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REVIEW

Innovative Training Strategies for Public Response to Out-of-Hospital Cardiac Arrest: A Scoping Review

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Introduction: Out-of-hospital cardiac arrest (OHCA) is a critical medical emergency requiring immediate intervention to improve patient outcomes. Training the lay public in emergency intervention techniques has significantly enhanced survival rates. Easily accessible training programs are essential for equipping individuals with the necessary knowledge and skills. However, challenges such as standardized guidelines and cost-effective program delivery must be addressed. This study aimed to explore innovative practices in training and provide recommendations for enhancing emergency response capabilities in OHCA.

Methods: The PRISMA Extension for Scoping Reviews (PRISMA-ScR) framework guided a comprehensive scoping review to identify relevant literature from PubMed, ScienceDirect, Scopus, EBSCOhost, and one search engine, Google Scholar. JBI tools were utilized to select high-quality articles, and thematic analysis was conducted to identify relevant innovations in OHCA training.

Results: This review analyzed 13 articles discussing various methods of CPR training for the general public, considering cost, ease of use, and effectiveness. The findings highlight innovative approaches to improving the public's emergency response to OHCA. Smartphone apps significantly increase the likelihood of CPR and defibrillator use by laypersons. Low-cost DIY manikins are a viable alternative when resources are limited. Short CPR training videos and hands-only CPR training proved effective in training lay responders, while feedback devices and XR and VR-based training increased participants' confidence in CPR. Policy-based approaches, such as mandated CPR training, can broadly increase training coverage. Although advanced technologies offer high effectiveness, the cost and complexity of implementation remain significant challenges.

Conclusion: The study provides valuable insights for developing innovative and effective training strategies to improve community emergency response to OHCA. However, further research should focus on long-term evaluation and integrating innovative technologies with low-cost training methods to develop more standardized and contextually appropriate training guidelines.

Keywords: emergency response, out of hospital cardiac arrest, public training

Introductions

Cardiac arrest, especially out-of-hospital cardiac arrest (OHCA), accounts for 15% of deaths worldwide, claiming the lives of nearly 356,461 people in the United States each year or about 1000 people per day, making it a significant health problem and only about 10% of those who experience this event can survive.[1] Cardiac arrest is the abrupt loss of heart function in a person who may or may not have been diagnosed with heart disease. It can come on suddenly or in the wake of other symptoms. Many individuals experiencing cardiac arrest do not receive timely and appropriate interventions, which are crucial for improving survival outcomes. The existing global strategies to address cardiac arrest are insufficient, leaving many preventable deaths unaddressed.[2] This significant gap in effective emergency response highlights the inadequacy of current strategies.

In cases of out-of-hospital cardiac arrest (OHCA), medically educated bystanders who initiated CPR earlier saw increased 30-day survival rates compared to laypeople bystanders, highlighting the need for improved layperson

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education programs.[3] According to the American Heart Association (2020), about 90% of OHCA victims die. However, immediate CPR can double or triple their chances of survival, with early bystander CPR increasing survival rates two to four times and potentially saving hundreds of thousands of lives annually.[4] Training the public in cardiac arrest response is crucial for engaging communities in the Chain of Survival and significantly improving survival rates.[5,6] Despite these benefits, delays in initiating CPR and defibrillation often result in poor survival outcomes, underscoring the need for better public education and coordination in emergency responses.[7,8] Addressing these barriers is essential for enhancing the role of public intervention in improving OHCA outcomes.

Bystander interventions, including cardiopulmonary resuscitation (CPR) and defibrillation, play a critical role in out-of-hospital cardiac arrest (OHCA) survival, significantly improving survival rates.[9] Previous studies supported the efficacy of bystander interventions, reinforcing the need for community-based interventions in global pre-hospital strategies.[10] Despite the proven benefits, many bystanders remain untrained and hesitant to perform CPR. This gap in training, particularly in cognitive knowledge and psychomotor skills, leads to suboptimal resuscitation quality. The lack of realistic scenarios and team-building exercises further limits the effectiveness of training programs in real-life situations, contributing to poor OHCA survival outcomes.[5,11]

The lack of training implemented within a population is significantly correlated with low bystander CPR rates and poor out-of-hospital cardiac arrest (OHCA) survival, along with a decline in the willingness to perform CPR.[12] Previous studies reported that there are modifiable barriers, such as uncertainty in diagnosing cardiac arrest, fear of harming the victim, concerns about legal consequences, and low self-assessment of one's abilities, which often hinder laypeople from performing life-saving actions like CPR.[13] Additionally, the accessibility of AEDs in public locations remains limited, hindering prompt defibrillation efforts.[14] These barriers highlight the need for more comprehensive and accessible training programs to ensure the public is adequately prepared to respond to cardiac emergencies.

Many research findings have discussed various practical training and learning methods that align with guidelines and have been proven to improve public knowledge and skills significantly. This includes automated external defibrillator training, measuring implementation and performance in communities and cardiac arrest centres, measuring cardiopulmonary resuscitation performance, using feedback devices and debriefing, and using social media to improve cardiopulmonary resuscitation applications.[15] While recent advances in training and technology have aimed to improve public knowledge and response to OHCA, there are still gaps in implementation and effectiveness.

