HELLENIC JOURNAL OF CARDIOLOGY VOL. 82, 2025: 86–98

REVIEW ARTICLE

The role of bystander CPR in out-of-hospital cardiac arrest: what the evidence tells us

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ABSTRACT

Out-of-hospital cardiac arrest (OHCA) is a global public health problem. Lay bystanders witness almost half of OHCA, so early recognition is critical to allow immediate initiation of cardiopulmonary resuscitation (CPR) by the bystander. The present investigation aims to analyze the most recent scientific evidence of the effect of bystander CPR on survival after an OHCA. A systematic literature review was carried out at the "Web of Science," "Scopus," and "PubMed" databases, including publications from the last 20 years. After inclusion/exclusion criteria, 37 articles were identified. Results indicate that patients who receive CPR are more likely to survive than those who don't, and CPR is associated with a good quality of life post-OHCA. Emphasis should be placed on practicing chest compressions only when the bystander has not mastered the artificial ventilation technique. Finding an AED is the first step to using it in an OHCA situation. Correct use of an AED by laypeople is associated with nearly double the survival rate after an OHCA when compared to standard CPR. It is important to promote CPR and AED training to non-professionals, such as community residents and youth, as training is associated with higher success rates of effective CPR-AED. A mobile phone positioning system to recruit trained laypeople or text message alerts to send citizen volunteers as well as assistance through a mobile app appear to have significant advantages in practicing effective CPR. The benefits of bystander CPR outweigh the risk of injury to victims, highlighting the need to disseminate training to laypeople.
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1. INTRODUCTION

Cardiac arrest is characterized by the sudden loss of cardiac function in an individual who may or may not have been diagnosed with heart disease.[1] This event is often fatal if appropriate procedures are not carried out quickly and effectively. Therefore, out-of-hospital cardiac arrest (OHCA) is a global public health problem, with a survival rate that varies between 2% and 22%.[2] The chain of survival summarizes the vital links needed to reverse the OHCA, and, in 3 of these links, the bystander plays an essential role for success.

Due to the importance of the bystander action, the European Resuscitation Council Guidelines for Resuscitation highlight its role in OHCA, arguing that

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Peer review under responsibility of Hellenic Society of Cardiology.

Manuscript received May 5, 2024; revised manuscript received August 26, 2024, accepted September 6, 2024. Available online September 12, 2024

ISSN 1109-9666 https://doi.org/10.1016/j.hjc.2024.09.002

systems and organizations should a) recognize the importance of bystander cardiopulmonary resuscitation (CPR) as a key component of the community response to OHCA; b) recognize that CPR carried out by a bystander is a voluntary act, with no moral or legal perception of acting; and c) support the bystander in minimizing the impact on their own health resulting from performing CPR.[3,4]

Early recognition of OHCA is critical to allow immediate initiation of CPR by the bystander. While the victim waits for emergency services to arrive, survival depends on bystanders who initiate CPR and use an automated external defibrillator (AED).[5] Several studies highlight the importance of bystander CPR as a contributing factor to improving survival rate in cases of OHCA.[6-12]

The primary objective of bystander training is to increase bystander CPR rates, AED use, and proper activation of the emergency response system during an OHCA.[13] Among 10 recommendations, the AHA[13] highlights the increase in the number of trained bystanders as the most important in improving survival in OHCA. Furthermore, the bystander intervention is associated with a reduction in the length of hospital stay and admission to the intensive care service, contributing to a better recovery of survivors.[10]

The relevance of training bystanders in CPR is defended by different studies, namely the training of a) bystanders for helping adults in OHCA, with compressions only, as an alternative to conventional CPR training[9,14,15]; b) primary caregivers and/or family members of high-risk patients[16-18]; and c) elementary school children, in high-quality CPR.[19-22]

Schools have the opportunity to promote the education of citizens in CPR, increasing the number of trained bystanders to serve society.[23] A meta-analytic study concluded that children are receptive and enthusiastic about learning CPR, making it effective and producing social benefits, and they can act as multipliers among family members and peers.[24]

The increase in motivation of bystanders to perform CPR may positively reflect in OHCA survival rates.[25] Motivation can be influenced by bystanders' participation in CPR training sessions.[26] Increasing CPR skills can result from several strategies: feedback devices during training of rescuer bystanders[27,28]; auditory guidance through music or a metronome if auditory feedback is not available[29,30]; and combination of instructor-led and self-instruction, with attendance at reinforcement learning courses at intervals of less than 2 years.[26,31]

Adequate training can also help bystanders to more easily overcome important situations flagged as potentially inhibiting their performance: 1) lack of confidence, 2) fear of legal disputes, 3) fear of disease transmission, and 4) embarrassment.[32] In summary, a sufficient and appropriate training offer, including also refresher courses, with a special focus on well-known barriers to CPR carried out by bystanders, has the potential to strengthen the chain of survival, which translates into a higher rate of survival in OHCA.[33]

Based on this framework, the present investigation aims to analyze the most recent scientific evidence of the effect of CPR performed by bystanders on survival after an OHCA. To this end, a systematic literature review was carried out, which, among other advantages, is structured around explicit, standardized, and systematic procedures, making the emergence of biases introduced by its authors less likely, as can be analyzed in the methodological field of the study, presented below.

