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REVIEW ARTICLE

The effect of standalone audio-visual feedback devices on the quality of chest compressions during laypersons' cardiopulmonary resuscitation training: a systematic review and meta-analysis

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Aims Individual studies that investigated the effect of standalone audio-visual feedback (AVF) devices during laypersons' cardiopulmonary resuscitation (CPR) training have yielded conflicting results. This review aimed to evaluate the effect of standalone AVF devices on the quality of chest compressions during laypersons' CPR training.

Method and result Randomized controlled trials of simulation studies recruiting participants without actual patient CPR experience were included. The intervention evaluated was the quality of chest compressions with standalone AVF devices vs. without AVF devices. Databases, such as PubMed, Cochrane Central, Embase, Cumulative Index to Nursing & Allied Health Literature (CINAHL), Web of Science, and PsycINFO, were searched from January 2010 to January 2022. The risk of bias was assessed using the Cochrane risk of bias tool. A meta-analysis alongside a narrative synthesis was used for examining the effect of standalone AVF devices.

Sixteen studies were selected for this systematic review. A meta-analysis revealed an increased compression depth of 2.22 mm [95% CI (Confidence Interval), 0.88–3.55, $P = 0.001$] when participants performed CPR using the feedback devices. Besides, AVF devices enabled laypersons to deliver compression rates closer to the recommended range of 100–120 per min. No improvement was noted in chest recoil and hand positioning when participants used standalone AVF devices.

Conclusion The quality of the included studies was variable, and different standalone AVF devices were used. Standalone AVF devices were instrumental in guiding laypersons to deliver deeper compressions without compromising the quality of compression rates. However, the devices did not improve the quality of chest recoil and placement of the hands.

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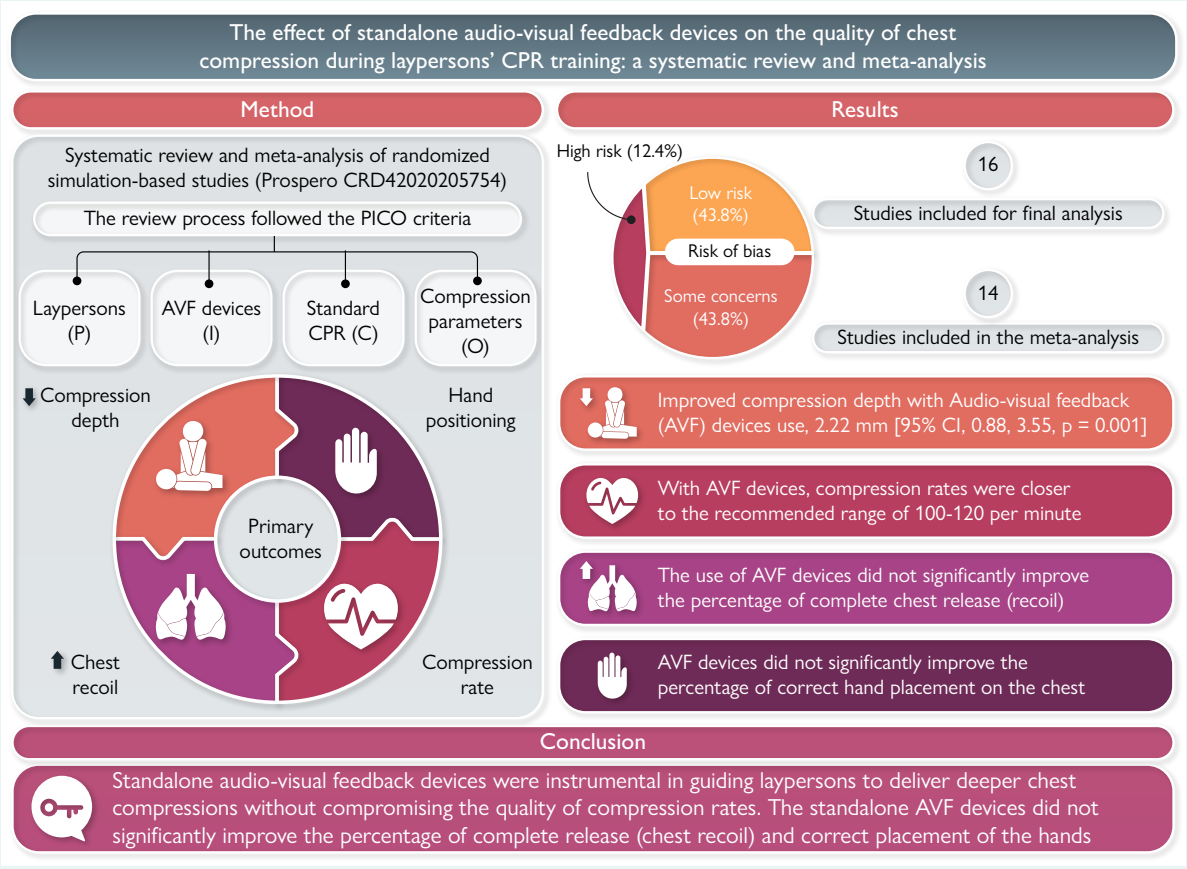
Graphical Abstract



Abbreviations. PICO: *P* = Participants; I = Intervention; C = Comparators; O = Outcomes; CPR = Cardiovascular resuscitation.

Keywords Audio-visual • Laypersons • CPR training • Feedback devices

Novelty

- This systematic review distinctly and solely reported the effect of standalone AVF devices during laypersons' CPR training.
- The systematic review described the effect of standalone real-time feedback devices on the skill retention of laypersons CPR performance.