Although beneficial, digital education and technology systems and brief educational videos are not widely utilized or accessible to all communities.[16] Dispatcher-assisted CPR has shown promise, but dispatcher training is not uniformly implemented.[10] Workplace-based distributed CPR training is underutilized, and cost-effective AED programs are not sufficiently widespread.[17,18] These gaps in recent advances and best practices indicate a need for more targeted and inclusive strategies to enhance public emergency response capabilities.

The urgency of this study is driven by the high mortality rate from out-of-hospital cardiac arrest (OHCA), indicating that current strategies for managing these emergencies are still inadequate. Although various training programs and technologies have been developed to improve public response to OHCA, their implementation and effectiveness remain significant gaps. Factors such as a lack of training, fear of taking action, and limited access to automated external defibrillators (AEDs) hinder the public's ability to respond quickly and effectively in emergencies. In addition, psychological barriers such as bystander hesitation and legal issues can affect the level of intervention by lay people.[19] Phenomena such as diffusion of responsibility, where individuals feel less responsible for acting when others are around, can reduce the likelihood of someone assisting. Furthermore, concerns about potential accusations of wrongdoing or discomfort when providing CPR to women can also inhibit life-saving measures.[20] Then, the effectiveness of CPR training can be evaluated through metrics such as long-term skill retention and CPR performance in real-world situations.

Global differences in OHCA survival rates reflect variations in the effectiveness of CPR training and its implementation.[21] Countries with structured CPR training policies, such as mandatory programs in schools and workplaces, show higher rates of bystander intervention and better clinical outcomes. Conversely, resource constraints and a lack of supportive policies lower survival rates. In addition, the effectiveness of training depends not only on the curriculum but also on the delivery strategy.[22] Digital technologies, such as AI applications and interactive educational videos, have improved skill retention compared to conventional methods, although accessibility remains challenging.[23–25] Therefore, this review aims to explore and synthesize

various innovations in emergency training and education for OHCA. Ultimately, it aims to significantly improve survival rates and health outcomes for individuals experiencing out-of-hospital cardiac arrest.

Materials and Methods

Study Design

The design used in this study is a scoping review. A scoping review is a flexible methodological approach to explore emerging and rapidly developing topics.[26] The PRISMA Extension for Scoping Reviews (PRISMA-ScR) is utilized in this literature review to identify training or learning approaches for improving public emergency response knowledge and capabilities in out-of-hospital cardiac arrest. This design offers a more comprehensive conceptual scope, enabling the explanation of various relevant research outcomes. The framework for this scoping review consists of five core stages: identifying the review question, identifying relevant research findings, selecting studies, mapping the data, and compiling, summarizing, and reporting the results.[26]

Search Strategy

The identification of articles was conducted systematically. Two authors, H.D. and A.N., independently performed a structured literature search using five central databases: PubMed, ScienceDirect, Scopus, EBSCOhost, and the search engine Google Scholar. Boolean operators "AND" and "OR" were applied to refine or broaden the search results across various tenses, utilizing the following keywords and MeSH terms (Table 1):

Eligibility Criteria

The process of selecting articles for this review was conducted by the authors following the PRISMA Extension for Scoping Reviews (PRISMA-ScR) guidelines (see Figure 1). The research question and the eligibility criteria for the reviewed articles were determined using the PCC approach (Population, Concept, and Context).

P (Population): General public/layperson/bystander/non- medical

C (Concept): Emergency response knowledge and rescue capability

C (Context): OHCA Training and learning

This review excluded inaccessible full-text articles not written in English or classified as secondary research. The inclusion criteria were full-text articles that were accessible, published in English, and categorized as primary studies (original articles). Furthermore, the review applied a publication year restriction of the last 10 years, in alignment with the AHA protocols on cardiac arrest, which continue to undergo innovation and development.

Data Collection and Analysis

Study Selection and Quality Appraisal

The authors independently selected studies that met the eligibility criteria, starting by checking for duplicates using Mendeley. Then, the authors evaluated the relevance of the studies based on the title, abstract, and full text according to the inclusion and exclusion criteria. Each study was assessed using the Joanna Briggs Institute 2022 critical appraisal checklist, scoring 1 for "Yes" and 0 for all other answers. All included articles met the eligibility criteria, and studies with a JBI score below 70% were excluded. There were no disagreements between the authors and supervisors regarding the eligibility of the selected studies.

Table 1 Keywords and meSH Terms

PCC	Keyword	MeSH Terms
P (Population)	General public/layperson/bystander/non-medical	Emergency Responders, Bystander CPR, First Aider
C (Concept)	Emergency response knowledge and rescue capability	Emergency medical services, Rescue Work
C (Context)	Out of Hospital Cardiac Arrest, CPR Training and Learning	Cardiac arrest, Out of Hospitals, Education, Training support

