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Measuring the effectiveness of a novel CPRcard™ feedback device during simulated chest compressions by non-healthcare workers

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INTRODUCTION There is a need for a simple-to-use and easy-to-carry CPR feedback device for laypersons. We aimed to determine if a novel CPRcard™ feedback device improved the quality of chest compressions.

METHODS We compared participants' chest compression rate and depth with and without feedback. Compression data was captured through the CPRcard™ or Resusci Anne's SimPad® SkillReporter™. Compression quality was defined based on 2010 international guidelines for rate, depth and flow fraction.

RESULTS Overall, the CPRcard group achieved a better median compression rate (CPRcard 117 vs. control 122, $p = 0.001$) and proportion of compressions within the adequate rate range (CPRcard 83% vs. control 47%, $p < 0.001$). Compared to the no-card and blinded-card groups, the CPRcard group had a higher proportion of adequate compression rate (CPRcard 88% vs. no-card 46.8%, $p = 0.037$; CPRcard 73% vs. blinded-card 43%, $p = 0.003$). Proportion of compressions with adequate depth was similar in all groups (CPRcard 52% vs. control 48%, $p = 0.957$). The CPRcard group more often met targets for compression rate of 100–120/min and depth of at least 5 cm (CPRcard 36% vs. control 4%, $p = 0.022$). Chest compression flow fraction rate was similar but not statistically significant in all groups (92%, $p = 1.0$). Respondents using the CPRcard expressed higher confidence (mean 2.7 ± 2.4; 1 = very confident, 10 = not confident).

CONCLUSION Use of the CPRcard by non-healthcare workers in simulated resuscitation improved the quality of chest compressions, thus boosting user confidence in performing compressions.

Keywords: bystander, cardiac arrest, CPR, feedback, resuscitation

INTRODUCTION

Studies of innovative cardiopulmonary resuscitation (CPR) feedback devices have shown promising results.[1-8] However, at least one study has highlighted the potential problems of reliance on devices, and another study has concluded that there was no benefit derived among trained responders.[9,10] In these studies, the feedback devices were attached to an automated external defibrillator (AED) or paired with a phone application; some were also hospital-based and could not be readily carried around by laymen. Also, in many of these studies, mixed results were observed in the CPR performance of healthcare workers or experienced life-savers.[11] Therefore, there is a need for a simple-to-use and easy-to-carry CPR feedback device for laypersons. Such a device could possibly improve the quality of bystander CPR.

The present study was nested in a community-based Dispatcher-Assisted first REsponder (DARE) training initiative, which simulates a rescuer-dispatcher sequence that is initiated by a call to Singapore's emergency medical service (EMS). Dispatchers who suspect a cardiac arrest then coach the caller to perform CPR until an ambulance crew arrives. Singapore's largely urban setting presents multiple challenges for EMS response. An ambulance takes an average of 11 minutes to arrive at the scene (less than 11 minutes in 85% of cases in 2015).[12] Since most collapses in Singapore occur at home in high-rise buildings, paramedics must also contend with vertical travel time. These challenges make it all the more important for bystanders to perform CPR while waiting for the arrival of the EMS.

The DARE training programme teaches compression-only CPR. Conventional standards for quality CPR entail adequate depth and rate of compressions with minimal pauses to provide rescue breaths. The quality and timeliness of compressions is vital to survival and good neurological outcomes.[13-17] Several studies comparing conventional CPR with compression-only CPR have found that the compression-only approach results in equal or slightly better outcomes.[18-20] When designing DARE, we asked ourselves the question, "*Practically, what will lay rescuers remember and perform in an emergency?*" We then aimed to train laypeople on what is effective, simple to remember and presents a lower risk of delaying a response.[20-24]

In this study, we provided each participant with a novel CPR feedback device, CPRcard™ (Laerdal Medical, Stavanger, Norway). The CPRcard has the look and feel of a typical credit card (55 mm × 85 mm × 1 mm) and contains a built-in accelerometer (Fig. 1).[6] It provides real-time visual feedback on compression rate and depth through two meters displayed on the card. By watching the displays, one can regulate the rate and depth of