Introduction

In the developed world, sudden cardiac arrest is a widespread health issue responsible for approximately 50% of cardiovascular deaths and 20% of all other deaths.[1,2] The annual incidence of an out-of-hospital cardiac arrest (OHCA) in Europe is between 67–170 per 100 000 population. Despite the availability of well-defined guidelines and resuscitation options, most cardiac arrests are still fatal.[3] However, patient survival rates vary from region to region. Average survival rates at hospital discharge after OHCA are 8% in Europe[4] and 10.8% in the United States of America (USA).[5]

The current cardiopulmonary resuscitation (CPR) guidelines emphasize an immediate start of providing high-quality CPR to maximize survival and minimize neurological damage.[6,7] A high-quality chest compression (CC) depends on correct hand positioning, a compression depth of 5–6 cm, and a compression rate of 100–120 per min, allowing the chest to recoil entirely between each compression.[7,8] A compression depth of 5–6 cm is directly associated with survival and favourable functional outcomes.[7–9] After adjusting the compression depth, patients were more likely to survive hospital discharge when chest compressions were between 100–120 per min.[10]

It is known that high-quality CPR is critical for patient survival.[9] However, healthcare professionals and laypersons perform suboptimal chest compressions during CPR.[9,11,12] One study revealed that the average compression depth was significantly higher in cardiac arrest survivors (53.6 mm, 95% CI: 50.5–56.7) compared to non-survivors (48.8 mm, 95% CI: 47.6–50.0).[9] CPR providers and healthcare professionals overestimate their CC skills while performing CPR without feedback guidance.[13] One study revealed that 77.2% of participants believed their compression depth was adequate; however, objective measurements revealed that only 39.4% achieved a compression depth between 5 and 6 cm.[13]

Feedback from qualified instructors is considered to be the gold standard for CPR training.[14] However, trainers' ability to accurately

determine participants' skills and competencies might not always be ideal. One way to improve the quality of CPR training is by using real-time monitoring devices with audio-visual feedback (AVF) mechanisms to guide the CC performance.[15] AVF devices evaluate CC parameters, provide real-time feedback, and guide rescuers to adjust their techniques.[16] These devices can be categorized into two groups: integrated and standalone. Integrated AVF devices are incorporated into complex multifunctional medical devices or simulation manikins.[17] On the contrary, standalone AVF devices are placed on the patient's chest or the rescuers' hands during chest compressions; furthermore, they are cheap, easy-to-learn, and portable.[7,12,18]

Recent reviews have reported improved quality of chest compressions by using feedback devices during CPR.[16,19,20] For example, Gugelmin-Almeida et al. and Kirkbright et al. studied the effect of real-time AVF devices during CPR training.[16,20] However, the populations studied in these systematic reviews were healthcare professionals and included both standalone and integrated AVF devices. Similarly, An et al. conducted a systematic review to assess the effectiveness of AVF devices during CPR training.[19] However, this systematic review included both healthcare professionals and laypersons and focused only on smart devices, such as smartphones and smartwatches.[19]

To our knowledge, no systematic reviews have distinctly and exclusively investigated the effect of using standalone AVF devices while training laypersons in CPR. Therefore, this systematic review and meta-analysis aimed to evaluate the effectiveness of standalone AVF devices on the quality of chest compressions during layperson CPR training. We investigated the depth of chest compressions, compression rate, chest recoil, and hand positioning as primary outcomes.

Methods

Eligibility criteria

A study protocol was developed and registered in PROSPERO with the registration number CRD42020205754. The review process followed the predefined sets of PICO criteria. We included studies that recruited participants (P) without experience in actual patients' CPR (laypersons). The intervention (I) was CPR training with standalone AVF devices. The comparison (C) was CPR training without standalone AVF devices. The outcome (O) included at least one of the CC parameters: compression depth, compression rate, chest recoil, and correct hand placement. Our study focused on randomized controlled simulation studies and had no language, country, or setting restrictions.

Exclusion criteria

The exclusion criteria for this study were: (1) studies that included health professionals, (2) studies that included participants whose duty is to save lives (e.g. lifeguards), (3) studies that included students in healthcare and healthcare-related professions with previous actual CPR experience, (4) studies that compared conventional CPR with AVF devices integrated into other bigger devices, such as defibrillators, and (5) studies of randomized clinical trials conducted in patients with cardiac arrest.

Search strategy

Databases, such as PubMed, Cochrane Central, Embase, CINAHL, Web of Science, and PsycINFO (EBSCO), were searched on 31 October 2020 (see Supplementary material online, *Data S1*). Reference lists of the included studies were hand-checked to find other potentially eligible studies. As per the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions, the search was rerun on 15 January 2022 to find relevant studies published after the first search.[21] Therefore, this study included peer-reviewed articles published between January 2010 and January 2022. This time frame was chosen based on the recommendations of 2010 resuscitation guidelines for using AVF devices during CPR training.[22,23] Search strings were created with the assistance of information specialists, and electronic searches were performed by a researcher trained in database searches.

Screening for eligibility

The search results were downloaded into a reference manager-Zotero, where the search duplications were removed. The titles and abstracts were screened by two independent reviewers (D.T.K. and L.P.) in Rayyan QCRI software. Finally, the retrieved full-text articles were screened by the same reviewers using the same criteria in the Rayyan QCRI software.[24] Reviewers resolved the differences after a detailed discussion. Rayyan QCRI is a free web and mobile application that helps researchers collaborate on the title, abstract, and full-text screening process.

Data extraction and risk of bias assessment

Data extraction was performed using the Cochrane extraction template for a randomized trial which was modified to fit our protocol. Authors extracted the following key items from each study: (1) general information, including the title of the article, first author with detailed contacts, year of publication, and aim of the study, (2) method, including the study design, randomization process, and sequence generation, (3) population, including the total number, setting, country, and date of the study, (4) interventions, including the total number of intervention groups and AVF devices used, (5) outcomes, time-points, unit of measurement, upper limits, and lower limits, and (6) main results, including the intervention result, missing participants, sample size, and summary data for each intervention. The quality of the selected studies was assessed using RoB 2.0 for randomized trials.[21] The risk of bias was reported as low with some concern or high. Studies were classified as having a high overall risk of bias if there was a high risk of bias or two concerns in the five domains (D1-D5). Data extraction and quality assessment were done by two independent reviewers (D.T.K and L.P). Disagreement was resolved after a detailed discussion between the two reviewers.

