± 19.0	<0.001 *	-5.7 (-8.7 − -2.6)
depth (mm) +	51.4±11.6	48.2 ± 14.7	0.008 *	-3.2 (-5.5 − -0.85)
adequate depth (%) ++	53.6 ±38.9	48.3 ± 44.2	0.15	-5.3 (-12.7 − 2.0)
adequate recoil (%) ++	64.2 ±36.5	64.8 ± 37.5	0.84	3.3 (-5.9 − 7.2)
Post-training test				

rate (cpm) +	119.2 ± 7.3	116.8 ± 5.5	<0.001 *	-2.3 (-3.5 – -1.2)
depth (mm) +	56.1 ±9.8	59.5 ± 7.9	<0.001 *	3.5 (1.9 – 5.1)
adequate depth (%) ++	73.7 ±37.3	87.3 ± 24.8	<0.001 *	13.6 (8.0 – 19.2)
adequate recoil (%) ++	66.9 ±34.6	87.4 ±22.9	<0.001 *	20.5 (15.3 – 25.7)

Welch's t test and Chi-Square test; CPR: cardiopulmonary resuscitation; CI: confidence interval

+ Mean and standard deviation for rate and depth measurement

++ Numbers (percentage) for the adequate depth and recoil

* p < .05 significant

Secondary outcome

The survey included participants' confidence levels before and after training regarding three parameters (rate, depth, and recoil) using the following question: "*On a scale of 1–10, with 1 being not confident and 10 being very confident, how much confidence do you have to perform chest compressions?*" Confidence regarding CPR performance did not differ between groups. The question "*How do you rate the ease of understanding the feedback from the instructor?*" was asked to address the ease of understanding. A significance difference was seen regarding the rate of feedback from the instructor; the QCPR-Classroom training group (10.0[9.0–10.0]) showed higher scores than the control group (10.0[8.5–10.0]; *p* = 0.01; Table 4).

Table 4. Survey regarding the ease of understanding the feedback from instructor and confidence levels before and after training on three parameters (rate, depth, and recoil)

Question	Control (n = 259)	QCPR Classroom (n = 238)	*p* value
*** How much confidence do you have to perform chest compressions before training?**			
rate	5.0 (3.0-8.0)	5.0 (3.0-7.0)	0.33
depth	5.0 (3.0-7.5)	5.0 (3.0-7.0)	0.27
recoil	5.0 (3.0-7.0)	5.0 (3.0-7.0)	0.37
*** How much confidence do you have to perform chest compressions after training?**			
rate	8.0 (7.0-9.0)	8.0 (7.0-9.0)	0.98
depth	8.0 (7.0-9.0)	8.0 (7.0-9.0)	0.96
recoil	8.0 (7.0-9.0)	8.0 (7.0-9.0)	0.76
**** How do you rate the ease of understanding the feedback from instructor?**			
rate	10.0 (8.5-10.0)	10.0 (9.0-10.0)	0.01*
depth	10.0 (8.0-10.0)	10.0 (9.0-10.0)	0.08
recoil	10.0 (8.0-10.0)	10.0 (9.0-10.0)	0.12

Wilcoxon test, Median (IQR)

* The survey was rated on "*On a scale 1 to 10, with 1 being not confident and 10 being very confident, how much confidence do you have to perform chest compression before and after training?*"

** The survey was rated on "*On a scale 1 to 10, with 1 being very difficult and 10 being very easy, how do you rate the ease of understanding the feedback from instructor?*"

DISCUSSION

The 2015 AHA Guidelines recommend and the AHA mandated in 2017 use of audiovisual feedback in all CPR training.[8,14,31] Previous studies indicate that use of feedback for CPR performance significantly improves CPR quality.[16–28] In our study, CPR quality was significantly better in the QCPR-Classroom than in the control group. The compression depth was 59.5 ± 7.9 mm in the QCPR-Classroom group and 56.1 ± 9.8 mm in the control group post-training. One hundred five and 90 participants in the QCPR-Classroom and control groups, respectively, compressed greater than 60 mm. None in the QCPR-

Classroom group performed below 50 mm in the post-test, but 64 in the control group still did not reach 50 mm.