2. MATERIAL AND METHODS

The present study was conducted following the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" guidelines[34] and is registered at the International Platform of Registered Systematic Review and Meta-analysis Protocols (INPLASY) under the number 202380015. The criteria employed in the search and presentation of results were based on the PICO approach (longitudinal studies): population, intervention, comparison, and observation or result.[35]

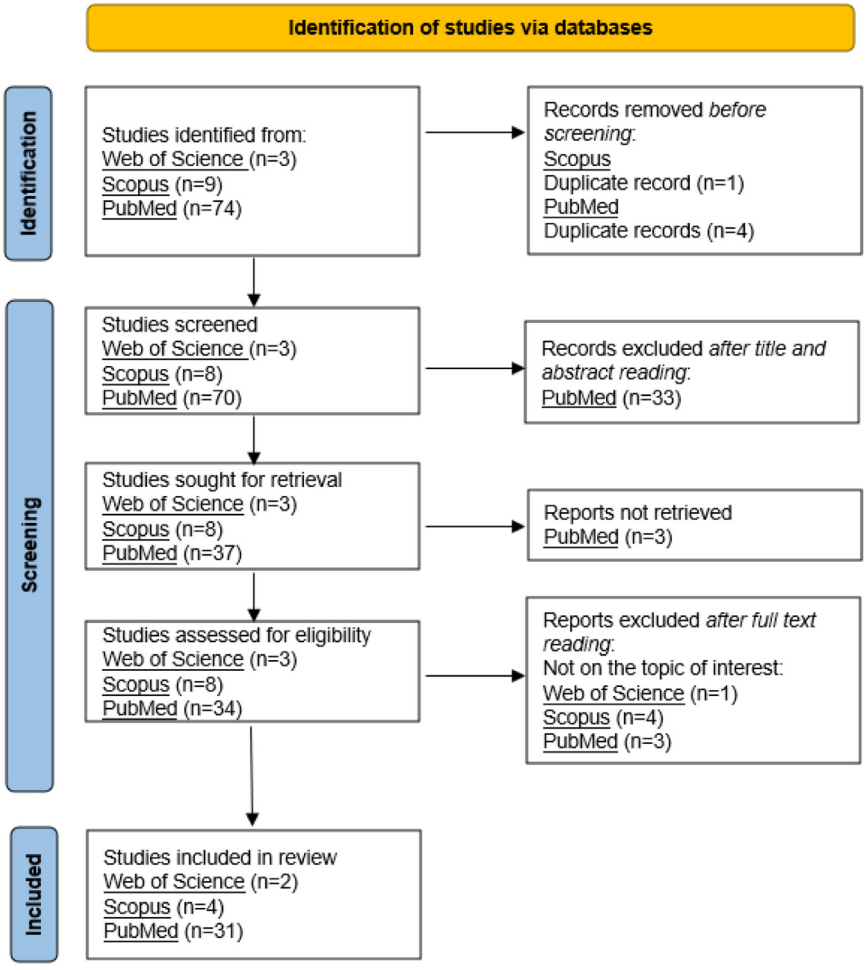
Databases consulted were "Web of Science," "Scopus," and "PubMed," and publications of the last 20 years were included (from 2003 to April 2023) in English. The search strategy involved the following MeSH terms: "cardiopulmonary resuscitation" AND "untrained personnel" AND "heart arrest."

Inclusion criteria involved cross-sectional or longitudinal studies with observational or comparative design, involving humans of all ages. Review studies, protocols, comments, and institutional positions or guidelines were not included. After identifying the studies, each one was evaluated for information on the outcome of interest (cardiopulmonary resuscitation performed by laypersons).

3. RESULTS

The search resulted in 81 publications after removing duplicate records. Subsequently, to title and abstract reading, 33 articles were excluded, 3 were not retrieved, and 8 others were disqualified after full-text reading, as they were not on the topic of interest. Thus, this systematic review was based on the remaining 37 publications (**Fig. 1**).

FIGURE 1 **Study flowchart. Note. Elaborated by the authors**



All studies included in this systematic review were conducted in countries of the northern hemisphere (Fig. 2). The United States of America (n = 7), Canada, Germany, Sweden, and South Korea (n = 4) were the main producers of research in this field.

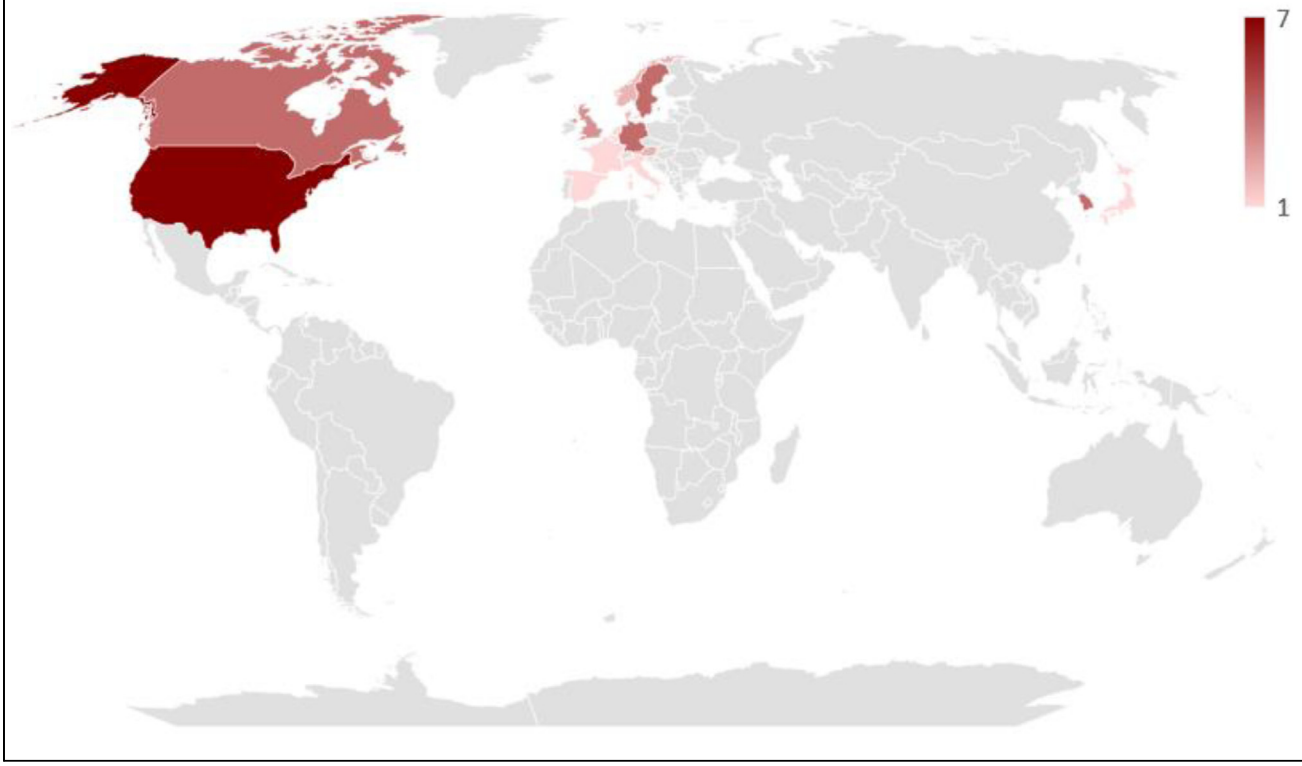
Among the studies included, 8 (22%) focused on survival after an OHCA witnessed by laypersons[36-43] and are presented in Table 1. CPR by a layperson seems to produce similar survival rates when compared to the one provided by a physician.[38] Data from the London Ambulance Service database revealed that lay bystanders witness almost half of the OHCA, and patients who receive CPR are more likely to survive than non-recipients of CPR.[37]

