Comparing real-time feedback modalities to support optimal cardiopulmonary resuscitation for undergraduate nursing students: A quasi-experimental cross over simulation study

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ABSTRACT

AIM: Optimal Cardiopulmonary Resuscitation (CPR) is reliant on a chain of well performed interventions and skills. To investigate whether CPR feedback devices improve performance for nursing students, the effects of three feedback modalities – Visual: Laerdal SimPad®; Visual-embodied metaphoric: Innosonian Brayden Pro®; and Visual-audio: Physio-Control TrueCPR® - was tested.

METHODS: A quasi-experimental cross over study compared performance metrics of participant exposure to three feedback modalities and standard adult Basic Life Support (BLS) without feedback in a simulated environment. Following baseline training, 64 participants performed adult single rescuer BLS on a manikin for each modality and without feedback for two minutes. Effective chest compressions (correct depth, thoracic recoil, pressure point, rate, no-flow fraction) and ventilation parameters were compared using Friedman and Wilcoxon tests.

RESULTS: Superior technical accuracy in CPR skills performance was evident with all feedback modalities when compared to no feedback p=<0.05); visual-audio feedback (TrueCPR®) was most effective (p=0.005). Participants demonstrated higher technical accuracy in CPR performance (30:2 cycles; chest compression number/rate/depth; chest recoil; pressure point; correct number of ventilations) when compared to no feedback (p=0.0001), despite achieving national certification three weeks prior to data collection.

CONCLUSION: This appears to be the first study to explore the use of feedback modalities during CPR performance in nursing students. These feedback devices can play a major role in improving measurable parameters of BLS and psychomotor skill capability. Modalities varied in their ability to improve performance; visual-audio feedback significantly improved chest compressions, ventilation and cycle performance, while visual-graph-based feedback improved flow fraction and ventilations.

KEYWORDS

Cardiopulmonary Resuscitation; Education, Nursing, Baccalaureate; Simulation Training; Formative Feedback.

KEY POINTS

- To our knowledge this is the first study to explore the use of real-time feedback modalities during CPR performance for undergraduate nursing students.
- Findings demonstrate there is good evidence supporting use of CPR feedback devices during training to improve psychomotor skill acquisition.
- CPR feedback devices vary in their ability to improve performance

INTRODUCTION

Even when delivered according to guidelines, manual CPR is inefficient, providing 10-30% of normal coronary blood flow and 30-40% of cerebral blood flow. [1] This inefficiency highlights the need for rescuers to deliver the highest-quality CPR possible, as performance is directly correlated with patient outcomes. [1-3] Resuscitation training is an essential element of skills training for Health Care Professionals (HCP), especially nurses as they are often first responders during in-hospital cardiac arrests. However, current literature highlights that following training, manual CPR performance decreases rapidly and below international standards. [4]

In 2010, the International Liaison Committee on Resuscitation (ILCOR) first identified the lack of objective real-time feedback to aid effective Chest Compressions (CCs) during CPR. [5] CPR prompting and feedback devices provide immediate feedback on performance so corrections can occur in real-time. [6] Subsequent ILCOR revisions (2015) recommended feedback devices to improve the quality of CPR training and practice. [7]

Integration of real-time feedback devices that provide information about CPR performance may therefore be useful for improving nursing students' psychomotor skills acquisition and retention, effectively preparing them for future practice as clinicians. Objective data on performance improvements using feedback is however currently limited. [8] With technological advances, a growing number of different prompt and feedback devices have been developed for both training and practice; research, however, appears limited on the impact of different modalities on CPR performance. The aim of this study was therefore to investigate the effects of three feedback modalities - Visual: Laerdal SimPad®; Visual-embodied metaphoric: Innosonian Brayden Pro®; and Visual-audio: Physio-Control TrueCPR® on CPR performance in nursing students.

METHODS

A quasi-experimental, randomised cross-over study was approved by the Human Research Ethics Committees of a University and funding body. A convenience sample of 65 undergraduate second and third-year Bachelor of Nursing students from one Australian University were recruited. A quasi-experimental, randomised cross over study design was used as it enabled examination of feedback device on performance within a single group of participants,[9] and randomisation of starting device to control for extraneous variables.

