ORIGINAL ARTICLE

A comparison of the effectiveness of QCPR and conventional CPR training in final-year medical students at a South African university

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ABSTRACT

Introduction: High-quality cardiopulmonary resuscitation (CPR) saves lives. Training on basic first aid manikins allows students to practice manoeuvres and provides realistic resistance to chest compressions. Conventional CPR has no real-time feedback to observe the quality of CPR. Quality cardiopulmonary resuscitation (QCPR) is technology using wireless sensors embedded in the manikin to measure the effectiveness of core CPR components. This study compared the effectiveness of CPR training of final-year undergraduate medical students using electronic-feedback QCPR adult manikins and conventional adult manikins. The effectiveness of compressions was compared and return on investment was investigated.
Methods: In an experimental study, 53 students were divided into two groups using simple random sampling. The QCPR group practised CPR on the QCPR manikins. The CPR group practised on conventional CPR manikins. Both groups were allowed to practice for approximately 10 minutes. After the training session, both groups were tested using the QCPR manikin. Only chest compression performance in adult-sized manikins were measured, recorded and compared.
Results: The median flow fraction for the QCPR group was 78.0% (interquartile range (IQR) 63–89%) and for the CPR group 80.0% (IQR 74–85%). The median number of compressions for the QCPR group was 104 (IQR 101–109) and for the CPR group 107 (IQR 79–124). Both groups achieved a 100% compression rate with adequate depth. The maximum total effectiveness of both groups was 99%. No statistically significant difference was seen for the overall percentage of compression effectiveness between the groups.
Conclusion: Participants achieved acceptable scores on most CPR compression metrics and complied with CPR guidelines in most cases. Efficacy of CPR training on conventional and QCPR manikins was comparable. CPR training in low resource settings can be just as effective on conventional manikins. Immediate feedback technology adds value to the training experience, allowing for individuals to adjust for deviations to set standards.

Introduction

Basic life support (BLS) provides the basis for saving lives after cardiac arrest and emphasise the actions to be taken to give the patient the best chance of survival [1]. According to the American Heart Association (AHA), only about 10% of adult patients with non-traumatic cardiac arrest who are treated by emergency medical services (EMS) survive to hospital discharge [1].

The BLS course mainly focuses on cardiopulmonary resuscitation (CPR) and how it pertains to saving lives after cardiac arrest. The course teaches students what rescuers need to know to perform high quality and effective CPR in a variety of settings. High-quality CPR allows for

recoil so that it is possible for the blood to enter the heart and continue circulating within the body with each compression. The building blocks for effective CPR include chest compressions, airway and breathing [1].

Chest compressions are emphasised in emergency response actions regarding CPR [2]. The recommended actions in high-quality adult CPR include a chest compression rate of 100–120 compressions per minute, chest compression depth of 5–6 cm, allowance for full chest recoil of the sternum to a neutral position, a limitation of interruptions between chest compressions to less than 10 seconds and a ventilation rate of one breathe every 6 seconds [1,2].

Stiell et al. [3] investigated the effectiveness of the current compression depth (3.8–5.0 cm) used by EMS workers. This was done in response to the 2010 International Guidelines for CPR's recommendation of an

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increase in depth. The study was conducted to assess the survival outcomes (e.g. return of spontaneous circulation (ROSC), one-day survival and survival to hospital discharge) of patients in relation to the compression depth used during CPR performed by EMS workers [3]. The probability of ROSC increased as the compression depth increased up to 5 cm, however, it decreased if it was more than 5 cm. The one-day survival and survival to hospital discharge values were directly proportional to compression depth [3]. The results of the study stated that a depth greater than 3.8 cm was necessary, but it could not support a claim that a depth greater than 5 cm was necessary [3].

High-quality CPR involves two ventilations per 30 compressions. When these ventilations are performed, chest rise should be seen in the patient, however, if ventilations are given with too much force, it can lead to inflation of the stomach with resultant regurgitation and possibly aspiration of regurgitated materials [4].

Basic first aid manikins allow for students to practice basic manoeuvres, such as a head tilt to open a patient's airway. The manikin also provides realistic resistance to chest compressions. With conventional CPR, there is no real-time feedback to observe the quality of chest compressions being performed [5].