A cohort study with 1-year survivors of OHCA[36] showed that receiving bystander CPR was associated with a good quality of life. Data from the Pan-Asian Resuscitation Outcomes Study[43] demonstrated that, among survivors of an OHCA, being at home led to poor rates of bystander CPR, bystander AED, and EMS response. These data emphasize the importance of promoting CPR training for community dwellers.

Three studies compared compression-only CPR and compressions associated to rescue breaths.[39,40,42] They indicate that, when performed by laypersons, CPR must emphasize chest compressions,[39] as no significant difference in survival is observed between these 2 types of CPR by laypersons.[40] Any type of CPR is associated with double survival when compared to not receiving CPR before emergency medical service arrival.[42]

A retrospective study conducted in the USA evaluated victims who received CPR by mistake, as they were not in cardiac arrest.[41] This occurred at a relatively low frequency, and CPR injured less than 2% of these victims. The authors believe that the benefits of

FIGURE 2 **Countries of the studies included in this systematic review**



bystander CPR outweigh the risk of injury to the victims.

The use of an automated external defibrillator (AED) by laypersons was studied in different ways by 9 (24%) groups of authors,[8,44-51] as shown in **Table 2**.

Finding an AED is the first step to using it in a situation of OHCA. Neves Briard et al.[51] studied the performance of different strategies to this end in a simulated environment. They observed that verbally providing bystanders with the nearest public AED's location was effective in reducing the time to defibrillation in comparison to no assistance or a geolocalizing app. The authors suggest that public AED localization is integrated to the assistance of emergency medical dispatch centers.

Survivors of an OHCA in the Danish Cardiac Arrest Registry were followed up for 1 year for anoxic brain damage, nursing home admission, or death.[8] The risk of all 3 outcomes was significantly lower among survivors who received bystander CPR or defibrillation when compared to the ones who did not receive bystander resuscitation.

The correct use of an AED by laypersons is associated with almost double the survival rate after an OHCA when compared to standard CPR.[50] A similar result was observed by Nichol et al.[49] CPR plus AED provided by trained lay volunteers was more effective in the survival of OHCA victims to hospital discharge. Defibrillation was cost-effective and had a low incremental cost. Despite this fact, an exploratory study on the use of AEDs on a mannequin revealed that, in a stressful situation, a bystander may not be able to correctly operate an AED, as an 80% failure rate was observed among the general population.[44]

To counteract this problem, Hallstrom et al.[46] conducted a prospective randomized trial with victims of OHCA and laypersons trained in CPR or CPR plus the AED in the USA and Canada. They concluded that training and equipping volunteers to use the AEDs doubled the number of survivors to hospital discharge.

Three other studies focused on training volunteers to use AEDs. Callejas et al.[45] conducted a defibrillation simulation in untrained persons or a video-trained group with 2 different AED devices. Both AED devices were safe, but the video-trained subjects, as expected, demonstrated higher success rates. The study by Christenson et al.[47] was a prospective randomized trial on training and retraining (after 3, 6, 9, or 12 months) CPR and AED skills. They observed that volunteers who acted in a structured emergency response plan were able to retain CPR and AED skills

TABLE 1 Studies on survival after an out-of-hospital cardiac arrest witnessed by laypersons (n = 8)