All those who agreed to participate and met the inclusion criteria received standardised adult BLS accreditation by a certified trainer three weeks prior to data collection (see Figure 2). Following informed consent, participants were randomised to a starting device to minimise testing effects and potential confounding variables such as practice exposure and participant fatigue. [5] Prior to data collection, participants were orientated to the three CPR feedback modalities and standard BLS without feedback using three stages: 1) a 10-minute revision of BLS algorithms; 2) introduction to each device and its mode of feedback; and 3) a device familiarisation session, where participants rotated between devices every two minutes to ensure they were confident with understanding device feedback and adjusting performance (see Figure 1). Manikins were located on a firm and even floor mat to ensure accurate measurements, as accelerometers and feedback devices can overestimate compression depth when used on a soft surface. [10, 11]

After orientation, participants performed two minutes of single-rescuer CPR with mouth-to-mouth ventilation (30:2) on a manikin without feedback according to the ANZCOR 2016 guidelines. [12] Participants then performed 2 minutes of single-rescuer CPR with mouth to mouth ventilation, guided by prompts from their feedback device.

For CPR quality measurements, we used three Laerdal Resusci Anne QCPR® manikins (LRAM) (Stavanger, Norway) connected to three Laerdal SimPad PLUS with SkillReporter® and one Innosonian Brayden Pro® Manikin (Seoul, Republic of Korea).

Before comparison analysis, we normalised data capture from the LRAM and Brayden manikins using the LUCAS CPR 3.1 automated mechanical compression device (Lucas-Physio-Control, Redmond, Washington), as it offered consistent quality CCs, reducing potential confounding variables such as user endurance level, body mass index and practice exposure. [13, 14] Effective CPR performance was defined as CCs rate (100-120 per minute), depth (>5cm); complete recoil of the chest, correct PP (lower half of the sternum) and adequate ventilations with volume of >600ml and no-flow time as time without CCs divided by the total time without spontaneous circulation. [12]

Real-time feedback Modalities

The SimPad, TrueCPR and Brayden devices calculated data in accordance with ILCOR and Australian Resuscitation guidelines. [4, 12] Each device is described below:

- Laerdal SimPad provides a visual interface with graphs and numerical indicators for CCs depth, rate and ratio to ventilations, Pressure Point (PP), ventilation volume and rate (see Figure 1. 'a'). [15]
- Brayden Pro is a torso CPR training manikin with a visual-embodied metaphoric, featuring realistic visible chest rise / lung compliance (see Figure 1. 'b'). Light emitting diode (LED) lamps located in the forehead, neck and thorax cyclically illuminate according to depth, speed and recoil of compressions and PP. Correct performance of depth (>5cm), speed (100-120/min) and thoracic release results in the lights flashing cyclically and 'normal circulation' on the forehead will illuminate. [16, 17]
- Physio Control TrueCPR provides real-time visual-audio feedback via a non-invasive dashboard on CCs performance, using a chest pad on the sternum and a back pad beneath the manikin (see Figure 1. 'c'). The target range of compression depth (50mm-60mm) is displayed using a visual-fan graph, with yellow arrows to indicate compressions that are too shallow or deep. An acoustic metronome guides a target rate (100 bpm), with the actual rate

displayed numerically on the dashboard. Visual and acoustic tones are also used to guide when ventilations should occur (30 compressions to 2 ventilations. [18]

Data management and analyses

Analysis of participant data involved a variety of modelling and data analysis techniques, including analysis of relationships between behavioural patterns (interactions of participants with feedback devices). For three of the four conditions (SimPad, TrueCPR and Brayden), task performance data was automatically captured by the LRAM. For the Brayden, task performance data was captured by the Brayden manikin. Non-parametric tests were conducted (IBM Corp. SPSS Statistics for Windows, Version 20.0. Armonk, NY), as data demonstrated non-normal distributions (Shapiro Wilk test; $n<2000$). Median and inter-quartile ranges are reported A Friedman test determined any differences between baseline (no feedback) and the three feedback devices. Pairwise comparisons were performed with a Bonferroni correction ($p<0.0125$) for multiple comparisons. A Wilcoxon sign-ranked test determined which device performed better ($p < 0.05$). P-values <0.05 were considered significant.

