

BMJ Open

BMJ Open is committed to open peer review. As part of this commitment we make the peer review history of every article we publish publicly available.

When an article is published we post the peer reviewers' comments and the authors' responses online. We also post the versions of the paper that were used during peer review. These are the versions that the peer review comments apply to.

The versions of the paper that follow are the versions that were submitted during the peer review process. They are not the versions of record or the final published versions. They should not be cited or distributed as the published version of this manuscript.

BMJ Open is an open access journal and the full, final, typeset and author-corrected version of record of the manuscript is available on our site with no access controls, subscription charges or pay-per-view fees (<http://bmjopen.bmj.com>).

If you have any questions on BMJ Open's open peer review process please email info.bmjopen@bmj.com

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:	<i>BMJ Open</i>
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

SCHOLARONE™
Manuscripts

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
601
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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]), $\geq 90\%$ 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 ± 9.8 mm and 119.2 ± 7.3 compressions per minute (cpm) in the control group and 59.5 ± 7.9 mm and 116.8 ± 5.5 cpm in the QCPR-Classroom group, respectively. The QCPR-Classroom group showed a significantly higher rate of achieving $\geq 90\%$ adequate depth than the control group ($p=0.001$). The difference between pre- and post-training of achieving $\geq 90\%$ 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.

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

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

7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

1 **Article Summary**

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

13 **Strengths and limitations of this study**

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

1 Introduction

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

14 Healthcare professionals were found to perform incomplete compression recoil in
15 46% of all cases and in 23.4% of cases involving paediatric patients [10-11]. However,
16 performing full recoil is emphasized in the GRA consensus, along with the use of a feedback
17 device during CPR training [8]. Incomplete recoil leads to insufficient time for blood to fill
18 into the heart, which eventually leads to less blood flow to the brain [12]. Coronary and
19 cerebral perfusion pressure can deteriorate due to incomplete decompression [13]. Full recoil
20 is one of the most important concepts for ensuring high-quality CPR [8,14-15]. However,
21 teaching the concept of recoil has been difficult for non-healthcare professionals, for which
22 little is known about what the best teaching method is. Key points during CPR training are

1 teaching to compress the chest 5 cm deep and allowing for full chest recoil, but these two
2 components are hard to achieve during training without a feedback device.

3 We are currently facing a period of transition to a new style of CPR training. Many
4 companies have introduced feedback devices, and research supports their effectiveness
5 [16-25]. However, most of them cannot monitor recoil, or they are unavailable for CPR
6 training that targets a large population. According to previous studies, the CPRcard (Laerdal
7 Medical, Stavanger, Norway) could be a promising device to ensure CPR quality during
8 large-scale CPR training [23-26]. Laerdal Medical (Stavanger, Norway) also recently
9 launched the “QCPR Classroom” concept, which provides real-time visual feedback for a
10 greater number of participants at once. The effectiveness of the QCPR Classroom device was
11 recently demonstrated by Kong et al. [27]. The purpose of this study is to examine the
12 effectiveness of CPR skills delivered by QCPR Classroom training in comparison to ordinary
13 CPR training. The hypothesis of the study was that QCPR Classroom would generate higher
14 achievement in CPR skill regardless of instructors’ teaching skill. We aimed to determine
15 whether QCPR Classroom could be the best practical model for CPR training.

16
17

1 **Methods**

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

5 6 *Patient and Public Involvement*

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

9 10 *Study population*

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

18 19 *Measurements*

20 Participants enrolled in the CPR+automated external defibrillator (AED) training.
21 The primary outcome was compression depth (mm), compression rate (compressions per
22 minute [cpm]), adequate depth (%), and adequate recoil (%). These measurements were
23 blindly measured both pre- and post-training for one minute. The scores from the survey

1 conducted after the training were considered as a secondary outcome. For data analysis, we
2 used a cutoff of 90 % compliance with depth > 5 cm.

4 *Study procedure*

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

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

18 To measure the effect of CPR training, one minute of chest compression was
19 measured without any feedback given as a pre-test. Similarly to the pre-test, one minute of
20 chest compression was also measured after the training as a post-test. Although one minute of
21 measurement may not be sufficient duration for CPR performance in real life, we focused on
22 the initial CPR performance by a single rescuer situation. A survey and baseline
23 characteristics, such as weight, height, and CPR training experience (Table 1), were also

1 collected after the post-training measurement. A metronome was set at 110 beats per minute
 2 (bpm) and used for every instance of hands-on practice during the QCPR Classroom session,
 3 but no metronome was used during the ordinary CPR training.

4
 5
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

6
 7 *Instrumentation*

8 Compression data was captured using the Laerdal QCPR Classroom mannequin
 9 system (Laerdal Medical, Stavanger, Norway), as shown in Figure 2. This prototype system
 10 for community CPR training provides real-time visual feedback from 42 mannequins, where
 11 icons representing CPR performance from each mannequin are visualized on an iPad tablet.
 12 We mirrored the iPad screen on a laptop using the application Reflector 2 (Squirrels[®], North
 13 Canton, OH, United States) in order to present real-time feedback on a large screen at the
 14 front of the classroom (Figure 3). QCPR Classroom uses Laerdal Little Anne mannequins,

1 and each one is instrumented with an optical compression sensor and microcontroller. The
2 microcontroller analyses the signal from the compression sensor and calculates the number of
3 compressions, compression depth, rate, and incomplete release. A compression score is
4 calculated using the rate, depth, and release. Each sensor was checked for depth accuracy
5 using a calibrated compression machine with $\pm 15\%$ considered as acceptable error.

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

17 *Statistical analysis*

18 The rate and depth measurements are shown as the mean and standard deviation.
19 Normal distributions and homogeneity of variance were confirmed by a Q-Q plot. The
20 difference between pre- and post-training measurements within the groups were analysed
21 using a paired t-test and McNemar test. Group comparison for both pre- and post-training
22 was conducted using Welch’s t-test and the chi-square test. For the analysis, the rates of
23 achievement of $\geq 90\%$ adequate depth and recoil were calculated as percentages and

1 considered as indexes of high competency. Analysing the percentage variables to compare
2 the numerical value using a parametric test, such as a t-test, would neglect the upper limit of
3 100 %, so we set a criterion of $\geq 90\%$ for their high-quality performance. The differences
4 and 95% confidence intervals are shown in tables. The medians and interquartile ranges are
5 presented for ordinal data. We compared the groups using the Wilcoxon single-rank test for
6 continuous variables. The data was analysed using JMP (V.11.2.0, the SAS Institute Inc.),
7 and p-values less than 0.05 were considered as significant.

8

9 **Results**

10 *Demographic characteristics*

11 A total of 642 people participated in this study. As shown in Figure 1, 145
12 participants were excluded due to incomplete data (n = 135), age under 15 years (n = 8), and
13 paramedics (n = 2). Significant age difference between the groups was found (22.4 ± 9.0 vs.
14 19.4 ± 5.6 ; $p < .0001$). After the CPR training, 497 participants were eligible for analysis,
15 with 259 people in the control group and 238 people in the QCPR Classroom group. The
16 demographic characteristics are shown in Table 1.

17

18 *Primary outcome*

19 All chest compression parameters at pre-training and post-training are shown in
20 Table 2. After the training, the mean compression depth of each student was 56.1 ± 9.8 mm in
21 the control group and 59.5 ± 7.9 mm in the QCPR Classroom group. Significantly more
22 participants in the QCPR Classroom group achieved $\geq 90\%$ of the adequate depth compared
23 to the control group ($p = 0.001$; Table 3). In the QCPR Classroom group, there was an

1 improvement of 39.1% (95% CI, 5.1-21.0) in achieving $\geq 90\%$ of the adequate depth (37.8%
 2 at pre-training vs. 76.9% at post-training). In the control group, the improvement was 29.7%
 3 (95% CI, 21.3-37.7) in achieving $\geq 90\%$ of the adequate depth (34.0% at pre-training and
 4 63.7% at post-training; $p < 0.0001$; Table 2).

5 Both groups demonstrated average compression rates of 100-120 cpm (Table 2). A
 6 statistically significant difference was found between groups in terms of recoil ($p < 0.0001$;
 7 Table 2). The control group demonstrated a 1.5% (95% CI, -6.9-1.0) increase in the
 8 percentage of achieving $\geq 90\%$ recoil (40.2% pre-training vs. 41.7% post-training; $p = 0.72$).
 9 The QCPR Classroom group demonstrated a 27.7% (95% CI, 19.0-36.0) increase in the
 10 percentage of achieving $\geq 90\%$ recoil (44.5% pre-training vs. 72.3% post-training; $p <$
 11 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	<i>p</i> value	Difference (95% CI)	Pre-training	Post-training	<i>p</i> 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	*	4.6 (3.5 - 5.8)	48.2 ± 14.7	59.5 ± 7.9	*	11.3 (9.8 - 12.8)
adequate depth $\geq 90\%$ ⁺⁺	88 (34.0)	165 (63.7)	*	29.7 (21.3 - 37.7)	90 (37.8)	183 (76.9)	*	39.1 (30.6 - 46.5)
recoil $\geq 90\%$ ⁺⁺	104 (40.2)	108 (41.7)	0.72	1.5 (-6.9 - 1.0)	106 (44.5)	172 (72.3)	*	27.7 (19.0 - 36.0)

50 paired-t test and McNemar test; CPR: cardiopulmonary

51 resuscitation; CI: confidence interval

52 ⁺ Mean and standard deviation for rate nad

53 depth measurement

1
2
3 ** Numbers (percentage) for $\geq 90\%$ of the
4 adequate depth and recoil achieved
5
6 * $p < .05$
7
8 significant

9
10 1

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

	Control (n = 259)	QCPR Classroom (n = 238)	<i>p</i> 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 \geq 90% ⁺⁺	88 (34.0)	90 (37.8)	0.37	3.8 (-4.6 – 12.2)
recoil $\geq 90\%$ ⁺⁺	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 \geq 90% ⁺⁺	165 (63.7)	183 (76.9)	0.001 *	13.2 (5.1 – 21.0)
recoil $\geq 90\%$ ⁺⁺	108 (41.7)	172 (72.3)	<0.001 *	30.6 (22.1 – 38.6)

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

48
49 + Mean and standard deviation for rate and
50 depth measurement

51
52 ⁺⁺ Numbers (percentage) for $\geq 90\%$ of the adequate depth and recoil
53 achieved

54
55 * $p < .05$ significant

1
2
3
4 1
5
6 2 *Secondary outcome*
7
8 3 The survey asked about participants' confidence levels before and after training
9
10 4 regarding three parameters (rate, depth, and recoil) using the following question: "On a scale
11
12 5 of 1-10, with 1 being not confident and 10 being very confident, how much confidence do
13
14 6 you have to perform chest compressions?" The confidence level toward CPR performance
15
16 7 was not different between the two groups. The question "how easy to understand the
17
18 8 instructor?" was asked to address the ease of understanding. In terms of rate, the QCPR
19
20 9 Classroom training group (10.0[9.0-10.0]) showed higher scores, compared to the control
21
22 10 group (10.0[8.5-10.0]; $p=0.01$; Table 4).
23
24
25

26
27 **Table 4. Survey regarding participants' confidence levels before and after training**
28 **regarding three parameters (rate, depth, and recoil)**

Question	Control (n = 259)	QCPR Classroom (n = 238)	<i>p</i> 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?			
	10.0		
rate	(8.5-10.0)	10.0 (9.0-10.0)	0.01*

	10.0		
depth	(8.0-10.0)	10.0 (9.0-10.0)	0.08
	10.0		
recoil	(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?”

1

2 Discussion

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

15 Significant age difference was found, but the previous studies indicated that chest
 16 compression delivered by the 13-14 year olds group was similar to what the adult performed
 17 and the researchers concluded the performance was depended on weight, age [29], as well as
 18 height, BMI, and sex [30]. In our study, the median and IQR for each group was 19(17-23)

1 and 17(16-21), so there is no height and weight difference between two groups and both
2 groups included over 15 years old, so we considered that the age difference was clinically
3 negligible to perform adequate CPR performance.

4 In our study, 72.3% of the participants in the QCPR Classroom group achieved
5 $\geq 90\%$ adequate recoil in post-training. Healthcare professionals were previously found to
6 perform incomplete chest recoil in 46% of cases [10]. Teaching the concept of recoil is not
7 easy, and we found that only 1.5% of participants achieved $\geq 90\%$ adequate recoil in the
8 control group. Contri et al. stated that instruction about recoil must be modified according to
9 the participants' physical characteristics [30]. However, during ordinary community CPR
10 training, the instructor cannot spend much time on each individual and find out who needs to
11 correct their performance.

12 This was the study to examine the effect of using "QCPR Classroom" training. As
13 Kong et al. concluded, overall CPR quality was improved through QCPR-Classroom based
14 training [27]. The QCPR Classroom group showed significant improvement in CPR skills
15 between post-training and pre-training, which demonstrates the advantages of the concept.
16 The control group also demonstrated significant improvements between post-training and
17 pre-training for rate, depth, and $\geq 90\%$ adequate depth (Table 2). As shown in Table 3, the
18 QCPR Classroom group was 13.2% higher on $\geq 90\%$ adequate depth than those in the
19 control group ($p=0.001$). The QCPR Classroom group was 30.6% higher on $\geq 90\%$ adequate
20 recoil than those in the control group ($p<0.001$). Higher adequate depth and recoil are the
21 significant advantages of the QCPR Classroom. This real-time visual in-action feedback
22 system has been provided a significant impact on CPR performance throughout the CPR
23 practice. The purpose of QCPR Classroom is to make it easy to objectively measure and

1 improve CPR performance in community CPR classes. In a large classroom, learners could
2 see their CPR performance on a big screen at the front of the class. Kong et al. randomized
3 the groups and the instructor only visible the feedback icon on iPad [27]. Students only
4 received objective feedback directly from instructor. Our study randomized the groups and
5 both students and instructor were visible the feedback icon on iPad by arranging on big
6 screen in front of the classroom.