Reference	Population	Intervention	Comparison	Observations
Stiell et al. (2003)[36]	268 adult OHCA patients who survived 1 year (Canada).	Prospective cohort study with telephone interview.	Health-related QoL and functional status.	Most survivors had good health-related QoL and functional status. Bystander CPR is strongly and independently associated with better quality of life. These results emphasize the importance of optimizing community citizen CPR readiness. Local and national initiatives should vigorously promote the practice of bystander CPR.
Dowie et al. (2003)[37]	3759 OHCA witnessed by lay bystanders or unwitnessed (UK).	None. Secondary data from the London Ambulance Service database.	Method: Analysis of the Utstein style audit tool for bystander CPR and response time.	Lay bystanders witnessed 49% of the cardiac arrests. Patients who received bystander CPR were significantly more likely to have return of spontaneous circulation in the field than non-recipients of CPR. The evaluation of initiatives and the government's performance standards can be facilitated by using the Utstein style and the event tree technique.
Estner et al. (2007)[38]	539 patients with OHCA (Germany).	Prospective observational study with OHCA patients.	Survival to OHCA treated by a physician, by a layperson, or by an EMS personnel.	CPR by a layperson is associated with an identical rate of survival compared with CPR first performed by a physician. The presence of a physician on the advanced life support team was not an independent predictor of improved survival at the time of hospital discharge.
Rea et al. (2010)[39]	1941 bystanders calling the emergency service for patients in cardiac arrest (USA and UK).	Randomized study on 2 CPR strategies.	Survival after chest compression alone or chest compression plus rescue breathing.	Chest compression alone may increase survival rate in patients with a cardiac cause of arrest and those with ventricular fibrillation. CPR performed by laypersons must emphasize chest compression and minimize rescue breathing.
Svensson et al. (2010)[40]	1276 patients of OHCA assisted by laypersons instructed by phone (Sweden).	Prospective randomized study comparing the efficacy of compression-only CPR and standard CPR.	Survival after compression-only CPR or standard CPR.	There was no significant difference in survival rates between groups. Phone instructions for compression-only CPR before the arrival of EMS personnel did not improve the outcome or survival rate as compared to standard CPR.
Haley et al. (2011)[41]	Victims who received bystander CPR but were not in cardiac arrest (USA).	None. Retrospective study on patient care records to identify injuries resulting from receiving bystander CPR.	Method: review of records from EMS of Milwaukee County, from March 2003 to February 2009.	672 incidents of bystander CPR were registered, and 77 (11.5%) were not identified as cardiac arrests by the EMS. 72 patients were evaluated for injuries, and 53% were admitted to the intensive care unit. One patient (1.4%) had an injury that was documented in the medical record as possibly related to CPR (rhabdomyolysis). Bystanders provided CPR for patients who were not in cardiac arrest at a relatively low frequency. Short-duration bystander CPR caused injury in less than 2% of victims. The benefits of bystander CPR for adults outweigh the risk of injury for those not in cardiac arrest.
Riva et al. (2019)[42]	OHCAs registered in the Swedish register between 2000 and 2017, including all ages and etiologies.	None. Observational nationwide cohort study.	CPR not initiated before EMS arrival (NO-CPR), chest compressions provided but no rescue breaths were not attempted (CO-CPR), and both chest compression and rescue breaths provided (S-CPR).	There was an almost twice higher rate of CPR before EMS arrival and a concomitant 6 times higher rate of CO-CPR over time. Any type of CPR associated with doubled survival rates when compared to NO-CPR. CO-CPR remains an option in future CPR guidelines, as it is associated with higher CPR rates and survival in OHCA.
Ting et al. (2020)[43]	8397 cases of OHCA in Singapore, of which 5990 (71.3%) cases of bystander CPR were residential.	None. Secondary prospective data from the Pan-Asian Resuscitation Outcomes Study.	Method: Analysis of survival to hospital discharge or survival in hospital at 30th day post-arrest.	Residential location was an independent predictor of survival in OHCA. Patients from residential-type arrests presented poorer rates of bystander CPR, bystander AED, and EMS response. This reinforces the need for continued education to residential populations.

Note. OHCA: out-of-hospital cardiac arrest, CPR: cardiopulmonary resuscitation, AED: automated external defibrillator, EMS: emergency medical service, QoL: quality of life.

TABLE 2 Studies on the use of automated external defibrillator by bystanders (n = 9)

Reference	Population	Intervention	Comparison	Observations
Roccia et al. (2003)[44]	50 adult subjects varying from general lay population to health professionals (USA).	Exploratory study on the use of AEDs by the general population on a CPR mannequin.	Correct use of AED among 5 categories of subjects, from lay general population to health professionals.	An 80 percent failure rate was observed in the general population group, while the other groups exhibited an inverse relationship between failure rate and amount of health care training. Previous exposure to an AED leads to more successful defibrillations. In a stressful situation, a layperson may not be able to successfully operate an AED.
Callejas et al. (2004)[45]	256 adult lay volunteers (USA).	Randomized study on the use of 2 different AEDs.	Defibrillation simulation in untrained group or video-trained group.	Both AED devices were safe when used by both groups of participants. Video-trained subjects demonstrated higher success rates in the use of AEDs. Human factors associated with the ease of use of AEDs may play a critical role in survival rates achieved by these devices.
Hallstrom et al. (2004)[46]	19,376 community volunteers from 993 community units (USA and Canada).	Prospective randomized trial with victims of OHCA and laypersons trained in CPR or CPR with an on-site AED.	Survival rate to OHCA due to cardiac causes after receiving CPR or CPR plus AED.	Training and equipping volunteers to use AEDs doubled the number of survivors to hospital discharge after OHCA. Trained laypersons can safely and effectively use AEDs. A structured response system can increase survival to cardiac arrest in public locations.
Christenson et al. (2007)[47]	2729 lay volunteers from 1260 facilities (USA and Canada).	Prospective randomized trial on training and retraining (after 3, 6, 9, or 12 months) CPR and AED skills.	Global competence of CPR and AED retention, determined by the instructor prior to retraining.	Volunteers acting within a structured emergency response plan may retain CPR and AED skills up to 12 months after initial and refresher training sessions. CPR skills degrade minimally over time, but more than 80% of the volunteers in CPR groups and more than 90% in AED groups remained competent enough at 12 months.
Andresen et al. (2008)[48]	1095 lay volunteers from companies and agencies in Berlin (Germany).	Prospective randomized trial on CPR and AED use skills retained.	Quality of CPR and AED use on a mannequin after 2, 4, or 7 h of theoretical and practical instruction.	The 7 h training group exhibited the best performance, but skill retention decreased in the 3 groups after 12 months when no 6-month retests were conducted. A 2-h training was sufficient to learn CPR and AED skills for an extended period, once a brief re-evaluation is performed after 6 months.
Nichol et al. (2009)[49]	Lay volunteers from 24 communities served by EMS systems that provided advanced life support (Canada and USA).	Prospective randomized trial on an emergency response system that trained lay volunteers trained in CPR only or CPR + AED.	Survival to hospital discharge and costs in OHCA receiving CPR or CPR + AED by lay volunteers.	CPR + AED was more effective in survival to hospital discharge. Defibrillation by volunteers was cost-effective, and CPR + AED had a low incremental cost. Training and equipping lay volunteers to defibrillate in public places may have a similar incremental cost-effectiveness to that of other common health interventions.
Weisfeldt et al. (2010)[50]	13,763 OHCA cases from the Resuscitation Outcomes Consortium Epistry Database (USA and Canada).	None. Population-based cohort study with persons with OHCA who received bystander CPR with or without the application of AED.	Method: Multiple regression analysis to assess the independent association between AED application and survival to hospital discharge.	Application of an AED in communities is associated with almost double (OR = 1.8) the survival rate after OHCA. Results highlight the critical importance of early defibrillation and registry of all public access defibrillators with local dispatch. The application of AEDs by laypersons emphasizes the relative higher importance of speed than training.
Kragholm et al. (2017)[8]	2855 patients who were 30-day survivors of an OHCA in the Danish Cardiac Arrest Registry from 2001 to 2012.	1-year follow-up study on anoxic brain damage, nursing home admission, or death.	Risks according to whether bystander CPR or defibrillation was performed, temporal changes in bystander interventions, and outcomes.	The risk of anoxic brain damage or nursing home admission at 1 year, as well as the risk of death from any cause, were significantly lower among survivors who received bystander CPR or defibrillation when compared to the ones who did not receive bystander resuscitation. Significant increases in the rates of bystander CPR and defibrillation accompanied the reduction in the risk of anoxic brain damage, nursing home admission, or death at 1 year during the study period.
Neves Briard et al. (2019)[51]	87 adult and elderly lay individuals (Canada).	Prospective randomized study on the use of public AEDs.	Performance of different strategies in finding an AED: no assistance, assistance from a geolocalization app, or verbal assistance.	In a simulated environment, verbally providing bystanders with the nearest public AED's location was effective in reducing the time to defibrillation in comparison to no assistance and also to the geolocalizing app. The integration of EMD-assisted public AED localization in the chain of survival may decrease time to first shock.