Outcome

The primary outcomes were related to CPR quality parameters, including compression depth, CC rate, chest recoil, and hand positioning on the chest. CPR skill retention and patient satisfaction were included as secondary outcomes.

Data synthesis and meta-analysis

A meta-analysis alongside a narrative synthesis was done for identifying associations within and between studies. Mean differences with 95% confidence intervals were calculated to estimate the effect size of standalone AVF devices on compression depth, compression rate, chest recoil, and hand positioning. RevMan meta-analysis software was used to analyse the data.[25] The Cochrane Review Manager calculator was used for imputing unreported data, such as the mean and standard deviation (SD). As recommended in the Cochrane Handbook for Systematic Reviews of Interventions, the mean was estimated from studies that reported medians for calculating the mean differences.[21] The mean and SD for some outcomes could not be calculated; hence, they were excluded from the meta-analysis.[26,27] Two studies with an overall high risk of bias were also excluded from the meta-analysis.[28,29] Eligible studies excluded from the meta-analysis were included in the narrative synthesis.

Since data from the crossover trials were reported as if they had been generated from a group comparative trial, we analysed them accordingly. We, therefore, assumed that the crossover trial was appropriate and that no critical carryover effect had occurred.[21]

Five studies had a multiple-arms randomized controlled trial design.[26,30–33] In four of them, two groups (one experiment and one control) were relevant to be included in the pairwise comparison of intervention groups.[26,30,32] In one study,[33] participants in the standard CPR group were compared to the other three standalone AVF groups, including the smartphone, CPRmeter, and PocketCPR groups. The three experimental groups were combined into a single group to create a single pairwise comparison as per the recommendation of the Cochrane Handbook for Systematic Reviews of Interventions.[21] To avoid confusion, all intervention arms of a multi-intervention study are mentioned in Supplementary material online, *Table S1*. However, a detailed description of the intervention groups relevant to our review is provided in text, tables, and graphs.

We assumed that the actual underlying effects varied across the studies. Hence, the random effect model was used for meta-analysis.[21] The I^2 test was used for measuring inconsistency across the trails. I^2 readings of 25%, 50%, and 75% corresponded to low, moderate, and high heterogeneity, respectively.[34] Inclusion in the meta-analysis was avoided when the I^2 value was more than 75%. A subgroup analysis was performed to determine if the overall effect of AVF devices varied across the subgroups. We identified three subgroups, including the study design (crossover vs. parallel), risk of bias ('some concern' vs. 'low risk'), and the duration of CPR performance (2 min vs. > 2 min). The risk of publication bias across studies was examined using a graphic funnel plot.

Results

The Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) flow diagram in *Figure 1* depicts the studies' selection process.[35] The literature search initially yielded 1374 articles, of which 353 were duplicates. Of the remaining 1021 articles, 940 were excluded while screening the title and abstract, thus, producing 81 articles for a full review. Finally, 16 studies were included.

Risk of bias assessment within the studies

Figure 2 shows the risk of bias in each domain (D1-D5) and the overall article. The five domains are as follows: risk of bias arising from the randomization process (D1), risk of bias due to deviations from the intended interventions (D2), risk of bias due to missing outcome data (D3), risk of bias in measuring the outcome (D4), and risk of bias in selecting the reported result (D5).[21] The risk of bias was evaluated using the RoB 2.0 randomized controlled trials (2019).[21] The randomization process was first evaluated for possible risk of bias. Four studies (25%) were rated as having 'some concern' for the first domain due to a lack of information on the randomization process.[26,28,30,31] Five studies (31.3%) were rated as 'some concern' for the second domain because researchers did not mention adequate blinding for the intervention.[28,29,36–38] Two studies (12.5%) were rated as 'some concern' in the third domain because data handling from missed participants was not mentioned.[29,39] In the fourth and fifth domains, all studies were rated as having a low risk of bias because the authors did not find biases related to measuring the outcomes (D4) and selecting reported results (D5). In the overall risk assessment, seven studies (43.8%) were classified as 'low risk,'[27,32,33,40–43] seven studies were classified as of 'some concern' (43.8%),[26,30,31,36–39] and two studies (12.5%) were classified as 'high risk'[28,29] (see Supplementary material online, *Figure S1*). Studies were assessed to have an overall 'high risk' of bias if there was one 'high risk' of bias or two 'some concern' in the five domains (D1-D5).

Risk of bias across studies

The heterogeneity of the studies varied based on the outcomes of the evaluated CC parameters. The heterogeneity of the four assessed CC parameters, including the depth, rate, chest recoil, and hand positioning, ranged between I^2 values of 33–88%. The heterogeneity of the subgroup analysed ranged from 43–95%. A funnel plot was drawn to examine heterogeneity associated with publication bias, and no significant asymmetry was found (see Supplementary material online, *Figures S2 and S3*).

Characteristics of the individual studies

Detailed characteristics of the included studies are presented in Supplementary material online, *Table S1*. Most of the studies (82.3%) recruited young university or college students.[27,29,32,33,36–43] Seven (43.7%) studies were conducted in Asia,[28,30,36,37,40,42,43] and nine (56.3%) in Europe.[26,27,29,32,33,38,39,41,43] Five (31.25%) studies recruited ≤ 50 participants,[28,37,40,42,43] other five (31.25%) recruited 50–110 participants,[26,31,32,38,41] and six (37, 5%) studies recruited > 100 participants.[27,29,30,33,36,39] Ten studies[26–28,30–32,36,37,39,40,42] used smart device-based apps with built-in accelerometers, including six smartphones,[26,28,32,33,36,42] two smartwatches,[37,40] and one tablet.[27] Four studies used devices that did not require apps to display feedback, including two TrueCPR,[38,41] one CPRmeter,[29] and one Smart-ring.[43] One multi-arm study used the pocketCPR, the CPRmeter, and a smartphone.[33] A description of the intervention, the primary outcomes, and a summary of the results are presented in Supplementary material online, *Table S2*.

