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Comparison between a low-cost model (CPR Pillow) and a mannequin in training hands only cardiopulmonary resuscitation (CPR): A randomised trial

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Clinical paper

Comparison between a low-cost model (CPR Pillow) and a mannequin in training hands only cardiopulmonary resuscitation (CPR): A randomised trial

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Abstract

Introduction: CPR is an important lifesaving skill that can improve outcomes of patients in cardiac arrest. Mass training of hands-only CPR is one of the ways to spread information and teach this skill. Need for expensive CPR mannequins are a limiting factor in conducting such mass training programmes. This study assessed the effectiveness of a low-cost CPR pillow model in training hands-only CPR.

Methodology: Two hundred and six undergraduate students underwent a two-hour CPR training session. They were randomly divided into two groups – mannequin group and CPR pillow group and practiced hands-only CPR on a standard mannequin and a low-cost CPR pillow model, respectively. Knowledge, attitude, and skill acquisition were objectively assessed and compared between the two groups.

Results: There was no statistical difference in hand positioning, chest compression rate and fraction, depth and overall CPR score between the two groups trained via mannequin and CPR Pillow ($P > 0.05$). The CPR pillow group had better percentage of chest recoil as compared to the mannequin group (86% vs 73%; $P < 0.001$).

Conclusion: The use of low-cost homemade CPR devices such as our CPR pillow model is an acceptable alternative to mannequin for training hands-only CPR to lay rescuers.

Keywords: Cardiopulmonary resuscitation, Hands-only CPR, CPR pillow, Mannequin

Introduction

The outcomes of Out of Hospital Cardiac Arrest (OHCA) patients in India paints a concerning picture. Studies show that survival to hospital discharge in OHCA is low (0–14.6%).[1,2] Return of independent mental functional status to prearrest levels was also observed in meagre percentage (0–5.7%) in survivors of OHCA.[3,4] This grim statistic highlights the importance of Cardiopulmonary Resuscitation (CPR) training amongst the public. Timely initiation of bystander CPR in OHCA is known to improve survival rates. The American Heart Association recommends training of lay rescuers in hands-only CPR.[5] However, widespread CPR training programmes are lacking.[6]

Since majority of OHCA occur at home, the relatives are the first to witness. However, the knowledge regarding bystander CPR among the public appears deficient.[7] The need of the hour is to have robust training programmes. Various initiatives such as school CPR

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programmes have been initiated in recent times targeting the receptive population of students in learning CPR. Such efforts, although successful, are few and sparse.[8,9]

Unavailability of mannequins forms a hindrance to have a successful community CPR training programme, owing to their excessive cost. Low-cost models might help us in filling the lacunae. We compared a low-cost model made using readily available materials (CPR pillow) with a standard CPR training mannequin in hands-only CPR training.

Methodology

This single-centre, randomised, controlled, assessor-blinded, superiority trial was conducted after seeking approval from the Institutional Ethics Committee (IEC1: 103/2022) and registering in the Clinical Trials Registry of India (CTRI/2022/08/044919). The study population included students pursuing Bachelor of Dental Sciences in a deemed-to-be university, in coastal Karnataka. Students pursuing undergraduate course were included in the study. Students who had previous training in basic life support were excluded from the study.

A training programme was organised was organised by the research team in collaboration with the dental college, for all students from three undergraduate classes (1st year, 2nd year and 3rd year respectively) on three different days for logistic reasons. Participants were enrolled after obtaining written informed consent. On each day, the students were randomised into two groups - CPR pillow group and Mannequin group. Randomisation was done by computer generated randomisation sequence using https://www.randomizer.org/. Recruitment and randomization were done by investigator AN who then was not involved in the further training program. A pre-test was conducted using a questionnaire (Appendix 1) which included questions related to knowledge, attitude, and confidence about hands-only CPR, which the students answered using Google Forms. The questionnaire was constructed in the online form portal and was pilot tested. Pilot testing was done by administering the questionnaire to a small group of undergraduate students (twenty) and taking their feedback (Beta testing). Feedback showed that questions were easy to understand and found relevant and no changes were necessary. Questionnaire was validated by five experts from the field of Emergency Medicine, Anaesthesiology and Critical Care. There were six knowledge questions, each of which was assigned 1 point for correct answer, and total score was 6 points. Attitude related questions were answered in Yes/ No and Confidence-related questions were answered on Likert scale.

