

An Assessment of the Effectiveness of an in-House Designed Low-Cost Trainer for Teaching Cardiovascular Examination in Comparison to Traditional Teaching Among Novice Undergraduate Medical Students

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Received: 2024 February 19

Revised: 2025 April 14

Accepted: 2025 October 29

Published online: 2025 October 29

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Citation:

Ramanathan S, Santhanakrishnan N, Ramananda Pai D, Yelahanka Channegowda N. An assessment of the effectiveness of an in-house designed low-cost trainer for teaching cardiovascular examination in comparison to traditional teaching among novice undergraduate medical students. Strides Dev Med Educ. 2026; 23(1):e1528.

doi:10.22062/sdme.2025.200941.1528

Abstract

Background: Teaching cardiovascular examination skills to large groups of undergraduate medical students poses critical challenges due to the limited availability of patients and peer practice limitations.

Objectives: This study aimed to evaluate the effectiveness of an indigenous designed low-cost trainer for teaching cardiovascular examination compared to the traditional training.

Methods: A half-body CPR mannequin was upgraded to teach cardiovascular physical examination by the addition of inflatable bladders for pulsations, and a Bluetooth speaker for heart sounds. Undergraduate medical students, divided into experimental and control groups, were trained by demonstration and practice on a simulator/volunteer. A quasi-experimental study with a non-equivalent control group design was conducted to compare the outcomes of the two teaching models. Performance was assessed by Objective Structured Practical Examination (OSPE) and compared. Feedback on confidence and satisfaction was gathered. A value <0.05 was considered statistically significant.

Results: The total OSPE scores showed no significant difference between the experimental and control groups ($p=0.184$) [P value <0.05 was considered statistically significant]. However, the control group performed significantly better in in-patient interaction skills ($p=0.008$). Student feedback indicated a preference for a combination of both traditional and simulator-based teaching methods, with 43% favoring this approach. Additionally, 33% preferred traditional methods alone, while 24% chose simulator-based teaching exclusively.

Conclusion: The indigenous designed low-cost cardiovascular examination trainer demonstrated comparable effectiveness to traditional teaching methods in skill acquisition. It offers a cost-effective alternative for large-scale medical education, though additional emphasis on patient interaction skills is placed while simulators are used. Student preferences suggest that a blended approach, combining both traditional and simulator-based methods, may be optimal for teaching cardiovascular examination skills.

Keywords: Cardiovascular Physical Examination; Simulation; Low-Cost; Medical Education

Background

The National Medical Council of India revised the undergraduate medical program to a competency-based curriculum, mapping the skills to be learned and mastered by a medical graduate. Clinical examination of

the cardiovascular system is one of the skills listed as a core competency to be acquired by first-year undergraduate students, and the recommended mode of teaching is DOAP [Demonstrate by student Observe Assist Perform] in a normal volunteer or in a simulated

environment (1). The facilitator traditionally demonstrates the skill on the healthy subjects, and students are instructed to practice the skills on their peers. Most of the facilitators encounter challenges in this form of teaching. Firstly, a large number of students ranging anywhere between 150-250 in number in most of the medical colleges across India, secondly, there exists a paucity of subjects or patients for the students to learn the skill concerned (2). Thirdly, practice on peers poses a few limitations, like a lack of standardization due to varied body types and body mass index, obesity, hesitancy among these millennial students to expose the precordium in front of their peers; this challenge is observed more among female students (3, 4). All these challenges are a few of the obstacles faced by the facilitators in this traditional mode of teaching. The alternative approach is by adopting various simulation-based skill teaching, which have their own pros and cons. High-fidelity mannequins are expensive, and simulated patients pose huge financial burdens on the institutes due to the large number of students (5). A systematic review on simulation-based cardiovascular physiology teaching states the shortcomings of existing models, especially the cost that makes the high-technology simulators unreachable in low-resource settings (6).

Objectives

To develop a cost-effective simulator with indigenous available material that would depict the basic features of cardiovascular examination, and to study the effectiveness of the heart simulator in skills teaching to medical graduates.

Methods

Study design and participants: "A quasi-experimental study with a non-equivalent group design was conducted by the Department of Physiology and the Medical Simulation Centre of a medical university in South India to evaluate the effectiveness of both teaching models."

Inclusion criteria: All the years I graduated, medical students of the current year were recruited since the intervention is a part of routine teaching (N = 250). Participants were informed that the assessment would be more of a formative type and not be included in their summative assessment, and consent was obtained from them.

Exclusion criteria: Students who missed any of the sessions or assessments were excluded (n=12).