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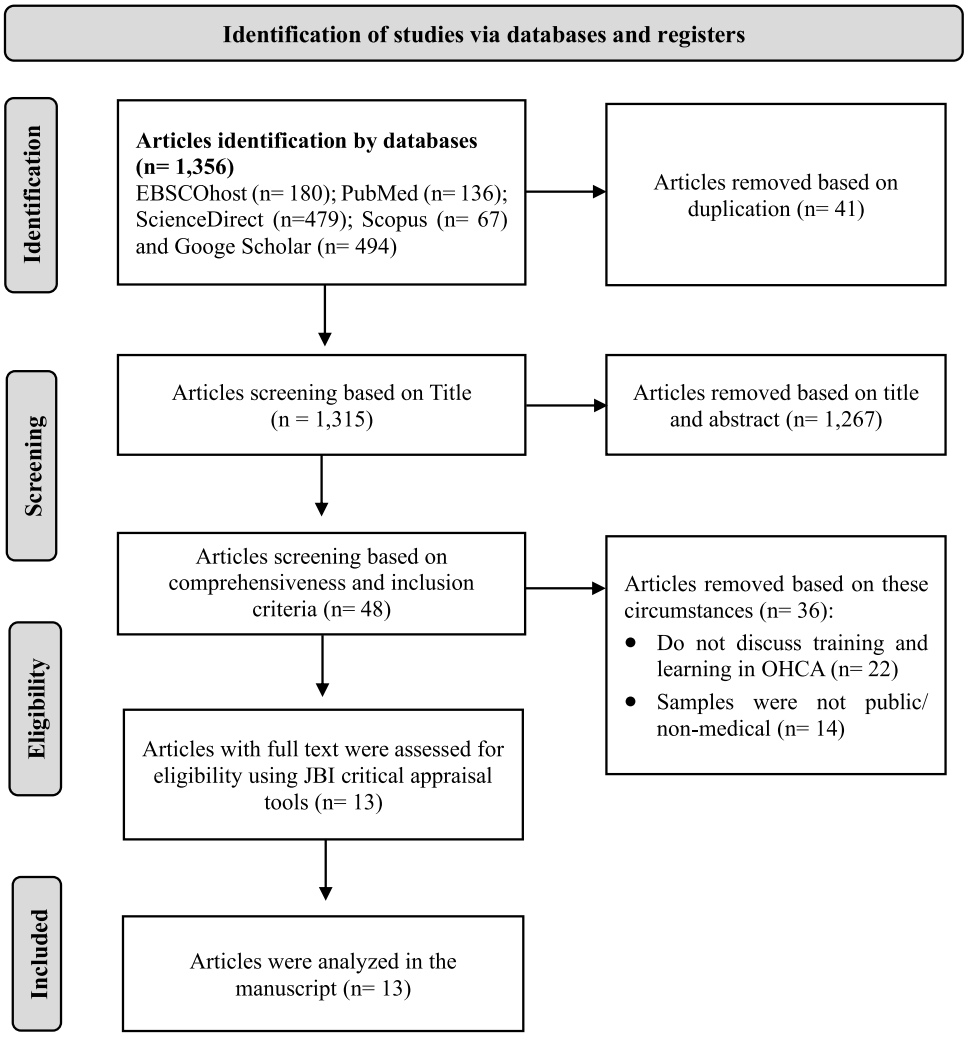

Figure 1 PRISMA Flow Diagram. Adapted from Page MJ, McKenzie JE, Bossuyt PM et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. Creative Commons.[27]

Data Extraction and Analysis

In this review, each article included in the search was summarized in a table that provides a detailed overview of all results related to the topic discussed. The information presented in the extraction table relates to the study characteristics: author, design, country and year, sample, intervention, and the study's results and limitations. All studies included are primary research studies. Therefore, data analysis was carried out thematically using a descriptive exploratory approach. The data analysis process began with identifying and presenting the data as a table based on the reviewed articles. After obtaining the data, the authors analyzed and explained each finding based on the review results. Finally, the authors double-checked the included studies to ensure accuracy and minimize errors.

Result

Study Selection Results

The initial identification from five databases using the predefined keywords resulted in 1,356 articles. A check for duplicates and screening based on titles and abstracts was then conducted, leaving 1,315 articles. During the title and abstract screening stage, the authors excluded 1,267 articles, leaving 48 to be screened based on the inclusion criteria. 13 articles were analyzed in this review, all of which passed the eligibility stage (See Figure 1).

Characteristics of the Included Studies

In this review, most of the studies analyzed had an experimental design, including five prospective studies, four retrospective studies, and one each of a quasi-experimental study, RCT, cross-sectional study, and case series study (see Table 2). The studies included were conducted in various countries, such as the United States of America (n=3), Denmark (n=4), Germany (n=2), Japan, India, Brazil, Spain, and others. The population included the general public, consisting of school children, laypeople, bystanders, and residents, with 15,450 participants. In Murk et al (2023),[24] the total number of participants was not specified, only mentioning nine different hospitals.

Study Outcome

This study identifies and categorizes various innovative training approaches to enhance the public's emergency response capabilities in cases of out-of-hospital cardiac arrest (see Table 3). One of the key findings is the effectiveness of mobile applications in coordinating emergency responses. Applications like KATRETTER and emergency responder dispatch systems via smartphones have proven efficient and cost-effective.[28,29] Training using low-cost DIY manikins (LoCoMan) and brief hands-free CPR videos has been highly effective in teaching basic CPR techniques at a minimal cost.[30,31] Implementing these methods makes it easier for the public to access the necessary training without incurring significant costs.

