# THE USE OF AUTOMATED REAL-TIME FEEDBACK DEVICES TO IMPROVE QUALITY DURING CPR TRAINING AND REAL CPR PERFORMANCE: A SYSTEMATIC REVIEW

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## Abstract

High quality cardiopulmonary resuscitation (CPR) is imperative to improve patient outcome after a cardiac arrest. However, it has been demonstrated that CPR quality is normally of suboptimal quality in both real-life resuscitation attempts or simulated training. Automated real-time feedback (ARTF) devices have been considered a potential tool to improve the quality of CPR and maximise retention of the skills. Although previous studies have supported the usefulness of such devices during training, others have conflicting conclusions with regards to its efficacy during real-life CPR. This systematic review of the literature aims to assess the effectiveness of ARTF for improving CPR performance during simulated training and real-life resuscitation in the adult and paediatric population.

Following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [1], articles published between January 2010 and November 2019 were searched from 7 electronic databases (SCIELO, LILACS, BVS, PubMed, Web of Science, Embase, Cochrane, Cinahl, Google Scholar) and reviewed according to the pre-defined eligibility criteria. CPR performance quality was assessed based on guideline compliance for chest compression rate, chest compression depth and complete chest recoil.

871 studies were found, and 32 studies met inclusion criteria. 14 randomised controlled trials (RCTs), 08 randomised trials (RTs) and 10 randomised cross-over trials (RCOTs). Each study used ARTF devices during CPR training or real CPR to analyse the performance of healthcare professionals for paediatric or adult population. According to the studies, the use of ARTF devices enhances CPR performance in terms of achieving the recommended chest compression rate, depth and recoil.

Based on the results of the studies analysed in this review, the use of ARTF can significantly help improve CPR performance during training of healthcare professionals. Further research is needed to reach the same conclusion for real-life CPR.

**Keywords**: CPR quality, CPR training, automated real-time feedback.

## 1 INTRODUCTION

Cardiac arrest is a sudden cessation of cardiac activity and circulation due to an electrical malfunction of the heart. The occurrence and survival rates vary extensively around the world with an estimate of 400,000 cases per year in the US and 300,000 occurrences in Europe [2,3]. Survival to hospital discharge rates range between 2% and 18%, making cardiac arrest a worldwide health challenge with high rates of morbidity, mortality and associated costs [4,5].

Appropriate cardiopulmonary resuscitation (CPR) is imperative to the perfusion of vital organs during a cardiac arrest, improving patient outcome. This is achieved by reaching the following metrics, established by current resuscitation guidelines: (i) chest compression rate between 100-120cpm (compressions per minute); (ii) chest compression depth of 4cm for infants, 5cm for children and 5-6cm for adults, (iii) release of pressure on the chest after each compression, (iv) minimising interruption, and (v) rescue breaths between each cycle of chest compressions [6-9]. However, it has been demonstrated that CPR quality is normally of suboptimal quality in both real-life resuscitation attempts or simulated training, having a negative impact on survival and/or patient neurological outcome [5,10,11].

Automated real-time feedback (ARTF) devices have been considered a potential tool to improve the quality of CPR and maximise retention of the skills. A number of ARTF devices have been developed to assist during CPR training and real-life resuscitation. The devices range from metronome only to audio-visual feedback and are based on quality data collected and measured during performance. The data is processed according to resuscitation guidelines and result in visual information or voice messages. The devices provide feedback in real-time and inform the rescuer whether the CPR being delivered is effective [12,13].

Although previous studies have supported the usefulness of such devices during training, others have conflicting conclusions with regards to its efficacy during real-life CPR [14-17]. This systematic review of the literature aims to assess the effectiveness of ARTF for improving CPR performance during simulated training and real-life resuscitation in the adult and paediatric population.

# 2 METHODOLOGY

This review was conducted following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.

## 2.1 Eligibility criteria

Inclusion criteria: articles published between January 2010 and November 2019 in adult and paediatric CPR training, and adult and paediatric real-life CPR.