The hands-only CPR training sessions were conducted by AHA certified BLS instructors for all the batches. The content was uniform. The training sessions were for 2 hours, which included an introduction to cardiopulmonary resuscitation and steps, video demonstration using original videos (https://www.youtube.com/@centreforCARE), and do-along practice videos. Each mannequin/CPR pillow hands-on practice group had six members with 1 instructor, and each participant practiced steps of hands-only CPR 3 times (twice with do-along videos and once with background music to popular songs which have beats at 100–120/min). The group, which was randomised to mannequin, was trained with commercially available mannequins (Laerdal QCPR). The group which was randomised to CPR pillow was trained with a pillow (size 26X16 inches) made of Polyester fibre fill, with an empty polyethylene terephthalate (PET) plastic bottle (500 ml) strapped at the centre in the upper half. The purpose of the plastic bottle was to give feedback of the right position (centre) due to the spring back sound during recoil (Fig. 1). We had made a custom-made pillow cover with markings of a chest, for students to be able to locate the centre of the chest (Fig. 2). All members of the group practised on the same set of 4 mannequins/4 pillows. Rest of the instructions and design of the training module remained the same. Instructors provided feedback to the students

Fig. 1 – CPR pillow model: A model made using a pillow with an empty plastic bottle strapped to the centre.

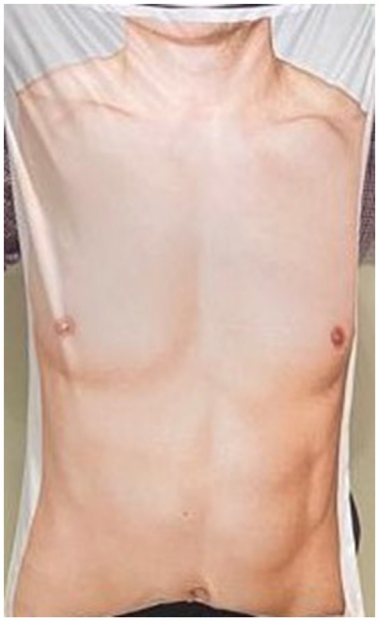

Fig. 2 – Custom Pillow Covers: Customised to go over the CPR pillow model and guide appropriate hand position for chest.

regarding the hand position, rate, and depth of chest compressions. PET bottles were replaced with new ones for every fresh training session.

Later in the day, an assessment session was conducted together for both the mannequin and CPR pillow groups. The students answered post-test questions pertaining to knowledge and attitude using the Google form questionnaire (Appendix 1). The students then had to perform hands-only CPR for 1 minute for their skills assessment. Four independent assessors who were AHA certified and blinded to which group students were trained, assessed the skills on four Laerdal qCPR mannequins. Objective assessment for the depth of hands-only CPR was done using the QCPR application of Laerdal, which was our primary end point. The application reveals parameters including chest compression fraction, percentage of time with adequate depth, percentage of time with adequate chest recoil, average rate, chest recoil and overall CPR score. Along with hand position, the assessors noted down the parameters from the QCPR app.

Data was entered using Microsoft Excel (Office 365) and analysed using SPSS v 26.0 (IBM Corporation, Chicago, Illinois, USA). Scoring of the questions was done as 0 for incorrect and 1 for correct answer for knowledge-based questions. Composite score was calculated by adding up the scores of individual questions (Maximum 6 points). In attitude related questions, positive response (Yes) was scored 1, and No was scored 0. For questions pertaining to confidence, a Likert scale from 1-5 was used. (Appendix 1). Variables were divided into categorical and continuous variables. Continuous variables were further divided into parametric and non-parametric variables using Shapiro-Wilk test and Histograms. Categorical variables were expressed using frequencies and percentages, and continuous variables were expressed using mean and standard deviation or median and interquartile range. For analysing differences within groups (Pre and post), Wilcoxon's sign rank test was used. For analysing differences between groups, Mann Whitney's U and Student's Independent T test was used. A p value of <0.05 was considered to be significant.