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

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

1 would not have passed according to objective measurements or evaluation by researchers
2 [31].

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

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

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

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

18 The definition of high-quality CPR highlights the importance of depth, rate, and
19 recoil. Performing good chest compression with these three factors leads to favourable
20 outcomes. However, CPR instructors must understand the difficulty of achieving appropriate
21 depth, rate, and recoil [42]. Moreover, recent guidelines increasingly emphasize the necessity
22 of high-quality CPR performance by not only EMTs or first responders, but also citizens [42].
23 School training in CPR is the most certain method of implementing high-quality CPR

1 training in the general population. However, school teachers are not professional CPR
2 instructors or trained in teaching CPR, so there is no guarantee of the teaching quality. QCPR
3 Classroom can deliver sufficient feedback even when school teachers do not have CPR
4 instruction skills. Future studies should examine the effect of QCPR Classroom training
5 conducted by school teachers who have no background in CPR instruction.

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

15 **Study limitations**

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

1

2 **Conclusion**

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

17

18 **Acknowledgments**

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

22

23 **Author Contributions**

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

9 **Funding**

10 None

12 **Conflict of Interests**

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

17 **Ethical Approval**

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

21 **Data statement**

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

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7

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

For peer review only

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, Lindhardtsen 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

- 1 among patients with bystander-witnessed out-of-hospital cardiac arrest in Japan. JAMA.
2
3
4 1 2015;314:247-54.
5
6 2
7
8 3 8. Global Resuscitation Alliance. Improving Survival from Out-of-Hospital Cardiac Arrest:
9
10 4 A Call to Establish a Global Resuscitation Alliance. (Accessed 2 December 2017, at
11
12 http://www.laerdalevents.com/gra/wp-content/pdf/call_to_establish.pdf)
13
14 5
15 6 9. American Heart Association. AHA requirement on Use of feedback devices in adult CPR
16
17 7 training courses. (Accessed 1 September 2017, at
18
19 [http://ahainstructornetwork.americanheart.org/idc/groups/ahaecc-public/@wcm/@ecc/doc](http://ahainstructornetwork.americanheart.org/idc/groups/ahaecc-public/@wcm/@ecc/documents/downloadable/ucm_495639.pdf)
20
21 [uments/downloadable/ucm_495639.pdf](http://ahainstructornetwork.americanheart.org/idc/groups/ahaecc-public/@wcm/@ecc/documents/downloadable/ucm_495639.pdf).)
22
23 9
24 10 10. Aufderheide TP, Pirralo RG, Yannopoulos D, et al. Incomplete chest wall decompression:
25
26 11 a clinical evaluation of CPR performance by EMS personnel and assessment of
27
28 12 alternative manual chest compression-decompression techniques. Resuscitation.
29
30 13 2005;64:353-362.
31
32 13
33 14 11. Sutton RM, Niles D, Nysaether J, et al. Quantitative Analysis of CPR Quality During
34
35 15 In-Hospital Resuscitation of Older Children and Adolescents. Pediatrics.
36
37 16 2009;124(2):494-9.
38
39 16
40 17 12. American Heart Association. Highlights of the 2015 American Heart Association
41
42 18 guidelines update for CPR and ECC. Texas, American Heart Association, 2015.
43
44 19 (Accessed 1 September 2017, at
45
46 20 <https://eccguidelines.heart.org/wp-content/uploads/2015/10/2015-AHA-Guidelines-Highli>
47
48 [ghts-English.pdf](https://eccguidelines.heart.org/wp-content/uploads/2015/10/2015-AHA-Guidelines-Highli))
49
50 21
51
52 22 13. Yannopoulos S, McKnite S, Aufderheide TP, Sigurdsson G, Pirralo RG, Benditt D, Lurie
53
54 23 KG. Effect of incomplete chest wall decompression during cardiopulmonary resuscitation

- 1 on coronary and cerebral perfusion pressures in a porcine model of cardiac arrest.
2 Resuscitation. 2005;64:363-72.
- 3 14. Neumar RW, Shuster M, Callaway CW, et al. 2015 American Heart Association
4 Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular
5 Care, Part 1: Executive Summary. *Circulation*. 2015;132:S315–67.
- 6 15. Perkins GD, Handley AJ, Koster RW, et al. European Resuscitation Council Guidelines
7 for Resuscitation 2015 Section 2. Adult basic life support and automated external
8 defibrillation. *Resuscitation*. 2015;95:81-99.
- 9 16. Abella BS, Edelson DP, Kim S, et al. CPR quality improvement during in-hospital cardiac
10 arrest using a real-time audiovisual feedback system. *Resuscitation*. 2007;73(1):54–61.
- 11 17. Hostler D, Everson-Stewart S, Rea TD, et al; Effect of real-time feedback during
12 cardiopulmonary resuscitation outside hospital: prospective, cluster-randomised trial.
13 *BMJ* 2011;342(d512):1-10.
- 14 18. Buleon C, Delaunay J, Parienti J.-J., Halbout L., Arrot X, Gerard J.-L., Hanouz J.-L.
15 Impact of a feedback device on chest compression quality during extended manikin CPR:
16 a randomized crossover study. *Am J Emerg Med*. 2016;34:1754-1760.
- 17 19. Bobrow BJ, Vadeboncoeur TF, Stolz U, et al. The influence of scenario-based training
18 and real-time audiovisual feedback on out-of-hospital cardiopulmonary resuscitation
19 quality and survival from out-of-hospital cardiac arrest. *Ann Emerg Med*.
20 2013;62(1):47-56.
- 21 20. Skorning M, Beckers SK, Brokmann JC, et al. New visual feedback device improves
22 performance of chest compressions by professionals in simulated cardiac arrest.
23 *Resuscitation*. 2010;81:53-58.

- 1
2
3
4 1 21. Buleon C, Parienti J-J, Halbout L, et al. Improvement in chest compression quality using
5
6 2 a feedback device (CPRmeter): a stimulation randomized crossover study. *Am J Emerg*
7
8 3 *Med.* 2013;31:1457-1461.
9
10
11 4 22. Kramer-Johansen J, Myklebust H, Wik L, et al. Quality of out-of-hospital
12
13 5 cardiopulmonary resuscitation with real time automated feedback: a prospective
14
15 6 interventional study. *Resuscitation.* 2006;71:283-292.
16
17
18 7 23. Cheng A, Brown LL, Duff JP, et al.; International Network for Simulation-Based
19
20 8 Pediatric Innovation, Research, & Education (INSPIRE) CPR Investigators. Improving
21
22 9 cardiopulmonary resuscitation with a CPR feedback device and refresher simulations
23
24 10 (CPR CARES Study): a randomized clinical trial. *JAMA Pediatr.* 2015; 169:137-44.
25
26
27 11 24. Cheng A, Overly F, Kessler D, et al.; International Network for Simulation-Based
28
29 12 Pediatric Innovation, Research, & Education (INSPIRE) CPR Investigators. Perception of
30
31 13 CPR quality: Influence of CPR feedback, Just-in-Time CPR training and provider role.
32
33 14 *Resuscitation* 2015;87:44-50.
34
35
36 15 25. White AE, Ng HX, Ng WY, Ng EKX, Fook-Chong S, Kua PHJ, Ong MEH. Measuring
37
38 16 the effectiveness of a novel CPRcardTM feedback device during stimulated chest
39
40 17 compressions by non-healthcare workers. *Singapore Med J* 2017;58:438-445.
41
42
43 18 26. Tanaka S, White AE, Sagisaka R, et al. Comparison of quality of chest compressions
44
45 19 during training of laypersons using Push Heart and Little Anne manikins using blinded
46
47 20 CPRcards. *Int Emerg Med.* 2017;10(1):20.
48
49
50 21 27. Kong SY, Shin SD, Song KJ, et al. Effect of instructor's real-time feedback using
51
52 22 QCPR-classroom device during layperson cardiopulmonary resuscitation (CPR) training
53
54
55
56
57
58
59
60

- 1 on quality of CPR Performances: A prospective cluster-randomised trial. *BMJ Open*.
2
3
4
5
6 2018;8:doi:10.1136/bmjopen-2018-EMS.25.
7
- 8 28. Hernández-Padilla JM, Suthers F, Granero-Molina J, Fernández-Sola C. Effects of two
9
10 retraining strategies on nursing students' acquisition and retention of BLS/AED skills: A
11
12 cluster randomised trial. *Resuscitation*. 2015;93:27-34.
13
14
- 15 29. Jones I, Whitefield R, Colquhoun M, Chamberlain D, Vetter N, Newcombe R, et al. At
16
17 what age can schoolchildren provide effective chest compressions? AN observational
18
19 study from the Heartstart UK schools training programme. *BMJ*. 2007;334:1201.
20
21
- 22 30. Contri E, Cornara S, Somaschini A, et al. Complete chest recoil during laypersons' CPR:
23
24 Is it a matter of weight? *Am J Emerg Med*. 2017;35:1266-1268.
25
26
- 27 31. Kaye W, Rallis SF, Mancini ME, et al. The problem of poor retention of cardiopulmonary
28
29 resuscitation skills may lie with the instructor, not the learner or the curriculum.
30
31
32 *Resuscitation*. 1991;21:67-87.
33
- 34 32. Parnell MM, Larsen PD. Poor quality teaching in lay person CPR courses. *Resuscitation*.
35
36 2007;73:271-278.
37
- 38 33. Wagner P, Lingemann C, Arntz HR, Breckwoldt J. Official lay basic life support courses
39
40 in Germany: is delivered content up to date with the guidelines? An observational study.
41
42
43 *Emerg Med J*. 2015;32(7):547-52.
44
- 45 34. Møller TP, Hansen CM, Fjordholt M, Pedersen BD, Østergaard D, Lippert FK. Debriefing
46
47 bystanders of out-of-hospital cardiac arrest is valuable. *Resuscitation*.
48
49 2014;85:1504-1511.
50
51
52
53
54
55
56
57
58
59
60

- 1
2
3
4 1 35. Hirose T, Iwami T, Ogura H, et al. Effectiveness of a simplified cardiopulmonary
5
6 2 resuscitation training program for the non-medical staff of a university hospital. *Scand J*
7
8 3 *Trauma Resusc Emerg Med*. 2014;22(31):1-7.
9
10 4 36. Lynch B, Einspruch EL, Nichol G, Aufderheide TP. Assessment of BLS skills: optimizing
11
12 5 use of instructor and manikin measures. *Resuscitation*. 2008;76:233-243.
13
14 6 37. Wik L, Steen PA, Bircher NG. Quality of bystander cardiopulmonary resuscitation
15
16 7 influences outcome after prehospital cardiac arrest. *Resuscitation*. 1994;28:195-203.
17
18 8 38. Van Hoeyweghen RJ, Bossaert LL, Mullie A, et al. Quality and efficiency of bystander
19
20 9 CPR. *Resuscitation*. 1993;26:47-52. *Emerg Med J*. 2014;0:1-6.
21
22 10 39. Gallagher EJ, Lombardi G, Gennis P. Effectiveness of bystander cardiopulmonary
23
24 11 resuscitation and survival following out-of-hospital cardiac arrest. *JAMA*.
25
26 12 1995;274:1992-1925.
27
28 13 40. Takei Y, Nishi T, Matsubara H, Hashimoto M, Inaba H. Factors associated with quality of
29
30 14 bystander CPR: the presence of multiple rescuers and bystander-initiated CPR without
31
32 15 instruction. *Resuscitation*. 2014;85:492-498.
33
34 16 41. Tanaka S, Rodrigues W, Sotir S, Sagisaka R, Tanaka H. CPR Performance in the Presence
35
36 17 of Audiovisual Feedback or Football Shoulder Pads. *BMJ Open Sport Exerc Med*.
37
38 18 2017;3(1):e000208.
39
40 19 42. Japan Resuscitation Council. Chapter 8 ETI: Education, Implementation, and Teams.
41
42 20 (Accessed 2 December 2017, at
43
44 21 <http://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/b7b5b647189bc07>
45
46 22 [f38f6fecf014cf5d9.pdf](http://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/b7b5b647189bc07)).
47
48 23
49
50
51
52
53
54
55
56
57
58
59
60

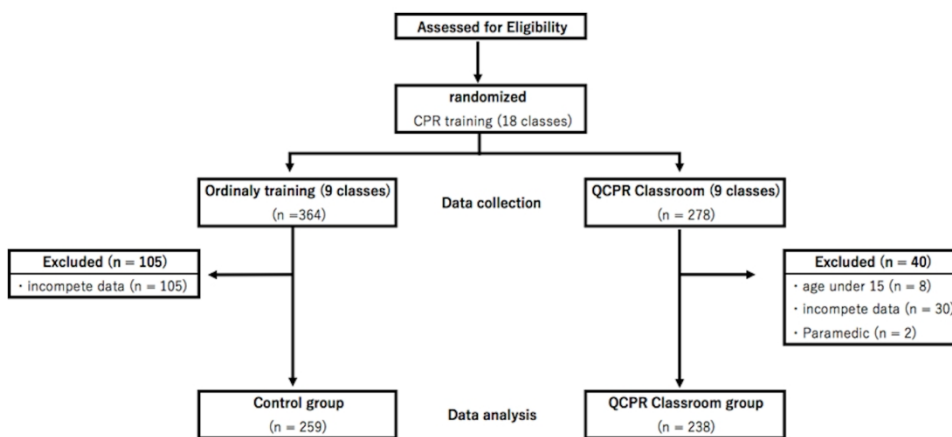


Fig 1. Flow chart of the study

Flow chart of the study



Fig 2. Image of QCPR Classroom feedback system

Image of QCPR Classroom feedback system

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60



Fig 3. Image of actual display on the front screen

Image of actual display on the front screen

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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 significance 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, phenomenology, 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.