This study also highlights the effectiveness of various other training methods. Training with low-cost CPR pillow models and standardized programs for emergency dispatchers has improved CPR skills among the public.[33,37] A unique finding is the use of extended reality (XR) technology in BLS training, which demonstrated high effectiveness despite

Table 2 Research Findings on the Cost and Ease of Implementation of Training Methods

Training Category	Cost Category	Ease	Effectiveness	Study
Smartphone app for citizen responders (CPR/AED)	Low	Easy to use, scalable	Highly effective for emergency response	Andelius et al (2020)[28]
KATRETTER community responder app	Low	Simple, minimal resources	Effective for emergency coordination	Pommerenke et al (2023)[29]
Low-cost DIY manikin (LoCoMan) training	Low	Easy, portable	Effective for basic CPR skills	Peixoto-Pino et al (2024)[30]
Hands-only CPR short video training	Low	Accessible via videos	Cost effective for basic CPR	Wanner et al (2016).[31]
Low-cost handmade and intermediate manikin programs	Low	Structured and easy	Effective for CPR training	Nakagawa et al (2021)[32]
Low-cost CPR pillow model training	Low	Simple, minimal resources	Improves hands-only CPR skills	Nehra et al (2024)[33]
Legislative-mandated CPR training	Low	Scalable with proper policies	Systematic and effective	Malta Hansen et al (2017)[34]
AI voice assistants for CPR instructions	Low	Easy to access via smart devices	Innovative and practical	Murk et al (2023)[24]
AEDs with audiovisual feedback	Moderate to high	Requires devices and trained personnel	Improves bystander CPR accuracy	Obling et al (2022)[35]
CPR with feedback devices	Moderate	Needs access to feedback tools	Effective for skill improvement	Wingen et al (2024)[36]
Live video streaming for dispatcher-assisted CPR	Moderate	Requires smartphones and dispatcher systems	Enhances dispatcher-assisted CPR	Lindaroth et al (2021)[25]
Standardized dispatcher CPR training	Moderate	Structured programs	Improves dispatcher-assisted CPR skills	Tsunoyama et al (2017)[37]
XR-based CPR training with VR and real manikins	High	Complex, requires advanced equipment	Highly effective but costly	Lee et al (2021)[38]

Abbreviations: AED, Automated External Defibrillator; AI, Artificial Intelligence; CPR, Cardiopulmonary Resuscitation; DIY, Do-It-Yourself; LoCoMan, Low-Cost DIY Manikin; VR, Virtual Reality; XR, Extended Reality.

Table 3 A Summary Review Article Is Equipped with a Matrix Table

Author (Years)	Design	Country	Sample	Intervention	Comparison	Results
Andelius et al (2020)[28]	Prospective	Denmark	819 suspected OHCAs; 438 confirmed cardiac arrests	Dispatching citizen responders via a smartphone app to perform CPR or retrieve AED	OHCAs where EMS arrived first	This program can improve • Citizen responders arrived before EMS in 42% of the included OHCAs. • When citizen responders arrived before EMS, the odds for bystander CPR increased (OR: 1.76; 95% CI: 1.07 to 2.91; p=0.027). • The odds for bystander defibrillation more than tripled (OR: 3.73; 95% CI: 2.04 to 6.84; p<0.001) compared with OHCAs in which citizen responders arrived after EMS.
Pommerenke et al (2023)[29]	Retrospective descriptive analysis	Germany	10,102 registered first responders in Berlin, Germany, covering 16,505 activations of the KATRETTER system from October 16, 2020, to October 16, 2022.	The KATRETTER app, a community first responder mobile application, was implemented to activate volunteer first responders for suspected out-of-hospital cardiac arrest (OHCA) cases. The app is freely available and does not require medical qualifications to register as a first responder.	The analysis compared the number of activations, accepted activations, first responders arriving on scene, patient contact, CPR performed, AED usage, and manual ventilation during the study period	• 10,102 first responders were registered in Berlin. There were 16,505 activations of the KATRETTER system, and first responders accepted 8,991 activations. In 6,549 cases, at least one first responder arrived on the scene. Patient contact was documented in 3,457 cases (38.4% of accepted activations).CPR was performed in 1,195 cases (34.6% with patient contact). An AED was used before EMS arrival in 152 cases (12.7% of resuscitations). Manual ventilation was performed in 224 cases (18.7% of resuscitations). • The study concluded that smartphone-based first responder applications like KATRETTER can effectively recruit many first responders and reduce the time without CPR until professional help arrives.

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Obling et al (2022)[35]	Retrospective Observational Study	Denmark	325 patients were treated with bystander AED use before the arrival of emergency medical services (EMS) from 2016 to 2019 in the Capital Region of Denmark.	Use Automated External Defibrillators (AEDs) with and without audiovisual feedback by bystanders during out-of-hospital cardiac arrest (OHCA).	Comparing the outcomes of using AEDs with audiovisual feedback to those without audiovisual feedback.	• The group using AEDs with audio-visual feedback had a lower rate of return of spontaneous circulation (ROSC) at hospital admission (33%) compared to the non-feedback group (45%). • No significant difference in 30-day survival was found between the feedback (27%) and nonfeedback (31%) groups. • AudiovisualAudiovisual feedback was associated with a decreased chance of ROSC (adjusted odds ratio, 0.53; 95% CI, 0.29–0.97; P=0.04), but not with 30-day survival.
Peixoto-Pino et al (2024)[30]	Quasi-experimental study	Spain	193 School Children	Low-cost DIY manikin (LoCoMan) training	Standard commercial manikin	• Both groups achieved acceptable CPR quality, with CG performing better in-depth and LG showing adequate chest recoil. • The study concluded that school-children can build and use a low-cost manikin with visual feedback. The integrative learning approach used in this study may be a feasible alternative methodology for training and learning HO-CPR in schools when commercial manikins are unavailable.