Note. OHCA: out-of-hospital cardiac arrest, CPR: cardiopulmonary resuscitation, AED: automated external defibrillator, EMD: emergency medical dispatch.

up to 12 months. Lastly, Andresen et al.[48] studied the quality of CPR and AED use on a mannequin after 2, 4, or 7 h of theoretical and practical instruction in volunteers from companies and agencies from Berlin. Although the 7 h training group exhibited the best performance, 2-h training was sufficient to learn CPR and AED skills, and retention decreased in the 3 groups after 12 months when no 6-month retests were conducted.

Table 3 presents the main results of studies on alert systems or mobile applications to assist persons in cardiac arrest (5 studies, 13%).

A randomized controlled trial involving a mobile phone positioning system to recruit trained laypersons was conducted in Sweden.[52] The system increased the rate of bystander CPR in comparison to the control group; however, no significant differences were observed in survival after 1 month.

Berglund et al.[53] conducted an observational study on a smartphone application to locate and recruit laypersons for CPR. The technology contributed to locate and measure the distance between the lay responder and the victim. In a quarter of the cases, lay responders were able to reach the victim before the emergency medical service.

Similarly, a comparative study on a text message alert system to dispatch citizen volunteers was carried out in Netherlands[54] and most contributed to increase survival in cases where OHCA was witnessed, occurred at home, when the ambulance arrived with delay, and when it occurred in the evening or night. Lee et al.[55] evaluated where volunteers registered to a training course and then to a CPR volunteer network activated by a text message alert system. Training increased bystander CPR, which, in turn, improved survival to hospital discharge.

A cross-sectional study in Denmark involved citizens recruited from a smartphone application to dispatch volunteers to OHCA resuscitation.[56] They answered a questionnaire on self-reported risk of physical injury. Results revealed that the risk of physical injury requiring treatment or hospitalization was minimal (<0.5%), and the risk of minor injuries with no need of hospital treatment was also low. The authors highlighted that it is safe for citizens to be dispatched to OHCA.

TABLE 3 Studies with alert systems or mobile applications to assist persons in cardiac arrest (n = 5)

Reference	Population	Intervention	Comparison	Observations
Ringh et al. (2015)[52]	667 victims of OHCA (Sweden).	Randomized controlled trial involving a mobile phone positioning system to recruit trained laypersons, activated by the EMS.	Bystander initiated CPR and survival rate.	Increased rate of bystander CPR in OHCA was observed with the mobile phone positioning system activated in comparison to the control group (not activated). However, no significant differences were observed in survival after 1 month.
Berglund et al. (2018)[53]	23,097 CPR trained laypersons who volunteered to assist patients suffering from suspected OHCA in Stockholm (Sweden).	Prospective observational study involving a smartphone application to locate and recruit laypersons for CPR.	Victim reaching by laypersons or EMS.	Smartphone technology made it possible to locate and measure the distance between the lay responder and the suspected cardiac arrest. In 26% of the cases of true OHCAs, lay responders were able to reach the victim before EMS or professional first responders. Lay responders provided CPR in 27% of the cases.
Pijls et al. (2018)[54]	422 cases of OHCA attended by volunteers or by standard care only (Netherlands).	Comparative study on a text message alert system to dispatch citizen volunteers to sudden OHCA.	Survival in 2 scenarios: 1) activation of the system but no volunteer attended, and 2) response of the volunteers.	The system most contributed to survival in cases where OHCA was witnessed (OR = 2.25), occurred at home (OR = 2.28), when the ambulance arrived with delay (OR = 2.63), and when it occurred in the evening or night (3.07). Results indicate that many OHCA victims can benefit from this type of alert system.
Lee et al. (2019)[55]	OHCA adult patients treated by an EMS provider within the study area in Seoul (South Korea), 1498 patients pre and 1696 post training program.	Resuscitation bundle program, where volunteers registered to a training course and then to the CPR volunteer network.	Bystander CPR, survival to discharge, and good neurological outcome at hospital discharge.	Compared with the pre-intervention period, bystander CPR increased and survival to discharge, and good neurological outcomes also improved in the after intervention period. The text message alert system can increase the resuscitation of the layperson and speed up survival rate.
Andelius et al. (2021)[56]	7334 citizens recruited from a smartphone application to dispatch volunteers to OHCA resuscitation (Denmark).	None. Cross-sectional study with citizens who accepted to participate in an OHCA-CPR.	Method: Questionnaire on self-reported risk of physical injury in citizen responders to OHCA.	Risk of physical injury requiring treatment or hospitalization was minimal (<0.5%), and risk of minor injuries with no need of hospital treatment was low. It is safe for citizens to be dispatched to OHCA in a big city.