Compression depth

Fourteen studies evaluated compression depth by reporting mean or median in millimetres.[28–33,36–43] Two studies assessed the quality of compression depth by investigating the proportion (%) of adequate depth.[26,27] Studies that reported proportion were excluded from the meta-analysis because the mean and SD could not be extracted for analysis.[26,27]

The meta-analysis for the twelve studies revealed an increase in compression depth of 2.22 mm (95% CI: 0.88–3.55; $P = 0.001$) when participants performed CPR using the standalone AVF devices (*Figure 3*).[30–33,36–43] A subgroup analysis was also done based on the risk of bias (see Supplementary material online, *Figure S4.1*), duration of CPR (see Supplementary material online, *Figure S4.2*), and study design (see Supplementary material online, *Figure S4.3*). Participants in the AVF groups still delivered deeper compressions than those in the control groups. Besides, two of the four studies excluded from the meta-analysis reported a significant improvement in the quality of compression depth when AVF devices were used.[27,29]

Compression rate

All studies included in this review assessed the quality of compression rate.[26–30,32,33,36–38,40–42,44,45] Eight studies reported significant differences in compression rates between the standard CPR and AVF groups.[26,28,30–33,36,39] In five studies that reported significant differences, the AVF groups delivered fewer compressions per minute.[26,30,32,33,36] Three of the eight studies reported significantly fewer compressions per minute when participants delivered CPR without AVF devices.[26,31,36]

Zapletal et al. compared three standalone AVF devices, Zoll PocketCPR, CPRmeter, and smartphone app, to the traditional CPR

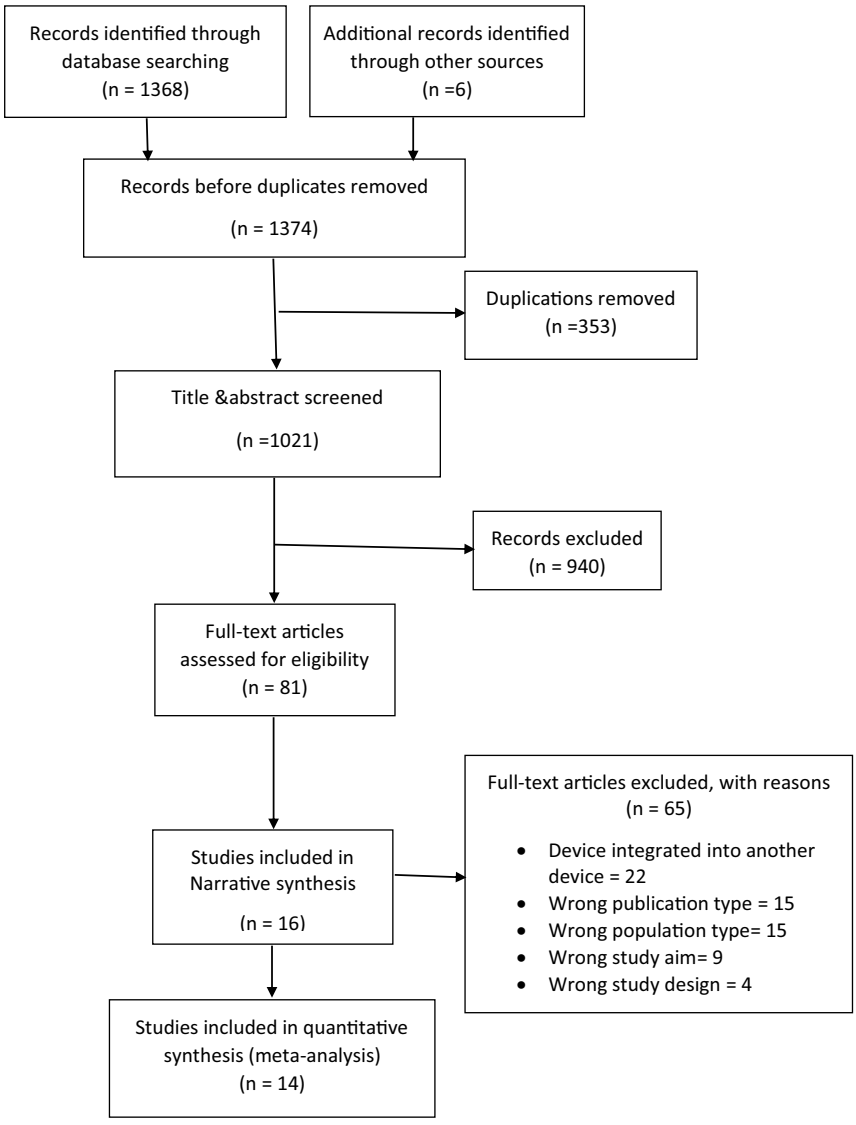


Figure 1 Prisma flow diagram depicting articles selection process.

and each other.[33] Participants in the Zoll PocketCPR and smartphone group delivered fewer compressions per minute than those in the standard CPR group.[33]

A meta-analysis of the compression rate revealed significant heterogeneity ($I^2 = 89\%$) (*Figure 4*), impeding us from running the overall meta-analysis. Studies were analysed in subgroups based on the risk of bias (see Supplementary material online, *Figure S5.1*), duration of CPR (see Supplementary material online, *Figure S5.2*), and study design (see Supplementary material online, *Figure S5.3*). A statistically significant decrease [−3.11 per min (95% CI: −5.34–0.88; $P = 0.006$)] in compression rates was seen in the experiment (AVF) group when participants performed CPR for two min (see Supplementary material online, *Figure S5.2*). The statistically significant decrease might not have clinical relevance because the compression rate stayed within the desired range. No significant difference [−1.91 per min (95% CI: −5.01–1.19; $P = 0.25$)] was reported in the studies with a low risk of bias (see Supplementary material online, *Figure S5.1*).