Sample size for the study was calculated using the software OpenEpi, for randomized clinical trial, with 80% power of the study and 5% alpha error, with the expected difference in proportion of adequate depth of CPR between standard CPR mannequin and low-cost model being 0.12 (0.95 low-cost model vs 0.83 standard mannequin).[10] These numbers were based on previous study[11] modified with our pilot data, which was performed on twenty dental students.

A total of ninety-five subjects per group was obtained as the final sample size, with total minimum sample size required to be 190.

Results

Socio-demographics

A total of 210 students in the BDS course (Bachelor of Dental Surgery) participated in the study. Out of them, 106 students were randomised to the mannequin group and 104 students were assigned to the pillow group. Four students did not complete the post-test due to personal time constraint and hence were excluded from the analysis. A total of 105 students were analysed in the mannequin group and 101 students in the CPR pillow group. Details given in CONSORT diagram (Fig. 3).

Among the 206 students analysed, 84 (40.8%) were from the first year, and 61 (29.6%) each from second and third year. Almost three fourth of them 150 (72.7%) were female students.

Pre and post intervention test scores within groups

There was significant improvement in knowledge and confidence after the training programme in both the CPR pillow and mannequin group, confirming the positive impact of the training session on the students in both groups.

Comparison between CPR pillow and mannequin groups

As shown in Tables 1 and 2, both the groups were comparable in their pre-intervention test scores in knowledge, attitude and confidence questions.

Post-intervention test scores: It was observed that there was no statistically significant difference among both groups in all knowledge questions as well as total scores after the training was given (Table 1). Similarly, as shown in Table 2, there was no statistically significant difference in attitude and confidence amongst both groups after the training was given, and both groups were able to have a positive attitude after the training. This highlights that the improvement of knowledge and confidence after training was comparable in both CPR pillow and mannequin groups.

Skill assessment

It was observed that there was no statistically significant difference among the two groups on the basis of hand position score, overall CPR score, chest compression fraction, average rate and compression score. Both groups performed well. However, there was a statistically significant difference between the two groups in one parameter. The CPR pillow group significantly scored better when it came to percentage of time with adequate chest recoil. The mannequin group scored better in terms of depth appropriateness, but it was not statistically significant (Table 3).

Discussion

In this study we compared the effectiveness of a low-cost model (CPR pillow) versus a standard commercially available mannequin for hands-only CPR training among undergraduate students. Findings from our study would suggest that the acquisition of skills of hands-only chest compressions when training with the CPR pillow is similar compared to when training with a standard mannequin. Secondly, we found that participants trained with the CPR pillow model had higher percentage of time with adequate chest recoil.

The low-cost CPR pillow was designed to be recreated using common items found in most homes like a soft pillow and a 500 ml Polyethylene terephthalate (PET) bottle. We strapped a 500 ml recycled, empty PET plastic bottle to the centre of the pillow as shown in (Figs. 1 and 2). We hypothesized that the empty PET bottle would be a guide to the proper hand placement as it would be strapped to the centre of the pillow, simulating the firmness of the sternum. Other possible advantages of the use of the bottle were the tactile feedback it would provide to the compression, and it would also improve recoil. A similar model was put forward by Mardie E. Burckes and Harold Hainfeld in the 1970s where a pillow with an attached Clorox plastic bottle was used as a chest piece.[12,13]

Previous studies have demonstrated the usefulness of homemade or low-cost CPR training mannequins. Robert Ohle et al.