Exclusion criteria: animal studies, observational studies, smart devices.

## 2.2 PICOS strategy

We used PICOS (participants, intervention, comparison, outcomes, and study design) framework to identify potential studies that could fit our eligibility criteria.

P – healthcare providers

I – use of ARTF during CPR training and real-life CPR (adult and paediatric population)

C – no ARTF during CPR training and real-life CPR

O – quality of CPR based on chest compression rate, depth and recoil compliant with guidelines from the European Resuscitation Council (ERC) [6,7], American Heart Association (AHA) [8,9] and International Liaison Committee on Resuscitation (ILCOR) [6,7].

S - interventional studies including randomised controlled trials (RCTs), randomised trials (RTs) and randomised cross-over trials (RCOTs)

## 2.3 Search strategy and appraisal

A comprehensive search of the published and unpublished literature was performed with the use of 8 electronic databases: SCIELO; LILACS; BVS; PubMed; Web of Science; Embase; Cochrane and Cinahl. Titles and abstracts from each source were reviewed by 3 researchers independently (DA, TP, LT) according to our predefined eligibility criteria.

Initial sources that met eligibility criteria via title and abstract were subsequently analysed by the researchers. We searched for all interventional studies, including randomized trials assessing the use of ARTF during CPR training and real-life CPR (adult and paediatric population) in which chest compression rate, chest compression depth and/or chest recoil were an explicit outcome.

In order to facilitate the record and analysis of eligible sources, each study was added to a spreadsheet according to the following: title, author, year of publication, country, type of study, number of participants, intervention, outcomes and results.

PRISMA statement was followed to create a four-phase flow diagram.

# 3 RESULTS

After the initial search, a total of 871 studies were found. 6 additional records were identified through other sources. Following removal of 196 duplicates, 681 sources were screened via titles and abstracts, resulting in 201 possible relevant studies. Upon full text analysis, 32 studies met inclusion criteria and were included in our review including 14 randomised controlled trials (RCTs) [14,17,18,20,23,24,29,32,33,38,40,42,44,45], 08 randomised trials (RTs) [25-28,31,36,37,41] and 10 randomised cross-over trials (RCOTs) [15,16,19,21,22,30,34,35,39,46]. The flow chart of the search and selection process is presented in Fig. 1.

Each study used ARTF devices during CPR training or real CPR to analyse the performance of healthcare professionals for paediatric or adult population.