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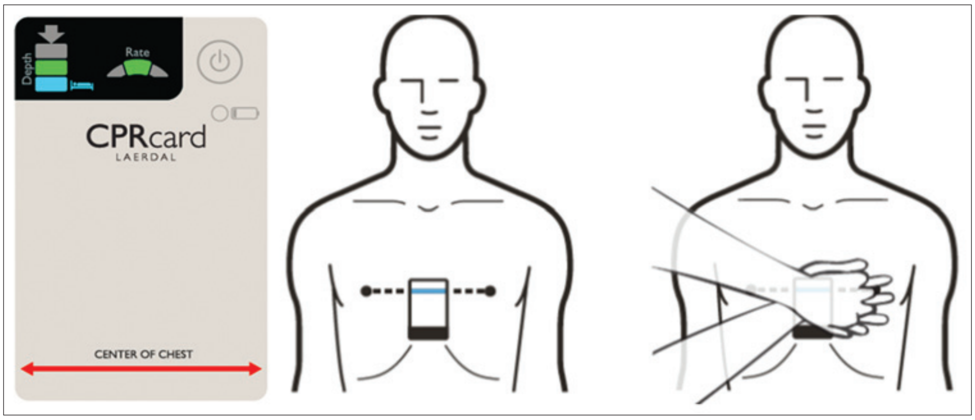

Fig. 1 Image shows the CPRcard and its placement during compression.

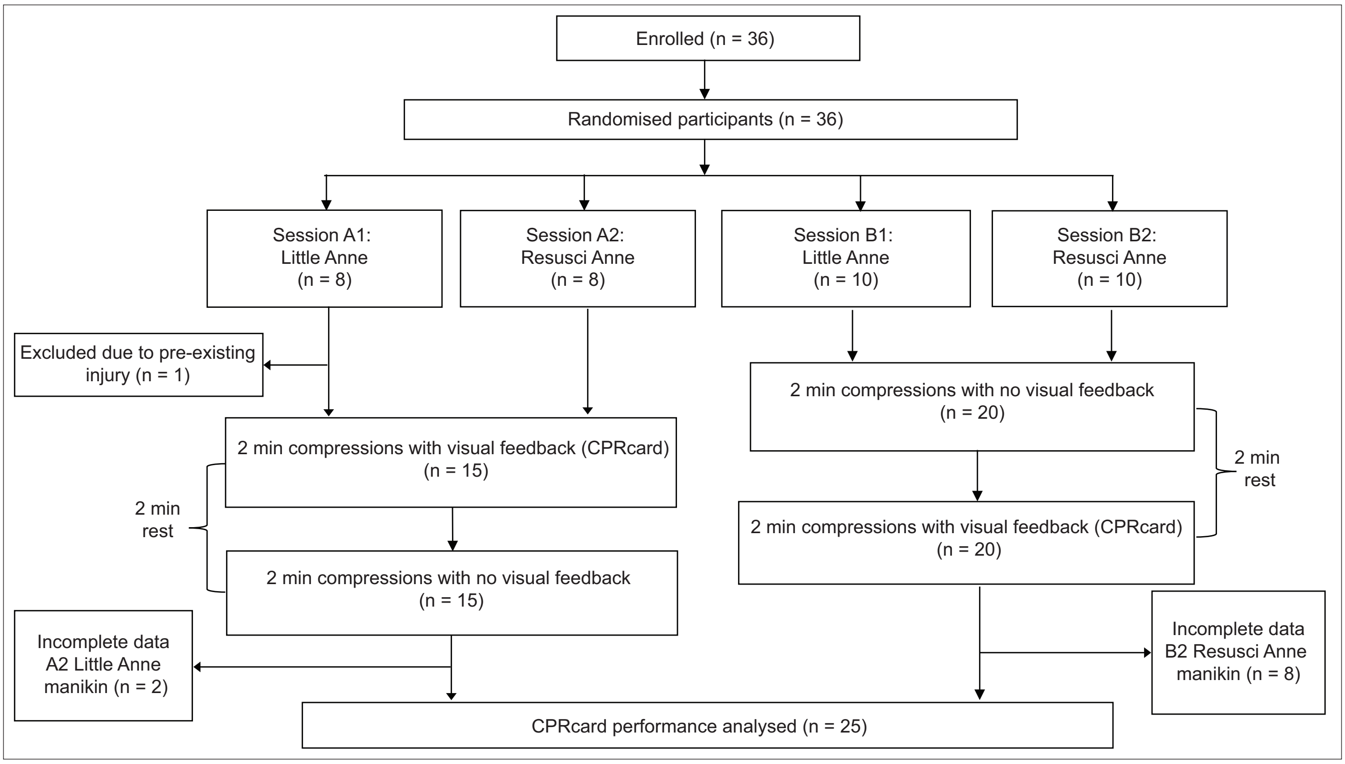

Fig. 2 Flowchart shows the selection of participants and training sequence.

compressions to achieve and sustain good quality compressions. Administering chest compressions aided by feedback should, theoretically, help the lay responder consistently perform better quality chest compressions compared to compressions done without feedback. Our goal was to observe whether laypersons using this novel feedback device for the first time during their training would indeed perform better quality chest compressions.

