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The use of CPR feedback / prompt devices during training and CPR performance: a systematic review

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Abstract

Objectives: In laypersons and health care providers performing cardiopulmonary resuscitation (CPR), does the use of CPR feedback / prompt devices when compared to no device improve CPR skill acquisition, retention, and real life performance? *Methods:* The Cochrane database of systematic reviews; Medline (1950- Dec 2008); EmBASE (1988 – Dec 2008) and Psychinfo (1988-Dec 2008) were searched using ("Prompt$” or “Feedback” as text words) AND ("Cardiopulmonary Resuscitation"[Mesh] OR "Heart Arrest"[Mesh]). Inclusion criteria were articles describing the effect of audio or visual feedback / prompts on CPR skill acquisition, retention or performance. *Results:* 509 papers were identified of which 33 were relevant. There were no randomized controlled studies in humans (LOE 1). Two non randomized cross over studies (LOE 2) and four with retrospective controls (LOE 3) in humans and 20 animal / manikin (LOE 5) studies contained data supporting the use of feedback / prompt devices. Two LOE 5 studies were neutral. Six LOE 5 manikin studies provided opposing evidence.

Conclusions: There is good evidence supporting the use of CPR feedback / prompt devices during CPR training to improve CPR skill acquisition and retention. Their use in clinical practice as part of an overall strategy to improve the quality of CPR may be beneficial. The accuracy of devices to measure compression depth should be calibrated to take account of the stiffness of the support surface upon which CPR is being performed (e.g. floor / mattress). Further studies are needed to determine if these devices improve patient outcomes.

Background

Survival from cardiac arrest remains poor[1, 2] despite significant advances in the science of resuscitation over the last decade. [3, 4] One explanation for advances in science not achieving their full therapeutic potential may be a failure to optimally implement evidence based guidelines into practice. [5, 6] A number of studies have shown that the quality of CPR during training and in clinical practice is often sub-optimal, with inadequate compression depth, interruptions in chest compression, prolonged pre and post shock pauses and hyperventilation occurring frequently. [7-10]

A number of devices have been developed which provide guidance during CPR. These have been used in both training and clinical settings. The devices range in complexity from a simple metronome, which guides compression rate to more complex devices that monitor and provide combined audiovisual feedback about actual CPR performance. The Skillmeter Anne (Laerdal, Orpington, UK) provides real time visual feedback and post event summary feedback via a monitor screen.[11, 12] Variables measured are: chest compression depth and rate, ratio of chest compressions to ventilations, hand position, ventilation volume and inflation rate. The Voice Advisory Manikin (VAM)(Laerdal, Orpington, UK) uses sensors from a manikin to provide real time visual feedback on compression rate and depth, no-flow duration, ventilation rate, and inflation rate[13]. This is supplemented by verbal instructions advising corrective action if the quality of CPR deviates beyond set parameters. The Q-CPR system (Philips Medical, Andover, MA) is designed for use during actual resuscitations. Information on the quality of CPR is obtained via defibrillator pads and an accelerometer placed on the victims chest[14]. It uses a similar system of audiovisual prompts to the VAM system. The PAR (public access resuscitator, O-two Medical Technologies, Ontario, Canada) delivers positive pressure ventilation (2 breaths) via a face mask followed by an audible tone indicating when chest compressions should be delivered[15]. Pressure sensing devices (CPREzy (Allied

Health, UK)[16] and CPRplus (Kelly medical[17]) combine a pressure sensing monitor which is placed on the victims chest during CPR with a metronome. These devices provide guidance on compression force, depth and rate, as well as release of compressions,

The aim of this study is to conduct a systematic review of the published literature on the use of CPR feedback / prompt devices during training and actual resuscitation attempts. To date, no head to head comparisons of different devices have taken place.

Methods

The review was conducted in accordance with the International Liaison Committee on Resuscitation (ILCOR) 2010 evidence evaluation process. Expert review of the search strategy and findings were conducted by the worksheet evaluation experts.

PICO question

This review sought to identify evidence to address the PICO (Patient / population, Intervention, Comparator, Outcome) question[18]: In laypersons and health care providers (HCPs) performing CPR (P), does the use of a CPR feedback / prompt device (I), when compared to no device (C), improve CPR skill acquisition, retention, and real life performance (O)?"