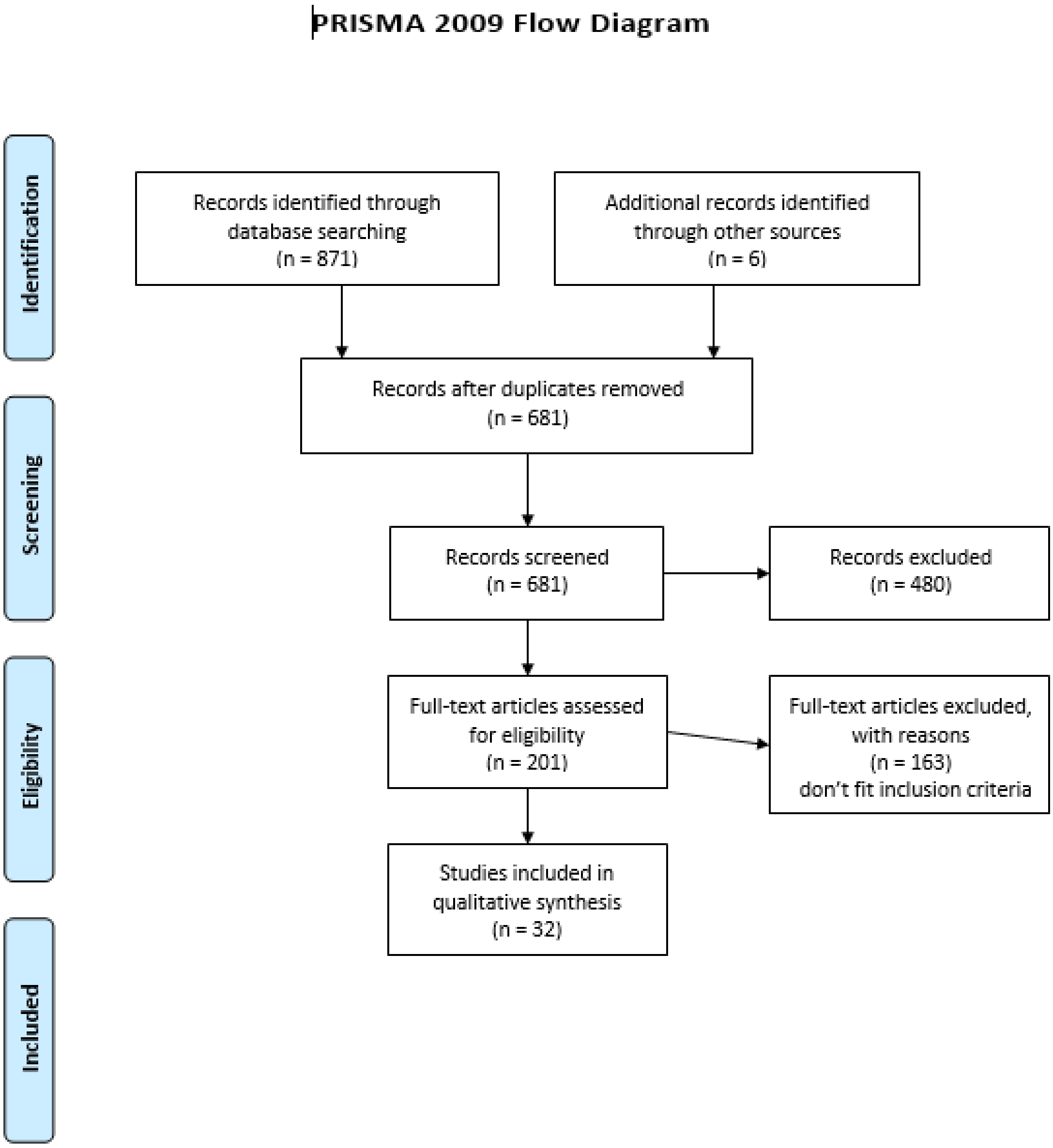


*Fig.1. PRISMA diagram (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)*

## 3.1 Analysis of individual studies

Due to the different elements included in this systematic review, the researchers classified the studies into three distinct groups: (1) the use of ARTF during paediatric CPR training, (2) the use of ARTF during adult CPR training and (3) the use of ARTF during real adult CPR performance, as demonstrated in Tables 1, 2 and 3. The researchers have not found any study about the use of ARTF during real paediatric CPR performance.

*Table 1. The use of ARTF during paediatric CPR training*

| *Author* | *Year* | *Country* | *Type* | *Intervention* | *Outcomes* |
|---|---|---|---|---|---|
| *Austin et al.* | *2017* | *USA* | *RCT* | *simulated paediatric CPR: metronome X visual X none* | *rate, depth, recoil* |
| *Calvete et al.* | *2017* | *Spain* | *RT* | *ARTF visual X none during simulated paediatric CPR* | *rate, depth recoil* |
| *Cheng et al.* | *2015* | *Canada, USA, UK* | *RCT* | *ARTF visual X none during simulated paediatric CPR and ARTF X none during training before simulated CPR* | *rate, depth* |
| *Gregson et al.* | *2016* | *UK* | *RCOT* | *CPR with and without ARTF* | *rate* |
| *Kandasamy et al.* | *2018* | *UK* | *RCT* | *ARTF X none during simulated infant CPR* | *rate, depth, recoil* |
| *Lin et al.* | *2018* | *Canada* | *RCT* | *distributed training + ARTF X normal training with no ARTF for paediatric CPR* | *rate, depth, recoil* |
| *Martin et al.* | *2013* | *UK* | *RCT* | *ARTF X none during simulated infant CPR* | *rate, depth recoil* |
| Sutton et al. | *2011* | *EUA* | *RT* | *instructor-only X ARTF only X instructor combined with ARTF during simulated infant CPR* | *rate, depth,* |