METHODS

In this prospective observational study, teachers from a local junior college were selected to participate. They were randomly selected to be trained at the school on a specific day, and each participant was then scheduled to attend one of two training sessions. The two training sessions differed in that one group started with feedback, while the other group started without. After a short two-minute break, each of the two arms crossed over and performed compressions under opposite conditions. For example, the group that started the first round with feedback did their second round without feedback. Fig. 2 shows the selection of participants and the training sequence.

To assess the compression quality of CPR, we provided each participant with one CPRcard. Participants performed compressions on either the Resusci Anne® or Little Anne® manikins (Laerdal Medical, Stavanger, Norway). The CPRcard collected real-time performance data for all cases, except for the no-card, no-feedback study arm, which used Resusci Anne's telemetry to record and assess compression quality.

The CPRcard feedback was calibrated to 2010 international guidelines for compression rate and depth. This was the standard extant at the time the study was conducted. The newly promulgated 2015 international guidelines define the parameters of quality CPR as: compression depth 5–6 cm; compression rate 100–120 per minute; compression flow fraction at least 60%; full chest recoil; and non-excessive ventilations.[25-27] The 2016

Singapore evidence-based standard varies only in the depth metric with a new standard of 4–6 cm.

Chest compression data was downloaded and calculated for the CPRcard group and the blinded-card control group. All chest compression performances were evaluated based on seven variables: (a) mean compression rate (i.e. mean number of compressions per minute); (b) mean compression depth in cm; (c) adequate compression rate (percentage of total compressions that were within the optimal 100–120 compressions per minute range); (d) adequate compression depth (percentage of total compressions that were ≥ 5 cm); (e) mean pause length in seconds (pauses are defined as ≥ 3 seconds of no compressions); (f) adequate flow fraction > 80% (flow fraction rate is the percentage of time when chest compressions are being performed without ≥ 3-second pause); and (g) adequate compression rate and depth combined (%).

Frequencies and percentages were used to describe elements of the participants' profile. The primary outcome – whether participants met targets for both compression rate (100–120 per minute) and depth (at least 5 cm) – was compared between the CPRcard group and control group using McNemar's test. We also compared the outcome between the two control groups performing compressions on the Little Anne (blinded-card) and Resusci Anne (no-card) manikins. We analysed other CPR parameters using Wilcoxon signed-rank test, as the distribution of the parameters was skewed. Medians and interquartile ranges were also calculated. McNemar's test was used for categorical variables. These CPR parameters were compared among the overall CPRcard group and the two control groups.

McNemar's test was used to compare the proportion of correct answers for CPR and AED knowledge between pre- and post-training surveys. Descriptive statistics (such as mean, median, standard deviation, minimum and maximum) were calculated to determine the participants' attitude toward and experience with using the CPRcard. This was measured using the Likert point scale score, where a lower number indicated a better experience. A two-tailed p-value < 0.05 was considered statistically significant. Analyses were completed using the STATA 13.0 statistical software package (StataCorp, College Station, TX, USA) with alpha set at 0.05. Study data was managed using REDCap (Research Electronic Data Capture, Vanderbilt University, Nashville, TN, USA), which was hosted at Singapore General Hospital. This study was conducted with the approval of the SingHealth Centralised Institutional Review Board (CIRB reference #2015/2475).

RESULTS

A total of 36 participants aged 25–70 years were enrolled in the study. One enrollee was unable to participate due to pre-existing injury and was excluded; 35 participants completed the training sessions, as well as the pre- and post-training surveys. Table I shows the demographic data of the participants. The majority of participants were 25–54 years old (85.7%), female (60.0%) and of Chinese ethnicity (85.7%). The average height and weight were 1.64 m and 60.4 kg, respectively. All the participants were university degree holders and 97.1% of them were employed as teachers. Almost half had been trained in basic life support skills in the past, which is not surprising since CPR is taught during compulsory national military service for all males. Only one person had a current certification. Due to incomplete data, only 25 participants with complete CPR compression data and survey data were included in the final analysis.