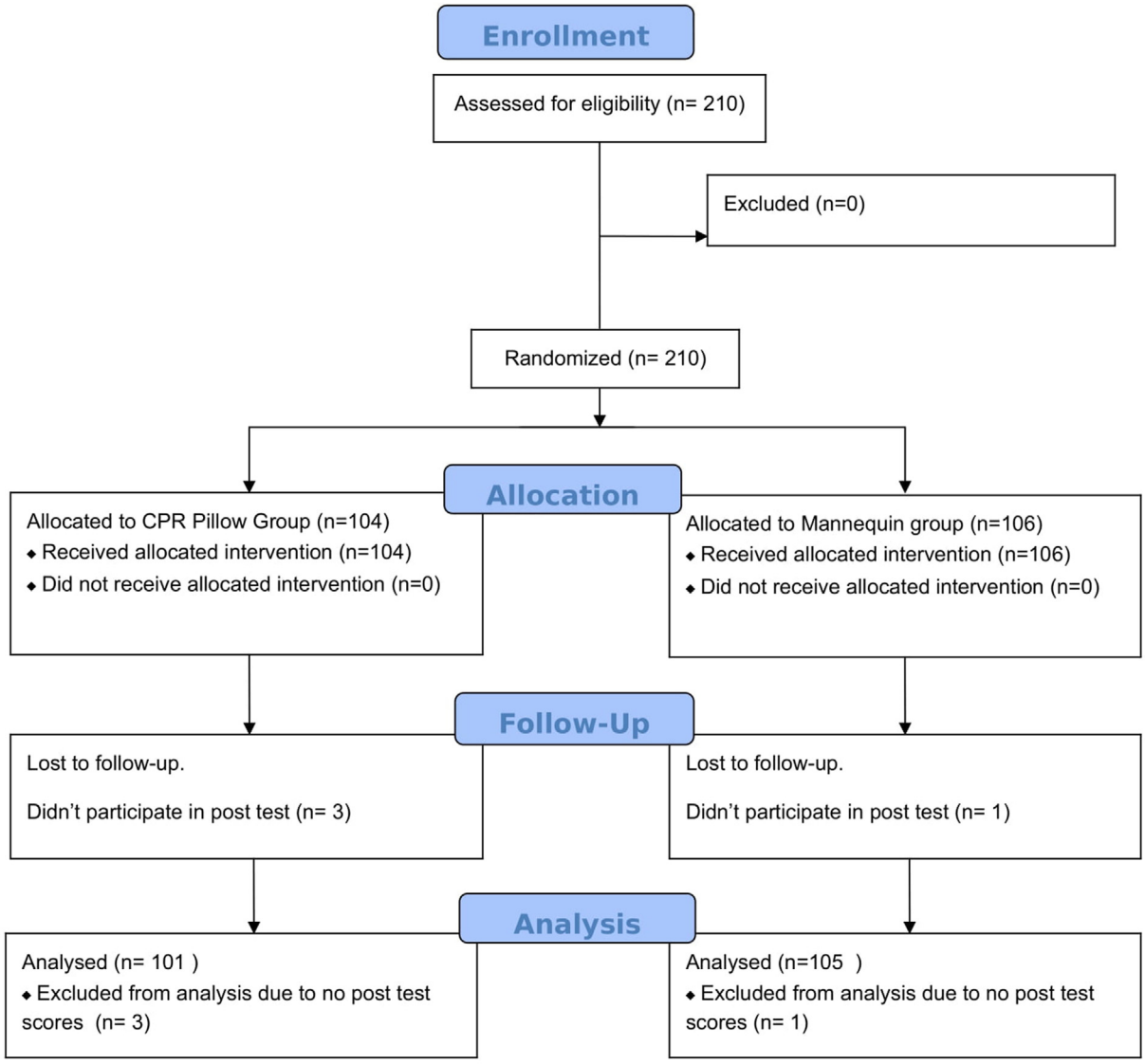

Fig. 3 – CONSORT flow chart.

demonstrated the non-inferiority of two toilet paper rolls model to standard training mannequin.[11] The mean CPR score they recorded with their model was comparable to the mean score recorded with our CPR pillow model and was also similar to those trained with the standard mannequin. CPR score is a proprietary algorithm developed by Laerdal to calculate the efficiency of high-quality CPR performed on specific qCPR mannequins. It takes into account all factors of high-quality CPR including (a) Compression depth, (b) Compression rate, (c) Inadequate recoil, (d) Hand position and (e) Chest compression fraction (also known as flow fraction).[14] CPR score gives a more realistic review of the CPR performed while improved chest compression fraction has been shown to improve patient outcomes.[15]

Piscopo et al found their pillow with PET bottle model to be as effective as a standard little Anne mannequin[16,17] in mass training CPR to school children. These findings were similar to our study, which highlights the scope for use of CPR pillow in mass training programmes.