*Table 2. The use of ARTF during adult CPR training*

| *Author* | *Year* | *Country* | *Type* | *Intervention* | *Outcomes* |
|---|---|---|---|---|---|
| *Aguilar et al.* | *2018* | *USA* | *RT* | *ARTF X none during simulated adult CPR* | *rate* |
| *Allan et al.* | *2013* | *Canada* | *RT* | *previous training X CPR with/without ARTF* | *depth* |
| *Buleón et al.* | *2016* | *France* | *RCOT* | *ARTF X none during simulated adult CPR* | *rate* |
| *Cheng et al.* | *2015* | *Canada, USA, UK* | *RCT* | *ARTF training before simulated CPR X ARTF during simulated CPR* | *rate, depth* |
| *Havel et al.* | *2010* | *Austria* | *RCOT* | *standard manual CPR X CPR with ARTF* | *rate, depth* |

| | | | | | |
|---|---|---|---|---|---|
| *Heard et al.* | *2019* | *USA* | *RCT* | *standard manual CPR X CPR with ARTF X video based* | *rate, depth* |
| *Iskrzycki et al.* | *2018* | *Poland* | *RCOT* | *ARTF X none during simulated adult CPR* | *rate, depth, recoil* |
| *Kornegay et al.* | *2018* | *USA* | *RCT* | *ARTF X none during simulated adult CPR* | *rate, depth* |
| *Kurowski et al.* | *2015* | *Poland* | *RT* | ARTF *(2 different) during simulated adult CPR* | *rate, depth* |
| *Lee et al.* | *2015* | *USA* | *RCOT* | *ARTF X none during simulated adult CPR* | *rate, depth* |
| *Lin et al.** | *2018* | *Canada* | *RCT* | *distributed training + ARTF X normal training with no ARTF for adult CPR* | *rate, depth, recoil* |
| *Lu et al.* | *2019* | *China* | *RCT* | *ARTF X none during simulated adult CPR* | *rate, depth* |
| *Pavo et al.* | *2016* | *Austria* | *RCT* | *standard BLS (no feedback) X ARTF X instructor only feedback* | *depth* |
| *Segal et al.* | *2011* | *France* | *RCOT* | *metronome based X ARTF for CPR on floor and dentist chair* | *depth* |
| *Skorning et al.* | *2010* | *Germany* | *RCOT* | *ARTF X none during simulated adult CPR* | *rate, depth* |
| *Skorning et al.* | *2011* | *Germany* | *RCOT* | *ARTF X none during simulated adult CPR* | *rate, depth* |
| *Tanaka et al.* | *2017* | *USA* | *RCOT* | *previous training X ARTF with/without football shoulder pads* | *rate, depth* |
| *Tanaka et al.* | *2019* | *Japan* | *RCT* | *standard CPR training X CPR training with ARTF* | *rate, depth, recoil* |
| *Truszewskli et al.* | *2016* | *Poland* | *RCOT* | *ARTF (3 different) X none during simulated adult CPR* | *rate, depth, recoil* |
| *Wang et al.* | *2018* | *China* | *RCT* | *ARTF X none during simulated adult CPR standing and kneeling* | *rate, depth* |
| *Wutzler et al.* | *2015* | *Germany* | *RT* | *ARTF X none during simulated adult CPR* | *rate, depth* |
| *Yeung et al.* | *2014* | *UK* | *RCT* | *ARTF (3 different) X none during simulated adult CPR* | *rate, depth* |