Quality cardiopulmonary resuscitation (QCPR) is a new technology that uses wireless sensors embedded in the manikin, allowing one to measure the effectiveness of core components of CPR, such as compression rate and depth, complete release, limited interruptions and appropriate ventilation volumes. This is done via a feedback device (such as a laptop or tablet) that allows one to view the real-time efficiency of the CPR being conducted on a manikin on the device using Bluetooth [5].

The use of real-time chest compression feedback devices is recommended over devices that simply provide prompts such as a clicking sound. Basic life support skills appear to be gained as efficiently through computer- or video-guided education systems as through personal instruction sessions and, as a result, a combination of video-guided and instructor-guided lessons are recommended [2]. Real-time feedback technology supports the rescuer with vocal or visual information on CPR quality to improve adherence to guidelines. Various feedback systems have been developed over the last few years [6].

Spence et al. [7] assessed the quality of the CPR skills of final-year medical students on high-fidelity manikins and found that students who were taught using video feedback had higher general skills than those taught with verbal feedback. The specific skills that were found to be of higher quality in the video-feedback cohort were ventilation quality, general score and skills retention.

A study by Wutzler et al. [8] conducted among healthcare practitioners revealed that optimal compressions improved after training on a manikin with audio-visual feedback. The compression depth and rate also improved significantly. Kirkbright et al. [9] conducted a similar study among healthcare practitioners to determine whether audio-visual feedback devices improve the quality of CPR delivered and patient outcomes after cardiac arrest. The study found that the quality of CPR was closer to recommended parameters in those trained with audio-visual feedback devices, but there was no evidence to support that these devices will improve patient outcomes.

Patient outcomes were the focus of research done by Couper et al. [10]. The study evaluated the effect of real-time audio-visual feedback on the survival of patients having in-hospital cardiac arrest as well as the quality of the CPR performed. Implementing real-time feedback with or without post-event debriefing did not have a noticeable effect on the improvement in patient- or process-focused outcomes.

The use of QCPR has been noted by Tanaka et al. [11] to aid in students achieving high-quality CPR actions concerning compression depth and full recoil. A study on secondary school students conducted by Cortegiani et al. [12] revealed that students trained with QCPR technology in the presence of an instructor performed higher quality CPR, with regards to complete release of compressions and compression rate, when compared with students who were taught with only instructor-based feedback. Three sub-scores for each of the skills are recorded separately and if the performance deviates from the resuscitation guidelines, the score is reduced. The sub-scores for each skill recorded is compressions, ventilation and flow fraction. Compression score, flow fraction and ventilation score all contribute to the total score. Compression score is usually based on the compression depth, rate of compressions delivered, recoil, number of compressions per cycle and the hand position. Ventilation scores are based on ventilation volume, rate number of pre-ventilations and inspiration time in pre-ventilations. This study was performed during an Anaesthesiology rotation, where airway management is often unnecessary because patients are intubated and on a ventilator. For this reason, ventilation scores were excluded from this study.

Flow fraction is defined as the percentage of time in which compressions were performed during CPR. Therefore, flow fraction should be 100% if only compressions were given, i.e. no ventilations. The target for flow fraction for a single rescuer performing CPR is 70%, with an 80% target for two-rescuer CPR [13].

Aim and objectives

The aim of this research was to compare the effectiveness of CPR compression training of final-year undergraduate medical students using electronic-feedback QCPR manikins and training using conventional manikins, and to evaluate the cost effectiveness of the QCPR vs conventional CPR training.

Methods

Study design

This was an experimental study. The independent variable of the practical training method was manipulated (conventional CPR training and training which makes use of live feedback), and the result on the dependent variable (effectiveness of CPR performed) was measured. This study was conducted at the Clinical Simulation and Skills Unit of the Faculty of Health Sciences, , University of the Free State, South Africa.

Study population and sampling

The study population consisted of final-year (fifth year of study) undergraduate medical students studying at the University of the Free State. The sample consisted of 53 students who were rotating at Anaesthesiology at the time of the study.

The students were divided into two groups (QCPR group and CPR group) using simple random sampling. Students were asked to draw numbers from a hat. The odd numbers were placed in the QCPR group and the even numbers in the CPR group. The researchers ensured that students did not swop numbers or move to another group.

Measurement

Method of data collection

As part of the longitudinal training programme, all participants in the study had previously received the same CPR training (via the conventional CPR training method) in their third year of the medical undergraduate programme. In their fifth year, students receive CPR training in the Anaesthesiology rotation and in the Family Medicine rotation. The fifth-year undergraduate medical students rotating at Anaesthesiology attended scheduled BLS lectures as part of their Anaesthesiology curriculum. A different group of fifth-year students (consisting of 6–8 students) attended the lecture every two weeks. This study was conducted during the Anaesthesiology CPR training session.