1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14	Researcher	#6	Researchers' characteristics that may influence the	7
15	characteristics and		research, including personal attributes, qualifications /	
16	reflexivity		experience, relationship with participants, assumptions	
17			and / or presuppositions; potential or actual interaction	
18			between researchers' characteristics and the research	
19			questions, approach, methods, results and / or	
20			transferability	
21				
22				
23				
24				
25	Context	#7	Setting / site and salient contextual factors; rationale	8
26				
27				
28	Sampling strategy	#8	How and why research participants, documents, or	n/a
29			events were selected; criteria for deciding when no	
30			further sampling was necessary (e.g. sampling	
31			saturation); rationale	
32				
33				
34				
35	Ethical issues pertaining	#9	Documentation of approval by an appropriate ethics	7
36	to human subjects		review board and participant consent, or explanation for	
37			lack thereof; other confidentiality and data security issues	
38				
39				
40	Data collection methods	#10	Types of data collected; details of data collection	7-8
41			procedures including (as appropriate) start and stop	
42			dates of data collection and analysis, iterative process,	
43			triangulation of sources / methods, and modification of	
44			procedures in response to evolving study findings;	
45			rationale	
46				
47				
48				
49				
50	Data collection	#11	Description of instruments (e.g. interview guides,	9-10
51	instruments and		questionnaires) and devices (e.g. audio recorders) used	
52	technologies		for data collection; if / how the instruments(s) changed	
53			over the course of the study	
54				
55				
56				
57	Units of study	#12	Number and relevant characteristics of participants,	8
58			documents, or events included in the study; level of	
59				
60				

		participation (could be reported in results)	
1			
2			
3	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
4			
5			
6			
7			
8			
9	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
10			
11			
12			
13			
14			
15			
16	Techniques to enhance trustworthiness	#15 Techniques to enhance trustworthiness and credibility of data analysis (e.g. member checking, audit trail, triangulation); rationale	10-11
17			
18			
19			
20			
21	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
22			
23			
24			
25			
26			
27	Links to empirical data	#17 Evidence (e.g. quotes, field notes, text excerpts, photographs) to substantiate analytic findings	n/a
28			
29			
30			
31	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
32			
33			
34			
35			
36			
37			
38			
39			
40	Limitations	#19 Trustworthiness and limitations of findings	20
41			
42			
43	Conflicts of interest	#20 Potential sources of influence of perceived influence on study conduct and conclusions; how these were managed	22
44			
45			
46			
47			
48	Funding	#21 Sources of funding and other support; role of funders in data collection, interpretation and reporting	22
49			
50			

The SRQR checklist is distributed with permission of Wolters Kluwer © 2014 by the Association of American Medical Colleges. This checklist was completed on 19. August 2018 using <http://www.goodreports.org/>, a tool made by the [EQUATOR Network](#) in collaboration with [Penelope.ai](#)

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:	<i>BMJ Open</i>
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

SCHOLARONE™
Manuscripts

1
2
3
4 1
5
6 2
7
8
9 3 Title: Effect of real-time visual device QCPR Classroom with a metronome sound in a
10
11 4 layperson CPR training: A cluster randomized control trial
12
13
14 5

15
16 6 Shota Tanaka ¹⁾, Kyoko Tsukigase ¹⁾, Takahiro Hara ²⁾, Ryo Sagisaka ²⁾, Helge Myklebust ³⁾,
17 7 Tonje S. Birkenes ³⁾, Hiroyuki Takahashi ¹⁾⁴⁾, Ayana Iwata ¹⁾, Yutaro Kidokoro ¹⁾, Momoyo
18 8 Yamada ¹⁾, Hiroki Ueta ⁵⁾, Hiroshi Takyu ²⁾, Hideharu Tanaka ¹⁾²⁾

- 19 9
20
21
22 10 1) Research Institute of Disaster Management and EMS, Kokushikan University
23 11 2) Graduate School of EMS System, Kokushikan University
24 12 3) Laerdal Medical, Stavanger, Norway
25 13 4) Department of Sports Medicine, Kokushikan University, Japan
26 14 5) Faculty of Emergency Medical Science, Meiji University of Integrative Medicine
27
28
29
30

31 15
32
33
34 16 Correspondence author: SHOTA TANAKA

35
36 17 Kokushikan University, 7-3-1, Nagayama, Tama City, Tokyo, JAPAN

37
38 18 E-mail: tanakamedical24@gmail.com

39
40 19 TEL/FAX: +81-42-339-7197
41
42
43
44 20

45
46 21 Keywords: cardiac arrest, bystander, CPR training, resuscitation, Mass CPR training
47
48

49 22 Word Count: 4133
50
51
52
53
54
55
56
57
58
59
60

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 ± 9.8 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, 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

1
2
3
4 1 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
5
6 2 QCPR-Classroom group (95% CI, 17.8-27.3; pre 64.8±37.5% vs. post 87.4±22.9%;
7
8
9 3 $p<0.0001$). The sound from a metronome set at 110 beats per minute had a positive influence
10
11 4 on the CPR performance.

12
13
14 5 **Conclusion** The QCPR-Classroom concept helped students achieve high-quality CPR
15
16 6 training, especially for proper compression depth and full recoil. To reach a good educational
17
18 7 achievement, a novel QCPR Classroom with a metronome sound is a recommended CPR
19
20
21 8 training model.
22
23

24 9

25
26 10
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1 **Article Summary**

2 The paper describes the use a novel "QCPR classroom" technique with a metronome sound to
3 educate laypeople in CPR. A large classroom in which learners could see their CPR
4 performance on a big screen at the front of the class was used. Students were randomized into
5 a control group and a QCPR classroom group. They were assessed on their ability to perform
6 1 minute of chest compression-only CPR. Post training results showed that the QCPR group
7 had 13.6% better adequate depth and 20.5% better adequate recoil than the control group.
8 However, there was no difference in average depth or rate between the two groups. The
9 American Heart Association recommends use of audiovisual feedback device during CPR
10 education. Benefits of visual feedback devices are well accepted and agreed. QCPR
11 classroom concept is a fancy new idea for mass-CPR training.

12 **Strengths and limitations of this study**

- 13 - One of the advantages of CPR training carried by QCPR Classroom concept is a good
- 14 educational achievement with fewer instructors.
- 15 - Arranging objective real-time feedback on big screen in front of everyone to visible to both
- 16 instructor and students made significantly improve CPR quality.
- 17 - No retention measurement was taken and the measurements were all students together

1 Introduction

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

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

22 We are currently facing a period of transition to CPR training with a feedback
23 device, as various feedback devices were introduced, and research supported their

1 effectiveness [16-28]. However, they are unavailable for CPR training that targets a large
2 population. Laerdal Medical (Stavanger, Norway) launched the “QCPR Classroom” concept,
3 which provides real-time visual feedback for a greater number of participants at once. The
4 effectiveness of the QCPR Classroom device was recently demonstrated by Kong et al. [29].
5 The purpose of this study is to examine the effectiveness of CPR skills delivered by QCPR
6 Classroom feedback in training in compared to standard CPR training. The hypothesis of the
7 study was that QCPR Classroom would generate higher achievement in CPR skill regardless
8 of instructors’ teaching skill. We aimed to determine whether QCPR Classroom could be the
9 best practical model for CPR training.

1 **Methods**

2 *Study population and design*

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

18 *Measurements*

19 Participants enrolled in the CPR+automated external defibrillator (AED) training.
20 The primary outcome was compression depth (mm), compression rate (compressions per
21 minute [cpm]), adequate depth (%), and adequate recoil (%). These measurements were
22 carried out without any feedback for the trainees on both pre- and post-training for one
23

1 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

1
2
3
4 1 follows: 1) Keys of compression: depth, rate, recoil, 2) single rescuer chest compression-only
5
6 2 CPR, 3) two bystander chest compression-only CPR, focusing on minimizing interruptions,
7
8 3 4) check respiration, 5) scene safety, check consciousness, and call for help 6) the use of
9
10 4 AED, 7) practice from "scene safety" to "resume chest compression after giving a shock", 8)
11
12 5 scenario-based training. A total of 18 CPR training sessions were studied, with 9 standard
13
14 6 CPR training (control group) and 9 QCPR Classroom sessions (Figure 1).

15
16
17
18
19 7 In the QCPR Classroom group, participants received subjective and objective
20
21 8 feedback from the instructor based on real-time feedback through the manikin, and
22
23 9 participants were able to correct themselves from feedback displayed on the screen of the
24
25 10 device (Figure 2). The control group was given only instructor's subjective feedback, so
26
27 11 metronome sound was not used, which hand clap was allowed to give based on instructor's
28
29 12 experience. As the AHA made the statement, audio-visual feedback is mandated to use [31].
30
31 13 QCPR Classroom only provides visual feedback, so we used sound as an auditory aid for
32
33 14 instruction in the QCPR Classroom group.

34
35
36
37
38
39 15 To measure the effect of CPR training, one minute of chest compression was
40
41 16 measured without any feedback given as a pre-test. Similarly to the pre-test, one minute of
42
43 17 chest compression was also measured after the training as a post-test. Although one minute of
44
45 18 measurement may not be sufficient duration for CPR performance in real life, we focused on
46
47 19 the initial CPR performance by a single rescuer situation. A survey and baseline
48
49 20 characteristics, such as weight, height, and CPR training experience (Table 1), were also
50
51 21 collected after the post-training measurement. The metronome was set at 110 beats per
52
53 22 minute (bpm) and used for every instance of hands-on practice during the QCPR Classroom
54
55 23 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

1 compressions, compression depth, rate, and incomplete release. A compression score is
2 calculated using the rate, depth, and release. Each sensor was checked for depth accuracy
3 using a calibrated compression machine with $\pm 15\%$ considered as acceptable error.

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

17 18 *Statistical analysis*

19 The rate and depth measurements are shown as the mean and standard deviation.
20 Normal distributions and homogeneity of variance were confirmed by a Q-Q plot. The
21 differences and 95% confidence intervals are shown in tables. The adequate depth and recoil
22 were calculated as percentages. Analysing the percentage variables to compare the numerical
23 value using a parametric test, such as a t-test. The difference between pre- and post-training

1 measurements within the groups were analysed using a paired t-test and McNemar test.

2 Group comparison for both pre- and post-training was conducted using Welch's t-test and the
3 chi-square test. The medians and interquartile ranges are presented for ordinal data. We
4 compared the groups using the Wilcoxon single-rank test. The data was analysed using JMP
5 (V.11.2.0, the SAS Institute Inc.), and *p*-values less than 0.05 were considered as significant.

7 **Results**

8 *Demographic characteristics*

9 A total of 642 people participated in this study. As shown in Figure 1, 145
10 participants were excluded due to incomplete data (*n* = 135), age under 15 years (*n* = 8), and
11 paramedics (*n* = 2). Significant age difference between the groups was found (22.4 ± 9.0 vs.
12 19.4 ± 5.6 ; *p* < .0001). A statistical difference in age among individuals in clusters, yet the
13 standard deviation and IRQ ranges overlap. The age variation was not clinically significant
14 due to overlap of precision measured. After the CPR training, 497 participants were eligible
15 for analysis, with 259 people in the control group and 238 people in the QCPR Classroom
16 group. The demographic characteristics are shown in Table 1.

18 *Primary outcome*

19 All chest compression parameters at pre-training and post-training are shown in
20 Table 2. After the training, the mean compression depth of each student was 56.1 ± 9.8 mm in
21 the control group and 59.5 ± 7.9 mm in the QCPR Classroom group. Significantly more
22 participants in the QCPR Classroom group achieved higher adequate depth compared to the
23 control group (*p* < 0.001; Table 3). In the QCPR Classroom group, there was an improvement

1 of 39.0% (95% CI, 33.8-44.2) in the percentage of the adequate depth (48.3±44.2% at pre-
 2 training vs. 87.3±24.8% at post-training). In the control group, the improvement was 20.0%
 3 (95% CI, 15.4-24.7) in the percentage of the adequate depth (53.6±38.9% at pre-training vs.
 4 73.7±37.3% at post-training; $p < 0.0001$; Table 2).