** Lin et al. 2018 – compared adult and paediatric CPR training and was included in both tables*

*Table 3. The use of ARTF during real adult CPR performance*

| Author | Year | Country | Type | Intervention | Outcomes |
|---|---|---|---|---|---|
| Bohn et al. | 2011 | Germany | RT | ARTF (audio) and ARTF (visual) on real adult CPR | rate, depth |
| Hostler et al. | 2011 | Canada, USA | RT | ARTF (audio) and ARTF (visual) on real adult CPR | depth, recoil |
| Vahedian-Azimi et al. | 2016 | IRAN | RCT | standard manual CPR or CPR with ARTF | rate |

### 3.1.1 Discussion

ARTF devices have been developed to improve the quality of CPR performance during resuscitation attempts or to improve acquisition and retention of CPR skills during training. However, there are a great variety of ARTF devices available and the differences between them result in dissimilar outcomes [12,15,22,24]. Some feedback devices offer information about performance, so that rescuers can make real time adjustments to their CPR attempt [38]. Others, such as metronomes, only provide prompts for the rescuer to perform chest compressions at a predetermined measurement, rate for example, but cannot assess the quality of the performance [24,45].

The use of ARTF devices has been examined in each study included in this review and it has been demonstrated that all feedback and/or prompt devices may not have the same impact on performance. Generally, CPR training utilising ARTF results in improved acquisition of CPR skills, longer retention and subsequent enhanced performance when compared to baseline or control groups [16-19,20,23,32,39,44,45]. Metrics such as chest compression rate, chest compression depth, recoil, hand-off time, fatigue reduction and general quality of CPR, significantly improved as a result of the use of ARTF during training in those studies. Conversely, few studies have demonstrated mixed effects with some results showing only modest improvements in CPR skill acquisition but not clinically significant to be considered true change [14,33,46] or no improvement at all [21] and others finding improved CPR measures with the use of ARTF but those results being no better or no worse than those associated with feedback from a trained human instructor [42].

Although the effect of ARTF during CPR training has mostly positive results regarding skill acquisition, retention and simulated performance, the impact of this improvement on clinical outcomes is less clear. Most studies could not demonstrate significant improvement in cardiac arrest survival associated with the use of a feedback device during real CPR performance in comparison to a standard resuscitation attempt [28,36]. Nevertheless, the study published by Vahedian-Azimi et al. (2016) established an improved adherence to current CPR guidelines and CPR quality, as well as increased rates of return of spontaneous circulation and a decrease in rib fractures [29].

Whilst it may be intuitive to assume that the use of ARTF will lead to improvements in cardiac arrest outcomes, none of the studies conducted to date provide definitive evidence of improved survival. However, because ARTF devices appear to enhance CPR quality during training and simulated management of cardiac arrest, the 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care recommends the use of feedback devices as an adjunct to CPR training [43].

## 4 CONCLUSIONS

This review provides good evidence supporting the use of ARTF devices during CPR training in both adult and paediatric population as a strategy to improve CPR skill acquisition and retention, and reducing fatigue during performance, which increases the chance of a successful outcome when CPR is performed. The evidence may also suggest that the use of ARTF devices in clinical practice, as part of an overall strategy to improve the quality of CPR, could likewise be beneficial. Further studies are required to assess if the improvements in quality of CPR related to the use of ARTF devices translate into real life cardiac arrest outcomes.

## 5 REFERENCES


[1] D. Moher, A. Liberati, J. Tetzlaff and D.G. Altman, “Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement”, *PLoS Med,* vol. 6, no. 7, pp. e1000097.

[2] A.S Go, D.Mozaffarian, V.L. Roger, et al., “Heart disease and stroke statistics—2014 update: a report from the American Heart Association”, *Circulation*, vol. 129, no. 3, pp. e28-292, 2014.