Search strategy

The Cochrane database of systematic reviews was searched using the terms resuscitation and basic life support. The electronic databases Medline (1950- Dec 2008); EmBASE (1988 – Dec 2008) and Psychinfo (1988-Dec 2008) were searched using OVID and the search terms ("Prompt$" or "Feedback" as text words) AND ("Cardiopulmonary Resuscitation"[Mesh] OR "Heart Arrest"[Mesh]). The American Heart Association (AHA) Resuscitation Endnote library, which contains over 15,000 cardiac arrest related references, was searched using the terms "feedback" or "prompt$" in abstracts.

Articles describing the effect of audio or visual feedback on CPR skill acquisition, retention or performance were eligible for inclusion. The titles of articles were reviewed for relevance independently by two reviewers (GDP / JY). Articles where the content was clearly unrelated were discarded. The abstracts of remaining articles were then reviewed and relevant studies identified for detailed review of the full manuscript. Where disagreement existed between reviewers at the title and abstract screening stage, articles were included for detailed review. Finally, the reference lists of narrative reviews were examined to identify any additional articles not captured by the main search strategy.

Evidence appraisal

Studies were reviewed in detail and classified by level of evidence (LOE) (Table 1) and quality (rated poor, fair or good) according to agreed definitions[18, 19]. Manikin studies were classified as level of evidence 5 irrespective of their study design. Higher quality evidence studies undertaken on manikins (e.g. randomised controlled trials) were classified as good. Lower quality of evidence manikin studies were rated as fair or poor. Studies were further classified according to whether they were supportive, neutral or opposing regarding the benefits of the use of CPR feedback / prompt devices.

Data presentation

Numerical data are summarised directly from the respective papers. Parametric data are presented as mean (standard deviation) and non parametric as median (interquartile range). Proportions are presented as a percentage. A P value of < 0.05 is considered significant.

Results

This search identified 509 papers. After removal of duplicates, 350 titles were reviewed for relevance. From this 36 titles appeared relevant to the research question leading to detailed review of abstracts. Eight further articles were discarded at this phase leaving 28 articles for full review. From the review of reference lists and review articles a further 5 studies were identified. There are no published randomised controlled trials (LOE 1) in human cardiac arrests that address this question. Two non randomized cross over studies in humans (LOE 2), four studies with retrospective controls in humans (LOE 3) and 20 animal / manikin (LOE 5) studies contained data supporting the use of feedback / prompt devices. Two LOE 5 studies were neutral. Six LOE 5 manikin studies provided opposing evidence. The level of evidence and quality of papers are summarised in Table 2.

Use during training – impact on skill acquisition

The impact of CPR feedback / prompt devices during training as an aid to skill acquisition has been examined in 8 manikin studies (Table 3). To qualify as a measure of skill acquisition, only studies which avoided using the feedback technology during skill testing were examined.

Manikin feedback (Voice advisory manikin / skill meter manikin)

Wik [13] conducted a randomized, controlled, cross-over study using an early version of the voice advisory manikin (VAM) system with 24 paramedic students that had previously been trained in BLS. Students were randomly allocated to perform CPR on a manikin for 3 min with or without feedback before crossing over to the other arm. The group which received feedback initially outperformed the no-feedback group during the first series of comparisons. The improvement was sustained after cross-over suggesting that feedback during the first series of comparisons had improved skill acquisition. Williamson found similar effects when CPR-naïve lay persons used a similar system of audiovisual prompts incorporated in an automated external defibrillator (Heartstart plus)[20]

