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Simulation and education

Cardiopulmonary resuscitation skill training and retention in teens (CPR START): A randomized control trial in high school students



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Abstract

Aim: High school students are currently the largest group of individuals in the US receiving CPR training every year. This study examines the effect of adding a real-time visual feedback device to a standard instructor-led CPR course on skill acquisition and retention in high school students.

Methods: All study participants underwent baseline CPR skill testing and received a standard instructor-led compression-only CPR course. We then randomized students to a 'Feedback Group', consisting of 2 min of CPR training using a real-time visual feedback device, or 'Standard Group' that continued to practice on the inflatable manikin. CPR skills for all students were tested afterwards using the feedback device and reported as a compression score (CS) derived from their chest compression depth, rate, hand position, and full chest recoil. We compared the CS at baseline, week-0 (immediately post-intervention), week-10, week-28, and week-52 between groups.

Results: A total of 220 students were included in the analyses (Feedback Group = 110, Standard Group = 110). Both groups showed similar CPR performance at baseline. At week-0, the Feedback Group had a significantly higher CS compared to the Standard Group (adjusted difference: 20% [95% CI: 11%–29%; $p < 0.001$]). This difference attenuated over time but remained significant at the week-10 and week-28 follow-up; however, by the week-52 follow-up, there was no significant difference between groups.

Conclusions: Using a real-time visual feedback device during CPR training significantly improves skill acquisition and retention in high school students and should be integrated into the high school CPR curriculum.

Keywords: Cardiopulmonary resuscitation, Feedback device, High school students, Skill acquisition, Skill retention

Introduction

Sudden cardiac arrest continues to be a leading cause of death in the United States (US) and Canada.¹ The implementation of

compression-only cardiopulmonary resuscitation (CPR) has resulted in higher bystander CPR rates and improved overall survival compared to cases where no CPR is performed in out-of-hospital cardiac arrest (OHCA).^{2–4} Teaching CPR in schools is one of the most sustainable ways of increasing the number of laypersons trained and

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improving bystander CPR rates.⁵ The 'Kids Save Lives' campaign supported by the International Liaison Committee on Resuscitation (ILCOR) and the World Health Organization (WHO), recommends CPR training annually from the age of 12 years in all schools worldwide.⁶ In 2011, the American Heart Association (AHA) published an advisory statement that recommended mandatory CPR training for schoolchildren in the US.⁷ As of 2018, 39 states and Washington, DC have passed laws that ensure more than 2 million students are trained every year in CPR before graduating from high school.⁸

Over the past decade, there have been substantial updates to adult CPR guidelines such as emphasizing high-quality compression-only CPR while training laypersons, and changing the optimal chest compression (CC) rate (100–120/min) and depth (≥ 5 cm).^{9,10} There is a gap in understanding and evaluating how effectively schoolchildren can perform CPR using the latest guidelines. Moreover, currently offered 'standard' (instructor-led CPR training using an inflatable manikin) courses do not report objective metrics of CPR skills and have fallen short in educational efficiency.^{11–13} For example, in a 2017 study by Brown et al.¹⁴ conducted on high school students trained using a standard school CPR course, approximately two-thirds of students tested 3-months and 6-months later did not perform CPR at the appropriate rate or depth.

Technological advancements in simulation education have led to the availability of various automated feedback devices that can be used as adjuncts to CPR training and have been shown to improve performance and skill retention.^{15,16} The most recent recommendations from ILCOR suggest the use of devices that provide directive feedback on compression rate, depth, release, and hand position during CPR training.^{17,18} Few studies have examined these devices' role in training schoolchildren based on current CPR guidelines, and none have focused on skill retention beyond 6-months.^{14,19} The objective of our study is to evaluate the effect of adding a real-time visual feedback device to a standard instructor-led course on skill acquisition and retention in high school students.