All the participants received the same one-hour theoretical lecture on CPR, presented by the same anaesthesiologist with more than 30 years' experience as an educator. Thereafter, the participants were divided into two groups for practical training. The QCPR group was put into a room and given access to the QCPR manikins and tablets with the programme.
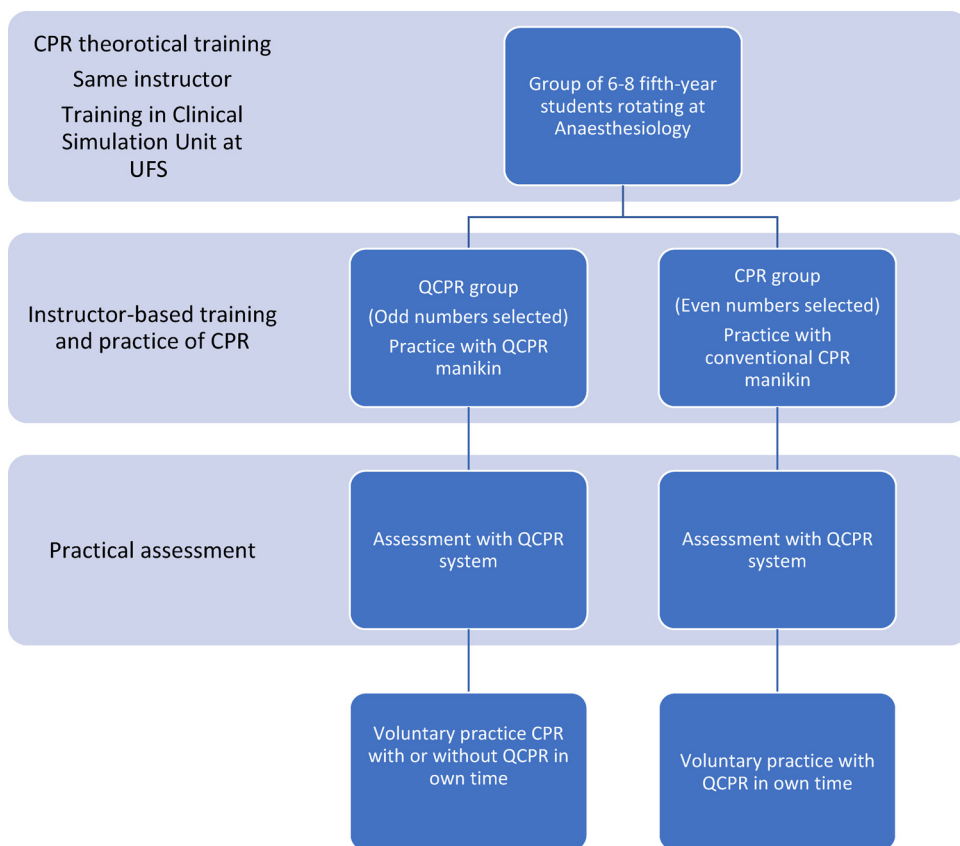
Fig. 1. A flow diagram to indicate the method of data collection concerning training, practice and practical assessment.

They were trained how to use the live feedback programme. The CPR group, in a different room, were given the opportunity to practice using conventional CPR manikins. Students in both groups were allowed to practice (in separate rooms) for approximately 10 minutes.

After the 10-minute practical training session, both groups were tested using the QCPR manikin and programme. The study was conducted during normally scheduled training sessions, allowing for 10 minutes' practice time only. This practical test occurred in the same environment using the same tools. The manikins were placed on the same surface to minimise changes in height and the same manikin was used in each practical test. The practical test was done for two minutes per person as this is one typical cycle in practical CPR before the medical practitioner switches with another to avoid exhaustion and to maintain effectiveness.

Participants who were in the CPR group and used conventional training methods were allowed to train with the QCPR manikin and programme after the research team had collected the necessary data. An hour was permitted for self-directed practice for each group after data collection, but students could also book self-directed practice in their own time. The data collection was carried out by members of the research group.

In Fig. 1, a schematic diagram summarising the method used for data collection is shown.