The effect of 20 minutes of VAM-facilitated refresher training (no instructor) was examined amongst 35 Basic Life Support (BLS) trained lay persons[21]. Compared to baseline, the quality of CPR (chest compressions and ventilations) improved after VAM training (both with and without using feedback during testing). A further study using the VAM system [22] compared VAM facilitated training (without instructor) to traditional instructor facilitated training in a randomized controlled manikin study amongst adult lay persons attending a paediatric CPR course. This study demonstrated modest improvements in CPR skill acquisition and lower ventilation and compression error rates immediately after training. Isbye[23] compared training with VAM against instructor facilitated training for CPR and bag-valve-mask (BVM) skills amongst second year medical students. Skill acquisition was tested (using a score card) immediately after training and 3 months later. The instructor facilitated group performed significantly better than the VAM group in the total score, both immediately after training. This difference was primarily related to the poorer BVM skills in the VAM group. In contrast, Spooner et al[11] conducted a randomized controlled trial with medical students to examine the effect of feedback from Skillmeter manikin during instructor led CPR training classes (teaching mouth to mouth ventilations as opposed to bag-valve-mask ventilation). This study showed that skill acquisition (compression depth and % correct chest compressions) was better in the group that trained with the Skillmeter manikin.

Metronome

The use of video self instruction (with a CPR feedback device that provided feedback on compression depth and informed compression rate using a metronome) versus instructor delivered training showed improved CPR performance and improved ventilations[24]. The individual contribution of the CPR feedback device cannot be separated from the effect of video self instruction.

Monsieurs *et al* [15] examined CPR skill performance amongst 152 nurses after randomly assigning staff to training using a pocket mask for ventilation or CAREvent Public Access Resuscitator (PAR, O-Two Medical Technologies, Ontario, Canada). The CAREvent® Public Access Resuscitator (PAR, O-Two Medical Technologies, Ontario, Canada) alternates two ventilations with 15 prompts for chest compressions. The group randomised to the PAR group achieved more chest compressions per minute than the group that had not been trained using PAR. There were other small improvements in compression rate and depth, total no flow time, tidal volume, and number of ventilations, although these were not judged as being clinically significant by the authors.

Use during training – impact on skill retention (skillmeter / VAM)

Three studies have looked at the effect that manikin feedback during initial training has on retention of CPR skills. Consistent with the findings in their skill acquisition study, Isybe[23] found lower CPR scores(due to poor ventilation with a bag-valve-mask) amongst medical students trained with VAM as opposed to instructor facilitated training. In the follow-up arm of the study by Spooner *et al* [11]participants randomised to skillmeter manikins demonstrated better chest compressions than the control arm 4-6 weeks after initial training. In a third study, Wik and colleagues randomised 35 lay persons to either one 20 minute VAM-facilitated training session followed, one month later, by 10 additional 3 minute sessions over five days, or the twenty minute session alone (control) and tested their skill retention [21]. After 6 months, both groups showed improvement over baseline in the percentage of correct inflations but only the group with additional subsequent training improved their chest compression rate, depth, duty-cycle and incomplete release from baseline, making it impossible to separate the effects of refresher training from the use of the VAM system.

Use during skill performance - Manikin studies

The use of feedback / prompt devices during CPR performance have been examined in 18 manikin studies[13, 15-17, 20, 21, 25-36]. The studies are summarized in Table 4. Eight of these studies showed improved compression depth [8, 13, 21, 25, 27, 29, 31, 33]whilst one showed reduced depth[32]. 6 studies showed improved compression rate[15, 20, 25-27, 32] (2 additional studies showed reduced variability in compression rate[16, 27]). Six studies showed improvement in percentage of correct compressions[15-17, 27, 31, 34]. Mixed effects were seen on correct hand positioning (3 showed improved positioning[16, 26, 31], 1 showed deterioration[33]). Fewer studies investigated the impact on ventilation (n=11). Of these ten showed improved ventilation performance with feedback / prompt devices, [13, 15, 20, 21, 25, 26, 28, 29, 32, 37] and one showed mixed changes. [30]

Three studies examined the utility of video / animations on mobile phones / PDAs to improve CPR performance. The studies gave mixed results. Two studies showed improved check list scores and quality of CPR [26, 28] or faster initiation of CPR[26] whilst the third study showed that multi-media phone CPR instruction required more time to complete tasks than dispatcher assisted CPR[36].

Use during skill performance - Human studies

No randomized controlled trials of CPR feedback devices have been conducted in humans. None of the studies conducted to date provide definitive evidence of improved survival or other patient focused outcomes when CPR prompt devices are used.