Methods

Study design

We conducted a two-arm parallel randomized controlled trial (RCT) of 11th and 12th-grade students (ages 16–18 years) at a single high school in the US. The Bronx High School of Science (BHSS), a competitive public school in New York City, was chosen as the setting for our study because it had recently introduced CPR training as a part of its health class curriculum, and has a culturally, ethnically, and economically diverse student body. All students enrolled in a health class offered during the Fall 2016 and Spring 2017 semesters were eligible to participate in our study, regardless of their prior experience or training in CPR. We obtained written informed consent from parents or legal representatives of minor participants and student assent before starting the study. Students who refused trial participation or were unable to perform CPR were excluded from the study. Ethics approval was obtained from the Institutional Board Review (IRB) at the Albert Einstein College of Medicine (IRB # 2016-6364) and the New York City Department of Education (IRB # 1485). The study was conducted in three phases from November 2016 to March 2018, during which students were trained and their CPR knowledge and skill performance evaluated: Pre-intervention phase, Intervention phase, and Post-intervention phase.

Pre-intervention phase

After enrollment, participants completed a 15-point questionnaire (see online Supplementary methods) regarding demographics, prior CPR training, and real-life CPR experience, including five questions on theoretical CPR knowledge. Students were pulled from their health class into an adjacent room and baseline CPR skills were measured by having them perform two minutes of compression-only CPR on a Resusci Anne[®] Q CPR[®] (Laerdal Medical Corporation, USA) training manikin connected to a SimPad[®] with SkillReporter[™] software that was able to calculate and record their overall CPR performance derived from their CC depth, rate, correct hand position, and full chest recoil. Only study investigators had access to these baseline test results. The next day, all study participants received standard CPR training, which consisted of a school teacher-facilitated 30-minute theoretical and practical group training session, using 'The CPR in Schools Training Kit' endorsed by the AHA.²⁰ Each kit includes a practice-while-watching training DVD and an inflatable manikin on which students practice compression-only CPR. Three health class teachers, certified in Basic Life Support (BLS), taught the CPR course during both semesters. Before study initiation, we provided teachers with a one-hour CPR training refresher based on the 2015 AHA guideline updates and an opportunity to familiarize themselves with the training kit.

Intervention phase

Study researchers assigned each participant with a unique identification number and randomized them using an online random sequence generator (<https://www.randomizer.org/>) to one of two groups: Feedback Group (FG) or Standard Group (SG). The researchers did not have foreknowledge of the allocation sequence. Each group received their intervention in a separate room. The FG performed two minutes of compression-only CPR training on the Resusci Anne[®] Q CPR[®] manikin, which provided real-time objective visual feedback, enabling them to adopt corrective measures based on the predefined adult CPR targets: CC rate 100–120/min, depth ≥ 5 cm, correct hand position, and allowing full chest recoil. The research assistant (RA) provided verbal prompts if the student had difficulty interpreting the feedback device. Simultaneously, the SG group continued to practice CPR on the inflatable manikin under the supervision of the school teacher. Given the study setup, it was not possible to blind the participants or investigators during the study's intervention phase.

Post-intervention phase

Within the two to three days following the intervention, we tested students from both groups by having them complete the same questionnaire and perform two minutes of compression-only CPR on the feedback manikin; these results were recorded for the week-0-time interval. During testing, only study investigators had access to the CPR scores, and neither group received any feedback. Students were reassessed at three other intervals over the following year: week-10, week-28, week-52 post-intervention. To maximize participation, we conducted these sessions during gym class over three to four days. During each follow-up session, we set up the feedback manikins in a room adjacent to the gym; students were temporarily removed from class, asked to perform 2-mins of CPR supervised by an RA masked to the group assignments, complete a brief questionnaire regarding CPR knowledge, and then return to their gym activities. The participants

were not shown their scores, nor did they receive feedback. We excluded students who missed >2 follow-up sessions from the study.