Skorning et al. found that correct depth was achieved in 73.1% of participants who used a feedback device and 45.2% of those who did not [20] Cortegiani et al. tested a QCPR-Skillreporter feedback model where school children were allowed to practice two-minute compression-only CPR sessions while receiving real-time feedback on a computer screen, aiming for a 60% overall compression score.[32] Following practice, the students received overall performance feedback from the computer. This model used equipment designed for smaller groups. While QCPR-Classroom can handle 42 mannikins simultaneously and feedback is given on only one parameter at the time, Cortegiani et al. used a system that can handle 6 mannikins simultaneously, giving feedback on depth, rate, and leaning simultaneously.[32]

Various types of manikins have been used for CPR training, but the quality of CPR training depends on the instructor, and little is known about training quality. The GRA has highlighted the importance of high-performance CPR, and knowledge is needed in the general population. Significant age difference was found, but previous studies indicated that chest compression delivered by 13–14-year-olds was similar to adult performance, and the researchers concluded that the performance depended on weight, age,[33] height, BMI, and sex.[34] In our study, the median and interquartile range for each group were 19 (17–23) and 17 (16–21), there was no height or weight difference between groups, and both groups included participants over 15 years old, so we considered that the age difference was clinically negligible for adequate CPR performance.

Healthcare professionals were previously found to perform incomplete chest recoil in 46% of cases.[11] Teaching the concept of recoil is not easy; we found only a 2.7% increase in the control group. Contri et al. stated that instruction about recoil must be modified according to the participants' physical characteristics.[34] However, during standard community CPR training, the instructor cannot spend much time on each individual to correct their performance.

This novel "QCPR Classroom" is a unique real-time visual in-action feedback system that has significantly impacted CPR performance with 42 manikins providing feedback simultaneously in a large group-training setting. As Kong et al. concluded, overall CPR quality was improved through QCPR-Classroom-based training.[29] The QCPR-Classroom group showed significant improvement in CPR skills between post- and pre-training, especially in the percentage of adequate depth and recoil. The purpose of QCPR Classroom is to make it easy to objectively measure and improve CPR performance in community CPR classes. In a large classroom, learners could see their CPR performance on a big screen at the front of the class. Kong et al. randomized the groups, and only the instructor saw the feedback icon on the iPad; they examined how "QCPR Classroom" training affects CPR performance improvement of laypeople in the large group setting.[29] Students only received objective feedback directly from the instructor. Our study randomized the groups, and both students and instructor were able to see the feedback icon on the iPad by arranging them on a big screen at the front of the classroom, allowing students to have real-time feedback. It is possible to provide high-quality CPR training with a lead-instructor:manikin:students ratio of 1:42:84, enabling good educational achievement with fewer instructors.

CPR training has been studied for decades by observing participants and comparing their performance to guidelines. The findings show that training does not provide sufficient practice,[35,36] it does not include DA-CPR,[37] participants lack preparedness for real situations,[36,38,39] and objective student feedback and assessment are not performed.[40] In 1991, Kaye et al. reported that instructors made CPR courses by themselves and included only 10 minutes of practical training.[35] The instructors also performed subjective assessments of the students to let the students pass the course even though the students would not have passed according to objective measurements or evaluation by researchers.[35]

The need for standardized training, more relevant training, and objective assessment has been known since the early 1990s, but most training teaches laypeople to perform CPR alone without dispatcher assistance, and they practice CPR without feedback or performance assessment. We generally do not know what quality of CPR participants will perform during resuscitation, but we know that good-quality bystander CPR is positively reflected in survival.[41–44] It is possible to make training for laypeople more relevant and effective by focusing on the most important learning objectives, prioritizing practical training, training people to work in teams with dispatchers, using objective feedback to stimulate good performance, and documenting the results for quality improvement and cultivating a culture of excellence. QCPR Classroom can provide objective feedback on the quality and quantity of CPR.