Quality of chest recoil and hand positioning

Only 12 of the 16 included studies investigated the extent of chest recoil between chest compressions.[26,28,31–33,36–40,42,43] In addition to the two studies with a high risk of bias,[28,29] two other studies were excluded from the meta-analysis because of the inability to calculate the mean and SD.[26,31] Therefore, eight studies were included in the meta-analysis.[32,36–40,42,43] The meta-analysis revealed no significant difference between the AVF devices and standard CPR groups, −0.03% (95% CI: −0.59–0.52; $P = 0.90$) (*Figure 5A*). In general, only two studies reported an improvement in the quality of chest recoil when standalone AVF devices were used during CPR.[26,31]

Six studies evaluated hand positioning on the chest,[26,28,31–33,38] in which two of them reported the proportion of correct hand positioning.[32,38] In two studies, participants in the AVF group had significantly

greater hand positioning accuracy than the standard CPR group.[26,31] Studies included in the meta-analysis showed no significant difference [1.97% (95% CI: −2.58–6.52; $P = 0.40$)] between the AVF and standard CPR groups (*Figure 5B*).

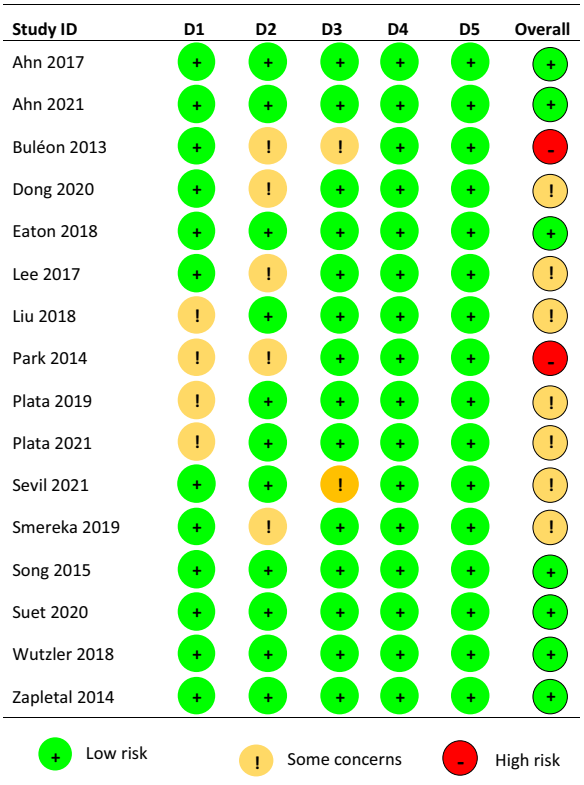


Figure 2 Risk of bias and quality assessment. D1: Randomization process, D2: Deviations from the intended interventions, D3: Missing outcome data, D4: Measurement of the outcome, D5: Selection of the reported result.

Skill retention and participants' satisfaction

Four studies investigated the effect of AVF devices on CPR skill retention (see Supplementary material online, *Table S3*).[32,36,38,39] Smereka et al. and Sevil et al. reported deeper compressions using AVF devices at the second time-point compared with the first time-point.[38,39] Three studies reported a statistically significant difference in compression rates at the second time-point.[36,38,39] Two studies reported an improvement in the percentage of adequate chest recoil when using AVF devices at the second time-point.[32,38] Sevil et al. and Smereka et al. assessed the percentage of correct hand positioning.[38,39] No significant difference was found between the control and the AVF groups at both time-points.[38,39]

In five studies, researchers evaluated participants' satisfaction with the AVF devices.[28,33,38,41,43] They evaluated satisfaction in varieties of ways using different scales. A significant difference was noted in most studies favouring standalone AVF devices.[33,38,41,43]

Discussion

The studies included in this review used standalone AVF devices for CPR training in laypersons only. Thus, unlike most previous reviews, heterogeneity in some of the outcomes was either low or moderate, allowing us to combine them for a meta-analysis. Contrastingly, most previous systematic reviews included studies using standalone and integrated AVF devices for evaluating CC performance during laypersons' and health professionals' CPR training.[16,18–20] Hence, the outcomes were complex, and heterogeneity was too high to combine results for a meta-analysis.[16,18–20]

The studies included in this review were also of variable quality and used different statistical methods. In the assessment of methodological rigour, seven studies were rated as 'some concern' (43.8%),[26,30,31,36–39] and two (12.5%) were rated as 'high risk'.[28, 29] The main reason for the reported risk of bias was a possible deviation from the intended interventions. Using the AVF device in the experiment group made it challenging to ensure that the participants and researchers were double-blinded.

Most studies reported significant improvement in one or more of the evaluated CC parameters when standalone AVF devices were used during CPR training.[26–29,31,32,36–39,42,43] The improvement was not