5 Both groups demonstrated average compression rates of 100-120 cpm (Table 2). A
 6 statistically significant difference was found between groups in terms of recoil ($p < 0.001$;
 7 Table 3). The control group demonstrated a 2.7% (95% CI, -1.7—7.1) increase in the
 8 percentage of recoil (64.2±36.5% pre-training vs. 66.9±34.6% post-training; $p = 0.23$). The
 9 QCPR Classroom group demonstrated a 22.6% (95% CI, 17.8—27.3) increase in the
 10 percentage of recoil (64.8±37.5% pre-training vs. 87.4±22.9% post-training; $p < 0.0001$;
 11 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- trainin g	Post- trainin g	<i>p</i> value	Differenc e (95% CI)	Pre- trainin g	Post- trainin g	<i>p</i> value	Differenc e (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	<0.000 1 *	4.6 (3.5 - 5.8)	48.2 ± 14.7	59.5 ± 7.9	<0.000 1 *	11.3 (9.8 - 12.8)
adequate depth (%) ⁺⁺	53.6 ±38.9	73.7 ±37.3	<0.000 1 *	20.0 (15.4 — 24.7)	48.3 ± 44.2	87.3 ± 24.8	<0.000 1 *	39.0 (33.8 — 44.2)

adequate								22.6
recoil	64.2	66.9	2.7 (-1.7	64.8 ±	87.4	<0.000	(17.8 -	
(%) ++	±36.5	±34.6	0.23 - 7.1)	37.5	±22.9	1 *	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

significan

t

1

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			3.3 (-5.9 —	
(%) ⁺⁺		64.2 ±36.5	64.8 ± 37.5	0.84	7.2)
Post-training test					
				<0.00	-2.3 (-3.5 - -
	rate (cpm) ⁺	119.2 ± 7.3	116.8 ± 5.5	1 *	1.2)
				<0.00	3.5 (1.9 -
	depth (mm) ⁺	56.1 ±9.8	59.5 ± 7.9	1 *	5.1)
	adequate depth			<0.00	13.6 (8.0 —
(%) ⁺⁺		73.7 ±37.3	87.3 ± 24.8	1 *	19.2)
	adequate recoil			<0.00	20.5 (15.3 —
(%) ⁺⁺		66.9 ±34.6	87.4 ±22.9	1 *	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

1

2 Secondary outcome

3 The survey included about participants' confidence levels before and after training
 4 regarding three parameters (rate, depth, and recoil) using the following question: "On a scale
 5 of 1-10, with 1 being not confident and 10 being very confident, how much confidence do you
 6 have to perform chest compressions?" The confidence level toward CPR performance was
 7 not different between the two groups. The question "how do you rate the ease of
 8 understanding the feedback from instructor?" was asked to address the ease of
 9 understanding. A significance difference was seen regarding the rate feedback from

1 instructor, which the QCPR Classroom training group (10.0[9.0-10.0]) showed higher scores,
 2 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)	<i>p</i> 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?"

3

4 Discussion

5 The 2015 AHA Guidelines recommend and the AHA announced in 2017 that use
 6 of audio-visual feedback would be mandated in all CPR training [8,14,31], and previous
 7 studies indicate that the use of feedback for CPR performance significantly improve CPR
 8 quality [16-28]. CPR quality was significantly better in the QCPR Classroom group than in
 9 the control group. There was a significant increase in the percentage of adequate depth and

1
2
3
4 1 recoil in the QCPR Classroom training group (39.0% increase in adequate depth and 22.6%
5
6 2 increase in recoil). However, there was 20.0% increase in adequate depth and 2.7% increase
7
8
9 3 in adequate recoil in the control group. Skorning et al. found 73.1 % of participant who used
10
11 4 a feedback device achieved correct depth and 45.2% of participant who did not use a
12
13
14 5 feedback device achieved correct depth [20]. Cartigiani et al. tested a QCPR Skillreporter
15
16 6 feedback model where school children were allowed to practice two-minute compression
17
18
19 7 only sessions CPR while receiving real time feedback on a computer screen, aiming at a 60%
20
21 8 overall compression score [32]. Following the practice, the students received overall
22
23
24 9 performance feedback from the computer. This model used equipment designed for smaller
25
26 10 groups. While QCPR Classroom can handle 42 mannikins simultaneously and feedback is
27
28
29 11 given on only one parameter at the time, Cartigiani et al. used a system that can handle 6
30
31 12 mannikins simultaneously which give feedback on depth, rate and leaning simultaneously
32
33
34 13 [32]. From our study, the compression depth was 59.5 ± 7.9 mm in the QCPR Classroom
35
36 14 group and 56.1 ± 9.8 mm in the control group on post-training. The number of subjects who
37
38
39 15 compressed greater than 60mm is 105 in the QCPR Classroom and 90 in the control group.
40
41 16 None of the subjects in the QCPR Classroom group performed below 50mm on post-test,
42
43
44 17 however, 64 subjects in the control group still did not reach 50mm on post-test.

46 18 Various types of manikins have been used for CPR training, but the quality of CPR
47
48
49 19 training is dependent on the instructor, and little is known about the training quality. The
50
51 20 GRA has highlighted the importance of high-performance CPR, and knowledge in the
52
53
54 21 general population is needed. Significant age difference was found, but the previous studies
55
56 22 indicated that chest compression delivered by the 13-14 year olds group was similar to what
57
58
59 23 the adult performed and the researchers concluded the performance was depended on weight,
60

1
2
3
4 1 age [33], as well as height, BMI, and sex [34]. In our study, the median and IQR for each
5
6 2 group was 19(17-23) and 17(16-21), so there is no height and weight difference between two
7
8
9 3 groups and both groups included over 15 years old, so we considered that the age difference
10
11 4 was clinically negligible to perform adequate CPR performance.
12
13

14 5 Healthcare professionals were previously found to perform incomplete chest recoil
15
16 6 in 46% of cases [11]. Teaching the concept of recoil is not easy, as we found that only 2.7%
17
18 7 increase in the control group. Contri et al. stated that instruction about recoil must be
19
20 8 modified according to the participants' physical characteristics [34]. However, during
21
22 9 standard community CPR training, the instructor cannot spend much time on each individual
23
24 10 and find out who needs to correct their performance.
25
26
27
28

29 11 This novel "QCPR Classroom" is a unique real-time visual in-action feedback
30
31 12 system has been provided a significant impact on CPR performance that 42 manikins provide
32
33 13 feedback at the same time in the large group training setting. As Kong et al. concluded,
34
35 14 overall CPR quality was improved through QCPR-Classroom based training [29]. The QCPR
36
37 15 Classroom group showed significant improvement in CPR skills between post-training and
38
39 16 pre-training, especially in the percentage of adequate depth and recoil. The purpose of QCPR
40
41 17 Classroom is to make it easy to objectively measure and improve CPR performance in
42
43 18 community CPR classes. In a large classroom, learners could see their CPR performance on a
44
45 19 big screen at the front of the class. Kong et al. randomized the groups and the instructor only
46
47 20 visible the feedback icon on iPad and has examined how "QCPR Classroom" training affects
48
49 21 CPR performance improvement of laypeople in the large group setting [29]. Students only
50
51 22 received objective feedback directly from instructor. Our study randomized the groups and
52
53 23 both students and instructor were visible the feedback icon on iPad by arranging on big
54
55
56
57
58
59
60

1
2
3
4 1 screen in front of the classroom, which would be given students to have real-time feedback
5
6 2 by themselves. Providing high quality CPR training with the lead-instructor:manikin:students
7
8
9 3 ratio of 1:42:84 can be possible. This is able to make that good educational achievement with
10
11 4 fewer instructors.

12
13
14 5 CPR training has been studied for decades by observing participants and comparing
15
16 6 their performance to guidelines. The findings show that training does not provide sufficient
17
18 7 practice [35,36], it does not include DA-CPR [37], participants lack preparedness for real
19
20 8 situations [36,38,39], and objective student feedback and assessment are not performed [40].
21
22
23
24 9 In 1991, Kaye et al. reported that instructors made CPR courses by themselves and included
25
26 10 only 10 minutes of practical training [35]. The instructors also performed subjective
27
28 11 assessments of the students to let the students pass the course, even though the students
29
30 12 would not have passed according to objective measurements or evaluation by researchers
31
32
33
34 13 [35].

35
36 14 The need for standardized training, more relevant training, and objective
37
38 15 assessment has been known since the early 1990s, but most training teaches laypeople to
39
40 16 perform CPR alone without dispatcher assistance, and they practice CPR without feedback or
41
42 17 performance assessment. We generally do not know what quality of CPR participants will
43
44 18 perform during resuscitation, but we know that good-quality bystander CPR has positively
45
46 19 reflected in survival [41-44]. It is possible to make training for laypeople more relevant and
47
48 20 effective by focusing on the most important learning objectives, prioritizing practical
49
50 21 training, training people to work in teams with dispatchers, using objective feedback to
51
52 22 stimulate good performance, and documenting the results for quality improvement and
53
54
55
56
57
58
59
60

1
2
3
4 1 cultivating a culture of excellence. QCPR Classroom can provide objective feedback on the
5
6 2 quality and quantity of CPR.
7

8
9 3 The use of feedback in a hospital setting was suggested [16], as well as in the EMS
10
11 4 field [17]. Tanaka et al. also suggested the implementation of feedback devices in athletic
12
13 5 training [45]. The use such a device is also highly recommended for even healthcare
14
15 6 professionals to use such a device. Laypeople who may encounter situations of cardiac arrest
16
17 7 rarely would need to use a feedback device in order to deliver high-quality CPR, which may
18
19 8 be directly linked to the chances for survival. An AED with a feedback device is the best
20
21 9 method for citizens to deliver higher-quality CPR. We believe that the combination of
22
23 10 training with QCPR Classroom and performing CPR with a feedback device in the field
24
25 11 would have a positive impact on survival rates.
26
27
28
29

30
31 12 In our opinion, recoil is the most difficult part for participants to perform within
32
33 13 such a short time, especially for those who are training in CPR for the first time. The
34
35 14 confidence level that learners had toward recoil was 8.0/10.0 in our study, which is the same
36
37 15 as for depth and rate in both groups. The hands are off the sternum when teaching full recoil,
38
39 16 and incomplete release would occur if the recoil concept was not mentioned. In our opinion,
40
41 17 instructors prioritize teaching the concepts of depth and rate rather than recoil because
42
43 18 feedback on recoil cannot be given as subjectively. In standard CPR training, we assume that
44
45 19 the main focus of participants tends to be compressing harder; therefore, participants easily
46
47 20 forget recoil and neglect to perform it. Our results showed a significantly increase in adequate
48
49 21 depth and no change in recoil in standard CPR training, which supports our hypothesis.
50
51 22 QCPR Classroom significantly improved the recoil performance, although it did not
52
53 23 influence the confidence level.
54
55
56
57
58
59
60

1
2
3
4 1 The definition of high-quality CPR highlights the importance of depth, rate, and
5
6 2 recoil. Performing good chest compression with these three factors leads to favourable
7
8
9 3 outcomes. However, CPR instructors must understand the difficulty of achieving appropriate
10
11 4 depth, rate, and recoil [46]. Moreover, recent guidelines increasingly emphasize the necessity
12
13
14 5 of high-quality CPR performance by not only EMTs or first responders, but also citizens
15
16 6 [46].

17
18
19 7 With the highlighted importance of objective feedback during CPR training, we
20
21 8 hope this pilot study on QCPR Classroom training could be considered as a model for future
22
23
24 9 CPR training. The role of instructors is to emphasize the importance of bystander CPR and
25
26 10 Public Access Defibrillation. Therefore, instead of focusing too much on the recoil or another
27
28
29 11 part of high-quality CPR, the importance of immediate initiation of CPR without hesitating
30
31 12 should be highlighted during the training. It is still very important to determine how to design
32
33
34 13 these environments and prioritize emergency action plans, such as contacting EMS personnel
35
36 14 and summoning other people.
37
38

39 15 40 41 16 **Study limitations**

42
43
44 17 In this study, strength was Arranging objective real-time feedback on big screen in
45
46 18 front of everyone to visible to both instructor and students made significantly improve CPR
47
48
49 19 quality. Our study has several limitations. First, the manikins' chest is not as hard as the
50
51 20 human body, so it is not the same in real life. Second, this study was conducted using CPR
52
53
54 21 training that targeted a large amount of lay people, who all performed CPR together. Since
55
56 22 chest compression was tested in this environment, the rate measurement may have been
57
58
59 23 influenced by other participants. The metronome was used in the QCPR Classroom group
60

1 only, but no metronome was used in the control group. Third, the instructors' knowledge may
2 have been questionable since the instructors were learning about the device as the training
3 proceeded. Fourth, the survey has been collected post-course including questions about how
4 the participants felt about their confidence prior to the training which may add a large
5 element of recall bias. Fifth, the potential lack of generalizability since the quality of
6 instructors and the standards of training may vary compared to other settings. Sixth, loss of
7 participants due to lack of data. This was occurred because of mechanical issue and CPR skill
8 data was not well registered on cloud. Finally, the study was only measured short-term
9 improvement, not the retention.