Note. OHCA: out-of-hospital cardiac arrest, CPR: cardiopulmonary resuscitation, EMS: emergency medical service.

Studies on CPR training are presented in **Table 4** (15 studies, 41%). Only one study investigated infant resuscitation techniques.[70] Authors concluded that the 2-thumbs encircling hand technique seemed to be more effective on a mannequin (as opposed to the 2-fingers technique) when explained over the phone by a trained emergency call responder.

The main difficulty in performing CPR on a mannequin seems to be ventilation skills.[58] On the other hand, compression-only CPR causes more fatigue in the lay rescuer than the standard 30 compressions and 2 ventilations procedure.[64]

When comparing standard instructions and intensified wording, van Tulder et al.[65] observed no differences when it comes to target compression depth executed by laypersons. Simple instructions and real-time feedback are key elements in training laypeople to perform good-quality CPR.[71]

Three studies focused on telephone-guided CPR.[57,59,60,68] Dorph et al.[57] evaluated the performance of elderly individuals with no experience in CPR, instructed to execute compression-only or 30:2 CPR on a mannequin. Overall performance was poor in both scenarios, and most problems were related to standard 30:2 procedure.

Ghuysen et al.[60] studied a protocol to assist previously untrained bystanders to initiate CPR. As expected, the telephone-guided group was superior in comparison to the unguided group in applying CPR on a mannequin. Another group of researchers compared guidance on mannequin CPR by telephone, telephone + smartphone application, or telephone + verbal motivation.[68] Verbal encouragement led to a significant increase in median chest compression depth compared to telephone CPR with real-time feedback by the application.

Six studies involved video-based instructions for CPR.[59,61,63,66,67,69] The prospective study by Neset et al.[59] involved 30 min of video-based self-instruction to perform CPR on a mannequin. The video allowed laypersons to perform 10 min of satisfactory quality CPR, being slightly higher in the groups that received verbal and visual feedback.

Lee et al. (2011) assessed the quality of CPR on a mannequin after audio-assisted instructions or video-demonstrated instructions. The video demonstration was more effective at improving chest compression rate and hand position than the audio instructions. Ecker et al.[67] also compared audio instructions (by phone) and video-assisted CPR to no assistance. They found that audio and video-assisted CPR were comparable and were both superior to unassisted CPR. Nonetheless, video assistance produced better hand positioning and more accurate compression depth. For the superiority of the video over audio instructions, it is recommended that it be implemented under the dispatching system by transitioning audio calls to video calls.[69]

In the same way, Plata et al.[66] compared the quality of CPR without instructions, with telephone assistance, app support with audiovisual feedback, or with telephone and app support. Compression rate, hand position, and thorax release were more efficient in groups with smartphone app support.

CPR can also be assisted by a mobile phone app. The metronome included in the app is useful to increase compression rate, despite ventilation remaining a problem.[63] A cohort study compared trained and untrained rescuers in OHCA victims in Japan.[62] The proportion of bystander CPR was higher in the trained group, who were 3.4 times more likely to perform CPR than those without training. The authors concluded that people with CPR training have a greater tendency to perform bystander CPR than the ones without it.

4. DISCUSSION

The aim of this study was to analyze scientific evidence on CPR performed by laypeople on survival after an OHCA. Our main finding is that patients who receive bystander CPR are more likely to survive than those who do not receive it, even with chest compressions only.

Evidence points to almost half of OHCA being witnessed by bystanders.[37] However, patient survival depends on bystander training to perform adequate CPR, as concluded by numerous authors.[6–12] Furthermore, evidence shows that CPR performed by laypeople produces similar survival rates to that performed by medical professionals.[38]

The good quality of life exhibited by OHCA survivors who received bystander CPR[36] emphasizes that the promotion of community training in CPR is urgent since AED rates and EMS response provided by bystanders are quite poor, particularly when the OHCA occurs in the victim's home.[43]

Training should particularly focus on the appropriate way to perform chest compressions.[9,14,15] Corroborating the literature, studies included in this review agree that there are no significant differences in survival rates of CPR performed with chest compressions alone and CPR performed with chest compressions and insufflations.[40] Patients who receive CPR before the arrival of emergency medical services on the scene can even double their survival rate.[42] It is also clear that the risk of injury when conducting CPR is very low for patients and CPR providers.[41,56]

TABLE 4 Studies on cardiopulmonary resuscitation training (n = 15)