The use of feedback in a hospital setting [16] as well as in the Emergency Medical Services field was suggested.[17] Tanaka et al. also suggested the implementation of feedback devices in athletic training.[45] The use of such a device is also highly recommended even for healthcare professionals. Laypeople who may encounter situations of cardiac arrest rarely need to use a feedback device to deliver high-quality CPR, which may be directly linked to the chances of survival. An AED with a feedback device is the best method for citizens to deliver higher-quality CPR. We believe that the combination of training with QCPR Classroom and performing CPR with a feedback device in the field would have a positive impact on survival rates.

Recoil is the most difficult part for participants to perform within such a short time, especially for those training in CPR for the first time. The confidence level of learners toward recoil was 8.0/10.0 in our study. The hands are off the sternum when teaching full recoil, and incomplete release would occur if the recoil concept was not mentioned. In our opinion, instructors prioritize teaching the concepts of depth and rate rather than recoil because feedback on recoil cannot be given as subjectively. In standard CPR training, we assume that the main focus of participants tends to be compressing harder; therefore, participants easily forget recoil and neglect to perform it. QCPR Classroom significantly improved recoil performance, although it did not influence the confidence level. With achieving appropriate depth, rate, and recoil, performing good chest compression leads to favorable outcomes. Recent guidelines increasingly emphasize the necessity of high-quality CPR performance by not only Emergency Medical Technicians or first responders but also citizens.[46]

With the highlighted importance of objective feedback during CPR training, we hope this pilot study on QCPR-Classroom training could be considered as a model for future CPR training. The role of instructors is to emphasize the importance of bystander CPR and Public Access Defibrillation. Therefore, instead of focusing too much on the recoil or another part of high-quality CPR, the importance of immediate initiation of CPR without hesitating should be highlighted during the training. It is still very important to determine how to design these environments and prioritize emergency action plans, such as contacting Emergency Medical Services personnel and summoning other people.

Study limitations

A strength of this study was that arranging objective real-time feedback on a big screen in front of everyone, visible to both instructor and students, significantly improved CPR quality. Our study has several limitations. First, the manikins' chest is not as hard as the human body, so chest compressions are not the same as in real life. Second, this study was conducted using CPR training that targeted a large amount of laypeople, who all performed CPR together. Since chest compression was tested in this environment, the rate measurement may have been influenced by other participants. The metronome was used in the QCPR-Classroom group only; no metronome was used in the control group. Third, the instructors' knowledge may have been questionable since the instructors were learning about the device as the training proceeded. Fourth, the survey was collected post-course including questions about the participants' confidence prior to the training, which may add a large element of recall bias. Fifth, there is a potential lack of generalizability since the quality of instructors and the standards of training may vary in other settings. Sixth, participants were lost due to lack of data. This occurred because of a mechanical issue, and CPR skill data were not well registered on the cloud. Finally, the study only measured short-term improvement, not retention.

CONCLUSION

The use of a novel “QCPR Classroom” prototype to educate a large group of laypeople with real-time visual CPR feedback has been described, and the effectiveness of training was assessed. The QCPR-Classroom training achieved a higher percentage of adequate depth and recoil than the standard training with subjective assessment by instructors and a higher percentage of adequate recoil. During in-action “QCPR Classroom” training with a metronome sound, displaying all students’ feedback on the big screen significantly provided accurate real-time visual feedback to achieve two important components together: compressing the chest with a depth over 5 cm and minimizing the incomplete release of the chest. Teaching CPR to larger groups of laypeople with a real-time feedback system, a novel QCPR Classroom with a metronome sound, is a recommended CPR training model.

Acknowledgements

The authors wish to thank all staff members at the Research Institute of Disaster Management and EMS at Kokushikan University for their assistance in this study. The authors also thank Laerdal Medical for their assistance in using QCPR Classroom.

Competing Interests

Tonje Søraas Birkenes and Helge Myklebust are employees of Laerdal Medical. They contributed the QCPR Classroom prototype, study design, and critical revision of the manuscript, but had no role in data collection, analysis of the results, or decision to publish. Other authors did not receive any payment, gift or anything from Laerdal Medical.