Outcomes

The study's primary outcome was the compression score (CS), which is a combined score derived from CC depth, CC rate, correct hand position, and full chest recoil per 2-min cycle calculated by the SkillReporter[®] software calibrated based on the 2015 AHA adult CPR targets. If CPR is carried out precisely per the resuscitation guidelines, then 100% is scored. If CPR performance deviates from the guidelines, the score is reduced. More information on the scoring algorithm can be obtained from the manufacturer's website.²¹

The secondary outcomes include (1) participants achieving "Advanced CPR Performer" status, defined as an overall CS of $\geq 75\%$ according to the manufacturer's guidelines; (2) individual

component CPR metrics such as mean compression *depth* and *rate*, and percentage of the time the student used correct *hand position* and allowed for full chest *recoil*; (3) theoretical knowledge and self-perceived comfort in performing CPR in real-life, collected via the questionnaire during each follow-up testing session. "Good CPR knowledge" was defined as answering ≥ 4 of 5 CPR knowledge questions correctly. Comfort in performing CPR was determined in the form of a yes/no answer.

Sample size

The sample size for the study was estimated based on a two-sample t-test under the equal variance assumption. One-hundred and ten students in each arm were recruited to achieve an 80% power at a 5% level of significance to detect a difference of 10 compression score units between the groups. The standard deviation was assumed at 24