Table II presents the comparison of CPRcard compression parameters across the study arms. Participants in the CPRcard group achieved a better median compression rate compared to the group with no feedback (i.e. all controls), whose median compression rate fell slightly outside the optimal 100–120 compressions per minute range (CPRcard 117 vs. all controls 122, p = 0.001). The CPRcard group achieved a better median compression rate compared to the no-card group (CPRcard 116 vs. no-card 122, p = 0.074) and blinded-card group (CPRcard 120 vs. blinded-card 122, p = 0.010). It also had a higher rate of adequate compressions within the target rate range compared to all controls (CPRcard 83% vs. all controls 47%, p < 0.001), the no-card group (CPRcard 88% vs. no-card 47%, p = 0.037) and blinded-card group (CPRcard 73% vs. blinded-card 43%, p = 0.003). A comparison of median compression depth showed that the CPRcard group and all controls performed equally well across all arms (CPRcard 4.90 cm vs. all controls 4.99 cm, p = 0.319). The overall proportion of participants who achieved total compressions with adequate compression depth was similar in all the groups (CPRcard 52% vs. all controls 48%, p = 0.957); when the CPRcard group was compared solely to the no-card group, the difference was larger (CPRcard 39% vs. no-card 25%, p = 0.358). Although the blinded-card group had a higher rate of compression within the adequate depth range compared to the CPRcard group (CPRcard 54% vs blinded card 69%, p = 0.426), it also had a much wider interquartile range (11.0–91.0).

In our composite measure of quality, participants in the CPRcard group delivered a higher percentage of quality CPR (i.e. met targets for both compression rate of 100–120 per minute and depth ≥ 5 cm) compared to the controls (CPRcard 36% vs. all controls 4%, p = 0.022), and this was statistically significant. The CPRcard group performed better than both the no-card (CPRcard 44.4% vs. no-card 0%, p = 0.125) and blinded-card (CPRcard 55.6% vs. blinded-card 6.7%, p = 0.219) groups. There was a shorter mean length of pause between the CPRcard and no-card groups (CPRcard 0 seconds vs. no-card 0.85 seconds, p = 0.028). Although flow fraction rate > 80% was the same overall (92.0%), a higher percentage of participants in the blinded-card group met the flow fraction target.

Table III presents the pre- and post-training survey results. When measuring the change in participants' knowledge of CPR, we found a statistically significant improvement in the post-training survey results (p ≤ 0.001), with the greatest improvement seen in the correct answer for Question 4 (pre-training 43% vs. post-training 100%; 57% increase, p ≤ 0.001). The poorest result (i.e. furthest from 100% correct) was observed for Question 5, with only 50% of participants giving the correct answer in the post-training survey.

Table IV shows the results of the post-training survey section pertaining to users' experience with the CPRcard. Participants strongly agreed with the statement, "*Using the CPRcard increases*

Table I. Participant demographics (n = 35).

Characteristics	No. (%)
Age category (yr)	
< 18	0
18–24	0
25–34	15 (42.9)
35–44	0
45–54	15 (42.9)
55–64	4 (11.4)
≥ 65	1 (2.9)
Height* (m)	1.64 ± 0.08
Weight* (kg)	60.4 ± 10.9
Gender	
Male	14 (40.0)
Female	21 (60.0)
Race	
Chinese	30 (85.7)
Malay	1 (2.9)
Indian	3 (8.6)
Others	1 (2.9)
Education	
Primary	0
'N' level, 'O' level and ITE	0
'A' level and diploma	0
Degree and above	35 (100.0)
Marital status	
Single, never married	11 (31.4)
Married	23 (65.7)
Widowed	0
Divorced/separated	1 (2.9)
Employment status	
Employed	34 (97.1)
Out of work	0
Homemaker	0
Retired	0
Student	1 (2.9)
Relative > 65 yr living in participant's home	
Yes	15 (42.9)
No	20 (57.1)
Religion	
Buddhist	7 (20.0)
Christian	13 (37.1)
Free-thinker	12 (34.3)
Hindu	2 (5.7)
Jewish	0
Islam	1 (2.9)
Others	0
Attendance at church/synagogue/mosque/temple	
Yes	14 (40.0)
No	21 (60.0)
Willing to participate in voluntary national FRP	
Yes	5 (14.3)
Maybe	21 (60.0)
No	9 (25.7)
Has taken BCLS/ACLS courses in the past	
Yes	17 (48.6)
No	18 (51.4)
CPR training status	
Current certification in CPR/AED	1 (2.9)
Previous training but not current	16 (45.7)
No training ever	18 (51.4)