Metronomes / Sirens

Four studies have investigated the use of metronomes / sirens to assist with the timing of chest compressions and other interventions. Berg [38]and Kern[39] used metronomes in a cross over trials during 6 paediatric and 23 adult resuscitation attempts respectively. Compared to baseline, chest compression rates and end-tidal CO_2 improved after activation of the metronomes. Chiang [40] used a metronome and siren to guide chest compression rate and duration of intubation attempts. Compared to historical controls (n=17), the intervention group (n=13) showed a significant improvement in the hands-off time per minute during CPR (12.7(5.3) s versus 16.9(7.9) s, $P < 0.05$) and the total hands-off time during CPR (164 (94) s versus 273(153) s, $P < 0.05$). The proportion of intubation attempts taking under 20 seconds also improved (56.3% versus 10%, $P < 0.05$). Fletcher [41] examined the effect of introducing a CPR education programme which included the use of metronomes to guide CPR in an ambulance service in the UK. The group found improvements in CPR and was associated with improved survival rates (3% to 7% P=0.02).

Q-CPR (Phillips / Laerdal Medical)

Abella conducted a prospective cohort study to examine the effect of introducing a prototype of the Q-CPR system during in-hospital resuscitation attempts[14]. Compared to the baseline pre-intervention group (n=55) compression and ventilation rates were less variable in the feedback group (n=101),. There were no significant improvements in the mean values of CPR variables, return of spontaneous circulation or survival to hospital discharge. By contrast, a similar study which introduced technology-CPR into the pre-hospital environment, found average compression depth increased from baseline (n=176) of 34(9)mm to 38(6) mm (95% CI 2-6, P < 0.001) in the feedback group (n=108)[42]. The median percentage of compressions with adequate depth (38-51 mm) increased from 24% to 53% (P < 0.001) with feedback and mean compression rate decreased from 121(18) to 109(12) min^{-1} (95% CI diff-16, -9, P = 0.001). There were no changes in the mean number of ventilations per minute, no flow time or survival (2.9% versus 4.3% (OR 1.5 (95% CI; 0.8, 3), P = 0.2).

Device Risks and Limitations

There may be some limitations to the use of CPR feedback / prompt devices. One LOE 5 manikin study [43] reports that chest compression devices may over estimate compression depth if CPR is being performed on a compressible surface such as a mattress on a bed. One LOE 5 reported harm to a single participant whose hand got stuck in moving parts of the CPR feedback device[33]. A further LOE 5 manikin study demonstrates that additional mechanical work is required from the CPR provider to compress the spring in one of the pressure sensing feedback devices[44].

Discussion

This review has identified evidence that the use of CPR feedback / prompt systems, either in addition to or in place of instructor facilitated training, can improve basic CPR skill acquisition and retention (as tested without use of the device). Automated feedback may be less effective than instructor feedback for more complex skills (e.g. bag-valve-mask ventilation)[23]. The use of CPR feedback / prompt systems during CPR performance on manikins consistently improves the quality of CPR. The utility of video / animations on mobile devices (phone / PDA) appears promising. Care should be taken to ensure that these devices do not overly distract or delay the rescuer from performing CPR.

There is evidence from studies in humans that CPR feedback / prompt devices improve CPR performance. Evidence from three non-randomised cross-over studies (one animal[45] and two human studies[38, 39]) show that metronomes improve chest compression rate and end-tidal CO_2. Four before / after studies evaluating the introduction of CPR feedback / prompt devices in clinical practice showed improved CPR performance[40-42]. There is a need to ensure that devices are safe, accurate, do not increase the work involved in CPR and can be used on a number of different support surfaces (e.g. floor, bed etc).