[3] C. Atwood, M.S. Eisenberg, J. Herlitz, et al., “ Incidence of EMS-treated out-of-hospital cardiac arrest in Europe”, *Resuscitation*, vol. 67, no. 1, pp. 75-80, 2005.

[4] C.X. Wong, A. Brown, D.H. Lau, et al., "Epidemiology of Sudden Cardiac Death: Global and Regional Perspectives", *Heart Lung Circ,* vol. 28, no. 1, pp. 6-14, 2019.

[5] J.P. Nolan, R.A. Berg, C.W. Callaway, et al., “The present and future of cardiac arrest care: international experts reach out to caregivers and healthcare authorities”, *Intensive Care Med,* vol. 44, no. 6, pp. 823-832, 2018.

[6] I. Maconochie, A. de Caen, R. Aickin, et al., “Part 6: Pediatric Basic Life Support and Pediatric Advanced Life Support: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations”, *Resuscitation*, vol. 95, pp. 147-170, 2015.

[7] G.D. Perkins, A.H. Travers, J. Considine, et al., “Part 3: Adult basic life support and automated external defibrillation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations”, *Resuscitation*, vol. 95, pp. 43-70, 2015

[8] D. Atkins, S. Berger, J. Duff, et al., “Part 11: Pediatric Basic Life Support and Cardiopulmonary Resuscitation Quality - 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care”, *Circulation,* vol. 132, no. 18, pp. 519-525.

[9] M. Kleinman, E. Brennan, Z. Goldberger, et al., “Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality - 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care”, *Circulation,* vol. 132, no. 18, pp. 414-435.

[10] D.E. Niles, J. Duval-Arnould, S. Skellett et al., “Characterization of Pediatric In-Hospital Cardiopulmonary Resuscitation Quality Metrics Across an International Resuscitation Collaborative”, *Pediatr Crit Care Med*, vol. 19, no. 5, pp. 421-432, 2018.

[11] S.K. Wallace, B.S. Abella, L.B. Becker, “ Quantifying the Effect of Cardiopulmonary Resuscitation Quality on Cardiac Arrest Outcome: A Systematic Review and Meta-Analysis”, *Circulation,* vol. 6, no. 2, pp. 148-156, 2013.

[12] A. Hirakawa, T. Hatakeyama, D. Kobayashi et al., “Real-time feedback, debriefing, and retraining system of cardiopulmonary resuscitation for out-of-hospital cardiac arrests: a study protocol for a cluster parallel-group randomized controlled trial”, *Trials,* vol. 19, no. 1, pp. 510, 2018.

[13] B.J. Bobrow, T.F. Vadeboncoeur, U. Stolz, et al., “The influence of scenario-based training and real-time audiovisual feedback on out-of-hospital cardiopulmonary resuscitation quality and survival from out-of-hospital cardiac arrest”, *Annals of Emergency Medicine*, vol. 62, no. 1, pp. 47-56, 2013.

[14] A.L. Austin, C.N. Spalding, K.N. Landa et al., “A Randomized Control Trial of Cardiopulmonary Feedback Devices and Their Impact on Infant Chest Compression Quality: A Simulation Study”, *Pediatr Emerg Care*, 2017.

[15] Z. Truszewski, L. Szarpak, A. Kurowski, et al., “Randomized trial of the chest compressions effectiveness comparing 3 feedback CPR devices and standard basic life support by nurses”, *Am J Emerg Med,* vol. 34, no. 3, pp. 381-385, 2016.

[16] M. Skorning, S.K. Beckers, J.C. Brokmann, et al., “New visual feedback device improves performance of chest compressions by professionals in simulated cardiac arrest”, *Resuscitation,* vol. 81, no. 1, pp. 53-58, 2010.

[17] P. Martin, P. Theobald, A. Kemp, et al., “Real-time feedback can improve infant manikin cardiopulmonary resuscitation by up to 79%—A randomised controlled trial”, *Resuscitation,* vol. 84, no. 8, pp. 1125-1130, 2013.