*Data presented as mean ± standard deviation. AED: automated external defibrillator; ACLS: Advanced Cardiac Life Support; BCLS: Basic Cardiac Life Support; CPR: cardiopulmonary resuscitation; FRP: First Responder Programme; ITE: Institute of Technical Education

my confidence level in performing compression", with a mean score of 2.7 ± 2.3, where 1 = very confident and 10 = not confident. Questions regarding the ease of accurately positioning the CPRcard on the manikin's chest and viewing the feedback lights during compressions also received good scores (mean 2.7 ± 2.3 and 2.9 ± 2.2, respectively, where 1 = very easy and 10 = not easy). The poorest score was received for Question 15, which asked participants if they experienced discomfort to their hand during compressions (mean 4.0 ± 2.7).

DISCUSSION

Overall, participants using the CPRcard performed better quality chest compressions compared to those who performed compressions without feedback. This is consistent with the results of other studies on feedback devices.[3,8,11] The positive effects of feedback from the CPRcard were observed in the higher number of compressions that came within the target range and the tighter grouping of performance data in and around the target rate and depth.

We were particularly intrigued by the potential of the CPRcard as a readily available tool to help lay bystanders respond to cardiac arrest with better quality chest compressions. As Kirkbright et al concluded, the body of research seems to indicate that the use of feedback devices during resuscitation can result in the rescuer performing compressions that are close to recommended standards.[11] Cheng et al's results with nursing students using the CPRcard were consistent with ours.[6] However, to the best of our knowledge, the present study is the first to test the effect of using this ultraportable personal feedback device among a non-healthcare cohort in simulated adult resuscitation.

We observed several clear advantages of the CPRcard. First, the card can be carried around like a standard credit card in a wallet or pocketbook. Its convenience makes it more likely to be immediately available and thus deployable early during an out-of-hospital cardiac arrest (OHCA; 70% of which occur in residential areas). Second, as the card is a discrete device that is not linked to another device, its utility is not dependent on possession of a smartphone or an AED, as with other feedback devices in the market; this observation is aligned with that of Cheng et al.[6] Third, the device provides constant feedback while compressions are performed and not 'correctively', as observed

Table II. Comparison of CPRcard parameters.

Parameter	CPRcard vs. all controls (both manikins; n = 25)			CPRcard vs. no-card (Resusci Anne manikin; n = 10)			CPRcard vs. blinded card (Little Anne manikin; n = 15)		
	Real-time visual feedback	No feedback	p-value	Real-time visual feedback	No-card	p-value	Real-time visual feedback	Blinded card	p-value
Compression rate* (/min)	117 (115.0–120.0)	122 (121.8–125.0)	0.001	116 (113.0–117.0)	122 (120.1–124.9)	0.074	120 (117.0–122.0)	122 (122.0–127.0)	0.010
Adequate compression rate* (%)	83 (66.0–90.0)	47 (28.0–51.0)	< 0.001	88 (82.0–90.0)	47 (34.6–52.7)	0.037	73 (64.0–88.0)	43 (16.0–51.0)	0.003
Compression depth* (cm)	5.0 (4.5–5.1)	5.0 (4.4–5.3)	0.319	4.7 (4.2–5.1)	4.5 (3.6–5.0)	0.386	5.0 (4.8–5.1)	5.1 (4.4–5.3)	0.319
Adequate depth* (%)	52 (31.0–73.0)	48 (11.0–73.0)	0.957	39 (18.0–58.0)	25 (1.3–53.4)	0.358	54 (45.0–73.0)	69 (11.0–91.0)	0.426
Met compression rate of 100–120/min & depth ≥ 5 cm†	9 (36.0)	1 (4.0)	0.022	4 (44.4)	0 (0.0)	0.125	5 (55.6)	1 (6.7)	0.219
Met flow fraction > 80%†	23 (92.0)	23 (92.0)	1.000	10 (43.5)	10 (43.5)	1.000	13 (56.5)	13 (86.7)	1.000

Data presented as *median (interquartile range) or †no. (%).