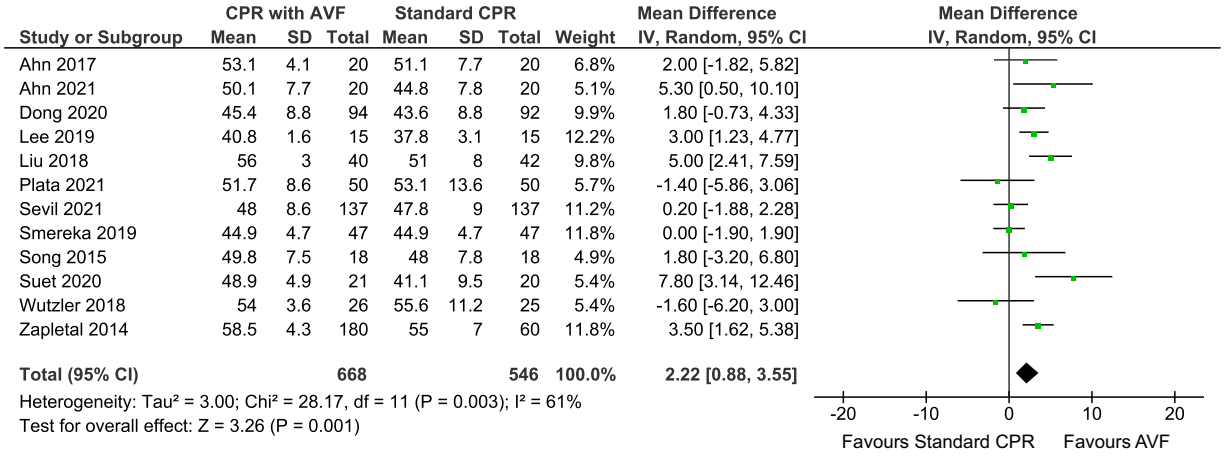


Figure 3 Forest plot showing compression depth (mm) of the AVF and the standard CPR groups.

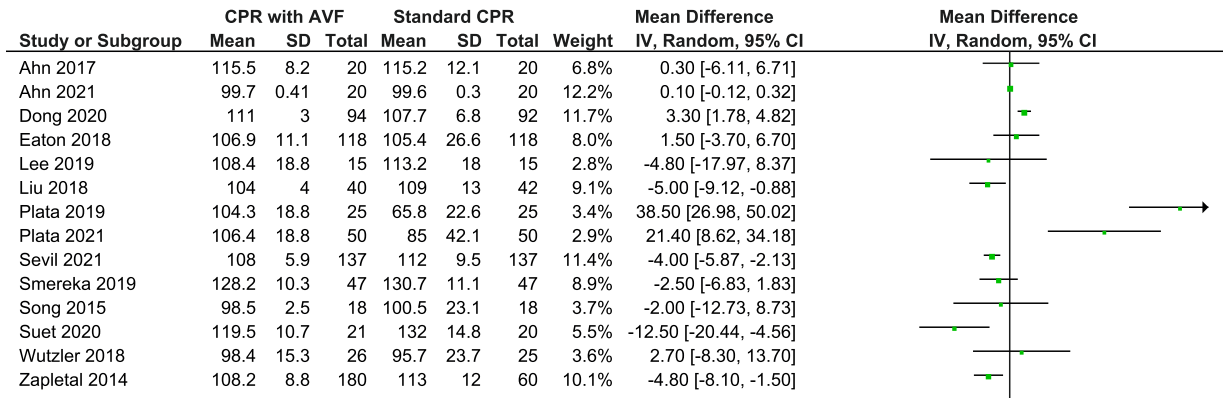


Figure 4 Forest plot showing compression per minute (rate) for the AVF and the standard CPR groups.

linear for all the CC parameters. However, we have sufficient evidence that standalone AVF devices help laypersons to deliver deeper compressions without compromising the quality of other compression parameters. Our findings correlate with previous systematic reviews documenting the improvement in the quality of compression depth by using AVF devices at a compression rate closer to the CPR guideline recommendations.[16,19,20,46] However, in contrast to the current review, most previous reviews included standalone and integrated AVF devices. Furthermore, the participants included in the previous reviews were either health professionals or a combination of laypersons and health professionals.

Despite using standalone AVF devices, in over half of the studies, participants did not achieve the recommended minimum compression depth of 50 mm.[28,29,32,36–39,42] An et al. conducted a systematic literature review to assess the effect of smart devices, such as smartphones and smartwatches, during laypersons' and health professionals' CPR training.[19] Only one study reported significant improvement when using AVF devices leading to sufficient compression depth.[19]

The current CPR guidelines recommend changing rescuers every two min to avoid excessive fatigue.[6,7] However, rescuer fatigue can occur even within the first two min, resulting in lower CC quality.[47,48] Our findings in the subgroup analyses indicated that compression depth was significantly higher when the AVF devices were used within the first two min. The improvement in compression quality when using the AVF devices decreased to an insignificant level when uninterrupted compressions lasted longer than two min. Thus, CPR staff fatigue seems to increase over time and reach a level where AVF devices are no longer helpful. Therefore, nurses and other CPR educators in community and healthcare settings must remember that AVF devices are only a small part of successful resuscitation.

The standalone AVF devices allowed laypersons to perform chest compressions at rates closer to the recommended rate of 100–120 per min. Eight of the 16 studies reported statistically significant differences between the AVF and standard CPR groups. In most studies, where a significant difference was found, participants in the AVF group performed fewer compressions in one min. However, compression rates remained within the recommended range of 100–120 per min.[26,28,30–33,36,39] Contrastingly, three studies reported significantly fewer compressions in one min when participants delivered CPR without the AVF devices,[26,31,36] and in three of them, the compression rate was below the recommended range of 100–120 per min.

Subgroup meta-analysis also revealed a slight decrease in compression rates in the AVF group when participants performed CPR for two min.[27,30–32,37–42] This result was consistent with previous reviews that reported improved compression quality when AVF devices were used during CPR training.[16,20] Consistent with our finding, a meta-analysis by Kirkbright et al. reported a significant decrease in compression rate when participants used AVF devices.[20] Our finding suggests that rescuers could adjust the compression rate to the recommended range of 100–120 per min quicker than they were able to adjust compression depth.[49] As previously reported,[11,50] lower compression rates when using AVF devices might have helped laypersons perform deeper chest compressions. Agostinucci et al. reported a significant decrease in compression depth ratio with an increase in compression rate.[11] Similarly, Bae et al. reported compression depths of 55, 53, and 51 mm at compression rates of 100, 120, and 140 per min, respectively, showing an inverse relationship between compression depth and rate.[50]