There is a growing body of evidence demonstrating the link between the quality of CPR and patient outcomes. Studies in the early 1990's first identified the link between the quality of CPR and patient outcome, with better quality CPR being associated with improved survival. [46, 47] Chest compression depth and rate, interruptions in chest compressions (particularly before defibrillation) influence on patient outcome.[12, 42, 48, 49]. The evidence in this review is largely supportive in demonstrating that CPR feedback/prompt devices are associated with improved quality of CPR. Whilst it may be intuitive to assume that this will lead to improvements in survival this cannot be assumed to be the case. Indeed, none of the studies to date have had sufficient power to show improved patient outcomes (return of spontaneous circulation, neurologically intact survival etc) with CPR feedback / prompt devices. A number of examples exist where early evidence of efficacy [50, 51] failed to translate into improved patient outcomes (e.g. ACD-CPR [52] and Autopulse chest compression device [53]). A large, cluster randomised controlled clinical trial (ClinicalTrials.gov identifier: NCT00539539) is in progress as part of the Resuscitation Outcomes Consortium .[54, 55] The purpose of this study is to evaluate whether or not real-time feedback on CPR process variables will increase survival during pre-hospital resuscitation. A further study, supported by the UK National Institute of Health Research is about to commence recruitment examining the impact of feedback technology on patient outcomes during in-hospital CPR. Judgement on the ability of these devices to improve patient outcomes should be withheld until the results of large randomised controlled trials such as these become available.

Authors conclusion and recommendation

This review provides good evidence supporting the use of CPR feedback / prompt devices during CPR training as a strategy to improve CPR skill acquisition and retention. The evidence suggests that the use of CPR feedback / prompt devices in clinical practice as part of an overall strategy to improve the quality of CPR may be beneficial. Further studies are required to assess if the improvements in quality of CPR brought about by these devices translate into improvements in patient focused outcomes. The accuracy of CPR feedback / prompt devices to measure compression depth should be calibrated to take account of the stiffness of the support surface upon which CPR is being performed (e.g. floor / mattress).

Disclaimer

This review includes information on resuscitation questions developed through the C2010 Consensus on Science and Treatment Recommendations process, managed by the International Liaison Committee on Resuscitation (www.americanheart.org/ILCOR). The questions were developed by ILCOR Task Forces, using strict conflict of interest guidelines. In general, each question was assigned to two experts to complete a detailed structured review of the literature, and complete a detailed worksheet. Worksheets are discussed at ILCOR meetings to reach consensus and will be published in 2010 as the Consensus on Science and Treatment Recommendations (CoSTR). The conclusions published in the final CoSTR consensus document may differ from the conclusions of in this review because the CoSTR consensus will reflect input from other worksheet authors and discussants at the conference, and will take into consideration implementation and feasibility issues as well as new relevant research.

Conflict of interest

JY, JS – none;. GDP has published on CPR feedback devices (Q-CPR, Resusci-Anne Skill meter; CPR-Ezy). DE published on CPR feedback devices and has received research support from AHA and AHRQ, as well as research support, speaking honoraria and consulting from Philips

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Table 1: ILCOR Levels of Evidence for Therapeutic Interventions

LOE 1: Randomised Controlled Trials (or meta-analyses of RCTs)
LOE 2: Studies using concurrent controls without true randomisation (eg. “pseudo”-randomised) (or meta-analyses of such studies)
LOE 3: Studies using retrospective controls
LOE 4: Studies without a control group (eg. case series)
LOE 5: Studies not directly related to the specific patient/population (eg. different patient/population, animal models, mechanical models etc.)

Table 2 : Summary of levels of evidence and quality of studies supporting, opposing or neutral to the use of CPR feedback / prompt devices.

Evidence Supporting Clinical Question

Good			**Abella 2007** **Kramer-Johansen 2006**		**Choa 2008** **Dine 2008** **Elding 1998** **Ertl 2007** **Handley 2003** **Oh 2008** **Milander 1995** **Perkins 2005** **Spooner 2007** **Sutton 2007** **Wik 2001** **Wik 2005** **Williamson 2005**
Fair		**Kern 1992**	**Chiang 2005** **Fletcher 2008**		**Beckers 2007** **Monsieurs 2005** **Noordergraaf 2006** **Thomas 1995** **Wik 2002**
Poor		**Berg 1994**			**Boyle 2002** **Lynch 2005**
	1	**2**	**3**	**4**	**5**
Level of evidence					

Evidence Neutral to Clinical question

Good					**Williamson 2005**
Fair					
Poor					**France 2006**
	1	**2**	**3**	**4**	**5**
Level of evidence					