11 **Conclusion**

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

1 **Acknowledgments**

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

6 **Author Contributions**

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

16 **Funding**

17 None

19 **Conflict of Interests**

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

1
2
3
4 15
6 **2 Ethical Approval**
78
9 3 The study was approved by the Institutional Review Board at Kokushikan
10
11 4 University, Japan under the registration number 16-RI002 on February 23rd, 2017.
1213
14 515
16 **6 Data Availability Statement**
1718
19 7 All relevant data are within the paper and its data are available from corresponding
20
21 8 author, ST, upon request.
2223
24 925
26 1027
28
29 11 Figure legends30
31 12 Figure 1. Flow chart of the study32
33 13 Figure 2. Image of QCPR Classroom feedback system34
35 14 Figure 3. Image of actual display on the front screen
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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

- 1
2
3
4 1 among patients with bystander-witnessed out-of-hospital cardiac arrest in Japan. JAMA.
5
6 2 2015;314:247-54.
7
8
9 3 8. American Heart Association. Highlights of the 2015 American Heart Association
10
11 4 guidelines update for CPR and ECC. Texas, American Heart Association, 2015.
12
13 (Accessed 1 September 2017, at [https://eccguidelines.heart.org/wp-](https://eccguidelines.heart.org/wp-content/uploads/2015/10/2015-AHA-Guidelines-Highlights-English.pdf)
14 5
15 [content/uploads/2015/10/2015-AHA-Guidelines-Highlights-English.pdf](https://eccguidelines.heart.org/wp-content/uploads/2015/10/2015-AHA-Guidelines-Highlights-English.pdf))
16 6
17
18
19 7 9. Japan Resuscitation Council. Chapter 1 BLS: Basic Life Support. (Accessed 3 February
20
21 8 2019, at [https://www.japanresuscitationcouncil.org/wp-](https://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/1327fc7d4e9a5dcd73732eb04c159a7b.pdf)
22
23 [content/uploads/2016/04/1327fc7d4e9a5dcd73732eb04c159a7b.pdf](https://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/1327fc7d4e9a5dcd73732eb04c159a7b.pdf)).
24 9
25
26 10 10. Global Resuscitation Alliance. Improving Survival from Out-of-Hospital Cardiac Arrest:
27
28 A Call to Establish a Global Resuscitation Alliance. (Accessed 2 December 2017, at
29 11
30 http://www.laerdalevents.com/gra/wp-content/pdf/call_to_establish.pdf)
31 12
32
33
34 13 11. Aufderheide TP, Pirrallo RG, Yannopoulos D, et al. Incomplete chest wall
35
36 14 decompression: a clinical evaluation of CPR performance by EMS personnel and
37
38 assessment of alternative manual chest compression-decompression techniques.
39 15
40 Resuscitation. 2005;64:353-362.
41 16
42
43
44 17 12. Sutton RM, Niles D, Nysaether J, et al. Quantitative Analysis of CPR Quality During In-
45
46 18 Hospital Resuscitation of Older Children and Adolescents. Pediatrics. 2009;124(2):494-9.
47
48
49 19 13. Yannopoulos S, McKnite S, Aufderheide TP, Sigurdsson G, Pirrallo RG, Benditt D, Lurie
50
51 20 KG. Effect of incomplete chest wall decompression during cardiopulmonary resuscitation
52
53 on coronary and cerebral perfusion pressures in a porcine model of cardiac arrest.
54 21
55 Resuscitation. 2005;64:363-72.
56 22
57
58
59
60

- 1
2
3
4 1 14. Neumar RW, Shuster M, Callaway CW, et al. 2015 American Heart Association
5
6 2 Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular
7
8 3 Care, Part 1: Executive Summary. *Circulation*. 2015;132:S315–67.
- 10
11 4 15. Perkins GD, Handley AJ, Koster RW, et al. European Resuscitation Council Guidelines
12
13 5 for Resuscitation 2015 Section 2. Adult basic life support and automated external
14
15 6 defibrillation. *Resuscitation*. 2015;95:81-99.
- 17
18 7 16. Abella BS, Edelson DP, Kim S, et al. CPR quality improvement during in-hospital
19
20 8 cardiac arrest using a real-time audiovisual feedback system. *Resuscitation*.
21
22 9 2007;73(1):54–61.
- 24
25 10 17. Hostler D, Everson-Stewart S, Rea TD, et al; Effect of real-time feedback during
26
27 11 cardiopulmonary resuscitation outside hospital: prospective, cluster-randomised trial.
28
29 12 *BMJ* 2011;342(d512):1-10.
- 31
32 13 18. Buleon C, Delaunay J, Parienti J.-J., Halbout L., Arrot X, Gerard J.-L., Hanouz J.-L.
33
34 14 Impact of a feedback device on chest compression quality during extended manikin CPR:
35
36 15 a randomized crossover study. *Am J Emerg Med*. 2016;34:1754-1760.
- 38
39 16 19. Bobrow BJ, Vadeboncoeur TF, Stolz U, et al. The influence of scenario-based training
40
41 17 and real-time audiovisual feedback on out-of-hospital cardiopulmonary resuscitation
42
43 18 quality and survival from out-of-hospital cardiac arrest. *Ann Emerg Med*. 2013;62(1):47-
44
45 19 56.
- 47
48 20 20. Skorning M, Beckers SK, Brokmann JC, et al. New visual feedback device improves
49
50 21 performance of chest compressions by professionals in simulated cardiac arrest.
51
52 22 *Resuscitation*. 2010;81:53-58.
- 54
55
56
57
58
59
60

- 1
2
3
4 1 21. Buleon C, Parienti J-J, Halbout L, et al. Improvement in chest compression quality using
5
6 2 a feedback device (CPRmeter): a stimulation randomized crossover study. *Am J Emerg*
7
8 3 *Med.* 2013;31:1457-1461.
9
10
11 4 22. Kramer-Johansen J, Myklebust H, Wik L, et al. Quality of out-of-hospital
12
13 5 cardiopulmonary resuscitation with real time automated feedback: a prospective
14
15 6 interventional study. *Resuscitation.* 2006;71:283-292.
16
17
18 7 23. Cheng A, Brown LL, Duff JP, et al.; International Network for Simulation-Based
19
20 8 Pediatric Innovation, Research, & Education (INSPIRE) CPR Investigators. Improving
21
22 9 cardiopulmonary resuscitation with a CPR feedback device and refresher simulations
23
24 10 (CPR CARES Study): a randomized clinical trial. *JAMA Pediatr.* 2015; 169:137-44.
25
26
27
28 11 24. Cheng A, Overly F, Kessler D, et al.; International Network for Simulation-Based
29
30 12 Pediatric Innovation, Research, & Education (INSPIRE) CPR Investigators. Perception of
31
32 13 CPR quality: Influence of CPR feedback, Just-in-Time CPR training and provider role.
33
34 14 *Resuscitation* 2015;87:44-50.
35
36
37
38 15 25. White AE, Ng HX, Ng WY, Ng EKX, Fook-Chong S, Kua PHJ, Ong MEH. Measuring
39
40 16 the effectiveness of a novel CPRcard™ feedback device during stimulated chest
41
42 17 compressions by non-healthcare workers. *Singapore Med J* 2017;58:438-445.
43
44
45
46 18 26. Tanaka S, White AE, Sagisaka R, et al. Comparison of quality of chest compressions
47
48 19 during training of laypersons using Push Heart and Little Anne manikins using blinded
49
50 20 CPRcards. *Int Emerg Med.* 2017;10(1):20.
51
52
53
54 21 27. Baldi E, Cornara S, Contri E, et al. Real-time visual feedback during training improves
55
56 22 layperson's CPR quality: a randomized controlled manikin study. *CJEM.* 2017;19(6):480-
57
58 23 487.
59
60

- 1
2
3
4 1 28. Yeung J, Meeks R, Edelson D, Gao F, Soar J, Perkins G. The use of CPR
5
6 2 feedback/prompt devices during training and CPR performance: A systematic review.
7
8
9 3 Resuscitation. 2009;80:743-751.
10
11 4 29. Kong SY, Shin SD, Song KJ, et al. Effect of instructor's real-time feedback using QCPR-
12
13 5 classroom device during layperson cardiopulmonary resuscitation (CPR) training on
14
15 6 quality of CPR Performances: A prospective cluster-randomised trial. BMJ Open.
16
17 7 2018;8:doi:10.1136/bmjopen-2018-EMS.25.
18
19 8 30. Nishiyama C, Iwami T, Kawamura T, Ando M, Yonemoto N, Hiraide A, Nonogi H.
20
21 9 Quality of chest compressions during continuous CPR; comparison between chest
22
23 10 compression-only CPR and conventional CPR. Resuscitation. 2010;81:1152-1155.
24
25 11 31. American Heart Association. AHA requirement on Use of feedback devices in adult CPR
26
27 12 training courses. (Accessed 1 September 2017, at
28
29 13 <http://ahainstructornetwork.americanheart.org/idc/groups/ahaecc->
30
31 14 [public/@wcm/@ecc/documents/downloadable/ucm_495639.pdf](http://ahainstructornetwork.americanheart.org/idc/groups/ahaecc-public/@wcm/@ecc/documents/downloadable/ucm_495639.pdf)).32
33
34
35
36
37
38
39 15 32. Cortegiani A, Russotto V, Montalto F, Iozzo P, Meschis R, Pugliesi M, et al. (2017) Use
40
41 16 of a Real-Time Training Software (Laerdal QCPR®) Compared to Instructor-Based
42
43 17 Feedback for High-Quality Chest Compressions Acquisition in Secondary School
44
45 18 Students: A Randomized Trial. PLoS ONE 12(1): e0169591.
46
47
48
49 19 33. Jones I, Whitefield R, Colquhoun M, Chamberlain D, Vetter N, Newcombe R, et al. At
50
51 20 what age can schoolchildren provide effective chest compressions? AN observational
52
53 21 study from the Heartstart UK schools training programme. BMJ. 2007;334:1201.
54
55
56 22 34. Contri E, Cornara S, Somaschini A, et al. Complete chest recoil during laypersons' CPR:
57
58 23 Is it a matter of weight? Am J Emerg Med. 2017;35:1266-1268.
59
60

- 1
2
3
4 1 35. Kaye W, Rallis SF, Mancini ME, et al. The problem of poor retention of cardiopulmonary
5
6 2 resuscitation skills may lie with the instructor, not the learner or the curriculum.
7
8 Resuscitation. 1991;21:67-87.
9 3
10
11 4 36. Parnell MM, Larsen PD. Poor quality teaching in lay person CPR courses. Resuscitation.
12
13 5 2007;73:271-278.
14
15
16 6 37. Wagner P, Lingemann C, Arntz HR, Breckwoldt J. Official lay basic life support courses
17
18 7 in Germany: is delivered content up to date with the guidelines? An observational study.
19
20 8 Emerg Med J. 2015;32(7):547-52.
21
22
23 9 38. Møller TP, Hansen CM, Fjordholt M, Pedersen BD, Østergaard D, Lippert FK.
24
25 10 Debriefing bystanders of out-of-hospital cardiac arrest is valuable. Resuscitation.
26
27 11 2014;85:1504-1511.
28
29
30 12 39. Hirose T, Iwami T, Ogura H, et al. Effectiveness of a simplified cardiopulmonary
31
32 13 resuscitation training program for the non-medical staff of a university hospital. Scand J
33
34 14 Trauma Resusc Emerg Med. 2014;22(31):1-7.
35
36
37 15 40. Lynch B, Einspruch EL, Nichol G, Aufderheide TP. Assessment of BLS skills:
38
39 16 optimizing use of instructor and manikin measures. Resuscitation. 2008;76:233-243.
40
41
42 17 41. Wik L, Steen PA, Bircher NG. Quality of bystander cardiopulmonary resuscitation
43
44 18 influences outcome after prehospital cardiac arrest. Resuscitation. 1994;28:195-203.
45
46
47 19 42. Van Hoeyweghen RJ, Bossaert LL, Mullie A, et al. Quality and efficiency of bystander
48
49 20 CPR. Resuscitation. 1993;26:47-52. Emerg Med J. 2014;0:1-6.
50
51
52 21 43. Gallagher EJ, Lombardi G, Gennis P. Effectiveness of bystander cardiopulmonary
53
54 22 resuscitation and survival following out-of-hospital cardiac arrest. JAMA.
55
56
57 23 1995;274:1992-1925.
58
59
60

- 1
2
3
4 1 44. Takei Y, Nishi T, Matsubara H, Hashimoto M, Inaba H. Factors associated with quality
5
6 2 of bystander CPR: the presence of multiple rescuers and bystander-initiated CPR without
7
8 3 instruction. *Resuscitation*. 2014;85:492-498.
9
10
11 4 45. Tanaka S, Rodrigues W, Sotir S, Sagisaka R, Tanaka H. CPR Performance in the
12
13 5 Presence of Audiovisual Feedback or Football Shoulder Pads. *BMJ Open Sport Exerc*
14
15 6 *Med*. 2017;3(1):e000208.
16
17
18 7 46. Japan Resuscitation Council. Chapter 8 ETI: Education, Implementation, and Teams.
19
20 8 (Accessed 2 December 2017, at [http://www.japanresuscitationcouncil.org/wp-](http://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/b7b5b647189bc07f38f6fecf014cf5d9.pdf)
21
22 9 [content/uploads/2016/04/b7b5b647189bc07f38f6fecf014cf5d9.pdf](http://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/b7b5b647189bc07f38f6fecf014cf5d9.pdf)).
23
24
25
26
27 10
28
29 11
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

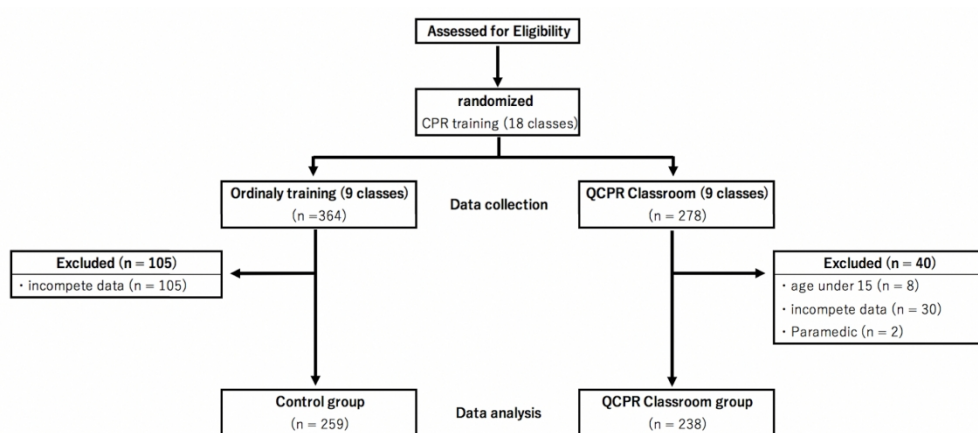


Fig 1. Flow chart of the study

Flow chart of the study

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60



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

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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:	<i>BMJ Open</i>
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