Therefore, the final sample size was 238 students (out of 250).

Design and functioning of the simulator

Assembling the heart simulator

Materials utilized: Half-body mannequin, Inflatable bladders connected to bulbs, Bluetooth speaker, as shown in Figure 1.

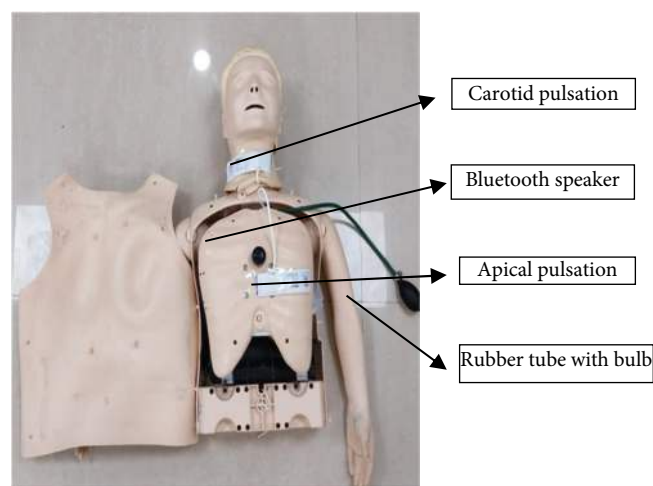


Figure 1. Half-body mannequin, Inflatable bladders connected to bulbs, Bluetooth speaker

Apical and carotid pulsations: Two inflatable bladders with tubes are attached to the bulb via a two-way valve. Placed underneath the skin of a half-body CPR mannequin, one at the location of the apex and another at the carotid triangle. Pumping of the bulb, the bladder gets inflated and deflated, which produces a palpable rise over the skin mimicking a normal apical and carotid pulsation. The bulb is pressed manually at the required rate by the facilitator. The rate is synchronized with the heart sounds with the aid of the metronome app. Expansion of the cuff due to bulb compression creates a palpable pulsation over the chest wall and neck. It is felt by the student by placing the palm over the chest and then localizing with the ulnar aspect of the hand, and finally with the tip of one finger. The manual compression of the bulb leads to palpable pulsations at the neck due to inflation and deflation of the bladder. The student locates and feels the pulsation at the carotid triangle with the standard examination protocol.

Carotid pulsation: A Bluetooth speaker is placed under the precordium equidistant from all four cardiac areas. Normal heart sounds and murmurs are played on a digital device [mobile phone, iPad] connected to the Bluetooth speaker. The student auscultates the sounds

by placing the stethoscope over 4 cardiac areas while simultaneously palpating the carotid pulsations on the right side of the neck. The heart sound that coincides with the carotid pulsations is identified as the first heart sound. The sound that follows the pulsation is the second heart sound. The bulb is pressed manually at the required rate by the facilitator. The rate is synchronized with the heart sounds with the aid of the metronome app. The process of development of the product is published as a short report under innovations (7).

Data collection and measurement

All 250 first-year medical students were included in the study. Since twelve students missed either one of the sessions, the remaining 238 (N=250-12) who underwent training by both models were recruited for the study. Students were grouped by sequential allocation into the experimental and control groups. They were grouped by placing roll number in alternating order by the clerical staff, who were blinded to the study to overcome the selection bias. Still, the limitation of non-randomization, such as confounders and risk of bias, exists. Students were exposed to two forms of teaching. Group A was taught using a simulator a few key components of the cardiovascular system, like examination of apex beat and auscultation of cardiac areas (mitral, tricuspid, aortic, and pulmonary) in groups of 10 with the help of the facilitator. Group B was taught by the traditional learning method, the same components of cardiovascular system examination, which is an initial demonstration by the facilitator, followed by peer examination among students.

Skill assessment: The students were assessed regarding the skill attainment component for apex beat examination using an OSCE/ OSPE checklist (Table 1). Table 1 contains the OSCE/ OSPE steps for the location of the apex beat.

The checklist was prepared by the investigator and validated by two senior faculty members and experts from the medical education department. Assessment was done by double-blinded faculty, and it was ensured that they were not a part of the teaching session.

Validation of Assessment Tool: The OSCE/OSPE checklist used to assess skill attainment was developed by the investigators based on standard clinical examination guidelines. To ensure its content validity, the checklist was reviewed by a panel of experts, including faculty members from the departments of Physiology and Medicine, as well as clinical skills educators with experience in undergraduate medical education. These experts evaluated the checklist items

for their relevance, clarity, and comprehensiveness in covering key components of cardiovascular examination skills. Face validity was established through iterative discussions with the panel to confirm that the checklist appeared to adequately measure the intended competencies. Minor modifications were made based on their feedback to improve item clarity and alignment with learning objectives.