Another important CC parameter that correlates with a higher survival rate is complete chest recoil between compressions.[51] Incomplete chest recoil due to excessive leaning impairs cardiac filling,[52] resulting in decreased cardiac output. The overall findings of this review indicated that the usage of standalone AVF devices was not superior to standard CPR in achieving complete chest recoil.[28,32,33,36–43] In one study,[33] participants in the PocketCPR group had a higher proportion of incorrect chest recoil than those in the CPRmeter group. Unlike the CPRmeter (pressure sensor), the PocketCPR uses an accelerometer that might not detect leaning during CPR. The innovation of standalone AVF devices that combine pressure sensors and accelerometers in a single device could positively impact the quality of chest compressions. In contrast to our result, Gugelmin-Almeida et al. noted a significant improvement in the percentage of chest recoil when AVF devices were used.[16] The difference in results was probably due to different study populations. In the review by Gugelmin-Almeida et al., all studies that reported significant improvement recruited CPR-trained emergency care nurses and physicians.[16]

The standalone AVF devices did not help reduce the risk of incorrect hand placement during laypersons' CPR training, probably, because the currently available standalone AVF devices do not provide real-time feedback on correct hand positioning.[33] Innovative medical devices that precisely locate hand positioning on the chest could help improve the quality of chest compressions. A study that compared the percentage of incorrect hand positions between the three standalone AVF devices reported a significant difference.[33] Participants in the PocketCPR and smartphone groups had a higher percentage of incorrect pressure points than those in the CPRmeter group,[33] because it was possible to fix the CPRmeter at the chosen site using an adhesive band supplied by the manufacturers.[33]

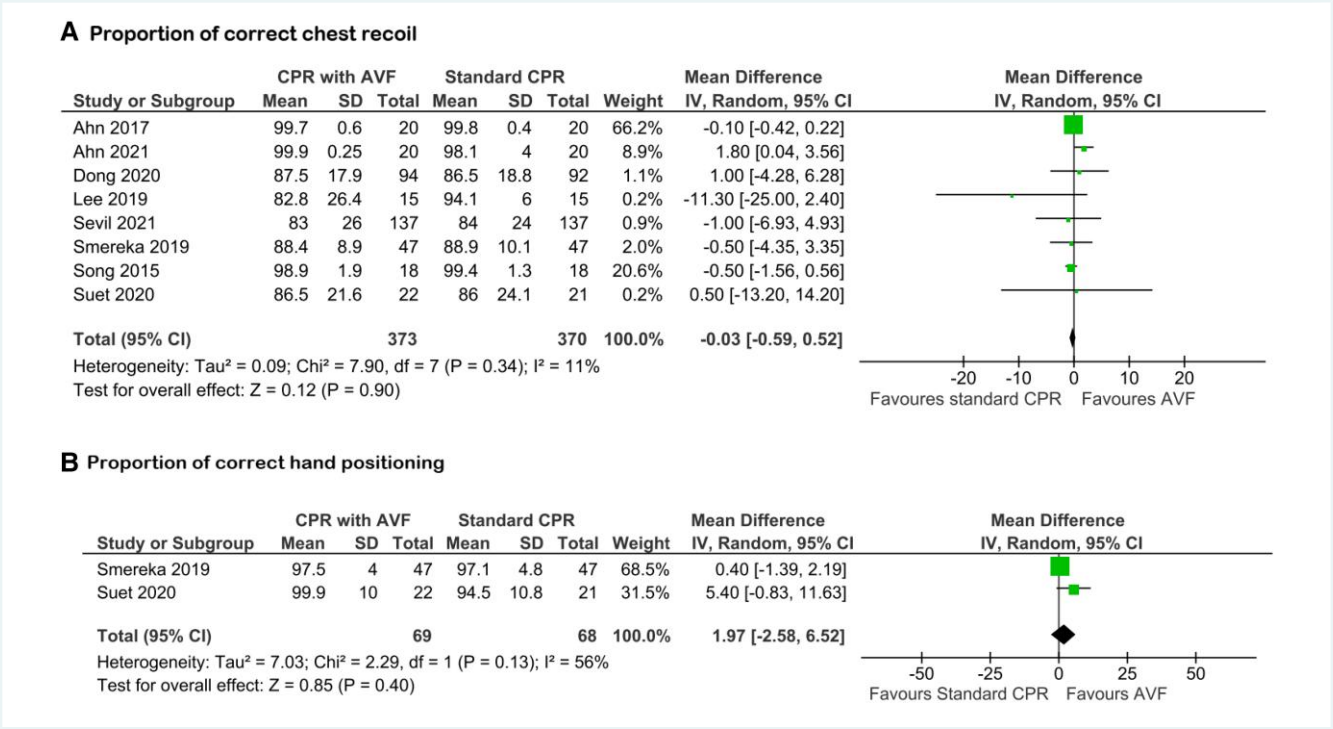


Figure 5 Forest plot showing the proportion of adequate chest recoil (*A*) and the proportion of correct hand positioning (*B*) of selected articles.

In most studies, using standalone AVF devices during CPR improved the retention of at least one CC parameter.[32,38,39] Our finding is compatible with the systematic reviews conducted by Gugelmin-Almeida et al., Kirkibright et al., and Yeung et al., which demonstrated the benefit of using AVF devices to improve CPR skill retention.[16,20,46] Three studies reported significant differences in compression rates.[36,38,39] These differences appeared to be clinically insignificant because, in most cases, both groups delivered chest compressions within the recommended interval of 100–120 per min. However, Smereka et al. documented significantly faster compressions in the AVF group at the first time-point, higher than the current recommendations, which were corrected at the second time-point.[38]

In two studies,[32,38] chest recoil decreased at the second time-point in both groups. However, the decrease was smaller in the experimental group. This finding suggests that training CPR using standalone AVF devices might help participants retain their chest recoil skills to perform better in the future. In contrast to the three studies that assessed CPR skill retention after three months,[32,36,39] Smereka et al. evaluated it after one month, and found a significant improvement in skill retention using AVF devices in all assessed parameters, except hand positioning.[38] This finding implies that the retention of chest CPR skills is better when refresher courses are given at shorter intervals using standalone AVF devices.