We did find that participants trained with the CPR pillow had a higher percentage of adequate chest recoil. This could be due to the fact that the pillow and bottle have two different recoil properties (pillow recoiling slower than the stiffer PET bottle), as compared to the spring mechanism within the mannequin. Repeating chest compressions would require both the pillow and the bottle to return to their precompression state. We hypothesis that this recoil property might unconsciously prime participants to allow adequate time for recoil. While we had comparable depth of compression in both our groups, Piscopo et al found their PET bottle model to have slightly superior compression depth compared to a standard mannequin.[17] Saul Drajer in his model was able to standardize the force needed for chest compression using a spring welded to a large plastic bottle. While this model is cheaper and portable, it would be difficult to replicate at home.[18] Even though people trained with the CPR pillow performed better in the chest recoil metric, the overall CPR score was similar in both groups. This finding would suggest that the training would translate to high quality CPR when performed on humans.

Table 1 – Comparison of Knowledge between CPR pillow and mannequin groups.

Category	Questions	Mannequin group $n = 105$ Median [IQR]	CPR Pillow group $n = 101$ Median [IQR]	*P* value*
Pre-intervention test scores	Response assessment	0[0–1]	0[0–1]	0.723
	Pulse/breath check	1[0–1]	1[1–1]	0.074
	Pulse check site	1[0–1]	1[0–1]	0.232
	CPR Hand position	0[0–1]	0[0–1]	0.985
	Chest compression rate	0[0–0]	0[0–0]	0.791
	Chest compression depth	0[0–0]	0[0–0]	0.930
	Total Score (out of 6)	2[1–3]	2[1–3]	0.354
Post-intervention test scores	Response assessment	1[1–1]	1[1–1]	0.114
	Pulse/breath check	1[1–1]	1[1–1]	0.723
	Pulse check site	1[1–1]	1[1–1]	0.190
	CPR Hand position	1[1–1]	1[1–1]	0.661
	Chest compression rate	1[1–1]	1[1–1]	0.539
	Chest compression depth	1[1–1]	1[1–1]	0.507
	Total Score (out of 6)	6[5–6]	6[5–6]	0.406
Between pre-and post-test	Score difference	−3[−5 to −2]	−3[−4 to −2]	0.646

* Mann-Whitney's U test.

Table 2 – Comparison of Attitude and Confidence between CPR pillow and mannequin groups.

Category	Questions	Mannequin group $n = 105$ Median [IQR]	CPR Pillow group $n = 101$ Median [IQR]	*P* value*
Pre-intervention scores	Need to learn CPR	1[1–1]	1[1–1]	0.740
	Willingness to perform CPR	1[1–1]	1[1–1]	0.559
	Encourage CPR learning	1[1–1]	1[1–1]	0.088
	Confidence to identify cardiac arrest (1–5)	2[2–3]	2[1–3]	0.242
	Confidence to perform CPR (1–5)	3[2–3]	2[1–3]	0.090
Post-intervention scores	Need to learn CPR	1[1–1]	1[1–1]	1.00
	Willingness to perform CPR	1[1–1]	1[1–1]	0.327
	Encourage CPR learning	1[1–1]	1[1–1]	1.00
	Confidence to identify cardiac arrest (1–5)	5[4–5]	5[4–5]	0.812
	Confidence to perform CPR (1–5)	5[4–5]	5[4–5]	0.708

* Mann-Whitney's U test.

Table 3 – Skill assessment comparison between CPR pillow and mannequin group.

Skills assessed	Mannequin Group $n = 105$ (Median with IQR)	CPR Pillow Group $n = 101$ (Median with IQR)	*P* value*
Hand Position Score (%)	100[100–100]	100[100–100]	0.131
Chest Compression Fraction (%)	100[100–100]	100[100–100]	0.561
Average Rate (per min)	119[113–126]	121[114.5–127]	0.443
Compression Score (%)	92[72–98]	94[81.5–98.5]	0.208
Percentage of time with adequate chest recoil (%)	88[39.5–100]	99[91–100]	**<0.001**
Percentage of time with appropriate depth (%)	100[98–100]	100[93–100]	0.151
Overall CPR Score‡ (%)	92[70–98]	94[77–98]	0.577

* Mann-Whitney's U test.