Evidence Opposing Clinical Question

Good					**Hostler 2005** **Isybe 2008** **Perkins 2008** **van Berkom 2008** **Zanner 2007**
Fair					**Perkins 2005**
Poor					
	1	**2**	**3**	**4**	**5**
Level of evidence					

Table 3 : Summary of evidence examining the effect of CPR feedback / prompt devices during CPR skill acquisition (A) and skill retention (R) on manikins

Chest compressions

Study	Device	Device Type	Group	Design	n	Compressions (feedback vs control)					
						Skill acquisition			Skill retention		
						Depth	Rate	% correct	Depth	Rate	% correct
Beckers 2007	CPREzy	Prompt/ feedback	1st year Medical students	Randomised crossover	202	71.2% vs 34.1% (p≤0.01)	93.7% vs 19.8% (p≤0.01)	x	71.9% vs 43.6% (p≤0.01)	No effect	x
Isbye 2008	VAM	Feedback	2nd year Medical students	RCT	43	No effect	No effect	x	No effect	No effect	x
Lynch 2005	Metronome + VSI	Prompt	Lay person	RCT	285	No effect	No effect	No effect	x	x	x
Monsieurs 2005	CAREvent ® Public access resuscitator	Prompt	Nurses	RCT	152	No effect	95±14 vs 99±4 (p=0.047)	No effect	x	x	X
Spooner 2007	Skillmeter	Feedback	Medical students	RCT	A=98 R=66	39.96mm vs 36.71mm (p=0.018)	No effect	58% vs 40.4% (p=0.023)	No effect	No effect	43.1% vs 26.5% (p=0.039)

Sutton 2007	VAM	Feedback	Lay person (P-BLS)	RCT	50	x	58.7±7.9 vs 47.6±10.5 (p<0.001)	Error rate 18.1±23.2 % vs 34.9±28.8 % (p<0.03)	x	x	x
Wik 2001	VAM	Feedback	Paramedic students	Before/ after comparison	24	92% vs 32% (p=0.002)	No effect	x	x	x	x
Wik 2002	VAM	Feedback	Lay person	RCT	A=35 R=30	91%±8 vs 77%±30 (p≤0.05)	no effect	x	81%±19 vs 46%±33 (p≤0.01)	101±11 vs 92±17 (p≤0.05)	x

Ventilations

Study	Device	Device Type	Group	Design	n	Ventilations (feedback vs control)					
						Skill Acquisition			Skill Retention		
						Rate	Volume	% correct	Rate	Volume	% correct
Beckers 2007	CPREzy	Prompt/ feedback	1st year Medical students	Randomised crossover	202	x	x	43.2% vs 30.8% (p≤0.02)	x	x	No effect
Isbye 2008	VAM	Feedback	2nd year Medical students	RCT	43	total no 0 (0-4) vs 8 (6-8) (p<0.0001)	0 (0-185) vs 543 (375-648) (p<0.0001)	x	Total no 0 (0-1) vs 7.5 (4-8) (p=0.0003)	0 (0-200) vs 450.5 (254.5-529.5) (p=0.0001)	x
Lynch 2005	Metronome + VSI	Prompt	Lay person	RCT	285	x	x	58% vs 39% (p=0.014)	x	x	x
Monsieurs 2005	CAREvent Public access resuscitator	Prompt	Nurses	RCT	152	6±1 vs 5±1 (P<0.001)	577±142 vs 743±279 (P=0.0002)	x	x	x	x

Spooner 2007	Skillmeter	Feedback	Medical students	RCT	A=98 R=66	x	No effect	No effect	x	no effect	No effect
Sutton 2007	VAM	Feedback	Lay person (P-BLS)	RCT	50	7.8±1.2 vs 6.4±1.4 ($p<0.001$)	x	Error rate 32.0±19.7% vs 50.7±24.1% ($p<0.005$)	x	x	x
Wik 2001	VAM	Feedback	Paramedic students	Before/ after comparison	24	x	x	64% vs 2% ($p=0.002$)	x	x	x
Wik 2002	VAM	Feedback	Lay person	Before/ After comparison	A= 35 R= 30	No effect	X	71%±27 vs 58%±30 ($p\leq0.01$)	No effect	x	58%±27 vs 18%±26 ($p\leq0.01$)