A pilot test of the checklist was conducted with a small group of students (not part of the final study sample) to ensure usability, timing, and inter-rater consistency. Feedback from this pilot was used to further refine the checklist before final implementation. Inter-rater reliability was discussed and calibrated among assessors to ensure consistent scoring.

Reliability testing of the assessment tool: "Inter-rater reliability was evaluated by three assessors independently scoring the same set of students, followed by a statistical analysis of the agreement between scores. Test-retest reliability was considered by re-evaluating a subset of students later to ensure Consistent performance assessment over time. Internal consistency of the checklist was also analyzed using Cronbach's alpha to confirm coherent item responses.

Data analysis

Data were entered into a Microsoft Excel spreadsheet and saved as a comma-separated value (CSV) file.

A frequency distribution of the teaching modality was calculated. Scores obtained were tested for normality using normal probability plots and the Shapiro-Wilk normality tests. The independent t-test was conducted to compare the mean test scores of students post the educational intervention among the control and intervention groups, and a P value <0.05 was considered statistically significant.

Feedback was obtained by an anonymized online Google form with Likert response closed-ended questions and an open-ended question to gather learners' perception of the simulator and their preference. The questionnaire was vetted by two experts for face and content validity. Question one was on the preferred method of learning, with one open-ended question explaining the reason for the preferred method and two questions about the realism of the simulator and confidence level among students. The open-ended questions were thematically analyzed individually by two investigators, who were then authenticated by the expert to identify emerging themes. The themes identified for the reasons to prefer the simulator were

user-friendly, repeated practice possible, and a realistic experience. The limitation expressed was a lack of human interaction and opportunity to learn doctor-patient communication.

Ethical approval: Institutional ethical clearance was obtained for the study [MGMCRI/2022/IRC/60/04/IHEC/162].

Statistical analysis: An Independent sample t-test was performed to compare the OSPE score of the two groups. It was ensured that assumptions of normality and equal variance were met before the test was applied. Feedback on the Likert responses was compiled, and the open-ended responses were analysed quantitatively.

Results

Out of the total 250 students, 12 students were excluded since they missed one of the teachings sessions, hence the sample size was 238.

The total score of both groups was almost equal ($p=0.184$). The control group performed significantly better in patient interaction skills (Step I: 0.84 vs 0.70, $p=0.008$). The total score of both groups was almost equal ($p=0.184$). The control group performed significantly better in patient interaction skills (Step I: 0.84 vs 0.70, $p=0.008$). It refers to the mean score of the two groups for step 1 of the OSPE checklist, "Explain the procedure to the subject and obtain consent," which were 0.84 versus 0.70, respectively. No significant differences were found in the other technical skills, indicating both the methods were equal with respect to the knowledge acquired, but traditional methods showed an advantage in patient interaction skills, which should be considered in curriculum design, as students found it difficult to explain the procedure and obtain informed consent from the mannequin (Table 2).

It refers to the mean score of the two groups for step 1 of the OSPE checklist, "Explain the procedure to the subject and obtain consent," which were 0.84 versus 0.70, respectively. No significant differences were found in the other technical skills, indicating both the methods were equal with respect to the knowledge acquired, but traditional methods showed an advantage in patient interaction skills, which should be considered in curriculum design, as students found it difficult to explain the procedure and obtain informed consent from the mannequin.

Student feedback: A total of 112 students chose to respond to the questionnaire, and student feedback indicated a preference for a combination of both

traditional and simulator-based teaching methods, with 43% favoring this approach. Additionally, 33% preferred traditional methods alone, while 24% chose simulator-based teaching exclusively. Indicating a combination has a better preference among the students. Student preferences for learning cardiovascular examination were clearly defined as 65% preferred demonstration and practice on the heart simulator (manikin), whereas 35% favored faculty demonstration followed by practice on peers.

This indicates a strong acceptance and perceived value of simulator-based learning among students. A substantial minority (35%) still prefer the traditional method of faculty demonstration followed by practice on peers. This suggests that while simulator-based learning is more popular, traditional methods still have a place in medical education (Figure 2a).

"Student feedback on the realism of the heart simulator was generally positive, with approximately 70% of students agreeing that the simulator was realistic, 23% remaining neutral, and 2% disagreeing with its realism (Figure 2b).