[18] A. Cheng, F. Overly, D. Kessler, et al, “ Perception of CPR quality: Influence of CPR feedback, Just-in-Time CPR training and provider role”, *Resuscitation,* vol. 87, pp. 44-50, 2015.

[19] L. Iskrzycki, J. Smereka, A. Rodríguez-Núñez, et al., “The impact of the use of CPRMeter monitor on the chest compressions quality: a prospective randomized trial, cross-simulation”, *Kardiologia Polska,* vol. 73, no. 3, pp. 574-579, 2018.

[20] Y. Lin, A. Cheng, V.J. Grant, et al., “Improving CPR quality with distributed practice and real-time feedback in pediatric healthcare providers - A randomized controlled trial”, *Resuscitation,* vol. 130, pp. 6-12, 2018.

[21] N. Segal, F. Laurent, L. Maman, et al. “Accuracy of a feedback device for cardiopulmonary resuscitation on a dental chair”, *Emerg Med Journ,* vol. 29, no. 11, pp. 861-866, 2011.

[22] S. Tanaka, W. Rodrigues, S. Sotir, et al., “CPR performance in the presence of audiovisual feedback or football shoulder pads”, *BMJ Open Sport Exerc Med*, vol. 3, no. 1, 2016.

[23] J.C. Wang, S.H. Tsai, Y.H. Chen, et al., “Kinect-based real-time audiovisual feedback device improves CPR quality of lower-body-weight rescuers”, *Am J Emerg Med,* vol. 36, no. 4, pp. 577-582, 2018.

[24] J. Yeung, R. Davies, F. Gao, et al., “A randomised controlled trial of prompt and feedback devices and their impact on quality of chest compressions—A simulation study”, *Resuscitation,*vol. 85, no. 4, pp. 553-559, 2014.

[25] R.M. Sutton, D. Niles, P.A. Meaney, et al., ““Booster” training: Evaluation of instructor-led bedside cardiopulmonary resuscitation skill training and automated corrective feedback to improve cardiopulmonary resuscitation compliance of Pediatric Basic Life Support providers during simulated cardiac arrest”, *Pediatr Crit Care Med,* vol.12, no.3, pp.116-121, 2011.

[26] S.A. Aguilar, N. Asakawa, C. Cofre, et al., “Addition of Audiovisual Feedback During Standard Compressions Is Associated with Improved Ability”, *West J Emerg Med*, vol.19, no.2, pp. 437-444, 2018.

[27] A. Kurowski, Ł. Szarpak , Ł. Bogdański et al., “Comparison of the effectiveness of cardiopulmonary resuscitation with standard manual chest compressions and the use of TrueCPR and PocketCPR feedback devices”, *Kardiologia Polska*, vol. 73, no.10, pp.924–930, 2015.

[28] D. Hostler, S. Everson-Stewart, T.D. Rea, et al., “Effect of real-time feedback during cardiopulmonary resuscitation outside hospital: prospective, cluster-randomised trial”, *BMJ. 342: d512, 2011.*

[29] A. Vahedian-Azimi, M. Hajiesmaeili, A. Amirsavadkouhi, et al., “Effect of the Cardio First Angel™ device on CPR indices: a randomized controlled clinical trial”, *Crit Care*, vol. 20, no. 1, pp. 147, 2016.

[30] M. Skorning, M. Derwall, J.C. Brokmann, et. al. “External chest compressions using a mechanical feedback device”, *Der Anaesthesist*., vol. 60, pp.717, 2011.

[31] A.Wutzler, M. Bannehr, S. von Ulmenstein,et al., “Performance of chest compressions with the use of a new audio–visual feedback device: A randomized manikin study in health care professionals”, *Resuscitation*, vol. 87, pp.81-85, 2015.

[32] J. Kandasamy, P. Theobald, I. Maconochie and M. Jones, “Can real-time feedback improve the simulated infant cardiopulmonary resuscitation performance of basic life support and lay rescuers?”, *Arch Dis Child,* vol. 108, no. 8, pp. 793-801, 2019.