(*Continued*)

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Table 3 (Continued).

Author (Years)	Design	Country	Sample	Intervention	Comparison	Results
Wingen et al (2024)[36]	Prospective randomized simulation study	Germany	Forty healthy adult volunteers aged 18–49 years without any medical background	Participants performed 2 minutes of compression-only CPR on a manikin without feedback (baseline), followed by 4×2 minutes of CPR with four different feedback devices in randomized order (CorPatch® Trainer, CPRBAND AIO Training, SimCPR®ProTrainer, Relay ResponseTM).	CPR metrics were compared between baseline (unassisted CPR) and each feedback device. The devices were also compared against each other for differences in CPR quality metrics and technical preparation time.	SimCPR®ProTrainer: Resulted in guideline-compliant chest compressions with improved chest compression depth and correct chest compression depth percentage compared to baseline. CorPatch® Trainer: The only device with audiovisual recoil instructions, resulting in improved chest recoil compared to baseline. Other devices showed significantly lower chest recoil rates. CPRBAND AIO Training and Relay ResponseTM: Did not support adequate CPR performance as effectively as SimCPR®ProTrainer. CPR Quality Metrics: There were significant differences in chest compression depth, rate, percentage of correct depth/rate, and technical preparation time among the devices. The use of a feedback device increased participants' CPR self-confidence.
Bobrow et al (2011)[23]	Prospective randomized controlled trial	United States	336 adults without recent CPR training	Four groups: (1) Control (no training); (2) 60-second video training; (3) 5-minute video training; (4) 8-minute video training including manikin practice	Compared the control group to the three experimental groups for their ability to perform CPR according to the START triage system	The study found that laypersons exposed to short Hands-Only CPR videos were likelier to attempt CPR and demonstrated better CPR skills than untrained individuals. Specifically, trained individuals had higher average compression rates and greater average compression depths than the control group. The 60-second video training group performed significantly better than the control group, and adding manikin practice to video training further improved CPR performance. The study concluded that brief CPR videos effectively train lay responders in Hands-Only CPR, suggesting the potential for increasing public CPR training through easily accessible short videos.

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Linderoth et al (2021)[25]	Retrospective study with follow-up on out-of-hospital cardiac arrest (OHCA) cases using live video during emergency calls.	Denmark	52 OHCA calls with 90 bystanders performing chest compressions.	Live video streaming from bystanders' smartphones to medical dispatchers was added to the communication after CPR was initiated.	CPR quality before and after the medical dispatcher had used live video to provide dispatcher-assisted CPR (DA-CPR).	• After video-instructed DA-CPR, 38 bystanders (42.2%) had incorrect hand positions, which improved for 23 bystanders (60.5%). • Compression rate was incorrect for 36 bystanders (40.0%) and improved for 27 bystanders (75.0%). • Compression depth was incorrect for 57 bystanders (63.3%) and improved for 33 bystanders (57.9%). • Hands-off time was reduced for 34 (37.8%) bystanders. • The adjusted odds ratios for improved CPR after video-instructed DA-CPR were: hand position 5.8 (95% CI: 2.8–12.1), compression rate 7.7 (95% CI: 3.4–17.3), and compression depth 7.1 (95% CI: 3.9–12.9).
Nakagawa et al (2021)[32]	Prospective observational study	Brazil	1,977 participants (1,630 in the 40-minute program, 347 in the 120-minute program)	Two CPR training programs: 40-minute program using low-cost handmade manikins 120-minute program using intermediate-fidelity manikins.	Success rates of developing and acquiring CPR skills were compared between the two programs and across different age groups.	The 40-minute program with low-cost handmade manikins was adequate for developing and acquiring overall CPR skills for ≥89% of participants. The success rate for specific CPR skills increased with age and with the more extended, intermediate-cost program. Skills such as checking local safety, assessing victim's responsiveness, calling for help, and assessing victim's breathing had higher success rates with the 120-minute program. Effective chest compression skills improved with age and were better achieved using the intermediate-fidelity manikins.
Nehra et al (2024)[33]	Randomized controlled trial	India	206 undergraduate students pursuing a Bachelor of Dental Surgery (BDS) at a university in coastal Karnataka, India.	The study compared hands-only CPR training using a low-cost CPR pillow model to standard mannequin training. The CPR pillow was made of a pillow with an empty plastic bottle strapped to the centre, while the mannequin group used commercially available Laerdal QCPR mannequins. Both groups received identical training content and sessions conducted by AHA certified instructors.	Standard mannequin training	The two groups had no statistical difference regarding hand positioning, chest compression rate, depth, and overall CPR score. However, the CPR pillow group had a significantly higher percentage of adequate chest recoil than the mannequin group (86% vs 73%, $P < 0.001$). The study concluded that the low-cost CPR pillow is an acceptable alternative to mannequins for training hands-only CPR to lay rescuers.

(*Continued*)

Table 3 (Continued).