The strong preference for simulator-based learning among students supports the use of these tools in medical education. However, the significant minority preferring traditional methods suggests a blended approach might be beneficial.

Ninety percent of students feel confident in performing CVS examinations on real patients/subjects after learning with the heart simulator. This suggests that the simulator is highly effective in preparing students for real-world clinical scenarios. Only 10% of students did not feel confident after using the simulator (Figure 2c). This could indicate areas for potential improvement in the simulator or the need for additional support for a small subset of students.

Discussion

This study evaluated the effectiveness of an in-house designed low-cost trainer for teaching cardiovascular examination skills to undergraduate medical students compared to traditional teaching methods. The results provide valuable insights into the potential of simulation-based learning in medical education, particularly in resource-constrained settings like ours.

Cost analysis of the simulator

- The cost of the materials used is 13000 INR
- The cost of a high-tech mannequin is 1800000 INR

Our study result showed no significant difference in overall OSPE scores between the simulator group and the traditional teaching group ($p=0.184$). This suggests that the low-cost simulator is as effective as traditional methods in teaching cardiovascular examination skills. This finding aligns with previous studies that have demonstrated the efficacy of simulation-based learning in medical education (8, 9).

However, it's noteworthy that the control group performed significantly better in in-patient interaction skills, highlighting the potential limitation of simulator-based training and emphasizing the importance of incorporating patient interaction elements in simulation-based curricula in the current setting. Previous studies on students' perception report that they rated standardized patients (SPs) more highly than mannequins to learn interviewing (10).

Yet another qualitative study found that students felt that low-technology mannequins could not adequately simulate verbal/non-verbal cues and human interaction. Students believed this deficit impacted their performance when interacting in real clinical settings (11).

Most students agreed that the heart simulator was realistic, with only a small minority (less than 5%) disagreeing. This high level of perceived realism likely contributes to the simulator's effectiveness as a learning tool. Moreover, an overwhelming 90% of students reported feeling confident in performing CVS examinations on real patients after using the simulator. This high confidence level suggests that the simulator effectively bridges the gap between theoretical knowledge and practical application, a crucial aspect of medical education (12). Interestingly, our study results demonstrated a greater percentage of students preferred learning with the simulator; there was also a strong preference (43%) for a combined approach using both traditional and simulator-based methods. This aligns with the concept of blended learning, which is effective in medical education (13). The preference for a combined approach may reflect students' recognition of the need for both technical skills and patient interaction skills in clinical practice.

A significant advantage of the developed simulator is its cost-effectiveness. At 13,000 INR, it is substantially cheaper than high-fidelity mannequins (1800000 INR). This makes it a viable option for medical schools in resource-limited settings, potentially democratizing access to high-quality

simulation-based learning (14). Recent research has also studied the benefits of such low-cost alternatives and suggests they are beneficial (15-17). The factors that determine the effectiveness of the simulators are the extent to which they are integrated into the regular curriculum and the acceptance of the educators involved in teaching (18, 19).

Implications for Medical Education

The findings of this study have several implications for medical education:

1. *Incorporation of Low-Cost Simulators:* The comparable effectiveness and high student acceptance of the low-cost simulator support its integration into medical curricula, especially in resource-constrained settings.
2. *Blended Learning Approach:* The student preference for a combined approach suggests that a blended curriculum, incorporating both simulator-based and traditional teaching methods, might be optimal.
3. *Focus on Patient Interaction Skills:* The better performance of the traditional group in patient interaction skills highlights the need to supplement simulator-based training with exercises focused on patient communication and interaction.

Confidence Building: The high confidence levels reported by students after using the simulator suggest that such tools can play a crucial role in preparing students for clinical practice, potentially reducing anxiety and improving performance in real patients.

Limitations: While this study provides valuable insights, there are some limitations. As the study was conducted at a single institution, this may limit its generalizability. No subgroup comparisons, such as between age or gender groups, were conducted. Future multi-center studies could provide more robust evidence. Additionally, long-term follow-up studies in the future could assess the retention of skills and confidence levels over time.

Future Directions: Future research could also focus on developing and evaluating methods to incorporate patient interaction skills more effectively into simulator-based training. This could involve the use of standardized patients in conjunction with the simulator or the development of virtual reality applications that simulate patient interactions. Evaluation of long-term retention of skills learnt by low-cost simulation must be done so that their utilization is justified.

Conclusion

In conclusion, this study demonstrates the potential of low-cost, indigenous designed simulators in teaching cardiovascular examination skills. The low cost and equivalent efficacy of such simulators compared to the high-technology mannequins make their utility feasible in low-resource settings.