3. RESULTS

Sixty-four participants completed data collection (one participant was lost to follow-up after randomization). Demographic characteristics and previous BLS certification and experiences are listed in Table 1. Participants were predominately female (n=57; 89%) aged between 18 to 52 years (m=26), and primarily Australian citizens/permanent residents (n=37; 58%). Findings of the comparisons across devices are described below in the following parameter sections – compression, time-related and ventilation. Data are reported in-text as whole numbers for ease of reading (more precision is reported in tables; to two decimal places).

Compression parameters

Chest Compression rate per minute

The number of CCs cycles (30:2 compression to ventilation) and adequate rate per minute, CCs depth, chest recoil and PP are reported here. The median (Mdn) CCs performance rates were 124 (IQR=114-130) without feedback; 113 (108-117) with SimPad, 109 (106-116) with TrueCPR and 117 (113-122) for Brayden; (see Table 2, row 1). all within Australian recommended guidelines[12] (see Table 3, row 1)The performance rate without feedback was statistically higher than rates for the three modalities ($p<0.05$). Significant differences were also noted between modalities; for Brayden compared with SimPad ($z = 5.229$, $p = 0.0001$) and TrueCPR ($z = 5.474$, $p = 0.0001$).

Number of Chest Compressions and adequate cycles

Similarly, the overall median number of CCs was 160.5 (153-177) without feedback and 158 (150-173) with Brayden (see Table 2, row 2); significantly lower and outside Australian recommended guidelines (see Table 3, row 2) compared to the other devices ($p = 0.0001$) - SimPad (167, IQR= 156-179) and TrueCPR (169.5, IQR= 158-178). The related number of cycles per minute similarly varied across modalities. Although the median values were similar across modalities, the median cycles were: 4.7, 4.6, 5.0 and 5.2 per minute for no feedback (IQR= 4-5), SimPad (IQR= 4-5), TrueCPR (IQR= 5-5) and Brayden (IQR= 5-6) conditions, respectively (see Table 2, row 3). Both SimPad and TrueCPR CC rate were within Australian recommended guidelines (see Table 3, row 3). The rate using Brayden was significantly higher compared to SimPad ($z = 5.110$, $p = 0.0001$) and TrueCPR ($z = 2.920$, $p = 0.004$).

Adequate Chest Compression depth, recoil and pressure point

The median adequate CCs depth was 4 (0-35) without feedback; well below recommended guidelines and significantly lower than the three other modalities ($p < 0.05$) – 88.5 (57-98), 96 (91-98) and 88 (69-96) for SimPad, TrueCPR and Brayden, respectively (see Table 2, row 4). Of note, no modality demonstrated a perfect score suggesting that even with feedback some participants were unable to achieve the correct depth (see Table 3, row 4). A statistical difference was noted for participants using TrueCPR, compared with a shallower depth when using SimPad ($z = 6.193$, $p = 0.0001$). Adequate chest recoil median was 41 (7-79) with no feedback (see Table 2, row 5); significantly lower compared to SimPad (91, IQR= 80-98) both outside of Australian guidelines (see Table 3, row 5); TrueCPR (84.5, IQR= 48-97) and Brayden (100, IQR= 98-100). Significant differences were also noted between modalities; SimPad compared with TrueCPR ($z = 3.564$, $p < 0.0001$); Brayden versus SimPad and

TrueCPR (z = 5.174, $p < 0.0001$). The median Adequate PP was 68 (5-100) without feedback and significantly lower ($p = 0.002$; $p < 0.0001$; $p < 0.0001$) compared to SimPad, True CPR and Brayden; 98 (47-100), 100 (100-100), and 99.5 (98-100), respectively (see Table 2, row 6). Differences were also between modalities; SimPad versus TrueCPR (z=4.938, $p < 0.0001$); Brayden versus SimPad (z = 3.988, p = 0.0001) and Brayden versus TrueCPR (z = 4.865, $p < 0.0001$). TrueCPR and Brayden resulted in performance within Australian guidelines (see Table 3, row 6).