Reference	Population	Intervention	Comparison	Observations
Dorph et al. (2003)[57]	20 elderly volunteers with no experience in CPR (Norway).	Randomized study with telephone instructions to provide chest compressions alone or CPR with ventilation.	Quality of CPR (hand position, chest compression rate, and mouth-to-mouth ventilation) on a mannequin.	Overall CPR performance had poor quality in both strategies, unlikely to affect outcome in a real setting. Most problems occurred in telephone-assisted standard CPR when compared to compressions alone. Protocol cards must be revised to effectively instruct this population.
Dare et al. (2008)[58]	51 lay volunteers in the UK.	Performing BLS without instruction on a mannequin. Repeating the operation after practical instructions.	Hand position, compression rate and depth, compression relaxation ratio, ventilation volume, and breathing interval pre and post training.	Volunteers improved their ability to perform cardiopulmonary resuscitation after training. A single trained rescuer can teach BLS skills to untrained bystanders during a cardiac arrest. Untrained bystanders acquire compression skills more readily than ventilation and may be more willing to assume this role.
Neset et al. (2010)[59]	64 lay volunteers aged 50-76 years old (Norway).	Prospective randomized study (CCC or cCPR, with or without feedback) involving 30 min video-based self-instruction class on a mannequin.	Chest compression depth and rate for 10 min, 5-7 months after training.	Laypersons were able to perform 10 min of satisfactory quality CPR. Quality of chest compressions was similar among groups, except for chest compression rate, which presented less variability and was slightly higher in the groups that received feedback. Verbal and visual feedback were effective in enhancing CPR quality.
Ghuysen et al. (2011)[60]	110 subjects, 60 untrained and 50 previously trained in CPR (Belgium).	Prospective randomized study aimed at evaluating a new French-language protocol for phone guidance in performing CPR.	5-min CPR on a mannequin performed by untrained non-guided group, untrained guided group, trained unguided group, trained guided group.	The protocol was efficient to assist previously untrained bystander to initiate CPR. The previously untrained guided group was superior to the unguided untrained group, approaching the level of the previously trained unguided individuals. Phone instructions in both guided groups resulted in improvements in airway management.
Lee et al. (2011)[61]	78 untrained volunteers (South Korea).	Prospective randomized study with CPR on a mannequin.	Quality of CPR after audio-assisted instructions or video-demonstrated instructions.	The video demonstration for CPR in a simulated cardiac arrest setting was more effective at improving chest compression rate and hand position than the audio instruction. However, this was not observed regarding compression depth. The instructional video has also shown to shorten the time before the start of chest compressions and to decrease interruptions when compared to the audio instructions.
Tanigawa et al. (2011)[62]	Cohort of persons aged 18 years or older with OHCA of intrinsic origin and their rescuers in Takatsuki, Osaka, Japan, from January to December 2008.	Collection of patient demographic data and details from the cardiac event. Neurological follow-up with survivors for 1 month. Interview with rescuers on their experience and CPR training and practice.	Trained and untrained rescuers' performance and neurologically favorable 1-month survival of victims.	Data were collected for 120 cases out of 170 OHCAs of intrinsic origin. Among the available rescuers, 60 (50.0%) had previous CPR training. The proportion of bystander CPR was significantly higher in the trained rescuer group than in the untrained one (75.0% and 43.3%; p = 0.001). Trained bystanders were 3.4 times more likely to perform CPR compared with those without training. The number of patients with neurologically favorable 1-month survival was too small to evaluate statistical difference between the groups (2 [3.3%] in the trained rescuer group *vs.* 1 [1.7%] in the untrained rescuer group; p = 0.500). People who had experienced CPR training had a greater tendency to perform bystander CPR than people without CPR training did.
Paal et al. (2012)[63]	141 laypersons, visitors of a trade fair in Italy.	BLS training (10 min) by a software installed on a mobile phone.	Software assisted (training and metronome) and unassisted BLS.	Assisted BLS augmented by a metronome resulted in a higher overall score and a better chest compression rate when compared to BLS without assistance. However, in the assisted group, time to calling the emergency and to starting chest compressions was longer. In both groups, laypersons did not ventilate satisfactorily.
Shin et al. (2014)[64]	36 lay volunteers (South Korea).	Prospective randomized crossover trial on CPR quality and rescuer fatigue.	30:2 CPR and compression-only CPR.	Chest compression rate was higher in 30:2 CPR group. Adequate chest compression was higher among men when compared to women. Volunteers from the compression-only group experienced more fatigue after 8 min than the ones in 30:2 CPR group.