Measuring tool

All participants were assessed with the same practical test in which they performed CPR on the QCPR manikins. The test involved measuring CPR metrics and were captured electronically on a tablet. The values yielded an overall percentage of effectiveness. The metrics were captured on a data collection form.

Methodological errors

To establish a standardised way in which results would be recorded, all researchers attended the same preparatory session to obtain a standardised method of data collection and interpretation of the results before the pilot study and practical testing commenced. An experienced staff member from the Clinical Simulation and Skills Unit guided this preparatory session.

Pilot study

A pilot study with six fifth-year undergraduate medical students rotating at Anaesthesiology was conducted. No changes were made to the manner in which data were collected, and the methods and data collection forms remained the same. The results of the pilot study were included in the main analysis.

Data analysis

The results from the participants' performance during the practical part of the QCPR were transferred as figures from feedback given by QCPR system on the tablet and were then recorded on data collection forms checked and transferred onto a Microsoft Excel spreadsheet. Data were analysed by the Department of Biostatistics, University of the Free State, using Statistical Analyses Software (SAS 9.4). Numerical variables were summarised by medians, minimum, maximum or percentiles. Categorical variables were summarised by frequencies and percentages. Differences between groups were evaluated using the Wilcoxon Two-Sample test for unpaired numerical data. Differences between groups for categorical unpaired data, statistical tests Chi-Square or Fisher's Exact Test were used.

Table 1
Results of performance by participants in the QCPR and CPR group

	QCPR Group (n=25) Median (range)	Interquartile range	CPR Group (n=28) Median (range)	Interquartile range
Flow fraction (%)	78.0 (63.0–89.0)	[76.0–81.0]	80.0 (74.0–85.0)	[78.5–82.0]
Average compression rate per minute (n)	104.0 (90.0–122.0)	[101.0–109.0]	107.0 (79.0–124.0)	[98.0–114.5]
Compressions of adequate depth (%)	100.0 (84.0–100.0)	[99.0–100.0]	100.0 (18.0–100.0)	[99.0–100.0]
Compressions of adequate rate (%)	90.0 (14.0–99.0)	[52.0–96.0]	81.5 (0–100.0)	[18.5–97.5]
Total effectiveness (%)	83.0 (64.0–99.0)	[74.0–94.0]	75.0 (49.0–99.0)	[73.0–82.5]
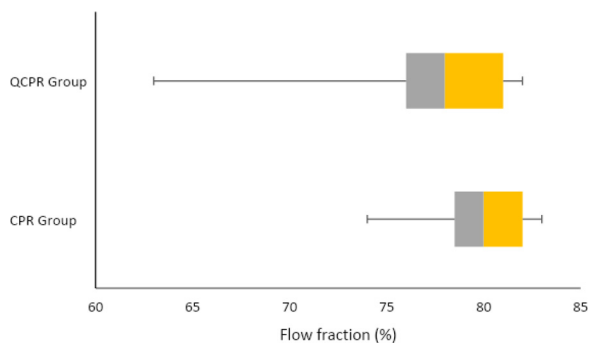
Fig. 2. The flow fraction (%) achieved by the participants in the QCPR and CPR groups.

Fig. 3. Average compression rate (compressions per minute) achieved by participants in the QCPR and CRP groups.

Fig. 4. The percentage of compressions of adequate rate attained by participants in the QCPR and CPR groups.

Ethical considerations

Ethics approval was obtained by the Health Sciences Research Ethics Committee (HSREC) of the University of the Free State: UF-SHSD2019/0530. Institutional permissions were obtained. The information document was made available in English and Afrikaans. It stated that participation was voluntary, that non-participation would not be held against the person in any way and that participants could withdraw at any time. A consent form was distributed and written informed consent was obtained from each participant. The data and details of the participants were kept confidential.

Results

Fifty-three students participated in the study. The QCPR group consisted of 25 participants and the CPR group consisted of 28 participants.

Flow fraction

The QCPR group (78.0%) had a slightly lower median percentage flow fraction than the CPR group (80.0%). In Fig. 2, the box and whisker diagram for the CPR group and the QCPR group is displayed. The lower quartile of the CPR group is slightly higher than the median value of the QCPR group, which suggest that they did better with the flow fraction.

Average compression rate per minute

The median average compression rate of 104 per minute for the QCPR group was slightly lower than the median of 107 compressions per minute achieved by the CPR group. In Fig. 3, the QCPR group has an interquartile range of 101.0–109.0, while the CPR group has an interquartile range of 98.0–114.5. This indicates that the QCPR group was more consistent in the number of compressions performed per minute when compared to the CPR group.