Author (Years)	Design	Country	Sample	Intervention	Comparison	Results
Malta Hansen et al (2017)[34]	Nationwide cross-sectional survey	Denmark	1240 Danish school leadership members and 1381 ninth-grade homeroom teachers	The study assessed the implementation of CPR training following 8 years of legislative mandates in Denmark. It involved a survey of school leadership and ninth-grade homeroom teachers, employing qualitative interviews and the Theory of Planned Behavior to construct the survey.	No	According to teachers, 28.4% of eligible classes had completed CPR training, and 10.3% had completed automated external defibrillator (AED) training. School leadership reported that 60.2% of schools had conducted CPR training during the 3 years prior to the survey. Factors significantly associated with completed CPR training included believing other schools were conducting training (OR 9.68), awareness of mandating legislation (OR 4.19), presence of a school CPR training coordinator (OR 3.01), teacher feeling competent to conduct training (OR 2.78), and having easy access to training material (OR 2.08). Despite mandating legislation, the study found that CPR training had not been systematically implemented in schools, indicating the need for increased awareness and structured implementation efforts.
Tsunoyama et al (2017)[37]	Retrospective before-and-after comparison study	Japan	532 non-traumatic out-of-hospital cardiac arrest (OHCA) patients were transported by eight emergency medical services (EMS) in Japan. The sample includes 249 cases before and 283 cases after the intervention.	The Japanese government developed a standardized training program for emergency call dispatchers to improve their skills in providing oral guidance on chest compression to bystanders. This program included basic medical education, the role of the dispatcher, identification of cardiac arrest signs, and oral guidance procedures delivered through classroom lectures and simulation training.	The study compared the provision of oral guidance and the incidence of chest compressions by bystanders one month before and after the training program was implemented.	After the training program, dispatchers' provision of oral guidance slightly increased from 63% to 69% (P = 0.13). Bystanders' implementation of chest compressions significantly increased from 40% to 52% (P = 0.01). Appropriate chest compressions increased from 34% to 47% (P = 0.01). The increase in chest compressions and appropriate chest compressions was observed primarily under the guidance of dispatchers.

Lee DK et al (2021)[38]	Prospective, multinational, multicentre, pragmatic, noninferiority, randomized controlled trial (XR BLS trial)	South Korea, USA, UK, Singapore	154 participants from Seoul National University Bundang Hospital (South Korea), Children's Hospital Los Angeles (USA), Royal Manchester Children's Hospital (UK), and the National University of Singapore (Singapore). Participants are non-healthcare providers aged 18 years or older.	Participants will be randomly assigned to either an extended reality (XR) group or a conventional group (1:1 ratio). The XR group will receive training using an XR BLS module, which combines virtual reality (VR) with real manikins for basic life support (BLS) training. The conventional group will receive instructor-led in-person training with a BLS video and a manikin with a feedback device.	The effectiveness of the XR-based BLS training will be compared with conventional BLS training.	The study aims to determine if the BLS skills gained through the XR method are not inferior to those gained through the conventional method. The hypothesis is that the XR-based training method will be as effective as conventional training regarding chest compression depth and overall BLS performance.
Murk et al (2023)[24]	Case series study	United States	Four voice assistants were tested: Amazon Alexa on Echo Show 5, Apple Siri on iPhone 14 Pro, Google Assistant on Nest Mini, and Microsoft Cortana on a Windows 10 laptop. Additionally, ChatGPT version 3.5 by OpenAI was tested.	Evaluation of the out-of-the-box ability of artificial intelligence voice assistants to provide appropriate CPR instructions. The study also tested a recently developed AI large language model (LLM) for its ability to provide CPR instruction.	The study compared the quality of responses from different voice assistants (Amazon Alexa, Apple Siri, Google Assistant, Microsoft Cortana) and ChatGPT version 3.5 to CPR-related queries.	Of the 32 responses, 19 (59%) were related to CPR. Nine (28%) suggested calling emergency services.11 (34%) provided any (verbal or textual) CPR instructions. Four (12%) provided verbal instructions. ChatGPT provided relevant CPR information for 100% of queries and textual CPR instructions for 75% of queries. Among the responses providing CPR instructions, 71% described hand positioning, 47% described compression depth, and 35% described compression rate. Conclusion: The study found that current artificial intelligence voice assistants have significant limitations in providing appropriate CPR instructions. Bystanders should prioritize calling emergency services over using a voice assistant for CPR guidance. Improvements in VA capabilities and standardization in CPR instruction content are needed.

Abbreviations: AED, Automated External Defibrillator; AI, Artificial Intelligence; BLS, Basic Life Support; CG, Control Group; CPR, Cardiopulmonary Resuscitation; DA-CPR, Dispatcher-Assisted Cardiopulmonary Resuscitation; DIY, Do-It-Yourself; EMS, Emergency Medical Services; HO-CPR, Hands-Only Cardiopulmonary Resuscitation; LLM, Large Language Model; LoCoMan, Low-Cost DIY Manikin; OHCA, Out-of-Hospital Cardiac Arrest; OR, Odds Ratio; ROSC, Return of Spontaneous Circulation; VA, Voice Assistant; VR, Virtual Reality; XR, Extended Reality.