Table III. Comparison of correct answers between pre-training and post-training surveys regarding knowledge about CPR and automated external defibrillator (n = 35).

Survey question	No. (%)		Difference (95% CI)	p-value
	Pre-training	Post-training		
1. What is the first thing you should do if you see a person collapse? Correct answer: (a) Check for danger and move him away if necessary	16 (45.7)	31 (88.6)	42.9 (24.5–63.7)	< 0.001
2. What is the correct number you should dial for an emergency ambulance? Correct answer: (b) 995	29 (82.9)	35 (100)	17.1 (18.0–32.5)	0.031
3. What should you do after you get through to the dispatcher on the emergency line? Correct answer: (c) Stay on the line while the dispatcher teaches me how to do CPR till the ambulance arrives.	20 (57.1)	33 (94.3)	37.2 (16.4–57.9)	0.001
4. How deep should chest compression be done for a collapsed person? Correct answer: (b) 5 cm	15 (42.9)	35 (100)	57.1 (37.9–76.3)	< 0.001
5 How fast should chest compression be done for a collapsed person? Correct answer: (c) 100 per min	3 (8.6)	17 (48.6)	40.0 (21.7–60.7)	< 0.001

Percentages are calculated based on available data. CI: confidence interval; CPR: cardiopulmonary resuscitation

Table IV. Participants' responses regarding usage of CPRcard (n = 35).

Question	Mean ± SD (min, max)
13. It was easy to power on the CPRcard?	2.8 ± 2.6 (1, 10)
14. It was easy to accurately position the CPRcard on the manikin's chest?	2.7 ± 2.3 (1, 10)
15. When using the CPRcard on the manikin, did you experience discomfort in your hand that was in contact with the card?	4.0 ± 2.7 (1, 10)
16. Do you agree with the following statement: I found both the compression depth and compression rate feedback lights easy to see when performing compression?	2.9 ± 2.2 (1, 9)
17. Do you agree with the following statement: Using the CPRcard increases my confidence level in performing compression?	2.7 ± 2.3 (1, 10)

Responses were rated using Likert point scale (1 = strongly agree, 10 = strongly disagree). SD: standard deviation; max: maximum; min: minimum

with other devices.[28] We contend that any device that provides constant feedback bestows a reaffirming effect and does not leave the users wondering if their compressions are on target or whether the device is working properly. At least one study has found that constant feedback staves off the onset of fatigue for some time compared to having no feedback.[29] Finally, the card stores compression performance data. If used for training, the data can help to track quality trends, which the user and trainer can use for performance improvement. When used in an emergency, the card can provide compression data for retrospective analysis of the event. If these advantages translate to the card's prevalence and use in an emergency, researchers will be able to collect data on bystander compressions during the early onset of cardiac arrest before professionals arrive on the scene. This has promising implications for studying the association between the quality of bystander CPR and clinical outcomes, which is currently a glaring gap in resuscitation research.

We expected to see compression quality improve with the use of feedback. Cheng et al tested the CPRcard for paediatric application among nurses.[6] Comparing the just-in-time arms, which is most comparable with our study, they found a 39% difference for adequate compression rate and a 10% difference for adequate depth, similar to our results of 36% and 4% difference for the adequate or in-target compression rate and depth, respectively. In the study by Wee and colleagues, which also involved nurses, the differences in in-target compression rate and depth between the groups with feedback and without feedback were 12.22% and 7.37%, respectively.[8] Similar patterns of improvement are also shown in other studies.[30,31]

There was one peculiarity in our results. The present study was embedded in a training initiative (i.e. DARE) that was designed to have trainers simulate the dispatcher's role, including counting out the compressions for proper pace. This counting should have synchronised the rate of both groups to some extent, resulting in similar outcomes. Instead, we observed a large difference between the in-target compression rates of the two groups (feedback 83% vs. no feedback 47%). This gap could be explained by the fact that the participants who did not receive feedback could not benefit from its reassuring effect and, thus, we see the effect of fatigue as posited in Buléon et al's study.[29]

Between the CPRcard group and all controls, we did not observe a statistically significant difference in compressions within the adequate depth target range. Again, this could be explained by the 'push hard-push fast' core instruction for compressions taught in training, or it could be that on average, our largely homogeneous, ethnically Chinese participant pool may be comparable in their strength and ability to compress the chest of this particular model of manikin regardless of feedback. An association between low body weight and declining compression quality has been established in the literature.[32] However, the effect of feedback can be seen again in the relatively narrower dispersion of depth data in and around the target range of the CPRcard group. Our review of the aforementioned literature on feedback devices suggests that improvement in compression depth is smaller than improvement in compression rate.