Time related parameters

<u>*No-flow time*</u>

The median total time without spontaneous circulation (no-flow time, see Table 2, row 7) was 8 (7-9) without feedback; significantly higher compared to the SimPad (6, IQR= 5-8), TrueCPR (6, IQR= 5-7) and Brayden (6, IQR= 5-8) modalities. Significant differences were noted for no-flow time with Brayden resulting in performance outside of guidelines (see Table 3, row 7), compared to SimPad (z=3.849, p=0.0001) and TrueCPR (z = 5.109, p = 0.0001).

Ventilation parameters

<u>*Number of ventilations and correct rate of ventilation*</u>

Median ventilation performance rate was outside of guidelines without feedback (Mdn= 10, IQR= 8-10), with SimPad (IQR= 8-10) and TrueCPR (IQR= 9-10), and significantly higher than Brayden ($p < 0.05$, Mdn= 5, IQR= 1-7) (see Table 3, row 8). Overall correct ventilations improved with SimPad (80, IQR= 70-90), but not with TrueCPR (40, IQR= 20-69) compared to no feedback (41, IQR= 11-80). With Brayden the ventilation performance was much worse (12, IQR= 0-24) (see Table 2, row 9). Correct ventilations with SimPad outperformed TrueCPR (z = 6.123, p = 0.0001) and Brayden (z = 6.831, p = 0.0001).

DISCUSSION

Three key findings from this comparison of performance feedback devices on CPR skill performance of undergraduate nursing students were identified. Improved technical accuracy in their CPR performance skills (30:2 cycles; CCs number/rate/depth; adequate chest recoil; adequate PP; correct number of ventilations) was demonstrated across all feedback devices when compared to standard BLS with no feedback. Visual-audio real-time feedback via TrueCPR was more effective for CCs and compliant ventilation and cycle performance. Some participants were however unable to perform effective CPR within international guidelines without feedback; despite all achieving national CPR certification three weeks prior to data collection. This finding reflects previous literature that CPR skill decay occurs within 3-6 months after initial training, regardless of educational modality.[9, 19-22]

The majority of participants' CPR psychomotor skills improved when feedback devices were used; a finding similar to other recent studies. [3, 23, 24] Of note, this current study demonstrated that without an audio prompt (metronome) or numerical chest compression feedback, the correct number of 30:2 compression to ventilation cycles was rarely achieved; a finding noted in previous studies with HCPs. [24, 25] The correct number of compressions to ventilations is crucial for organ perfusion, with too high or low cycle performance demonstrating adverse neurological outcomes. [3]

Without visual or audio guidance, participants performed CCs outside the recommended 100-120 compressions per minute. While a high compression rate just above guidelines may appear less harmful, a rate above 120 per minute may reduce coronary blood flow and cause rescuer fatigue, affecting overall CPR quality. [26] Visual-graph-based and visual-audio feedback also improved the incidence of correct compression ratios and proportion of complete hand release, compared to standard BLS. This type of feedback improved overall mean compression depth and percentage of compressions with complete chest recoil, satisfying one of the knowledge gaps identified in the ILCOR 2018 recommendations. [27] The percentage of no-flow fraction also improved significantly with feedback; a similar finding to an RCT with 107 HCPs. [8] Correct hand placement also significantly improved during CCs with the feedback devices; an important finding as incorrect PP can reduce perfusion for patients, and risk physical strain or injuries for rescuers. [28]

Positive effects of real-time feedback were also evident in participants' ventilation skills in this study, with a combination of visual and audio feedback. Individual ventilation volume and minute volumes were lower without specific ventilation volume feedback. Poor overall ventilation performance was associated with TrueCPR, a device with no ventilation flow or volume feedback. It is recommended that future versions of devices should incorporate ventilation feedback, as under or overinflating the thorax during CPR effects coronary blood flow to the peripheries. [29] Although other studies compared feedback devices for compression performance (e.g. [30]) to our knowledge, this current study is the first to include and compare ventilation performance data across devices.