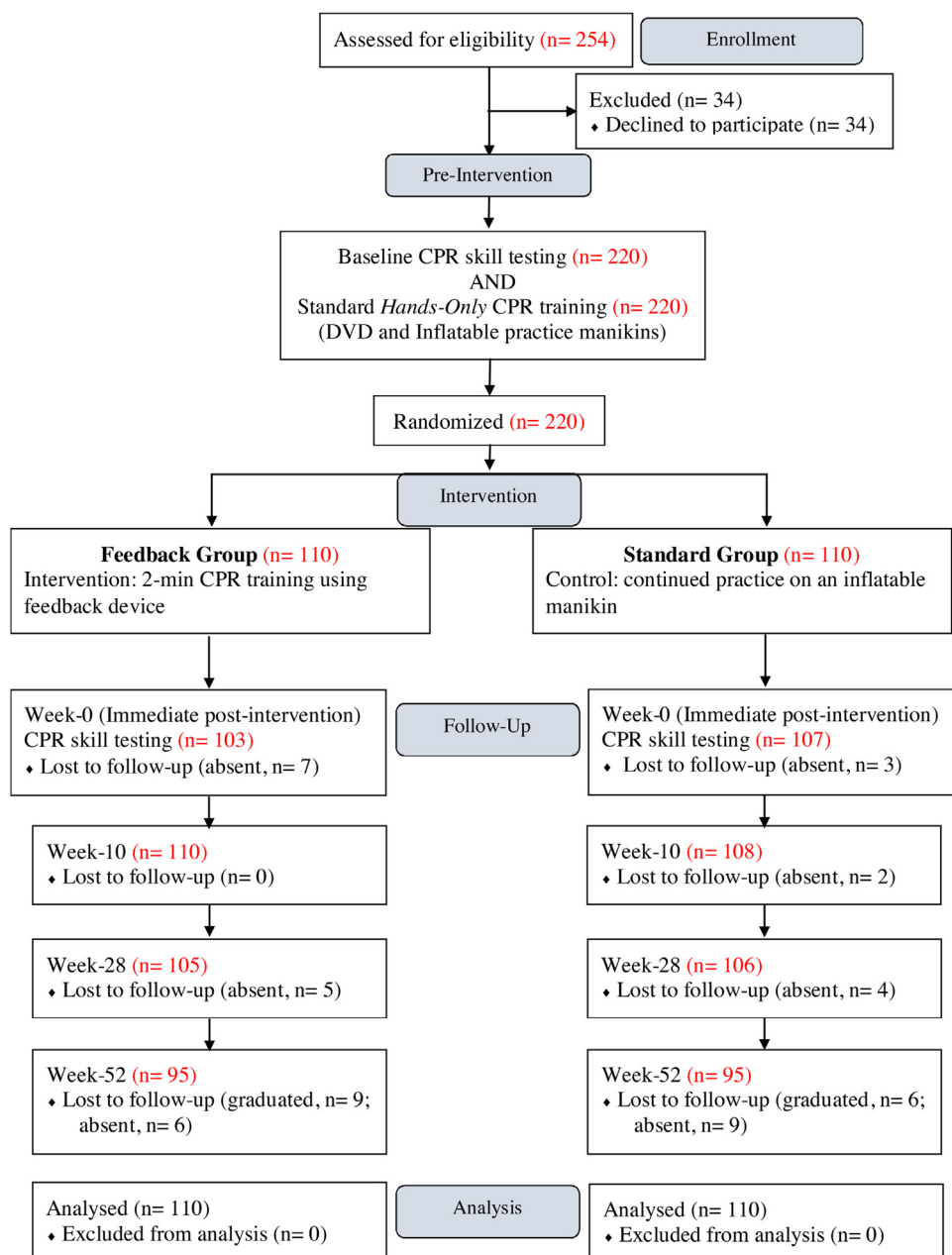


Fig. 1 – Study participation flow diagram.

units based on previous literature,¹⁹ and the size was inflated to account for a 15 percent attrition.

Statistical methods

The distribution of students' demographic, anthropometric, and baseline characteristics was summarized using descriptive statistics. The continuous scale variables were presented as means (standard deviations), while the categorical variables were summarized using frequency counts (percentages).

The primary outcomes of interest examining the difference in the trajectory of compression score between the two intervention arms over time and assessment of change in the average compression score within each arm was achieved by fitting a marginal covariance pattern model (CPM). The CPM model was fitted using a restricted maximum likelihood estimation with Kenward-Roger degrees-of-freedom that included treatment arm, time, and time by treatment interaction. An exchangeable correlation structure was used to adjust for within-subject correlation and was selected based on AIC criteria. A repeated measure logistic regression with a generalized estimating equation approach was used for modelling dichotomous outcomes. The exchangeable correlation structure was used to model the within-subject correlation based on QIC criteria. All models were adjusted for gender, BMI, school teacher, as well as the student's pre-intervention measurement as confounders. Post-hoc statistical differences between groups at individual time points were adjusted for multiple comparisons using a Bonferroni correction. All data were analysed using STATA 15.0 (StataCorp, College Station, TX).

Results

Between November 2016 and March 2017, we recruited 254 participants, of which 34 were excluded (Fig. 1). We included a total of 220 high school students, 117 from the Fall semester, and 103 from the Spring semester in the final analysis. No student missed more than two follow-up sessions. Participant baseline characteristics, and pre-intervention CPR knowledge and skill, were similar between the FG and SG groups (Table 1).

Mean compression scores (CS)

Fig. 2 presents the mean CS across both groups at each follow-up interval. Immediately following the intervention, we found a significantly higher CS in the FG compared to the SG (adjusted difference: 20% [95% CI: 11%–29%; $p < 0.001$]). This difference attenuated over time but remained significant at the week-10 and week-28 follow-up; however, by the week-52 follow-up, there was no significant difference between groups.

Advanced CPR performers

At week-0, the FG had a significantly higher estimated percentage of students achieving a compression score of $\geq 75\%$ compared to SG (adjusted difference: 23% [95% CI: 10%–37%; $p < 0.001$]) (Fig. 3). This difference attenuated over time, and by the week-28 follow-up, there was no significant difference between groups.

Table 1 – Demographic and baseline characteristics of study participants randomized to each study group.¹

Demographic characteristic ^a	Feedback group (n = 110)	Standard group (n = 110)
Age, mean (SD), years	16 (0.5)	16 (0.5)
Sex		
Female	49 (45)	48 (44)
Grade ^b		
11th	101 (92)	104 (95)
12th	9 (8)	6 (5)
Height, mean (SD), cm	170 (9)	171 (10)
Weight, mean (SD), kg	62 (12)	64 (15)
BMI, mean (SD), kg/m ²	21 (3)	22 (4)
Received prior CPR training	19 (17)	28 (25)
Performed CPR on a real person	0 (0)	1 (1)
Health class teacher		
D	33 (30)	36 (33)
S	46 (42)	46 (42)
K	31 (28)	28 (25)
Pre-intervention CPR skills		
Compression score, mean (SD)	15 (23)	18 (24)
Compression depth, mean (SD), mm	35 (12)	37 (12)
Compression rate, mean (SD), min ⁻¹	110 (26)	109 (23)
Correct hand position	69 (39)	67 (38)
Full chest recoil	76 (31)	76 (31)
Good CPR knowledge	57 (52)	50 (47)
Comfort in performing CPR in real life	40 (37)	32 (30)

Standard Deviation (SD), Body Mass Index (BMI), Cardiopulmonary Resuscitation (CPR).