[33] A. Cheng, L.L. Brown, J.P. Duff, et al., “Improving cardiopulmonary resuscitation with a CPR feedback device and refresher simulations (CPR CARES Study): a randomized clinical trial”, *JAMA Paediatr.,* vol. 169, no. 2, pp. 137-144, 2015.

[34] S. Lee, J. Oh, H. Kang, et al., “Proper target depth of an accelerometer-based feedback device during CPR performed on a hospital bed: a randomized simulation study”, *The American Journal of Emergency Medicine*. vo. 33,no.10, pp. 1425-1429,2015.

[35] C. Havel, W. Schreiber, H. Trimmel, et al., “Quality of closed chest compression on a manikin in ambulance vehicles and flying helicopters with a real time automated feedback”, *Resuscitation*, vo. 81, no. 1, pp. 59-64, 2010.

[36] A. Bohn, T. P.Weber, S. Wecker, et al., “The addition of voice prompts to audiovisual feedback and debriefing does not modify CPR quality or outcomes in out of hospital cardiac arrest--a prospective, randomized trial”, *Resuscitation*, vo.82, no. 3, pp. 257-262, 2011.

[37] K.S. Allan, N. Wong, T. Aves, et al., “The benefits of a simplified method for CPR training of medical professionals: A randomized controlled study”, *Resuscitation*, vol. 84, no.8, pp.1119-1124, 2013.

[38] J.G. Kornegay, N. Von Foerster, A.Laurie, et al., “Does Accelerometer Use Lead to Higher Quality CPR for Advanced”, *Eurasian J Emerg Med*.vol.17, no.4, pp.153-8, 2018.

[39] C. Buléon, J.Delaunay, J.J. Parienti, et al., “Impact of a feedback device on chest compression quality during extended manikin CPR: a randomized crossover study”, *Amer J Emerg Med*, vol. 34, no. 9, pp. 1754-1760, 2016.

[40] T.C. Lu, Y.T. Chang, T.W. Ho, et al., “Using a smartwatch with real-time feedback improves the delivery of high-quality cardiopulmonary resuscitation by healthcare professionals”, *Resuscitation*, vol.140, pp.16-22, 2019.

[41] L.G. Calvete, R.B.Furelos, J.D.M.González, et al., “Utility of a simple lighting device to improve chest compressions learning”, *Revista Española de Anestesiología y Reanimación*, vol. 64, no. 9, pp. 506-512, 2017.

[42] N. Pavo, G.Goliasch, F. Nierscher, et al., “Short structured feedback training is equivalent to a mechanical feedback device in two-rescuer BLS: a randomised simulation study”, *Scand J Trauma Resusc Emerg Med,* vol. 24, no. 70, pp. 1-8, 2016.

[43] F. Bhanji, A.J. Donoghue, M.S. Wolf, et al., “Part 14: Education: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care”, *Circulation*, vol.132, no. 2), pp. 561–573, 2015.

[44] D.G. Heard, K.H. Andresen, K.M Guthmiller, et al. “Hands-Only Cardiopulmonary Resuscitation Education: a Comparison of On-Screen With Compression Feedback, Classroom, and Video Education”, *Ann Emerg Med,* vol. 73, no. 6, pp. 599-609, 2019.

[45] S. Tanaka, K. Tsukigase, T. Hara, “Effect of real-time visual feedback device 'Quality Cardiopulmonary Resuscitation (QCPR) Classroom' with a metronome sound on layperson CPR training in Japan: a cluster randomized control trial”, *BMJ Open,* vol.9, no.6, e026140, 2019.

[46] R.K. Gregson, T. J. Cole, S. Skellett, et al. “Randomised crossover trial of rate feedback and force during chest compressions for paediatric cardiopulmonary resuscitation”, *Arch Dis Child,* vol. 102, no. 5, pp. 403-409, 2016.