1
2
3
4 1
5
6 2
7
8
9 3 Title: Effect of real-time visual feedback device “Quality Cardiopulmonary Resuscitation
10
11 4 (QCPR) Classroom” with a metronome sound on layperson CPR training in Japan: A cluster
12
13
14 5 randomized control trial
15

16 6
17
18 7 Shota Tanaka ¹⁾, Kyoko Tsukigase ¹⁾, Takahiro Hara ²⁾, Ryo Sagisaka ²⁾, Helge Myklebust ³⁾,
19
20 8 Tonje S. Birkenes ³⁾, Hiroyuki Takahashi ¹⁾⁴⁾, Ayana Iwata ¹⁾, Yutaro Kidokoro ¹⁾, Momoyo
21
22 9 Yamada ¹⁾, Hiroki Ueta ⁵⁾, Hiroshi Takyu ²⁾, Hideharu Tanaka ¹⁾²⁾
23

24 10

- 25 11 1) Research Institute of Disaster Management and EMS, Kokushikan University
26
27 12 2) Graduate School of EMS System, Kokushikan University
28
29 13 3) Laerdal Medical, Stavanger, Norway
30
31 14 4) Department of Sports Medicine, Kokushikan University, Japan
32
33 15 5) Faculty of Emergency Medical Science, Meiji University of Integrative Medicine
34

35 16

36 17 Correspondence author: SHOTA TANAKA

37
38
39 18 Kokushikan University, 7-3-1, Nagayama, Tama City, Tokyo, JAPAN

40
41 19 E-mail: tanakamedical24@gmail.com

42
43
44 20 TEL/FAX: +81-42-339-7197
45

46 21

47
48
49 22 Keywords: cardiac arrest, bystander, CPR training, resuscitation, Mass CPR training

50
51 23 Word Count: 4223
52
53
54
55
56
57
58
59
60

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–

1 44.2; $p < 0.0001$) and 20.0% improvements (95% CI, 15.4–24.7; $p < 0.0001$) in the QCPR-
2 Classroom and control groups, respectively. The difference in adequate recoil between pre-
3 and post-training was 2.7% (95% CI, -1.7–7.1; pre $64.2 \pm 36.5\%$ vs. post $66.9 \pm 34.6\%$; $p =$
4 0.23) and 22.6% in the control and QCPR-Classroom groups (95% CI, 17.8–27.3; pre $64.8 \pm$
5 37.5% vs. post $87.4 \pm 22.9\%$; $p < 0.0001$), respectively.

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

1
2
3
4 **1 Strengths and limitations of this study**
5

- 6 2 - One of the advantages of CPR training using the QCPR-Classroom concept is good
7
8
9 3 educational achievement with fewer instructors.
10
11 4 - Arranging objective real-time feedback on a big screen in front of everyone, visible to both
12
13
14 5 instructor and students, significantly improved CPR quality.
15
16 6 - The QCPR-Classroom group had 13.6% better adequate depth and 20.5% better adequate
17
18
19 7 recoil than the control group.
20
21 8 - No retention measurement was taken, and the measurements were of all students together.
22
23
24 9 - This was manikin-based training, so it was not the same as in real life since the chest was
25
26
27 10 not as hard as the human body.
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1 INTRODUCTION

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

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

19 We are currently facing a period of transition to CPR training with a feedback
20 device as various feedback devices have been introduced, and research has supported their
21 effectiveness.[16–28] However, they are unavailable for CPR training targeting a large
22 population. Laerdal Medical (Stavanger, Norway) launched the “QCPR Classroom” concept,
23 which provides real-time visual feedback for a greater number of participants at once. The

1 effectiveness of the QCPR-Classroom device was recently demonstrated by Kong et al.[29]
2
3
4
5
6
7 2 This study aims to examine the effectiveness of CPR skills delivered with QCPR-Classroom
8
9 3 feedback compared to standard CPR training. The hypothesis was that QCPR Classroom
10
11 4 would generate higher achievement in CPR skill regardless of instructors' teaching skill. We
12
13
14 5 aimed to determine whether QCPR Classroom could be the best practical model for CPR
15
16 6 training.
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

1 2 3 4 1 **METHODS**

5 6 2 **Patient and public involvement**

7
8 3 Patients and/or the public were not involved in this study. The study population
9
10 4 was focused on CPR trainees.

11 12 13 14 5 15 16 6 **Study population and design**

17
18 7 Prior to CPR training and study enrollment, oral informed consent was obtained
19
20 8 from all participants. The study was approved by the Institutional Review Board at
21
22 9 Kokushikan University. Sample size calculation was based on adequate depth from our pilot
23
24 10 trial in which we examined the effect of the QCPR Classroom. We calculated a sample size
25
26 11 of 232 with 90% power to detect a percentage of adequate compression depth between two
27
28 12 groups ($\alpha = 0.05$). To reach a power of 90%, 41 participants were needed per group in
29
30 13 parallel, and the design effect was 5.66; 15% was detected as a deficit due to a mechanical
31
32 14 issue, so 272 per group was calculated as a sample size. A total of 642 people were recruited
33
34 15 from among CPR trainees enrolled in the Heart Saver Japan CPR training, which was held
35
36 16 between March and September 2017. The inclusion criterion was age over 15 years. The
37
38 17 exclusion criteria were the presence of upper extremity injury within the past 6 months and
39
40 18 working as a healthcare professional regularly involved in resuscitation, such as Emergency
41
42 19 Medical Technicians, paramedics, and emergency room physicians or nurses. Previous CPR
43
44 20 training status and quantity and timing of previous trainings were not used as inclusion or
45
46 21 exclusion criteria.

47 48 49 22 50 51 23 **Measurements**

1
2
3
4 1 The primary outcome was compression depth (mm), compression rate (cpm),
5
6 2 adequate depth (%), and adequate recoil (%). These measurements were obtained both pre-
7
8
9 3 and immediately post-training. No feedback was provided to the participants. The
10
11 4 measurement duration was one minute as the bystander should change every minute during
12
13
14 5 chest compression-only CPR.[30] This was because the quality of chest compression-only
15
16 6 CPR was demonstrated to decrease due to fatigue, and this can alter the results. The scores
17
18
19 7 from a survey conducted after the training were considered a secondary outcome. The survey
20
21 8 included the participants' confidence about the rate, depth, and recoil pre- and post-training
22
23
24 9 as well as the ease of understanding feedback from the instructor. The survey is available in
25
26 10 the Appendix.
27
28
29
30
31

32 **Study procedure**

33
34 13 A cluster randomized controlled trial was used (allocation ratio 1:1). A researcher
35
36 14 (R.S) generated a randomization list, and block-two randomization was performed. R.S. was
37
38
39 15 not involved in the data collection and worked on statistics independently. Each session was
40
41 16 randomly assigned to the intervention (standard or QCPR Classroom). Four lead instructors
42
43
44 17 who had worked as healthcare professionals and had over five years of experience teaching
45
46 18 CPR were selected from the Heart Saver Japan organization. Data were collected during the
47
48
49 19 Heart Saver Japan CPR + Automated External Defibrillator (AED) training sessions. The
50
51 20 training focused on Basic Life Support, including CPR skills and AED, according to the
52
53
54 21 Japan Resuscitation Council 2015 Guideline. Students were not medical personnel, so we
55
56 22 instructed compression-only CPR. No pre-assignment or e-learning was given. The training
57
58
59 23 started with a PowerPoint presentation-based instructor-led lecture followed by psychomotor
60

1
2
3
4 1 practice. Psychomotor practice focused on chest-compression CPR. The sequence of the
5
6 2 psychomotor practice is as follows: 1) Keys of compression: depth, rate, recoil; 2) single-
7
8 3 rescuer chest compression-only CPR; 3) two-bystander chest compression-only CPR
9
10
11 4 focusing on minimizing interruptions; 4) check respiration; 5) scene safety, check
12
13
14 5 consciousness, and call for help; 6) use of AED; 7) practice from “scene safety” to “resume
15
16 6 chest compression after giving a shock”; and 8) scenario-based training. A total of 18 CPR
17
18 7 training sessions were studied with 9 standard CPR training (control group) and 9 QCPR-
19
20
21 8 Classroom sessions (Figure 1).

22
23
24 9 In the QCPR-Classroom group, participants received subjective and objective
25
26 10 feedback from the instructor based on real-time feedback through the manikin, and
27
28
29 11 participants were able to correct themselves based on feedback displayed on the screen of the
30
31 12 device (Figure 2). The control group received instructor’s subjective feedback, so a hand clap
32
33
34 13 was used based on the instructor’s experience instead of using a metronome sound. As the
35
36 14 AHA stated, audio-visual feedback is mandated for use.[31] QCPR Classroom only provides
37
38
39 15 visual feedback, so we used sound as an auditory aid for instruction in the QCPR-Classroom
40
41 16 group.

42
43
44 17 To measure the effect of CPR training, one minute of chest compression was
45
46 18 measured without any feedback given as a pre-test. Similarly, one minute of chest
47
48
49 19 compression was also measured after the training as a post-test. Although one minute of
50
51 20 measurement may not be sufficient for CPR performance in real life, we focused on the
52
53
54 21 initial CPR performance in a single-rescuer situation. A survey and baseline characteristics,
55
56 22 such as weight, height, and CPR training experience (Table 1), were also collected after the
57
58
59 23 post-training measurement. The metronome was set at 110 beats per minute and used for
60

1 every instance of hands-on practice during the QCPR-Classroom session, but no metronome
 2 was used during the standard CPR training.

3
 4
 5
 6
 7
 8
 9
 10
 11 **Table 1. Demographic Characteristics**

	Control (n = 259)	QCPR Classroom (n = 238)	<i>p</i> 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

4
 5
 6
 7
 8
 9
 10
 11
 12
 13
 14
 15
 16
 17
 18
 19
 20
 21
 22
 23
 24
 25
 26
 27
 28
 29
 30
 31
 32
 33
 34
 35
 36
 37
 38
 39
 40
 41
 42
 43
 44
 45
 46
 47
 48
 49
 50
 51
 52
 53
 54
 55
 56
 57
 58
 59
 60

4
 5 **Instrumentation**

6 Compression data were registered using the Laerdal QCPR-Classroom manikin
 7 system (Laerdal Medical, Stavanger, Norway), as shown in Figure 2. This prototype system
 8 for community CPR training provides real-time visual feedback from 42 manikins while
 9 icons representing CPR performance from each manikin are visualized on an iPad tablet. We
 10 mirrored the iPad screen on a laptop using the application Reflector 2 (Squirrels®, North
 11 Canton, OH, United States) to present real-time feedback on a large screen at the front of the
 12 classroom (Figure 3). QCPR Classroom uses Laerdal Little Anne manikins, and each is

1
2
3
4 1 instrumented with an optical compression sensor and microcontroller. The microcontroller
5
6 2 analyses the signal from the compression sensor and calculates the number, depth, and rate of
7
8
9 3 compressions and incomplete release. A compression score is calculated using the rate, depth,
10
11 4 and release. Each sensor was checked for depth accuracy using a calibrated compression
12
13
14 5 machine with $\pm 15\%$ considered to indicate acceptable error.

16 6 The microcontroller also compares the compression performance with guidelines
17
18 7 from the 2015 AHA requirements. Deviations from the guidelines are reported as “too
19
20
21 8 shallow,” “incomplete release,” “too fast,” or “too slow,” and deviation in each factor is
22
23
24 9 presented as yellow icons on the tablet. If the compression performance is good, a green
25
26 10 “Everything OK” icon is presented. Data from the tablet is sent to a Microsoft Azure cloud
27
28
29 11 service and made available as downloadable .csv files, which include the following
30
31 12 parameters from each manikin and CPR session: the number of compressions, average
32
33
34 13 compression rate, average compression depth, number of compressions with adequate depth,
35
36 14 number of compressions with acceptable release, compression score, time, and location of
37
38
39 15 use. The control group also used the same Laerdal Little Anne manikins. However, we did
40
41 16 not use a screen to show students objective feedback. During the training in the control
42
43
44 17 group, lead-instructors were not allowed to access iPad, so they only gave subjective
45
46 18 feedback to the students.

47
48
49 19

50 51 20 **Statistical analysis**

52
53
54 21 The rate and depth measurements are shown as the mean and standard deviation.
55
56 22 Normal distributions and homogeneity of variance were confirmed by a Q-Q plot. The
57
58
59 23 differences and 95% confidence intervals are shown in tables. The adequate depth and recoil
60

1 were calculated as percentages. The difference between pre- and post-training measurements
2 within the groups were analyzed using a paired t-test and McNemar test. Group comparison
3 for both pre- and post-training was conducted using Welch's t-test and chi-square test. The
4 medians and interquartile ranges are presented for ordinal data. We compared the groups
5 using the Wilcoxon single-rank test. The data were analyzed using JMP (V.11.2.0, the SAS
6 Institute Inc.), and *p*-values less than 0.05 were considered significant.

8 RESULTS

9 Demographic characteristics

10 A total of 642 people participated in this study. As shown in Figure 1, 145
11 participants were excluded due to incomplete data (*n* = 135), age under 15 years (*n* = 8), and
12 being paramedics (*n* = 2). Significant age difference between the groups was found (*p*
13 $\leq .0001$). A statistical difference was found in age among individuals in clusters, but the
14 standard deviation and interquartile range overlapped. The age variation was not clinically
15 significant due to overlap of precision measured. After the CPR training, 497 participants
16 were eligible for analysis with 259 in the control group and 238 in the QCPR-Classroom
17 group. The demographic characteristics are shown in Table 1.