Funding

None

Author Contributions

ST carried out all the studies, participated in the sequence alignment, and drafted the manuscript. ST, KT, TH, RS, HM, TB, HTaky, and HTana were involved in the study design. ST, KT, TH, and HTana contributed to the study implementation. HM and TB developed the concept and contributed to technological support. ST, KT, TH, HTaka, AI, HU, YK, MY and HTana were involved in the data collection. RS conducted statistical analysis. ST, RS, and HTana performed data analysis. HTaky, HM, and TB contributed critical revisions to the manuscript. HTana also revised and approved the final manuscript. All authors read and approved the final submission.

Ethical Approval

The study was approved by the Institutional Review Board at Kokushikan University, Japan under the registration number 16-RI002 on February 23rd, 2017.

Data Availability Statement

All relevant data are within the paper and its data are available from corresponding author, ST, upon request.

Figure legends

Figure 1. Flow chart of the study

Figure 2. Image of QCPR Classroom feedback system

Figure 3. Image of actual display on the front screen

References

1. Mozaffarian D, Benjamin EJ, Go AS, et al. Heart disease and stroke statistics–2016 update: a report from the American Heart Association. Circulation. 2015;133:e38-e360.
2. Hasselqvist-Ax I, Riva G, Herlitz J, Rosenqvist M, Hollenberg J, Nordberg P, Ringh M, Jonsson M, Axelsson C, Lindqvist J, Karlsson T, Svensson L. Early cardiopulmonary resuscitation in out-of-hospital cardiac arrest. N Engl J Med. 2015;372:2307-2315.
3. Wissenberg M, Lippert FK, Folke F, Weeke P, Hansen CM, Christensen EF, Jans H, Hansen PA, Lang-Jensen T, Olesen JB, Lindhardsen J, Fosbol EL, Nielsen SL, Gislason GH, Kober L, Torp-Pedersen C. Association of national initiatives to improve cardiac arrest management with rates of bystander intervention and patient survival after out-of-hospital cardiac arrest. JAMA. 2013;310:1377-1384.
4. Hansen CM, Kragholm K, Pearson DA, et al. Association of bystander and first-responder intervention with survival after out-of-hospital cardiac arrest in North Carolina, 2010–2013. JAMA. 2015;314:255-264.
5. Iwami T, Kawamura T, Hiraide A, et al. Effectiveness of bystander-initiated cardiac-only resuscitation for patients with out-of-hospital cardiac arrest. Circulation. 2007;116:2900-2907.
6. Takahashi H, Sagisaka R, Natsume Y, Tanaka S, Takyu H, Tanaka H. Does Dispatcher-Assisted CPR generate the same outcomes as spontaneously delivered Bystander CPR in Japan? Am J Emerg Med. 2018;36(3):384-391.
7. Nakahara S, Tomio J, Ichikawa M, Nakamura F, Nishida M, Takahashi H, Morimura N, Sakamoto T. Association of bystander interventions with neurologically intact survival

among patients with bystander-witnessed out-of-hospital cardiac arrest in Japan. JAMA. 2015;314:247-54.

8. American Heart Association. Highlights of the 2015 American Heart Association guidelines update for CPR and ECC. Texas, American Heart Association, 2015. (Accessed 1 September 2017, at https://eccguidelines.heart.org/wp-content/uploads/2015/10/2015-AHA-Guidelines-Highlights-English.pdf)

9. Japan Resuscitation Council. Chapter 1 BLS: Basic Life Support. (Accessed 3 February 2019, at https://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/1327fc7d4e9a5dcd73732eb04c159a7b.pdf).

10. Global Resuscitation Alliance. Improving Survival from Out-of-Hospital Cardiac Arrest: A Call to Establish a Global Resuscitation Alliance. (Accessed 2 December 2017, at http://www.laerdalevents.com/gra/wp-content/pdf/call_to_establish.pdf)

11. Aufderheide TP, Pirrallo RG, Yannopoulos D, et al. Incomplete chest wall decompression: a clinical evaluation of CPR performance by EMS personnel and assessment of alternative manual chest compression-decompression techniques. Resuscitation. 2005;64:353-362.