Continued on the next page

TABLE 4 Continued

Reference	Population	Intervention	Comparison	Observations
van Tulder et al. (2014)[65]	32 adults, visitors of a shopping mall (Austria).	Prospective, investigator-blinded setting on 10 min of compression-only CPR on a mannequin.	Compression depth and overall quality of CPR after receiving standard verbal wording on CPR or intensified wording.	Repeating the target depth at every 20s or intensifying instructions significantly worsened compression depth. An increase of 5 mm in compression depth associated with 99% increase in the odds of shock success. Intensified wording and/or repetitive target depth instruction were not more effective than the standard instruction.
González-Salvado et al. (2016)[17]	81 laypeople and 74 health professionals (Spain).	Brief training on early initiation of CPR, hand position, depth of compression, and values according to the guidelines.	Rate, depth of compression, thoracic recoil, hand position, and CPR performance on a mannequin by laypeople and health professionals.	After brief training, laypeople were able to perform good-quality hands-only CPR on a mannequin. Both groups were able to reach a frequency of 100-120/min, but the rate was lower among health professionals. 50% of the participants achieved the recommended compression depth. No significant differences were observed in thoracic recoil. Simple instructions, real-time feedback, and motivation might have been strategic elements of the training.
Plata et al. (2019)[66]	100 laypersons aged 18-65 years old (Germany).	Prospective randomized mannequin trial study.	Quality of 8-min CPR on a mannequin without instructions, with telephone assistance, app support with audiovisual feedback, or with telephone + app support.	Compression rate was more efficient in the app and telephone + app groups. There was no difference regarding compression depth between groups. Hand position and thorax release were better in groups with smartphone app support. The smartphone application alone or combined with dispatcher positively impacted quality of bystander CPR (except for compression depth). Widely available and easy-to-use apps can be a useful tool for laypersons.
Ecker et al. (2020)[67]	144 adult laypersons from Cologne (Germany).	First aid on a mannequin during a simulated cardiac arrest: 1) video-assisted CPR, 2) telephone-assisted CPR, or 3) control (unassisted CPR).	Compression frequency, compression depth, and correct hand position in the 3 groups.	Video-assisted CPR was superior to unassisted CPR and was comparable to telephone-assisted CPR. However, video-assisted CPR led to a significantly better hand position compared with other study groups. Video CPR assistance also resulted in more accurate chest compression depth.
Plata et al. (2021)[68]	150 adult laypersons from Cologne (Germany).	Guidance on mannequin CPR by 1) telephone, 2) telephone + smartphone application, or 3) telephone + additional verbal motivation.	Median compression depth and median compression rate in the 3 groups.	Median compression depth on mannequin was not statistically different among the study groups. Verbal encouragement every 20 s led to a significant increase in median chest compression depth compared to telephone CPR with real-time feedback by a smartphone application.
Lee et al. (2021)[69]	131 adult volunteers from Seoul (South Korea).	6 min of CPR in a mannequin, following audio instructions or video assistance.	Quality of bystander chest compressions performed under 3 different protocols: C-CPR, V-CPR as soon as starting compressions, and V-CPR after 60 chest compressions.	Overall improvement in chest compression quality was observed in the V-CPR groups regardless of transition time. V-CPR could be implemented safely under the current dispatching system by transitioning audio calls to video calls, as the caller performs better quality bystander CPR by receiving real-time feedback from the dispatcher. Local medical directors should consider developing video call protocols and visual feedback into each dispatch center system for high-quality bystander CPR.
Tellier et al. (2022)[70]	33 non-health professional adult volunteers recruited in social networks (France).	Randomized crossover study on 2 different infant resuscitation techniques on a manikin.	2-fingers technique and 2-thumbs encircling hand technique.	2-thumbs encircling hand technique seems to be more effective than 2-fingers technique for infant cardiac arrest when explained by trained emergency responder over the phone. However, lack of release must require attention in the transmission of instructions.

Note. OHCA: out-of-hospital cardiac arrest, CPR: cardiopulmonary resuscitation, BLS: basic life support, EMS: emergency medical service, QoL: quality of life, C-CPR: conventional dispatcher-assisted cardiopulmonary resuscitation, V-CPR: video call-based dispatcher-assisted cardiopulmonary resuscitation, CCC: continuous chest compression, cCPR: conventional 30:2 CPR.

Regarding the use of AED by bystanders, verbally providing them with the location of the closest AED seems to be the most effective method for reducing defibrillation time; it is even better than smartphone geolocation applications.[51] Appropriate AED use may double the survival rate after an OHCA when compared to conventional CPR.[50] However, in simulated situations with high levels of stress, bystanders show high rates of inappropriate handling of the AED.[44]

Training interventions on CPR with AED use must also consider the interference of stress, as besides increasing survival rate, bystander CPR and AED may contribute to avoid intensive care admission and to accelerate hospital discharge after an OHCA.[10] Furthermore, simple and inexpensive interventions (e.g., recorded videos) can also be effective.[45,59,61,67] Studies indicate that laypersons may retain CPR and AED skills for up to 12 months, and in some cases, a 2-h training session is sufficient.[47,48]

In around a quarter of OHCAs, lay rescuers can reach the victim before the emergency medical service.[53] In this way, training laypersons may increase participation in voluntary networks, contributing to an increase in bystander CPR rate.

The greatest difficulties reported in CPR training on manikins are related to ventilation techniques, particularly when CPR is performed by elderly people.[57] To guarantee good-quality CPR, it is essential to promote the use of simple instructions and to provide continuous feedback in real time, as advocated by Baldi et al.[27] and Yeung et al.[28] When remote instructions are needed (e.g., telephone call), real-time verbal encouragement leads to a significant increase in the average depth of chest compressions when compared to feedback provided by mobile applications.[68]

Nonetheless, elements such as compression rate, hand position, and chest release can be trained with the support of smartphone applications.[66] Training strategies may also benefit from the use of a metronome to control the frequency of compressions,[63] corroborating Hafner et al.[29] and Hong et al.[30] The proportion of CPR performed by bystanders is higher in trained groups, which are more likely to perform CPR in cases of OHCA when compared to untrained individuals.[26]

The implementation of mobile technologies in CPR can contribute to improving assistance in the ever-changing world of cardiovascular diseases, leading to more effective interventions via hybrid approaches combining traditional practices with technology.[72]

5. CONCLUSIONS

A large proportion of OHCA is witnessed, and the survival of patients depends on the rapid, safe, and effective action of bystanders. In this context, it is necessary to increase community training in CPR, particularly caregivers and family members of high-risk patients. There is a need to simplify the training protocol for laypeople, especially elderly citizens, focusing on the efficient execution of chest compressions, as the risk of physical injuries caused by CPR is minimal to both victim and bystander.

Oral information provided to bystanders regarding the location of the AED tends to be the most effective method for reducing defibrillation initiation time. Proper AED use approximately doubles the survival rate after OHCA compared to conventional CPR. However, high levels of stress may result in inadequate handling of the AED by bystanders. Audiovisual aids are welcome to assist in such situations.

Mobile applications to locate AEDs and trained laypeople to assist an OHCA are desirable strategies to increase the rate of CPR and enable volunteers to arrive before emergency medical services, thus increasing survival rates after an OHCA.

DECLARATION OF INTERESTS

No conflict of interest.

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KEYWORDS **Out-of-hospital cardiac arrest, Cardiopulmonary resuscitation, Bystander, Survival**