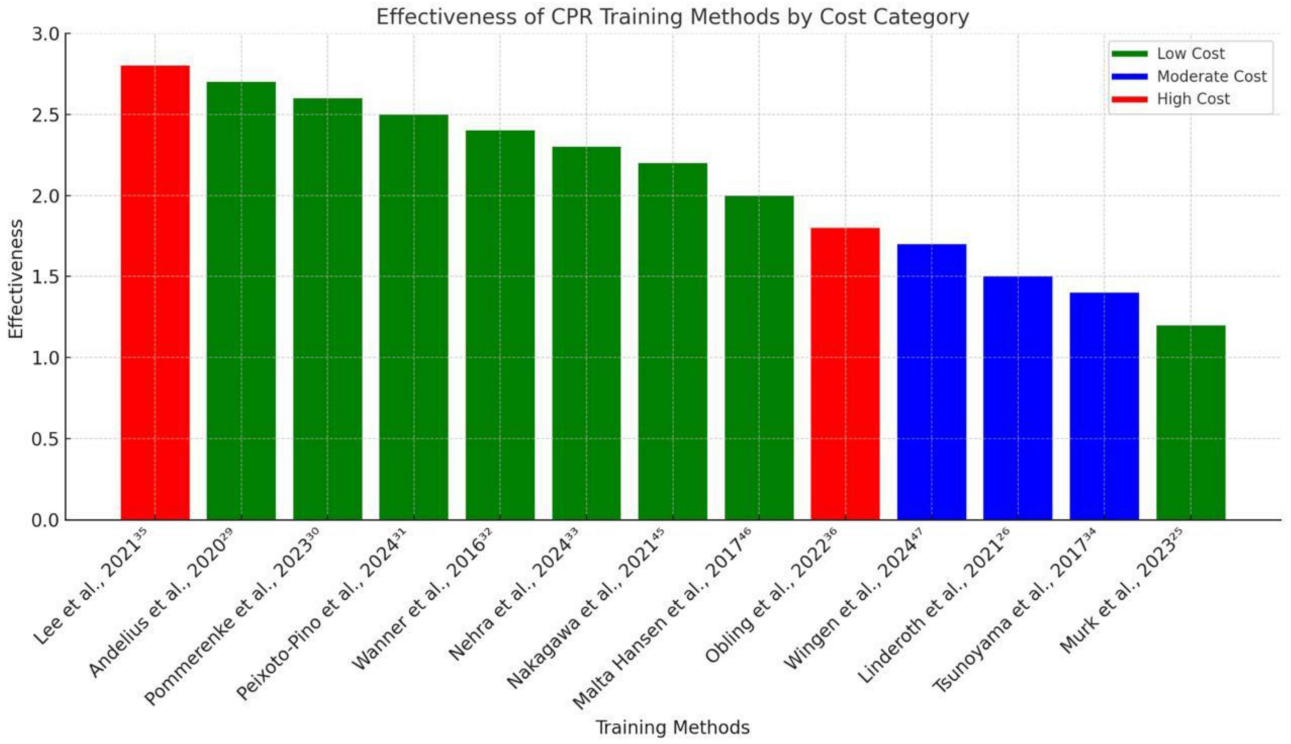

Figure 2 The Relationship Between Cost and Effectiveness of Various CPR Training Methods.

higher costs.[38] Furthermore, using AEDs with audiovisual feedback and live video streaming from the public's smartphones to medical dispatchers has also proven helpful in providing dispatcher-assisted CPR.[25,35] The study concludes that a combination of these methods can be implemented based on the availability of resources and the specific needs of communities to improve emergency response and survival rates in cases of out-of-hospital cardiac arrest.

The visualization of this table helps illustrate the relationship between the cost and ease of implementation of the training methods identified in the study. Low-cost methods are more accessible and easier to implement for the general public. In contrast, high-cost methods, such as XR-based training, offer greater effectiveness but require more substantial resources for execution.

This graph clearly illustrates that low-cost training methods are more accessible and easier to implement. In contrast, high-cost methods offer greater effectiveness but are less convenient to execute. An unexpected finding from this study is that low-cost training methods can deliver highly effective and efficient results (See Figure 2). For instance, training using smartphone apps, DIY manikins, and short hands-only CPR videos has proven to be efficient in improving CPR skills with minimal costs. On the other hand, some high-cost methods, such as using AEDs with audiovisual feedback, do not always result in significant improvements in OHCA survival rates. However, it is undeniable that higher costs can often correlate with quality, as seen in extended reality (XR) and virtual reality (VR)–based Basic Life Support (BLS) training, which has shown excellent outcomes in simulating realistic emergencies. Researchers suggest standardization and further development of training methods to ensure greater effectiveness. Future research could also focus on adapting these technologies for other training scenarios and exploring how their integration with low-cost methods could create more comprehensive and efficient training solutions.

Discussion

This study successfully identified various innovative and effective training approaches, demonstrating that low-cost methods, such as smartphone applications, DIY manikins, and short compression CPR video training, effectively improve public CPR skills.[28,30,31] These findings challenge the traditional assumption that high costs always correlate

with training effectiveness. According to cognitive learning theory, training effectiveness is more influenced by instructional design and participant engagement than the expenses incurred.[39] Mobile applications such as KATRETTER, which efficiently coordinates emergency responses, highlight how simple yet purpose-driven technology can significantly impact.[29] This effectiveness is further supported by literature suggesting that active participant involvement in the learning process, through interactive simulations and real-time feedback, enhances knowledge retention and skill development.[40]

Furthermore, training with short hands-only CPR videos and low-cost DIY manikins facilitates access to training for the broader community without incurring significant expenses. This study expands the understanding of the importance of accessibility and sustainability in emergency training programs. According to the health services accessibility theory, programs that are easily accessible to all societal levels are more effective in improving emergency preparedness and response.[41] These findings are supported by research showing that short training videos can enhance CPR efforts by the general public, proving that simple and inexpensive methods can yield significant outcomes.[31] This approach aligns with the standards for implementing more inclusive and sustainable training programs.