Compressions of adequate depth

Both groups achieved a median percentage of adequate compression depth of 100.0%. Only two participants in the CPR group achieved a
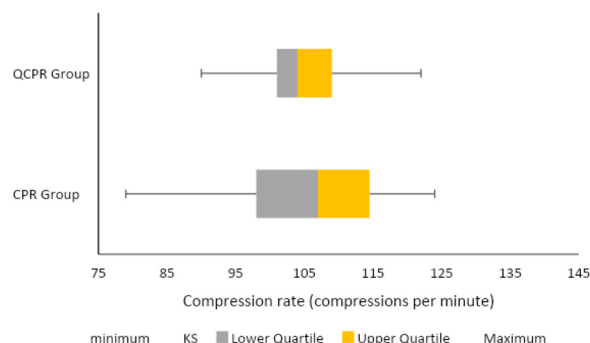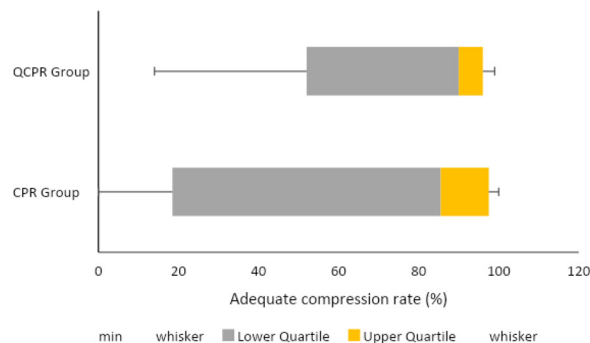
percentage below 80.0% (18.0% and 38.0%, respectively). The average depth for both groups was 5 cm.

Compressions of adequate rate

Compared to the other parameters, the median percentage for adequate compression rate showed a greater difference between the two groups, with 90.0% for the QCPR group and 81.5% for the CPR group (Fig. 4). The QCPR group has a lower quartile value of 52.0%, while the CPR group has a lower quartile value of 18.5%. This indicates that 75.0% of participants in the QCPR group achieved a percentage higher than 50.0%.

Total effectiveness percentages

The QCPR group's median percentage of total effectiveness was 83.0% compared to the 75.0% of the CPR group. Over half (56.0%, n=14) of the QCPR group achieved total percentages between 80.0%–100.0%. In comparison, only 28.6% (n=8) of the CPR group achieved total percentages over 80.0%.

A p-value of 0.0658 showed that there was no statistically significant difference between the QCRP group and the CPR group. No statistically significant differences for flow fraction, average compression

rate, compression of adequate depth and compression of adequate rate were found.

Discussion

Flow fraction

The flow fraction is the percentage of the time in which compressions is given, and minimising interruptions in chest compressions is paramount [14]. The optimal goal for chest compression fraction has not been defined, but the AHA expert consensus is that a chest compression fraction of 80% is achievable in a variety of settings [14]. According to literature, the target for flow fraction when CPR is performed by a single rescuer is 70%–80% [13]. In our study, the median flow fraction for the QCPR group was 78.0% (IQR 63–89) and for the CPR group 80.0% (IQR 74–85). These results compare well with an Australian study where 98% of the participants achieved the required flow fraction [15].

Although flow fraction is used as a variable to compare the effectiveness of CPR, it is not an adjustable factor. In other words, while performing CPR, the rescuer is not aware of what the flow fraction is at that point and cannot alter CPR performance to obtain the target for flow fraction.

Compression rate

According to the AHA and the European Resuscitation Council (ERC), high-quality CPR is achieved when 100–120 compressions are done per minute [2,16]. Thus, 100 compressions per minute as the average rate of compressions is the target. A person with an average rate of 130 would be graded lower than a person with 100 because the higher rate does not allow for sufficient recoil – thus, a higher rate is not necessarily better. The median number of compressions for the QCPR group was 104 (IQR 101–109) and for the CPR group 107 (IQR 79–124).

Both groups had a similar maximum, while the minimum values differed greatly. The CPR group had a minimum value of 79, while the QCPR group had a minimum of 90 compressions per minute which is much closer to the target.

The participants allocated to the QCPR group altered their rate of compressions frequently in their effort to perform a higher quality of resuscitation. The immediate feedback provided by the QCPR system assisted participants in adjusting the compression rate to stay within the prescribed parameters.