^a All data are presented as frequency (percentage) unless otherwise indicated.

^b Grade at the start of the study.

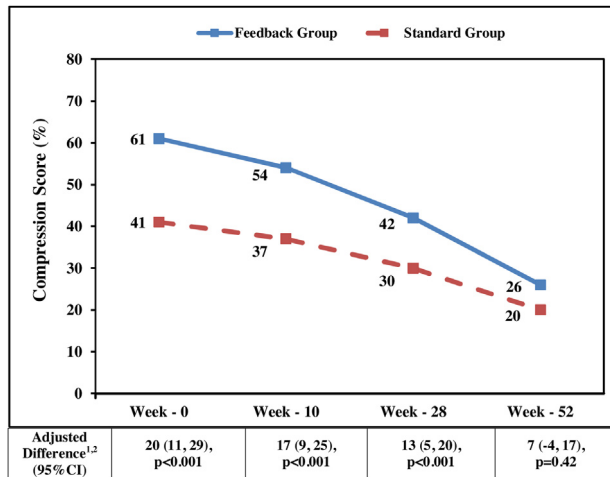


Fig. 2 – Comparison of the mean compression score (CS) between the Feedback Group and the Standard Group at week-0 (immediate post-intervention), week-10, week-28, and week-52.

¹Adjusted for baseline compression score, BMI, sex, and health class teacher.

²Differences are rounded to nearest whole number and may therefore differ from graph.

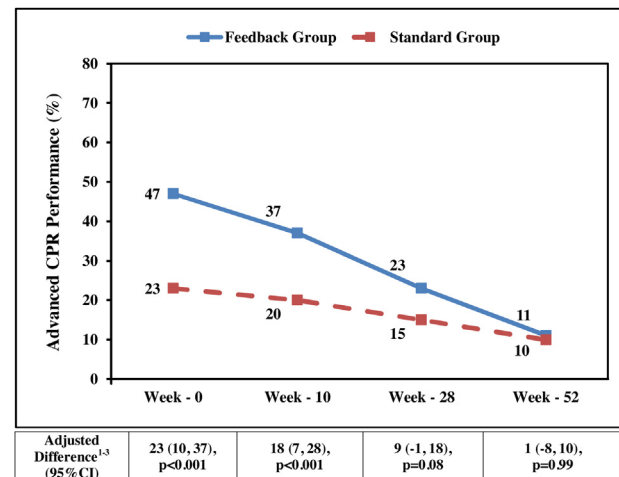


Fig. 3 – Comparison of the percentage of students who performed 'Advanced CPR' between the Feedback Group and the Standard Group at week-0 (immediate post-intervention), week-10, week-28, and week-52.

¹Adjusted for baseline compression score, BMI, sex, and health class teacher.

²Differences are rounded to nearest whole number and may therefore differ from graph.

³Advanced CPR Performer was defined as achieving an overall compression score of $\geq 75\%$.

Component CPR metrics

Following the intervention, the FG achieved significantly greater CC depth than the SG (adjusted difference: 5 mm [95% CI: 2–8; $p < 0.001$]). We observed a statistically significant difference in CC depth at week-0, week-10, week-28, and week-52 (Fig. 4). Participants in both groups had similar mean CC rates, within the recommended range (100–120/min), at every follow-up point. For both correct hand position and full chest recoil, the FG performed significantly better than the SG only at the week-0 and week-10 assessments. By week-28, differences in scores for these two metrics were no longer statistically significant.