‡ CPR score is a proprietary composite score calculated using data from hand position, compression rate, depth and recoil.

Even though the fidelity of our mannequins is low, we gave importance to the 'Fiction contract' between the learners and trainees. The session had fixed goals and realism was introduced as case scenario's where one would find patients with cardiac arrest. We gave good hands-on practice with immediate feedback through our trainers during the training sessions.

Our teaching module utilised short videos, discussion, and a demonstration of the BLS protocol by a trainer on a mannequin.

The participants then practiced hands only CPR on the pillow CPR/mannequin model three times. This type of shortened hands only CPR training format have been used successfully in mass CPR training such as in the community and schools by Rachel Ko et al.[19] and Mathew et al.[20] Hands-only CPR training in India, as conducted by Ramesh et al.[21] was shown to be effective. We found an improvement in knowledge and attitude of the participants following our training session. Similar improvements in knowledge and comparable skill acquisition were noted in a mass training programme with handmade mannequin.[22] A large community-based study by Nishiyama et al.[23] has demonstrated the benefits of such hands only CPR training on a large scale. They conducted video-based CPR training in almost 15% of Toyonaka city population (57173 residents) over a period of five years. They saw an increasing trend in the proportion of high-quality CPR performed by bystanders over the 5 years (11.7% vs 20.7%). There is a positive correlation between high quality bystander CPR performance and survival of out of hospital cardiac arrests.[24]

There were a few limitations in our study. The study population sampled was homogenous. Since all the study participants were undergraduate dental students, the results may vary when the CPR pillow is used in mass training in the community where the population will be of various ages and educational backgrounds. We also assessed the efficacy in learning hands-only CPR only for 1 minute on the same day as the training. Further studies would be needed to look at the retention of BLS principles over time and doing hands-only CPR for longer duration. Our CPR pillow model was designed to only simulate hands-only CPR. This restricts our teaching to hands-only CPR, and we will not be able to demonstrate bag mask ventilation nor defibrillation with this model. Finally, using PET bottles in the model would have environmental and sustainability concerns. Even though we can recycle PET bottles, they are made from plastics, which due to its delayed biodegradability is not an ideal material. Additional studies needed to see how many times PET bottle can be used before losing shape and recoil.

Future directions would include testing the feasibility of the homemade CPR pillow for virtual training and refresher of CPR skills.

Conclusion

The use of low-cost homemade CPR devices such as our CPR pillow model is an acceptable alternative to mannequin for training hands-only CPR to lay rescuers. This low-cost CPR model can help in mass training communities in CPR in resource limited settings.

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Institutional Ethics Committee Approval

IEC1: 103/2022.

CTRI Registration number

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CRediT authorship contribution statement

Abhinav Nehra: Methodology, Investigation, Data curation, Writing – review & editing. **Prithvishree Ravindra:** Conceptualization, Methodology, Investigation, Data curation, Writing – original draft. **Rachana Bhat:** Conceptualization, Methodology, Investigation, Writing – review & editing. **Savan Kumar Nagesh:** Methodology, Investigation, Validation, Writing – original draft. **Yash Alok:** Methodology, Formal analysis, Writing – original draft. **S. Nisarg:** Methodology, Investigation, Validation, Writing – review & editing. **Sagar Shanmukhappa Maddani:** Methodology, Investigation, Validation, Writing – review & editing. **Jayaraj Mymbilly Balakrishnan:** Conceptualization, Methodology, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.resplu.2023.100518.

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QUESTIONNAIRE

E5(26)

Comparison between a low-cost model (CPR Pillow) and a mannequin in training hands only cardiopulmonary resuscitation (CPR): A randomised trial

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- **Some questions may have more than one correct answer;** in which case, you must mark **all** the correct answers.

Abstract

Question 1: This study assessed the effectiveness of a low-cost CPR pillow model in training hands-only CPR. Which of the following is **NOT TRUE** about CPR training?