Compression depth

Regarding the percentage of compressions given with adequate depth (5 cm but not more than 6 cm), the target would be to obtain 100%, thus all compressions would reach an adequate level of depth for the CPR to be effective [2,3,16]. Both groups in our study achieved a 100% compression rate with adequate rate. The IQR for both groups were 99%–100% and compared well with other studies [15].

From an observational perspective, the QCPR feedback clearly showed the depth of compression performed by the participants. Depth of compressions can also be adjusted easily. Towards the end of the two-minute testing period, participants would start to fatigue. This led to a decrease in the force with which they perform compressions, thus decreasing the depth and overall quality of compressions. It is postulated that participants in the QCPR group noticed this trend of decreasing depth as they fatigue and therefore knew to pay attention to this aspect as the time of CPR performance progressed.

For the average depth, the ideal depth would be 5 cm as measured by the QCPR manikin [2,3,16]. As noted in the above explanation about the number of compressions with adequate depth, the average depth for the QCPR group was 5 cm. The CPR group obtained the same results, except for the minimum value of 4.7 cm. Once a compression is performed to the correct depth, it is just as important that the compression is fully released for proper recoil to occur [1].

When comparing the compressions with adequate depth and the percentage of compressions fully released, it was noticed that the QCPR group would fare well in terms of compression depth but not in terms of compression release, as they were able to monitor their progress. The QCPR feedback system indicates compression depth and release. Students were more focused on achieving a perfect compression rate, explaining the inadequate recoil.

Overall percentage

It is important to note that the overall percentage of "effectiveness" referred to here is provided by the QCPR manikin when interpreting the data. In calculation this percentage, the software takes all of the participant's measurements/values into account by a predetermined equation that was not in our control.

With the maximum overall effectiveness of both groups being 99%, it can be assumed that by the use of either method of training, near-ideal high-quality CPR can be achieved. No statistically significant difference was seen for the overall percentage of effectiveness between the two groups. If the test could be applied to each of the different parameters, it may give a better comparison between the two groups.

Financial implications

An important aspect to consider is the financial implications of the QCPR manikins and programme. In this research setting, conventional CPR manikins (purchased before the availability of QCPR technology), was compared with QCPR manikins installed with QCPR upgrade kits at a cost of $135 each [17].

A conventional CPR manikin retails for approximately $315, while a QCPR manikin (which has the QCPR technology already installed) retails for $400. This price excludes the purchase of a laptop or tablet needed for the live feedback to view the real-time efficiency [5]. One is able to purchase an upgrade kit for the conventional manikin, which will equip it with the QCPR technology.

Table 1.

From the results and discussion, conventional CPR and QCPR technology were academically and clinically comparable. Although feedback to participants helped them to adjust the rate and depth of compression, the conventional CPR manikins are just as effective to train students on the principles of CPR.

Study limitations

The study was conducted as a student research project, with a limited time frame resulting in a small study population. Transference and retention of skills were not possible in the study's time frame and could have given another perspective. The study can be repeated with a larger population and a longer time after the training session.

There could have been bias in terms of the participants' prior or baseline knowledge or training on CPR. All the students would have had the same training in CPR within the undergraduate medical programme, but some students might have had prior or outside CPR training.

The onset of fatigue and the fitness, strength and gender of participants were not considered and could be included in future studies.

Conclusion

Effective CPR training saves lives. Participants achieved acceptable scores on most CPR compression quality metrics and complied with CPR guidelines in most cases. In this study, the efficacy of CPR training on conventional and QCPR manikins was comparable. CPR training in low resource settings can be just as effective on conventional manikins. Technology adds value to the immediate feedback, but it is not essential to train effective CPR.

Dissemination of results

The results of the study were presented to fellow undergraduate medical students during a student research forum and at the annual Faculty Research Forum of the Faculty of Health Sciences at the University of the Free State. The results were also shared with all the BLS instructors at the university.

Authors' contributions

Authors contributed as follows to the conception or design of the work; the acquisition, analysis, or interpretation of data for the work; and drafting the work or revising it critically for important intellectual content: MJL contributed 40%; RvW and CvR 10%; and 5%; [blinded]AA, CdK, EdV, TdW, TJ, BP, JP and SU% and RvW. All authors approved the version to be published and agreed to be accountable for all aspects of the work.

Conflict of Competing Interest

The authors declare no conflict of interest.

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