19 Primary outcome

20 All chest-compression parameters at pre- and post-training are shown in Table 2.
21 After the training, the mean compression depth of each student was 56.1 ± 9.8 mm in the
22 control group and 59.5 ± 7.9 mm in the QCPR-Classroom group. Significantly more
23 participants in the QCPR-Classroom group achieved higher adequate depth compared to the

1 control group ($p < 0.001$; Table 3). In the QCPR-Classroom group, there was an
 2 improvement of 39.0% (95% CI, 33.8–44.2) in the percentage of adequate depth. In the
 3 control group, the improvement was 20.0% (95% CI, 15.4–24.7; $p < 0.0001$; Table 2).

4 Both groups demonstrated average compression rates of 100–120 cpm (Table 2). A
 5 statistically significant difference was found between groups in terms of recoil ($p < 0.001$;
 6 Table 3). The control group demonstrated a 2.7% (95% CI, –1.7–7.1) increase in the
 7 percentage of recoil ($p = 0.23$). The QCPR-Classroom group demonstrated a 22.6% (95% CI,
 8 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- trainin g	Post- trainin g	<i>p</i> value	Differenc e (95% CI)	Pre- trainin g	Post- trainin g	<i>p</i> value	Differenc e (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	<0.000 1 *	4.6 (3.5 – 5.8)	48.2 ± 14.7	59.5 ± 7.9	<0.000 1 *	11.3 (9.8 – 12.8)
adequate depth (%) ++	53.6 ±38.9	73.7 ±37.3	<0.000 1 *	20.0 (15.4 – 24.7)	48.3 ± 44.2	87.3 ± 24.8	<0.000 1 *	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	<0.000 1 *	(17.8 – 27.3)

55 paired-t test and McNemar test; CPR:
 56 cardiopulmonary resuscitation; CI:
 57 confidence interval
 58
 59
 60

1
2
3 + Mean and standard

4 deviation for rate and depth

5 measurement

6
7 ++ Numbers (percentage) for

8 the adequate depth and

9 recoil

10 * $p < .05$

11 significant

12 t

13
14
15
16
17
18
19
20
21
22
23
24
25 1

26
27
28
29
30 2

31
32 **Table 3. The difference of CPR performance competency between the control group**
33 **and QCPR Classroom group at pre- and post-training**

	Control (n = 259)	QCPR Classroom (n = 238)	<i>p</i> 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				

					-2.3 (-3.5 – -
				<0.00	
	rate (cpm) ⁺	119.2 ± 7.3	116.8 ± 5.5	1 *	1.2)
					3.5 (1.9 –
				<0.00	
	depth (mm) ⁺	56.1 ± 9.8	59.5 ± 7.9	1 *	5.1)
	adequate depth			<0.00	13.6 (8.0 –
	(%) ⁺⁺	73.7 ± 37.3	87.3 ± 24.8	1 *	19.2)
	adequate recoil			<0.00	20.5 (15.3 –
	(%) ⁺⁺	66.9 ± 34.6	87.4 ± 22.9	1 *	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

1

2 Secondary outcome

3 The survey included participants' confidence levels before and after training
 4 regarding three parameters (rate, depth, and recoil) using the following question: "On a scale
 5 of 1–10, with 1 being not confident and 10 being very confident, how much confidence do you
 6 have to perform chest compressions?" Confidence regarding CPR performance did not differ
 7 between groups. The question "How do you rate the ease of understanding the feedback from
 8 the instructor?" was asked to address the ease of understanding. A significance difference
 9 was seen regarding the rate of feedback from the instructor; the QCPR-Classroom training
 10 group (10.0[9.0–10.0]) showed higher scores than the control group (10.0[8.5–10.0]; p =
 11 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?"

1

2 DISCUSSION

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

1
2
3
4 1 Classroom group performed below 50 mm in the post-test, but 64 in the control group still
5
6 2 did not reach 50 mm.
7

8
9 3 Skorning et al. found that correct depth was achieved in 73.1% of participants
10
11 4 who used a feedback device and 45.2% of those who did not [20] Cortegiani et al. tested a
12
13 5 QCPR-Skillreporter feedback model where school children were allowed to practice two-
14
15 6 minute compression-only CPR sessions while receiving real-time feedback on a computer
16
17 7 screen, aiming for a 60% overall compression score.[32] Following practice, the students
18
19 8 received overall performance feedback from the computer. This model used equipment
20
21 9 designed for smaller groups. While QCPR-Classroom can handle 42 mannikins
22
23 10 simultaneously and feedback is given on only one parameter at the time, Cortegiani et al.
24
25 11 used a system that can handle 6 mannikins simultaneously, giving feedback on depth, rate,
26
27 12 and leaning simultaneously.[32]
28
29
30
31
32
33

34 13 Various types of manikins have been used for CPR training, but the quality of CPR
35
36 14 training depends on the instructor, and little is known about training quality. The GRA has
37
38 15 highlighted the importance of high-performance CPR, and knowledge is needed in the
39
40 16 general population. Significant age difference was found, but previous studies indicated that
41
42 17 chest compression delivered by 13–14-year-olds was similar to adult performance, and the
43
44 18 researchers concluded that the performance depended on weight, age,[33] height, BMI, and
45
46 19 sex.[34] In our study, the median and interquartile range for each group were 19 (17–23) and
47
48 20 17 (16–21), there was no height or weight difference between groups, and both groups
49
50 21 included participants over 15 years old, so we considered that the age difference was
51
52 22 clinically negligible for adequate CPR performance.
53
54
55
56
57
58
59
60

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

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

1
2
3
4 1 CPR training has been studied for decades by observing participants and comparing
5
6 2 their performance to guidelines. The findings show that training does not provide sufficient
7
8 3 practice,[35,36] it does not include DA-CPR,[37] participants lack preparedness for real
9
10 4 situations,[36,38,39] and objective student feedback and assessment are not performed.[40]
11
12
13
14 5 In 1991, Kaye et al. reported that instructors made CPR courses by themselves and included
15
16 6 only 10 minutes of practical training.[35] The instructors also performed subjective
17
18 7 assessments of the students to let the students pass the course even though the students would
19
20
21 8 not have passed according to objective measurements or evaluation by researchers.[35]
22
23

24 9 The need for standardized training, more relevant training, and objective
25
26 10 assessment has been known since the early 1990s, but most training teaches laypeople to
27
28 11 perform CPR alone without dispatcher assistance, and they practice CPR without feedback or
29
30 12 performance assessment. We generally do not know what quality of CPR participants will
31
32 13 perform during resuscitation, but we know that good-quality bystander CPR is positively
33
34 14 reflected in survival.[41–44] It is possible to make training for laypeople more relevant and
35
36 15 effective by focusing on the most important learning objectives, prioritizing practical
37
38 16 training, training people to work in teams with dispatchers, using objective feedback to
39
40 17 stimulate good performance, and documenting the results for quality improvement and
41
42 18 cultivating a culture of excellence. QCPR Classroom can provide objective feedback on the
43
44 19 quality and quantity of CPR.
45
46
47
48
49

50
51 20 The use of feedback in a hospital setting [16] as well as in the Emergency Medical
52
53 21 Services field was suggested.[17] Tanaka et al. also suggested the implementation of
54
55 22 feedback devices in athletic training.[45] The use of such a device is also highly
56
57 23 recommended even for healthcare professionals. Laypeople who may encounter situations of
58
59
60

1 cardiac arrest rarely need to use a feedback device to deliver high-quality CPR, which may be
2 directly linked to the chances of survival. An AED with a feedback device is the best method
3 for citizens to deliver higher-quality CPR. We believe that the combination of training with
4 QCPR Classroom and performing CPR with a feedback device in the field would have a
5 positive impact on survival rates.

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

18 With the highlighted importance of objective feedback during CPR training, we
19 hope this pilot study on QCPR-Classroom training could be considered as a model for future
20 CPR training. The role of instructors is to emphasize the importance of bystander CPR and
21 Public Access Defibrillation. Therefore, instead of focusing too much on the recoil or another
22 part of high-quality CPR, the importance of immediate initiation of CPR without hesitating
23 should be highlighted during the training. It is still very important to determine how to design

1
2
3
4 1 these environments and prioritize emergency action plans, such as contacting Emergency
5
6 2 Medical Services personnel and summoning other people.
7
8
9 3

11 4 **Study limitations**

14 5 A strength of this study was that arranging objective real-time feedback on a big
15
16 6 screen in front of everyone, visible to both instructor and students, significantly improved
17
18 7 CPR quality. Our study has several limitations. First, the manikins' chest is not as hard as the
19
20 8 human body, so chest compressions are not the same as in real life. Second, this study was
21
22 9 conducted using CPR training that targeted a large amount of laypeople, who all performed
23
24 10 CPR together. Since chest compression was tested in this environment, the rate measurement
25
26 11 may have been influenced by other participants. The metronome was used in the QCPR-
27
28 12 Classroom group only; no metronome was used in the control group. Third, the instructors'
29
30 13 knowledge may have been questionable since the instructors were learning about the device
31
32 14 as the training proceeded. Fourth, the survey was collected post-course including questions
33
34 15 about the participants' confidence prior to the training, which may add a large element of
35
36 16 recall bias. Fifth, there is a potential lack of generalizability since the quality of instructors
37
38 17 and the standards of training may vary in other settings. Sixth, participants were lost due to
39
40 18 lack of data. This occurred because of a mechanical issue, and CPR skill data were not well
41
42 19 registered on the cloud. Finally, the study only measured short-term improvement, not
43
44 20 retention.
45
46
47
48
49
50
51
52
53
54 21

56 22 **CONCLUSION**

57
58
59
60

1
2
3
4 1 The use of a novel “QCPR Classroom” prototype to educate a large group of
5
6 2 laypeople with real-time visual CPR feedback has been described, and the effectiveness of
7
8
9 3 training was assessed. The QCPR-Classroom training achieved a higher percentage of
10
11 4 adequate depth and recoil than the standard training with subjective assessment by instructors
12
13
14 5 and a higher percentage of adequate recoil. During in-action “QCPR Classroom” training
15
16 6 with a metronome sound, displaying all students’ feedback on the big screen significantly
17
18
19 7 provided accurate real-time visual feedback to achieve two important components together:
20
21 8 compressing the chest with a depth over 5 cm and minimizing the incomplete release of the
22
23
24 9 chest. Teaching CPR to larger groups of laypeople with a real-time feedback system, a novel
25
26 10 QCPR Classroom with a metronome sound, is a recommended CPR training model.
27
28
29
30

31 **Acknowledgements**

32 The authors wish to thank all staff members at the Research Institute of Disaster
33
34 14 Management and EMS at Kokushikan University for their assistance in this study. The
35
36
37 15 authors also thank Laerdal Medical for their assistance in using QCPR Classroom.
38
39

40 **Competing Interests**

41
42 17 Tonje Søråas Birkenes and Helge Myklebust are employees of Laerdal Medical.
43
44
45 18 They contributed the QCPR Classroom prototype, study design, and critical revision of the
46
47
48 19 manuscript, but had no role in data collection, analysis of the results, or decision to publish.
49
50 20 Other authors did not receive any payment, gift or anything from Laerdal Medical.
51
52

53 **Funding**

54
55 23 None
56
57
58 24

59 **Author Contributions**

1 ST carried out all the studies, participated in the sequence alignment, and drafted
2
3
4 1 the manuscript. ST, KT, TH, RS, HM, TB, HTaky, and HTana were involved in the study
5
6 2 the manuscript. ST, KT, TH, RS, HM, TB, HTaky, and HTana were involved in the study
7
8
9 3 design. ST, KT, TH, and HTana contributed to the study implementation. HM and TB
10
11 4 developed the concept and contributed to technological support. ST, KT, TH, HTaka, AI,
12
13
14 5 HU, YK, MY and HTana were involved in the data collection. RS conducted statistical
15
16 6 analysis. ST, RS, and HTana performed data analysis. HTaky, HM, and TB contributed
17
18
19 7 critical revisions to the manuscript. HTana also revised and approved the final manuscript.
20
21
22 8 All authors read and approved the final submission.
23
24
25

10 **Ethical Approval**

11 The study was approved by the Institutional Review Board at Kokushikan
12 University, Japan under the registration number 16-RI002 on February 23rd, 2017.
13

14 **Data Availability Statement**

15 All relevant data are within the paper and its data are available from corresponding
16 author, ST, upon request.
17
18