- **A:** CPR is an important lifesaving skill
- **B:** CPR can improve outcomes of patients in cardiac arrest
- **C:** The only way to spread information and teach this skill is by mass training of hands-only CPR
- **D:** Expensive CPR mannequins limit the facilitation of mass training programmes

Introduction

Question 2: The outcomes of Out of Hospital Cardiac Arrest (OHCA) patients in India show that survival to hospital discharge in OHCA is as low as .....?

- **A:** 0–14.6%
- **B:** 0–5.7%
- **C:** 0-28%
- **D:** 0-1%

Question 3: Is it **TRUE** that the knowledge regarding bystander CPR among the public appears to be adequate?

- **A:** YES
- **B:** NO

Results

Question 4: Among the 206 students analysed, ... were female students.

- **A:** 40.8%
- **B:** 29.6%
- **C:** 72.7%
- **D:** 90%

Question 5: Is it **TRUE** or **FALSE** that a significant improvement in knowledge and confidence after the training programme in both the CPR pillow and mannequin group confirmed the positive impact of the training session on the students in both groups?

- **A:** TRUE
- **B:** FALSE

Question 6: For which of the following was there a statistically significant difference between the two groups?

- **A:** Hand position score
- **B:** Overall CPR score
- **C:** Compression score
- **D:** Depth appropriateness
- **E:** Percentage of time with adequate chest recoil

Discussion

Question 7: It was found that participants trained with the ..... model had a higher percentage of time with adequate chest recoil.

- **A:** CPR pillow
- **B:** Standard mannequin

Question 8: Which **other advantages**, apart from those that were hypothesised, did the empty PET bottle strapped to the centre of the pillow have?

- **A:** Gave tactile feedback
- **B:** Was a guide to the proper hand placement
- **C:** Improved recoil
- **D:** Added to the compression
- **E:** Simulated the firmness of the sternum

Question 9: *Piscopo et al.* found their pillow with PET bottle model to be ..... a standard Little Anne mannequin in mass training CPR to school children.

- **A:** Less effective than
- **B:** As effective as
- **C:** More effective than

Question 10: It was found that participants trained with the CPR pillow have a ..... percentage of adequate chest recoil due to the pillow and bottle having two different recoil properties.

- **A:** Higher
- **B:** Lower

Question 11: The overall CPR score was similar in both groups, even though people trained with the ..... performed better in the chest recoil metric.

- **A:** Mannequin
- **B:** CPR pillow

Question 12: Is there a positive correlation between high-quality bystander CPR performance and survival of out-of-hospital cardiac arrests?

- **A:** YES
- **B:** NO

Question 13: Environmental and sustainability concerns could be asssociated with which one of the following limitations in this study?

- **A:** A homogeneous study population
- **B:** Assessing learning hands-only CPR for only 1 minute on the same day as the training
- **C:** The design of the CPR pillow model was to only simulate hands-only CPR
- **D:** The use of PET bottles in the model

Question 14: Future directions for study should include testing the feasibility of the homemade CPR pillow for which of the following?

- **A:** Virtual training
- **B:** Refresher of CPR skills

Conclusion

Question 15: What has been shown in this study regarding the use of low-cost homemade CPR devices, such as the CPR pillow model in this study?

- **A:** An acceptable alternative to a mannequin for training hands-only CPR to lay rescuers
- **B:** A help in the mass training of communities in CPR in resource-limited settings
- **C:** Homemade devices differed too much in terms of efficacy in training
- **D:** Homemade devices provided a false sense of achievement

THE END

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I hereby declare that the completion of this document is my own effort without any assistance.

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This activity is accredited for **THREE (3) CLINICAL** CEU'S. You have to achieve 70% to pass this activity.

ANSWER SHEET

E5(26)

Comparison between a low-cost model (CPR Pillow) and a mannequin in training hands only cardiopulmonary resuscitation (CPR): A randomised trial

*Time spent on activity	hour						min				
	A	B	C	D	E		A	B	C	D	E
1						8					
2						9					
3						10					
4						11					
5						12					
6						13					
7						14					
						15					

How relevant was the content of this activity to your scope of practice?			
Not at all	Somewhat	Mostly	Extremely

RETURN ANSWER SHEET TO

Online members, complete your answer sheet online

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