12. Sutton RM, Niles D, Nysaether J, et al. Quantitative Analysis of CPR Quality During In-Hospital Resuscitation of Older Children and Adolescents. Pediatrics. 2009;124(2):494-9.

13. Yannopoulos S, McKnite S, Aufderheide TP, Sigurdsson G, Pirrallo RG, Benditt D, Lurie KG. Effect of incomplete chest wall decompression during cardiopulmonary resuscitation on coronary and cerebral perfusion pressures in a porcine model of cardiac arrest. Resuscitation. 2005;64:363-72.

14. Neumar RW, Shuster M, Callaway CW, et al. 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care, Part 1: Executive Summary. Circulation. 2015;132:S315–67.

15. Perkins GD, Handley AJ, Koster RW, et al. European Resuscitation Council Guidelines for Resuscitation 2015 Section 2. Adult basic life support and automated external defibrillation. Resuscitation. 2015;95:81-99.

16. Abella BS, Edelson DP, Kim S, et al. CPR quality improvement during in-hospital cardiac arrest using a real-time audiovisual feedback system. Resuscitation. 2007;73(1):54–61.

17. Hostler D, Everson-Stewart S, Rea TD, et al; Effect of real-time feedback during cardiopulmonary resuscitation outside hospital: prospective, cluster-randomised trial. BMJ 2011;342(d512):1-10.

18. Buleon C, Delaunay J, Parienti J.-J., Halbout L., Arrot X, Gerard J.-L., Hanouz J.-L. Impact of a feedback device on chest compression quality during extended manikin CPR: a randomized crossover study. Am J Emerg Med. 2016;34:1754-1760.

19. Bobrow BJ, Vadeboncoeur TF, Stolz U, et al. The influence of scenario-based training and real-time audiovisual feedback on out-of-hospital cardiopulmonary resuscitation quality and survival from out-of-hospital cardiac arrest. Ann Emrg Med. 2013;62(1):47-56.

20. Skorning M, Beckers SK, Brokmann JC, et al. New visual feedback device improves performance of chest compressions by professionals in simulated cardiac arrest. Resusciation. 2010;81:53-58.

21. Buleon C, Parienti J-J, Halbout L, et al. Improvement in chest compression quality using a feedback device (CPRmeter): a stimulation randomized crossover study. Am J Emerg Med. 2013;31:1457-1461.

22. Kramer-Johansen J, Myklebust H, Wik L, et al. Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: a prospective interventional study. Resuscitation. 2006;71:283-292.

23. Cheng A, Brown LL, Duff JP, et al.; International Network for Simulation-Based Pediatric Innovation, Research, & Education (INSPIRE) CPR Investigators. Improving cardiopulmonary resuscitation with a CPR feedback device and refresher simulations (CPR CARES Study): a randomized clinical trial. JAMA Pediatr. 2015; 169:137-44.

24. Cheng A, Overly F, Kessler D, et al.; International Network for Simulation-Based Pediatric Innovation, Research, & Education (INSPIRE) CPR Investigators. Perception of CPR quality: Influence of CPR feedback, Just-in-Time CPR training and provider role. Resuscitation 2015;87:44-50.

25. White AE, Ng HX, Ng WY, Ng EKX, Fook-Chong S, Kua PHJ, Ong MEH. Measuring the effectiveness of a novel CPRcard™ feedback device during stimulated chest compressions by non-healthcare workers. Singapore Med J 2017:58:438-445.

26. Tanaka S, White AE, Sagisaka R, et al. Comparison of quality of chest compressions during training of laypersons using Push Heart and Little Anne manikins using blinded CPRcards. Int Emerg Med. 2017;10(1):20.

27. Baldi E, Cornara S, Contri E, et al. Real-time visual feedback during training improves layperson's CPR quality: a randomized controlled manikin study. CJEM. 2017;19(6):480-487.

28. Yeung J, Meeks R, Edelson D, Gao F, Soar J, Perkins G. The use of CPR feedback/prompt devices during training and CPR performance: A systematic review. Resuscitation. 2009;80:743-751.