As future practitioners, nursing students are in a unique position to improve patient outcomes following cardiac arrest, by acquiring comprehensive and effective CPR skills prior to transitioning into professional practice. Previous studies have however identified poor psychomotor skill efficacy and significant skill decay post-training [31, 32]; a finding reflected in the current study. Despite undertaking nationally recognised BLS accreditation three weeks prior, or experience with CPR in clinical practice, participants were unable to perform effective CPR during standard BLS. The overall standard without feedback was very low; mean optimal compressions occurred only about one-third of compressions while adequate ventilations was less than a half.

While few studies have assessed nursing students [33, 34], research with HCPs and lay persons suggest that feedback devices improve CPR psychomotor skills by providing objective feedback during training, in addition to traditional instructor led courses. [30, 35, 36] Findings from this study confirm that students demonstrated a significant and immediate improvement in performance, shifting from not meeting, to meeting national standards. [12] The shift was based solely on feedback provided by the devices, clearly demonstrating that real-time feedback devices are sufficient to produce an immediate significant improvement in CPR psychomotor skills. This is consistent with findings of studies with HCPs using feedback devices. [8, 36]

Use of a combined audio metronome tone and visual compression rate feedback (visual-audio feedback) improved the quality of CCs and had a positive impact on chest compression depth in this study. An explanation may be that TrueCPR has an accurate system for monitoring both depth and rate of compressions; a user is therefore able to correct the quality of compressions in real-time. This finding is similar to previous studies that compared audio-visual feedback devices that utilise a metronome function (e.g. VAM, Zoll AED, CPR, Zoll Pocket CPR) with HCPs and laypersons. [36, 37] In a similar European study, nurses' CCs significantly improved when using audio-visual feedback (TrueCPR) versus standard BLS [3], demonstrating that a metronome may be sufficient feedback to improve performance. Note however that ventilation performance was note measured, an important component of BLS.

The current study appears to be the first to evaluate visual embodied feedback guidance of both CCs and ventilations. Mixed findings were noted with use of simple forehead light, resulting in less effective skill performance (too fast compressions and cycles; higher no-flowtime). This appears to demonstrate that when using real-time feedback, users require specific or more obvious skill parameter feedback to correct performance and increase engagement. Despite lower performing feedback compared to other devices, the forehead light feedback indicator resulted in effective PP performance within guidelines.

METHODOLOGICAL STRENGTHS AND LIMITATIONS

A number of strengths and limitations are noted. One methodological advantage was use of a Lucas 3.1 chest compression device to standardise data captured by the devices providing confidence in the data collected and validity of results. This appears to be the first study to compare ventilation performance data across feedback devices, enabling comparison of compression and ventilation performance, and broadening our understanding of the impact of feedback on ventilation performance, an integral component of BLS.

The quasi-experimental design may limit the strength of findings, although using participants as their own control may mitigate any perceived limitation. Other potential limitations are also noted. Collecting data in a controlled simulation environment, eliminating the stress and distraction of other interventions (e.g. AED) may reduce transferability to actual clinical practice. Selection bias may also have influenced study results. As students volunteered, participants may have been those more motivated to learn and therefore not representative of all students. Use of manikins in educational practice are standardized and used for practice to reduce risk to participants and patients. There is however no evidence yet that the use of feedback during CPR training using manikins, improves patient outcomes.

6 CONCLUSION

Using CPR feedback devices during training improves psychomotor skills acquisition in nursing students. This finding has potential wide-ranging implications for tertiary education, national BLS training and accreditation protocols for clinical practice readiness. Further investigations into the role of real-time feedback and CPR psychomotor retention is however required to meet the challenge of skill decay over time. CPR feedback devices vary in their ability to improve performance. Future devices could incorporate elements to enhance learning and technical application of psychomotor skills, such as adding a metronome, numerical rate counter or ventilation volume feedback.

A paradigm shift in undergraduate BLS education is required to enhance current training methods and integrate new technology. As future first responders to a cardiac arrest, nursing students need effective training in BLS. Given that CPR skills decay rapidly, the value of students completing one course in BLS without feedback is questionable, when attempting to ensure preparedness for future practice. More frequent use of feedback devices within undergraduate education could allow students to tailor psychomotor skills training to their own needs and overcome personal limitations.

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