In general, studies reported better satisfaction and performance when participants used standalone AVF devices.[33,38,41] Using AVF devices to objectively measure the quality of CPR was very satisfying for participants. Previous studies demonstrated that manikin-guided feedback was more effective than standard instructor-based feedback during CPR training of healthcare professionals.[53,54] High-quality chest compressions depend on specific compression parameters with a precise range of measurements,[7] making it difficult for instructors to identify inappropriate compression depth, rate, and recoil. Hence, an instructor-based assessment might not be as efficient as an AVF device-based quality assessment during CPR training.[54] It could also save energy because the participants did not have to count simultaneously. Furthermore, they could focus on monitoring the quality of their delivered compressions. The feedback from the AVF device could also be empowering if the participants felt that they are doing it correctly.

However, in a study by Park, participants negatively commented on hand and back pain, unstable posture, and wrong compression location while using the smartphone as a real-time feedback device.[28] Discomfort and difficulty holding the device in place while performing the chest compressions were the other disadvantages.[19,28] Standalone AVF devices should be comfortable and user-friendly to influence compression quality positively. Furthermore, wearable devices that do not need to be placed on the chest or held in hand could have a significant advantage over currently used standalone AVF devices.

Analysing the effect of AVF devices on actual patient CPR was not the topic of this review. Nevertheless, recent systematic reviews have reported conflicting results.[55–57] Miller et al. conducted a meta-analysis to evaluate the effect of standalone AVF devices in cardiac arrest patients. They reported an improvement in return of spontaneous circulation and survival to hospital discharge.[57] Similarly, Wang et al. concluded that standalone AVF devices improved patient outcomes better than defibrillator-associated AVF devices.[55] Lyngby et al. found no improvements in return of spontaneous circulation and survival to hospital discharge when defibrillator-based AVF devices were used during CPR.[56] To verify the advantage of standalone AVF devices in actual patient resuscitation, high-quality research with a longitudinal approach is needed.

This systematic review has some limitations. The authors of the included studies used different analysis methods for calculating the CC outcomes. Some studies used the mean, while others used the median as a measure of central tendency. The mean was estimated from studies that reported medians as recommended by the Cochrane Handbook for Systematic Reviews of Interventions.[21] The method developed by McGrath et al. was used for estimating the mean value from studies reporting the median.[58] The technique developed by McGrath et al.[58]

could overcome the limitations of the previously used methods in estimating the mean and SD in skewed data.[55,59] Readers should still consider these limitations when interpreting the calculated statistical values in the meta-analysis.

The study participants of the included studies were predominantly young university students in health sciences.[29,32,33,36–38,40–42] This profile differed from the rescuers who would most likely witness and begin CPR in the community in two ways: (1) They were expected to understand the cardiac arrest and CPR concepts better. (2) They were younger and in good health compared to most rescuers in communities who are older mothers, fathers, or spouses with possible coexisting diseases, in most cases. Consequently, the findings of this review might not reflect the CPR training and performance of laypersons in the general population.

Our findings were discussed as per the current American Hear Association (AHA) and European Resuscitation Council (ERC) guidelines.[6,7] However, in some of the included studies, compression quality was evaluated according to the 2005,[29] 2010,[28,33,42] and 2015[26,27,30,32,36–41,43,45] CPR guidelines. Therefore, the conclusion of this review should be appreciated and inferred in the context that the reference values of the compression depth and rate were not the same in all included studies.

Finally, resources from grey literature, conference abstracts, opinion pieces, and letters to the editor were not included in this study. Additionally, only randomized trials were considered in the review. Therefore, our conclusion did not consider possible relevant reports from the above-mentioned sources and research designs.

Implications for nursing and other health professionals

First, the current CPR guidelines recommend using AVF devices for improving the quality of chest compressions during CPR training.[14,15] However, most AVF devices are integrated with more complex defibrillators and simulation manikins. Hence, they are not available in smaller healthcare institutions and the community. Therefore, nurses and other CPR trainers may consider using these portable and easy-to-use standalone AVF devices to train laypersons and inexperienced healthcare professionals where integrated AVF devices and the skills required to operate them are not readily available.

Second, integrated AVF devices are too expensive for many developing countries, even in tertiary referral hospitals and higher education institutions. Hence, to improve the quality of CPR training, nursing educators from developing countries and institutions with limited resources could consider using standalone AVF devices, which are much cheaper and as effective as integrated AVF devices.

Third, CC depth is probably the most critical component of CC for improved patient survival. Unfortunately, evidence indicated that rescuers did not compress the chest deeply enough despite using AVF devices. Therefore, nurses and other healthcare professionals should consider this limitation while training rescuers in CPR using standalone AVF devices.

Fourth, subgroup analysis on the duration of compression indicated that CPR fatigue increased over time and reached a level where AVF devices were no longer superior to the standard CPR. Therefore, nurses and other CPR educators should remember that AVF devices are only a small part of successful resuscitation, and they cannot replace the need for frequent rotation of rescuers during CPR.

Conclusion

The diverse nature of the devices used in the included studies and the dissimilarity of the methodology used for analysing the data impeded us from establishing precise recommendations on the usage of AVF devices for training adult laypersons in CPR. However, there was supportive evidence that AVF devices used during laypersons' CPR training improved the quality of at least one of the evaluated CC parameters. Using real-time AVF devices during laypersons' CPR training shows a clear advantage in delivering quality CPR in terms of compression depth without compromising other compression parameters. Standalone AVF devices enabled laypersons to deliver CC closer to the recommended range of 100–120 per min. Participants' satisfaction and confidence in CPR were higher when standalone AVF devices were used during CPR training.

Supplementary material

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Data availability

The authors confirm that most of the data supporting the findings of this study are available within the article and its supplementary material. However, more data supporting this study's findings are available on request from the corresponding author.

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