CPR knowledge and comfort in performing CPR in real-life

Both groups showed substantial improvement in their theoretical CPR knowledge as well as their self-perceived comfort in performing CPR in a real-life situation immediately after the intervention and at each of the follow-up points compared to their baseline; however, there was no significant difference between groups at any time point (Fig. 5).

For results of linear trends (slope calculations) of the primary and secondary outcomes between the Feedback Group and Standard Group over time, refer to online Supplemental results.

Discussion

In this longitudinal randomized control trial in high school students, we demonstrated that incorporating real-time visual feedback during CPR training significantly improved skill acquisition compared to standard practice. This was seen in our primary outcome, CS, as well as our secondary outcomes; namely, the percentage of 'Advanced' CPR performers, mean compression depth, and percentage of the time the student used correct hand position and allowed for full chest recoil. We

found that most of these differences between groups were attenuated over time: some by week-28 after the initial training and the majority by week-52. In addition to improvements in CPR skills, both groups showed substantial improvement in their theoretical CPR knowledge as well as their self-perceived comfort in performing CPR in real-life at each of the follow-up sessions compared to baseline. However, the addition of a feedback device to CPR training did not result in a significant difference between groups for these last two metrics.

Our study builds on the results from a similar study by Cortegiani et al. in 2017.¹⁹ These authors found that one week after training, students in the FG had a significantly higher median CS compared to SG (90% vs. 67%). While this study was similar to ours in methodology, equipment used, and outcomes measured, there are two key differences. First, the authors found that students in both groups overall achieved a much higher CS than in our study. The overall effect of the addition of a feedback device, however, to the standard training was roughly similar – approximately 20% initial improvement in CS. These higher scores could be attributed to a longer training session, which required students of both groups to practice until they reached a minimum level of mastery, as well as individualized coaching provided to the students by an instructor during the training phase. Feedback, coupled with in-person debriefing, has shown to improve CPR quality markedly.^{22–24} This educational model, while more robust, is time consuming and less feasible in a school setting with typical class periods that last only 30–40 min. Second, these authors measured only one post-intervention time point. We measured skill retention over a year and found that the benefit of using a feedback device during CPR training persisted for up to 28 weeks. While both groups showed a substantial decline in performance, our results suggest that a refresher course introduced before that time could boost performance and improve retention rates.