While such simulators can effectively teach technical skills and build student confidence, a blended approach that also emphasizes patient interaction skills may provide the most comprehensive preparation for clinical practice.

Acknowledgements: The study was a collaborative work of the Medical Simulation Centre and the Department of Physiology, Mahatma Gandhi Medical College, Sri Balaji Vidyapeeth, Puducherry, India.

Conflict of interests: There is no conflict of interest.

Ethical approval: Institutional ethical clearance was obtained for the study [MGMCRI/2022/IRC/60/04/IHEC/162].

Funding/Support: None.

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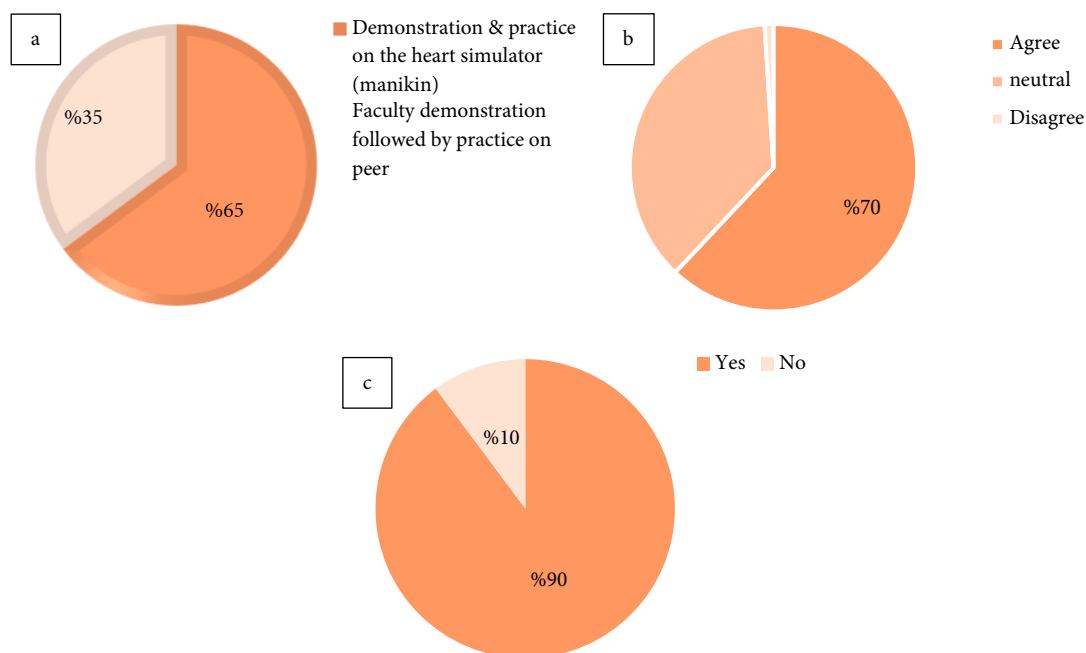


Figure 2. a) Preferred method for skills practice, b) Simulator realism, c) Confidence in performing on a patient

Table 1. Model OSPE Checklist

Questions: Locate the apex beat of the given subject and report the finding				
Step	Expected performance	Score		
		Satisfactory performance	Need improvement	Not done
1	Introduces him/herself, asks the subject to relax, explains the procedure, and obtains informed consent	1.0	0.5	NIL
2	Exposes the chest and inspects the chest wall for apical impulse	1.0	0.5	NIL
3	Places the palm over the precordium and feels for the apex beat. Locate with the ulnar border and then point the apex beat with a finger	1.0	0.5	NIL
4	Counts the intercostal space to identify the exact location of the apex beat	1.0	0.5	NIL
5	Reports the findings	1.0	0.5	NIL

Table 2. OSPE score

Step	Group A (mean (SD))	Group B (mean(SD))	t	df	p (two-tailed)
I	0.70 (0.41)	0.85 (0.36)	-3.037	238.0	0.008*
II	0.74 (0.41)	0.86 (0.34)	-2.488	234.0	0.21
III	0.57 (0.47)	0.61 (0.34)	-0.762	220.4	0.447
IV	0.36 (0.41)	0.38 (0.46)	-0.359	238.9	0.720
V	0.33 (0.44)	0.37 (0.47)	-0.686	241.0	0.493
TOTAL	2.78 (1.70)	3.09 (1.50)	-1.510	238.3	0.184

*Steps I show statistically significant differences between groups, $p=0.008$, **Steps III–V and TOTAL are not statistically significant ($p > 0.05$).