29. Kong SY, Shin SD, Song KJ, et al. Effect of instructor's real-time feedback using QCPR-classroom device during layperson cardiopulmonary resuscitation (CPR) training on quality of CPR Performances: A prospective cluster-randomised trial. BMJ Open. 2018;8:doi:10.1136/bmjopen-2018-EMS.25.

30. Nishiyama C, Iwami T, Kawamura T, Ando M, Yonemoto N, Hiraide A, Nonogi H. Quality of chest compressions during continuous CPR; comparison between chest compression-only CPR and conventional CPR. Resuscitation. 2010;81:1152-1155.

31. American Heart Association. AHA requirement on Use of feedback devices in adult CPR training courses. (Accessed 1 September 2017, at http://ahainstructornetwork.americanheart.org/idc/groups/ahaecc-public/@wcm/@ecc/documents/downloadable/ucm_495639.pdf.).

32. Cortegiani A, Russotto V, Montalto F, Iozzo P, Meschis R, Pugliesi M, et al. (2017) Use of a Real-Time Training Software (Laerdal QCPR®) Compared to Instructor-Based Feedback for High-Quality Chest Compressions Acquisition in Secondary School Students: A Randomized Trial. PLoS ONE 12(1): e0169591.

33. Jones I, Whitefield R, Colquhoun M, Chamberlain D, Vetter N, Newcombe R, et al. At what age can schoolchildren provide effective chest compressions? AN observational study from the Heartstart UK schools training programme. BMJ. 2007;334:1201.

34. Contri E, Cornara S, Somaschini A, et al.Complete chest recoil during laypersons' CPR: Is it a matter of weight? Am J Emerg Med. 2017;35:1266-1268.

35. Kaye W, Rallis SF, Mancini ME, et al. The problem of poor retention of cardiopulmonary resuscitation skills may lie with the instructor, not the learner or the curriculum. Resuscitation. 1991;21:67-87.

36. Parnell MM, Larsen PD. Poor quality teaching in lay person CPR courses. Resuscitation. 2007;73:271-278.

37. Wagner P, Lingemann C, Arntz HR, Breckwoldt J. Official lay basic life support courses in Germany: is delivered content up to date with the guidelines? An observational study. Emerg Med J. 2015;32(7):547-52.

38. Møller TP, Hansen CM, Fjordholt M, Pedersen BD, Østergaard D, Lippert FK. Debriefing bystanders of out-of-hospital cardiac arrest is valuable. Resuscitation. 2014;85:1504-1511.

39. Hirose T, Iwami T, Ogura H, et al. Effectiveness of a simplified cardiopulmonary resuscitation training program for the non-medical staff of a university hospital. Scand J Trauma Resusc Emerg Med. 2014;22(31):1-7.

40. Lynch B, Einspruch EL, Nichol G, Aufderheide TP. Assessment of BLS skills: optimizing use of instructor and manikin measures. Resuscitation. 2008;76:233-243.

41. Wik L, Steen PA, Bircher NG. Quality of bystander cardiopulmonary resuscitation influences outcome after prehospital cardiac arrest. Resuscitation. 1994;28:195-203.

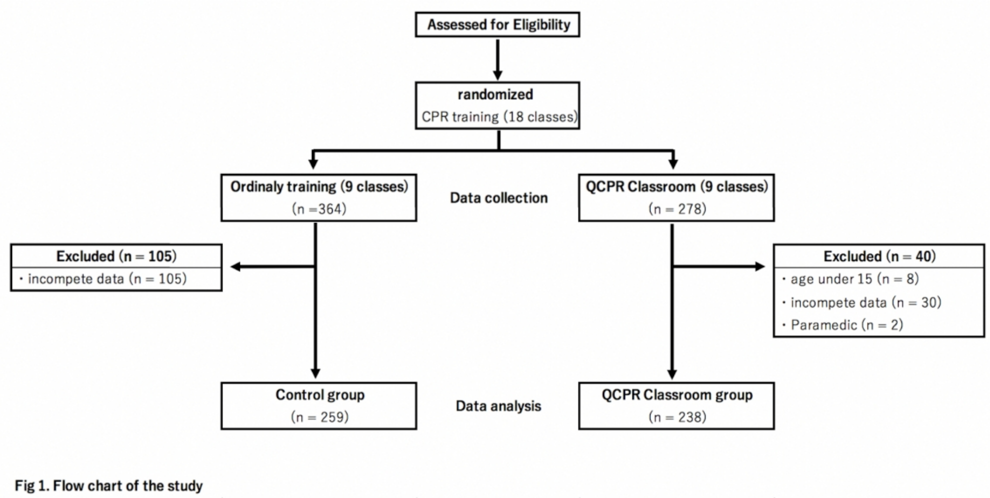
42. Van Hoeyweghen RJ, Bossaert LL, Mullie A, et al. Quality and efficiency of bystander CPR. Resuscitation. 1993;26:47-52. Emerg Med J. 2014;0:1-6.