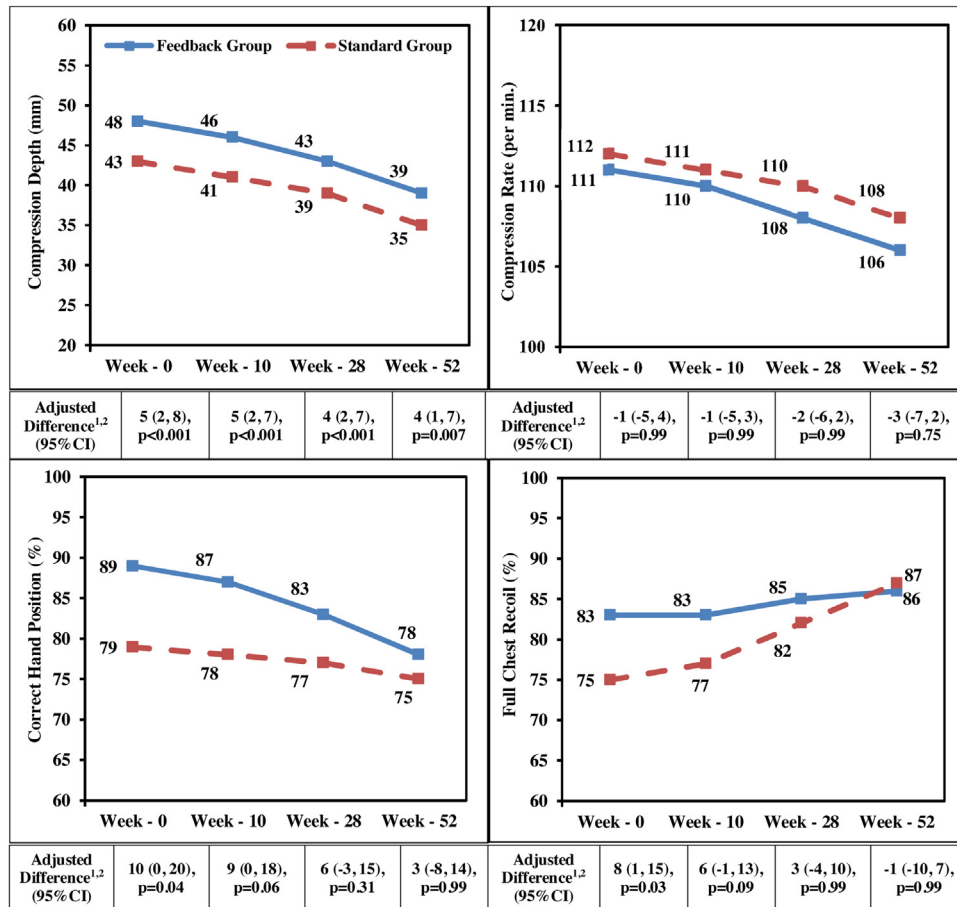


Fig. 4 – Comparison of the key chest compression metrics performed that are compliant with the American Heart Association guidelines for depth, rate, correct hand position, and full chest recoil between the Feedback Group and the Standard Group at week-0 (immediate post-intervention), week-10, week-28, and week-52.

¹Adjusted for baseline compression score, BMI, sex, and health class teacher.

²Differences are rounded to nearest whole number and may therefore differ from graph.

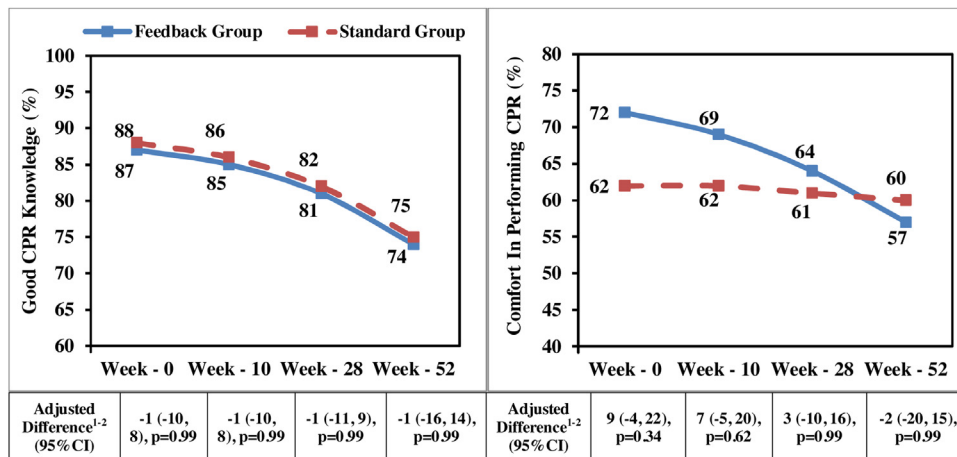


Fig. 5 – Comparison of the students' theoretical CPR knowledge as well as their self-perceived comfort in performing CPR in a real-life situation between the Feedback Group and the Standard Group at week-0 (immediate post-intervention), week-10, week-28, and week-52.

¹Adjusted for baseline compression score, BMI, sex, and health class teacher.

²Differences are rounded to nearest whole number and may therefore differ from graph.