We observed another peculiarity in that the blinded-card group had a higher percentage of compressions in the in-target depth range compared to the unblinded-card (i.e. CPRcard) group. This could be because the unblinded group was challenged with trying to regulate compression depth to generate an in-target light on the meter, whereas the blinded group was free to simply push down hard on the chest. Although this finding was not statistically significant, the effect of the card was again observed in the far narrower depth-data dispersion (unblinded 45–73 vs. blinded 11–91; Table II).

We observed improvements in the rate of correct answers across all questions (Table III). However, we were dismayed at the high rate of incorrect responses to Question 5, which pertains to 'how fast' compressions should be performed. We surmised that although the appropriate compression rate was mentioned in the training video, this information could have been missed by the participants amidst the copious amount of information being shared in the short span of time. Past research suggests that a longer duration of training could, with caveat, improve retention of skill and knowledge.[33] Similar to the findings of our study, Gombeski et al's study also showed that the scores for questions on compression rate and depth were relatively lower than those for other questions in their review quiz.[33]

In previous DARE CPRcard trainings, some participants pointed out that they experienced minor discomfort to the palm of the hand that was in contact with the card during compressions. However, as this was reported in only a few cases (the exact number was not known), no alarm was raised. Anecdotally, from our observations of the impressions on the palms, we opine that this could have occurred in some participants (both men and women) because their palm is softer, which makes it more susceptible to discomfort during compression. It is also possible that older participants may experience more of such discomfort due to a thinning of the skin with age. During compression, the edge of the card leaves an impression that usually goes away shortly after, with no long-term effects that we are aware of. In our opinion, this is not a matter of great concern compared to the issues faced when using bulkier devices, as shown in other studies.[34,35] However, mindful of the implications for prolonged use in an emergency situation, we highlighted this problem to the manufacturer and suggested that a rubber rim be added to the edge of the card, or that the card's edge be rounded to minimise discomfort to the palm.

Swor et al identified the following predictors of bystander CPR: (a) the collapse occurred in a public place; (b) witnessed arrest; (c) bystander had CPR training; (d) bystander had a post-high school education; and (e) bystander was in the young-old age group.[36] Overwhelmingly, participants in our study agreed that the CPRcard gave them more confidence as responders in performing CPR (Table IV). We hope that its ease of use and the hands-only approach to CPR, as well as the increased confidence it gives users, will motivate trained bystanders to respond to OHCAs in greater numbers and in any setting, particularly in residential areas where there is the greatest room for improvement.

The present study had several limitations. First, DARE training was designed to simulate emergency system activation and laymen participation in dispatcher-assisted CPR over the phone. As trainers took on the role of dispatcher and counted at proper cadence (i.e. '1 and 2 and 3...' etc.) during the compression duty-cycle, the counting could have resulted in an underestimation of the card's effect on compression rate. This could explain the similarity in median compression rate in the feedback vs. no feedback groups' performances. Second, the Resusci Anne SkillReporter was used to measure the compressions for the no-card group; however, the SkillReporter and CPRcard data are not necessarily harmonised because of differences in technology. Although a crossover effect cannot be ruled out, we hypothesised that by alternating the order of feedback vs. no-feedback performances between the 'A' and 'B' arms (Fig. 2), the risk of this effect was neutralised. Finally, because this is an experiment nested in an actual training intervention, we could not ethically interfere with the trainers who corrected compression postures and hand positions, as required from time to time. This might have had an effect on performance (e.g. a participant may have stopped to adjust his or her hand position), but we surmised that these corrections were minimal and distributed evenly across the trial arms, and thus did not skew the results.

In conclusion, the present study found that the use of the CPRcard feedback device during CPR training effectively improved the quality of CPR compressions performed by participants who were non-healthcare workers. Participants in our study found that the card was easy to use and that using it increased their confidence in performing compressions.

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