43. Gallagher EJ, Lombardi G, Gennis P. Effectiveness of bystander cardiopulmonary resuscitation and survival following out-of-hospital cardiac arrest. JAMA. 1995;274:1992-1925.

44. Takei Y, Nishi T, Matsubara H, Hashimoto M, Inaba H. Factors associated with quality of bystander CPR: the presence of multiple rescuers and bystander-initiated CPR without instruction. Resuscitation. 2014;85:492-498.

45. Tanaka S, Rodrigues W, Sotir S, Sagisaka R, Tanaka H. CPR Performance in the Presence of Audiovisual Feedback or Football Shoulder Pads. BMJ Open Sport Exerc Med. 2017;3(1):e000208.

46. Japan Resuscitation Council. Chapter 8 ETI: Education, Implementation, and Teams. (Accessed 2 December 2017, at http://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/b7b5b647189bc07f38f6fecf014cf5d9.pdf).



Flow chart of the study

Fig 2. Image of QCPR Classroom feedback system

Image of QCPR Classroom feedback system

Fig 3. Image of actual display on the front screen

Image of actual display on the front screen

Date: ____/_____/_____

Research Institute of Disaster Management and EMS,
Kokushikan University

Survey

We conduct this survey for those who had a CPR training. Thank you for your cooperation to take part in this survey. The result will only use for a research purpose and will be kept in the strictest confidentiality. Please make a circle (o) or fill in the blank.

1. Number of mannikin:__________ **2. Sex: male / female**

3. Age: __________ **years old** **height:** __________ **cm** **weight:** __________ **kg**

4. Have you ever taken CPR training course? Yes / No

5. if "Yes" on question 4, did you take within a year? Yes / No

Question 6: On a scale 1 to 10, with 1 being very difficult and 10 being very easy, …

6. How do you rate the ease of understanding the feedback from instructor?

(1) rate	(1 = very difficult)	1	2	3	4	5	6	7	8	9	10	(10 = very easy)
(2) depth	(1 = very difficult)	1	2	3	4	5	6	7	8	9	10	(10 = very easy)
(3) recoil	(1 = very difficult)	1	2	3	4	5	6	7	8	9	10	(10 = very easy)

Question 7 & 8: On a scale 1 to 10, with 1 being not confident and 10 being very confident, …

7. How much confidence do you have to perform chest compression before training?

(1) rate	(1 = not confident)	1	2	3	4	5	6	7	8	9	10	(10 = very confident)
(2) depth	(1 = not confident)	1	2	3	4	5	6	7	8	9	10	(10 = very confident)
(3) recoil	(1 = not confident)	1	2	3	4	5	6	7	8	9	10	(10 = very confident)

8. How much confidence do you have to perform chest compression after training?

(1) rate	(1 = not confident)	1	2	3	4	5	6	7	8	9	10	(10 = very confident)
(2) depth	(1 = not confident)	1	2	3	4	5	6	7	8	9	10	(10 = very confident)
(3) recoil	(1 = not confident)	1	2	3	4	5	6	7	8	9	10	(10 = very confident)

9. Please feel free to comments

Table 1: CONSORT 2010 checklist of information to include when reporting a cluster randomised trial