The research findings also reveal that although costly, advanced technologies such as extended reality (XR) in BLS training deliver excellent results in simulating real-life emergencies. This challenges the assumption that high costs do not always correlate with improved patient survival rates. This aligns with the theory of technological innovation, which posits that adopting new technologies can enhance efficiency and effectiveness in the long term.[42] However, the effectiveness of these technologies highlights the need for standardization and further development of training methods to ensure that all technologies, whether low-cost or high-cost, can deliver optimal outcomes.[35]

In addition, this study highlights that some high-cost training methods, such as using AEDs with audiovisual feedback, do not always result in significant improvements in OHCA patient survival rates. This suggests that other factors, such as the quality of training and user experience, also play a critical role. According to the theory of training effectiveness, the quality and relevance of training content are more important than the cost or technology employed.[43] These findings underscore the need for a critical evaluation of the cost-effectiveness of each training method and a deeper consideration of factors that influence training outcomes.

The combination of diverse training methods can be implemented based on resource availability and the specific needs of each community. This approach addresses research gaps related to the lack of comprehensive synthesis and enhances the understanding of best practices in emergency training. Integrating proven low-cost and high-cost training methods can create more comprehensive and efficient training solutions. Therefore, further research is needed to explore how advanced technologies can be adapted for other training scenarios and how their integration with low-cost methods can develop more inclusive and effective training programs.

There are several challenges in implementing digitally based interventions. Accessibility and implementation of technology in resource-limited regions face several significant challenges.[44] One of the main obstacles is limited technological infrastructure, which results in limited access to technological services in rural areas.[45] Some areas do not even have adequate electricity, limiting the use of technology. In addition, the digital divide is also caused by differences in digital skills or abilities and frequency of internet use. Other challenges include the cost of technology devices, internet services, and software licenses, which can create financial barriers, especially for individuals and communities with limited resources. Addressing these barriers requires strategies such as hybrid training approaches that combine low-cost community-based methods with digital innovation and public-private partnerships to help subsidize technology costs and expand access for underserved populations.[46]

Researchers must prioritize several strategic steps to address the existing gaps and challenges in OHCA emergency training and education research. First, it is essential to emphasize the standardization of CPR training guidelines and other emergency interventions. With consistent guidelines aligned with best practices, training can be delivered more effectively, improving public emergency response capabilities overall. Additionally, researchers must ensure that cost-effectiveness is considered at every program development and implementation stage. This approach will help guarantee that training programs remain sustainable and accessible to all segments of society.

Regarding the identified gaps or challenges, researchers need not worry, as solutions have been outlined in this study's findings. For instance, low-cost methods such as smartphone applications, DIY manikins, low-cost CPR pillows, and

hands-only CPR video training have proven highly effective in improving public CPR skills with minimal expenses. These approaches address cost-related challenges and ensure that training is accessible to everyone without significant financial barriers.[28,29] Furthermore, the findings on the effectiveness of short CPR videos and CPR training using pillow models demonstrate that simple and inexpensive methods can yield significant outcomes. If researchers face issues related to accessibility or costs, they can leverage these findings to develop more inclusive and sustainable training programs.[23,33]

Strengths and Limitations of Study

This review has certain limitations. Firstly, the scarcity of experimental studies on this topic may reduce the comprehensiveness of the findings. Secondly, the variability in study designs and participant populations presents several challenges, such as limited applicability to specific contexts, inconsistencies in the quality of training programs, differences in outcome measures, and a lack of long-term follow-up assessments. Furthermore, it is important to recognize potential biases in study selection, mainly regarding regional differences in access to training and socioeconomic factors that may affect adopting innovative training methods. These disparities influence training interventions' scalability and equitable distribution across diverse settings.

Despite these limitations, this review integrates a wide range of study designs—including prospective and retrospective studies, quasi-experimental research, and randomized controlled trials—offering a well-rounded perspective. Additionally, by incorporating studies from multiple countries, such as Denmark, Germany, Spain, the United States, Brazil, India, Japan, and South Korea, this review enhances the applicability of its findings across different cultural and healthcare environments. Moreover, it examines various innovative training methods, including mobile applications, affordable manikins, video-based instruction, and virtual reality, which have the potential to improve both the accessibility and effectiveness of CPR training. A key strength of this review lies in Tables 2 and 3, which provide a structured comparison of the most effective training approaches, spanning both low-cost and high-cost solutions. This comparative analysis helps readers quickly grasp the critical insights from the study while highlighting practical training strategies for diverse resource settings.

Conclusion

Analysis of 13 articles suggests that the effectiveness of CPR training does not always depend on high costs. Low-cost methods such as smartphone apps, brief training videos, and DIY manikins have significantly improved CPR skills. In contrast, although effective in realistic simulations, expensive technologies such as VR and XR do not constantly significantly improve OHCA survival. Therefore, training program design must consider the balance between cost and effectiveness to maximize training resources and outcomes.

Theoretically, this study enriches the literature on community emergency responses and innovative interventions in increasing OHCA survival rates. These findings can be applied to develop more effective and affordable CPR training programs for health workers and the general public. However, there are limitations, such as variations in study design and population, as well as the need for long-term evaluation. Therefore, further research is needed to integrate innovative technologies with low-cost training methods to produce training manuals that are more standardized and suited to local contexts.

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