Integration of CPR training into the school curriculum should be based on an evidence-based educational pathway, by defining the goals to be achieved for knowledge, skills and attitudes.²⁵ Our study shows that regardless of the method used, CPR training in school children improves student CPR knowledge and self-perceived comfort in performing CPR in a real-life situation. Wingen et al.²⁶ reported similar results in the level of knowledge and self-confidence in 14 to 18-year-old schoolchildren up to 6 months after training. Others have demonstrated the benefits of CPR training on willingness, attitudes, and intentions toward helping others in younger schoolchildren aged 12.5–14.5 years.^{27,28} These attributes are known to be strong independent predictors of actually performing bystander CPR in real-life.^{29,30}

The key to any successful CPR training program is knowledge and skills retention. Prior research has shown that 'low dose, high frequency' refresher training, also known as 'distributed practice', in which participants perform brief but frequent CPR training sessions, significantly improves the quality and retention of skills.^{31–34} While it has been shown that qualified school teachers can provide effective CPR training,^{35,36} the feasibility of repetitive training throughout the school year has not been previously studied in the high school setting. Given our study methodology, we demonstrated that brief 2-min CPR testing on a feedback manikin during school hours throughout the year could be performed with minimal academic disruption or resource utilization. If the students were allowed to train while receiving real-time feedback at each of these brief follow-up visits, perhaps their skills could be retained for a greater period of time.

Limitations

Our study has several limitations. First, despite conducting our study at one of the most culturally, ethnically, and economically diverse schools in the country, we recognize that our results from this single magnet high school might not be generalizable to other high school students. Second, the masking of teachers and study participants to the intervention was not possible given the nature of the study design. To ensure every student received the same quality of training, students were randomized after receiving their standard CPR training. While this may have minimized bias, participants could have changed their behaviour by knowing their group assignment. The data collectors and data analysts were masked to the group assignments at every follow-up testing session. Third, randomization was performed at the student level; this could have resulted in possible knowledge exchange between the students and subsequently, information contamination between study arms. This could have dulled the association between the intervention and outcome; despite this, we were able to demonstrate convincing results in favour of using a feedback device during CPR training for high school students. Fourth, as previously discussed, due to time constraints, each student in the FG was limited to only 2-minutes of CPR training with the feedback device. Longer training times would have allowed students to practice critical skills, receive directed feedback, and improve performance until they attain mastery; all of which could have potentially resulted in higher scores. Fifth, we appreciate that the addition of feedback equipment to CPR training may lead to increased training costs; given the already limited resources and funding schools receive, this could be a barrier to implementation. Finally, the effect that feedback devices have on the acquisition and retention of CPR skills in a simulated resuscitation may not be realized in a real-life cardiac arrest. Several studies in other settings, however, have shown

that high-fidelity simulation skills translate to improved outcomes in real patients.³⁷

Conclusion

Using a real-time visual feedback device during CPR training significantly improves CPR skill acquisition and retention in high school students and should be integrated into the high school CPR curriculum to improve CPR performance. Given that high school students are currently the largest group of individuals in the US receiving CPR education, improving their training has the potential to be highly impactful in increasing the rates of bystander CPR initiation and the number of lives that may be saved.

Funding source and other support

We received funding from The Committee of Interns and Residents/SEIU Healthcare, Patient Care Trust Fund. We utilized the funds to purchase one Resusci Anne QCPR manikin and one SimPad used in the study. Mrs. Shannon Schneider (Senior Client Executive - Manhattan, the Bronx, and Hudson Valley, Laerdal Medical, USA) provided us with two additional Resusci Anne QCPR manikins and SimPads at no cost, which were returned once we completed the study. The funders and Laerdal Medical had no role in study design, data collection, analysis, decision to publish, or manuscript preparation.

Conflict of interest

None.

CRedit authorship contribution statement

Haamid Chamdawala: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Visualization, Writing - original draft, Writing - review & editing. **James A. Meltzer:** Conceptualization, Data curation, Formal analysis, Methodology, Visualization, Writing - original draft, Writing - review & editing. **Viswanathan Shankar:** Data curation, Formal analysis, Methodology, Writing - original draft, Writing - review & editing. **Dina Elachi:** Conceptualization, Data curation, Investigation, Methodology, Writing - original draft, Writing - review & editing. **Shannon M. Jarzynka:** Conceptualization, Data curation, Investigation, Methodology, Writing - original draft, Writing - review & editing. **Abigail F. Nixon:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing - original draft, Writing - review & editing.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.resplu.2021.100079>.

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