Section/Topic	Item No	Standard Checklist item	Extension for cluster designs	Page No *
Title and abstract				
	1a	Identification as a randomised trial in the title	Identification as a cluster randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)[1,2]	See table 2	2
Introduction				
Background and objectives	2a	Scientific background and explanation of rationale	Rationale for using a cluster design	5-6
	2b	Specific objectives or hypotheses	Whether objectives pertain to the the cluster level, the individual participant level or both	6
Methods				
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	Definition of cluster and description of how the design features apply to the clusters	8
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons		**n/a**
Participants	4a	Eligibility criteria for participants	Eligibility criteria for clusters	7
	4b	Settings and locations where the data were collected		**7**
Interventions	5	The interventions for each group with sufficient details to allow replication, including how	Whether interventions pertain to the cluster level, the individual participant level or both	7-8

		and when they were actually administered		
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	Whether outcome measures pertain to the cluster level, the individual participant level or both	7-8
	6b	Any changes to trial outcomes after the trial commenced, with reasons		**n/a**
Sample size	7a	How sample size was determined	Method of calculation, number of clusters(s) (and whether equal or unequal cluster sizes are assumed), cluster size, a coefficient of intracluster correlation (ICC or *k*), and an indication of its uncertainty	7
	7b	When applicable, explanation of any interim analyses and stopping guidelines		**n/a**
Randomisation:				
Sequence generation	8a	Method used to generate the random allocation sequence		**8**
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	Details of stratification or matching if used	8
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	Specification that allocation was based on clusters rather than individuals and whether allocation concealment (if any) was at the cluster level, the individual participant level or both	n/a
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who	Replace by 10a, 10b and 10c	8

		assigned participants to interventions		
	10a		Who generated the random allocation sequence, who enrolled clusters, and who assigned clusters to interventions	8
	10b		Mechanism by which individual participants were included in clusters for the purposes of the trial (such as complete enumeration, random sampling)	8
	10c		From whom consent was sought (representatives of the cluster, or individual cluster members, or both), and whether consent was sought before or after randomisation	7
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	**participants**	**7-8**
	11b	If relevant, description of the similarity of interventions		**n/a**
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	How clustering was taken into account	11-12
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses		**n/a**
Results				

Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	For each group, the numbers of clusters that were randomly assigned, received intended treatment, and were analysed for the primary outcome	12, Fig 1
	13b	For each group, losses and exclusions after randomisation, together with reasons	For each group, losses and exclusions for both clusters and individual cluster members	12, Fig 1
Recruitment	14a	Dates defining the periods of recruitment and follow-up		**7**
	14b	Why the trial ended or was stopped		**n/a**
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Baseline characteristics for the individual and cluster levels as applicable for each group	10, Table 1
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	For each group, number of clusters included in each analysis	12
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	Results at the individual or cluster level as applicable and a coefficient of intracluster correlation (ICC or k) for each primary outcome	12-16
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended		**n/a**
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing		**n/a**

		pre-specified from exploratory		
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms[3])		**n/a**
Discussion				
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses		**21-22**
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	Generalisability to clusters and/or individual participants (as relevant)	16-21
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence		**n/a**
Other information				
Registration	23	Registration number and name of trial registry		**n/a**
Protocol	24	Where the full trial protocol can be accessed, if available		**n/a**
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders		**23**

** Note: page numbers optional depending on journal requirements*

[1] Hopewell S, Clarke M, Moher D, Wager E, Middleton P, Altman DG, et al. CONSORT for reporting randomised trials in journal and conference abstracts. *Lancet* 2008, 371:281-283

[2] Hopewell S, Clarke M, Moher D, Wager E, Middleton P, Altman DG at al (2008) CONSORT for reporting randomized controlled trials in journal and conference abstracts: explanation and elaboration. *PLoS Med* 5(1): e20

[3] Ioannidis JP, Evans SJ, Gotzsche PC, O'Neill RT, Altman DG, Schulz K, Moher D. Better reporting of harms in randomized trials: an extension of the CONSORT statement. *Ann Intern Med* 2004; 141(10):781-788.