19 **Figure legends**

20 Figure 1. Flow chart of the study

21 Figure 2. Image of QCPR Classroom feedback system

22 Figure 3. Image of actual display on the front screen
23
24

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

- 1
2
3
4 1 among patients with bystander-witnessed out-of-hospital cardiac arrest in Japan. JAMA.
5
6 2 2015;314:247-54.
7
8
9 3 8. American Heart Association. Highlights of the 2015 American Heart Association
10
11 4 guidelines update for CPR and ECC. Texas, American Heart Association, 2015.
12
13 (Accessed 1 September 2017, at [https://eccguidelines.heart.org/wp-](https://eccguidelines.heart.org/wp-content/uploads/2015/10/2015-AHA-Guidelines-Highlights-English.pdf)
14 5
15 [content/uploads/2015/10/2015-AHA-Guidelines-Highlights-English.pdf](https://eccguidelines.heart.org/wp-content/uploads/2015/10/2015-AHA-Guidelines-Highlights-English.pdf))
16 6
17
18 7 9. Japan Resuscitation Council. Chapter 1 BLS: Basic Life Support. (Accessed 3 February
19
20 8 2019, at [https://www.japanresuscitationcouncil.org/wp-](https://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/1327fc7d4e9a5dcd73732eb04c159a7b.pdf)
21
22 9 [content/uploads/2016/04/1327fc7d4e9a5dcd73732eb04c159a7b.pdf](https://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/1327fc7d4e9a5dcd73732eb04c159a7b.pdf)).
23
24
25 10 10. Global Resuscitation Alliance. Improving Survival from Out-of-Hospital Cardiac Arrest:
26
27 11 A Call to Establish a Global Resuscitation Alliance. (Accessed 2 December 2017, at
28
29 12 http://www.laerdalevents.com/gra/wp-content/pdf/call_to_establish.pdf)
30
31
32 13 11. Aufderheide TP, Pirrallo RG, Yannopoulos D, et al. Incomplete chest wall
33
34 14 decompression: a clinical evaluation of CPR performance by EMS personnel and
35
36 15 assessment of alternative manual chest compression-decompression techniques.
37
38
39 16 Resuscitation. 2005;64:353-362.
40
41
42 17 12. Sutton RM, Niles D, Nysaether J, et al. Quantitative Analysis of CPR Quality During In-
43
44 18 Hospital Resuscitation of Older Children and Adolescents. Pediatrics. 2009;124(2):494-9.
45
46
47 19 13. Yannopoulos S, McKnite S, Aufderheide TP, Sigurdsson G, Pirrallo RG, Benditt D, Lurie
48
49 20 KG. Effect of incomplete chest wall decompression during cardiopulmonary resuscitation
50
51 21 on coronary and cerebral perfusion pressures in a porcine model of cardiac arrest.
52
53
54 22 Resuscitation. 2005;64:363-72.
55
56
57
58
59
60

- 1
2
3
4 1 14. Neumar RW, Shuster M, Callaway CW, et al. 2015 American Heart Association
5
6 2 Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular
7
8 3 Care, Part 1: Executive Summary. *Circulation*. 2015;132:S315–67.
- 9
10
11 4 15. Perkins GD, Handley AJ, Koster RW, et al. European Resuscitation Council Guidelines
12
13 5 for Resuscitation 2015 Section 2. Adult basic life support and automated external
14
15 6 defibrillation. *Resuscitation*. 2015;95:81-99.
- 16
17
18 7 16. Abella BS, Edelson DP, Kim S, et al. CPR quality improvement during in-hospital
19
20 8 cardiac arrest using a real-time audiovisual feedback system. *Resuscitation*.
21
22 9 2007;73(1):54–61.
- 23
24
25 10 17. Hostler D, Everson-Stewart S, Rea TD, et al; Effect of real-time feedback during
26
27 11 cardiopulmonary resuscitation outside hospital: prospective, cluster-randomised trial.
28
29 12 *BMJ* 2011;342(d512):1-10.
- 30
31
32 13 18. Buleon C, Delaunay J, Parienti J.-J., Halbout L., Arrot X, Gerard J.-L., Hanouz J.-L.
33
34 14 Impact of a feedback device on chest compression quality during extended manikin CPR:
35
36 15 a randomized crossover study. *Am J Emerg Med*. 2016;34:1754-1760.
- 37
38
39 16 19. Bobrow BJ, Vadeboncoeur TF, Stolz U, et al. The influence of scenario-based training
40
41 17 and real-time audiovisual feedback on out-of-hospital cardiopulmonary resuscitation
42
43 18 quality and survival from out-of-hospital cardiac arrest. *Ann Emerg Med*. 2013;62(1):47-
44
45 19 56.
- 46
47
48 20 20. Skorning M, Beckers SK, Brokmann JC, et al. New visual feedback device improves
49
50 21 performance of chest compressions by professionals in simulated cardiac arrest.
51
52 22 *Resuscitation*. 2010;81:53-58.
- 53
54
55
56
57
58
59
60

- 1
2
3
4 1 21. Buleon C, Parienti J-J, Halbout L, et al. Improvement in chest compression quality using
5
6 2 a feedback device (CPRmeter): a stimulation randomized crossover study. *Am J Emerg*
7
8 3 *Med.* 2013;31:1457-1461.
9
10
11 4 22. Kramer-Johansen J, Myklebust H, Wik L, et al. Quality of out-of-hospital
12
13 5 cardiopulmonary resuscitation with real time automated feedback: a prospective
14
15 6 interventional study. *Resuscitation.* 2006;71:283-292.
16
17
18 7 23. Cheng A, Brown LL, Duff JP, et al.; International Network for Simulation-Based
19
20 8 Pediatric Innovation, Research, & Education (INSPIRE) CPR Investigators. Improving
21
22 9 cardiopulmonary resuscitation with a CPR feedback device and refresher simulations
23
24 10 (CPR CARES Study): a randomized clinical trial. *JAMA Pediatr.* 2015; 169:137-44.
25
26
27
28 11 24. Cheng A, Overly F, Kessler D, et al.; International Network for Simulation-Based
29
30 12 Pediatric Innovation, Research, & Education (INSPIRE) CPR Investigators. Perception of
31
32 13 CPR quality: Influence of CPR feedback, Just-in-Time CPR training and provider role.
33
34 14 *Resuscitation* 2015;87:44-50.
35
36
37
38 15 25. White AE, Ng HX, Ng WY, Ng EKX, Fook-Chong S, Kua PHJ, Ong MEH. Measuring
39
40 16 the effectiveness of a novel CPRcard™ feedback device during stimulated chest
41
42 17 compressions by non-healthcare workers. *Singapore Med J* 2017;58:438-445.
43
44
45
46 18 26. Tanaka S, White AE, Sagisaka R, et al. Comparison of quality of chest compressions
47
48 19 during training of laypersons using Push Heart and Little Anne manikins using blinded
49
50 20 CPRcards. *Int Emerg Med.* 2017;10(1):20.
51
52
53
54 21 27. Baldi E, Cornara S, Contri E, et al. Real-time visual feedback during training improves
55
56 22 layperson's CPR quality: a randomized controlled manikin study. *CJEM.* 2017;19(6):480-
57
58 23 487.
59
60

- 1
2
3
4 1 28. Yeung J, Meeks R, Edelson D, Gao F, Soar J, Perkins G. The use of CPR
5
6 2 feedback/prompt devices during training and CPR performance: A systematic review.
7
8
9 3 Resuscitation. 2009;80:743-751.
10
11 4 29. Kong SY, Shin SD, Song KJ, et al. Effect of instructor's real-time feedback using QCPR-
12
13 5 classroom device during layperson cardiopulmonary resuscitation (CPR) training on
14
15 6 quality of CPR Performances: A prospective cluster-randomised trial. BMJ Open.
16
17 7 2018;8:doi:10.1136/bmjopen-2018-EMS.25.
18
19 8 30. Nishiyama C, Iwami T, Kawamura T, Ando M, Yonemoto N, Hiraide A, Nonogi H.
20
21 9 Quality of chest compressions during continuous CPR; comparison between chest
22
23 10 compression-only CPR and conventional CPR. Resuscitation. 2010;81:1152-1155.
24
25 11 31. American Heart Association. AHA requirement on Use of feedback devices in adult CPR
26
27 12 training courses. (Accessed 1 September 2017, at
28
29 13 <http://ahainstructornetwork.americanheart.org/idc/groups/ahaecc->
30
31 14 [public/@wcm/@ecc/documents/downloadable/ucm_495639.pdf](http://ahainstructornetwork.americanheart.org/idc/groups/ahaecc-public/@wcm/@ecc/documents/downloadable/ucm_495639.pdf)).32
33
34
35
36
37
38
39 15 32. Cortegiani A, Russotto V, Montalto F, Iozzo P, Meschis R, Pugliesi M, et al. (2017) Use
40
41 16 of a Real-Time Training Software (Laerdal QCPR®) Compared to Instructor-Based
42
43 17 Feedback for High-Quality Chest Compressions Acquisition in Secondary School
44
45 18 Students: A Randomized Trial. PLoS ONE 12(1): e0169591.
46
47
48
49 19 33. Jones I, Whitefield R, Colquhoun M, Chamberlain D, Vetter N, Newcombe R, et al. At
50
51 20 what age can schoolchildren provide effective chest compressions? AN observational
52
53 21 study from the Heartstart UK schools training programme. BMJ. 2007;334:1201.
54
55
56 22 34. Contri E, Cornara S, Somaschini A, et al. Complete chest recoil during laypersons' CPR:
57
58 23 Is it a matter of weight? Am J Emerg Med. 2017;35:1266-1268.
59
60

- 1
2
3
4 1 35. Kaye W, Rallis SF, Mancini ME, et al. The problem of poor retention of cardiopulmonary
5
6 2 resuscitation skills may lie with the instructor, not the learner or the curriculum.
7
8 Resuscitation. 1991;21:67-87.
9 3
10
11 4 36. Parnell MM, Larsen PD. Poor quality teaching in lay person CPR courses. Resuscitation.
12
13 5 2007;73:271-278.
14
15
16 6 37. Wagner P, Lingemann C, Arntz HR, Breckwoldt J. Official lay basic life support courses
17
18 7 in Germany: is delivered content up to date with the guidelines? An observational study.
19
20 8 Emerg Med J. 2015;32(7):547-52.
21
22
23 9 38. Møller TP, Hansen CM, Fjordholt M, Pedersen BD, Østergaard D, Lippert FK.
24
25 10 Debriefing bystanders of out-of-hospital cardiac arrest is valuable. Resuscitation.
26
27 11 2014;85:1504-1511.
28
29
30 12 39. Hirose T, Iwami T, Ogura H, et al. Effectiveness of a simplified cardiopulmonary
31
32 13 resuscitation training program for the non-medical staff of a university hospital. Scand J
33
34 14 Trauma Resusc Emerg Med. 2014;22(31):1-7.
35
36
37 15 40. Lynch B, Einspruch EL, Nichol G, Aufderheide TP. Assessment of BLS skills:
38
39 16 optimizing use of instructor and manikin measures. Resuscitation. 2008;76:233-243.
40
41
42 17 41. Wik L, Steen PA, Bircher NG. Quality of bystander cardiopulmonary resuscitation
43
44 18 influences outcome after prehospital cardiac arrest. Resuscitation. 1994;28:195-203.
45
46
47 19 42. Van Hoeyweghen RJ, Bossaert LL, Mullie A, et al. Quality and efficiency of bystander
48
49 20 CPR. Resuscitation. 1993;26:47-52. Emerg Med J. 2014;0:1-6.
50
51
52 21 43. Gallagher EJ, Lombardi G, Gennis P. Effectiveness of bystander cardiopulmonary
53
54 22 resuscitation and survival following out-of-hospital cardiac arrest. JAMA.
55
56
57 23 1995;274:1992-1925.
58
59
60

- 1
2
3
4 1 44. Takei Y, Nishi T, Matsubara H, Hashimoto M, Inaba H. Factors associated with quality
5
6 2 of bystander CPR: the presence of multiple rescuers and bystander-initiated CPR without
7
8 3 instruction. *Resuscitation*. 2014;85:492-498.
9
10
11 4 45. Tanaka S, Rodrigues W, Sotir S, Sagisaka R, Tanaka H. CPR Performance in the
12
13 5 Presence of Audiovisual Feedback or Football Shoulder Pads. *BMJ Open Sport Exerc*
14
15 6 *Med*. 2017;3(1):e000208.
16
17
18 7 46. Japan Resuscitation Council. Chapter 8 ETI: Education, Implementation, and Teams.
19
20 8 (Accessed 2 December 2017, at [http://www.japanresuscitationcouncil.org/wp-](http://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/b7b5b647189bc07f38f6fecf014cf5d9.pdf)
21
22 9 [content/uploads/2016/04/b7b5b647189bc07f38f6fecf014cf5d9.pdf](http://www.japanresuscitationcouncil.org/wp-content/uploads/2016/04/b7b5b647189bc07f38f6fecf014cf5d9.pdf)).
23
24
25
26 10
27
28 11
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

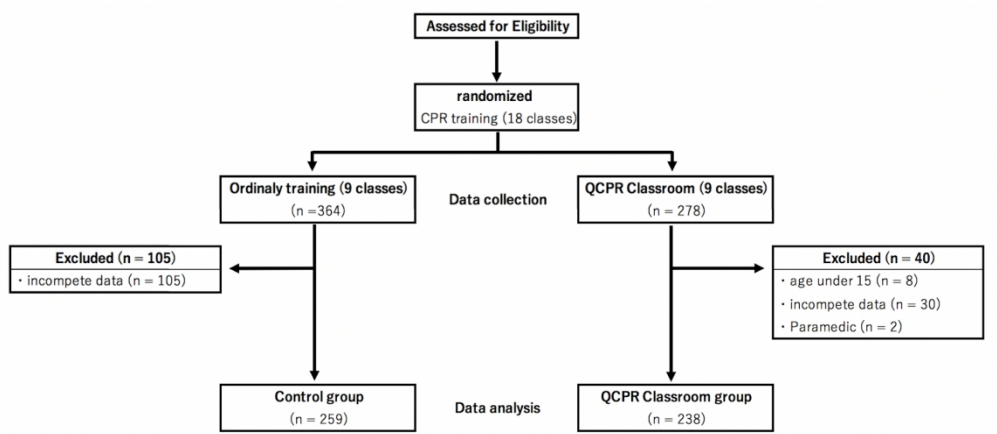


Fig 1. Flow chart of the study

Flow chart of the study



Fig 2. Image of QCPR Classroom feedback system

Image of QCPR Classroom feedback system

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60



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.