Table 4 : Summary of evidence examining the effect of CPR feedback / prompt devices during skill performance on manikins

Study	Device	Device type	Group	Design	n	Compressions (Feedback vs control)			
						Depth	Rate	% correct	Other
Beckers 2007	CPR-Ezy	Prompt / Feedback	1st year medical students	Randomised crossover	202	71.2% participants vs 34.1% (P≤0.01)	93.7% participants vs 19.8% (P≤0.01)	x	x
Boyle 2002	CPR-Ezy	Prompt / Feedback	Non-clinical hospital staff	Before / after comparison	32	x	↓ variance	42.1±5.2% vs 12.8±3.7% (P<0.001)	Improved hand position
Choa 2008	Cell phone	Prompt	CPR naïve Laypersons	RCT	44	No effect	% correct rate 72.4±3.7% vs 57.6±3.8% P=0.015	x	Improved check list score; hand position and time to start CPR
Dine 2008	Q-CPR	Feedback	Nurses	RCT	65	58% vs 19% participants correct depth (P=0.002)	↓ variance	x	X
	Q-CPR + debriefing					x	84% vs 45%	64% vs 29%	X

							participants correct (P=0.001)	(P=0.005)	
Elding 1998	CPR-plus	Prompt / Feedback	Nurses	Randomised cross over	40	x	x	92±1% vs 73±10% (P=0.001)	Reduced number of compressions with excess pressure
Ertl 2007	Multimedia PDA	Prompt	BLS trained lay persons	RCT	101	x	x	73.5% vs 44.2% participants (P=0.003)	OSCE score 14.8±3.5 vs 21.9±2.7 (P<0.01)
Handley 2003	VAM incorporated in AED	Feedback	Nurses	RCT	36	56.0%±32.2vs 11.4±20.7% P<0.00005	No effect	x	Reduced shallow compressions
Hostler 2005	VAM	Feedback	EMS staff	Randomised cross over	114	No effect	x	No effect	X
Monsieurs 2005	CAREvent® Public access resuscitator	Prompt	Nurses	RCT	152	No effect	95±14 vs 99±4 (p=0.047)	No effect	Increased compression number and reduced no flow time
Noordergraaf 2006	CPR-Ezy	Prompt / Feedback	Healthcare staff	? RCT (design unclear)	224	% participants too shallow 43% vs 9.8% Mean depth 45±4mm vs	No effect	94% vs 64% (P=0.0001)	Improved hand position

						40±9mm (p=0.0001)			
Oh 2008	Metronome	Prompt	Medical / nursing students	RCT	80	Reduced compression depth 35.8±8.2mm vs 39.3±9.5mm (P<0.01)	Improved rate 115.5 ±13.7 vs 100.1±3.2 (P<0.01)	x	No effect on hand position
Perkins 2005	CPR-Ezy	Prompt / Feedback	Medical students	Randomised cross over	20	42.9±4.4mm vs 34.2±7.6mm (P=0.0001)	No effect	x	Higher proportion of compressions too low
Thomas 1995	CPR-Plus	Prompt/ Feedback	Flight nurses	Before / after comparison	10	x	x	95.7±3.2% vs 33.4±12.1% P<0.01	X
Wik 2001	VAM	Feedback	Paramedic students	Before / after comparison	24	92% vs 32%	No effect	x	Increased duty cycle (44% vs 41%)
Wik 2002	VAM	Feedback	BLS trained laypersons	Before / after comparison	35	91%±8 vs 77%±30 (p≤0.05)	No effect	X	X
Wik 2005	VAM	Feedback	BLS trained laypersons	Before / after comparison 12 months after	28	87±9 vs 32±33% P<0.008	No effect	x	x

				initial training					
Williamson 2005	Heartstart AED	Prompt	Untrained laypersons	Randomised cross over	24	No effect	87.3±19.4 vs 52.3±31.4 (p=0.003)	No effect	X
Zanner 2007	Cell phone	Prompt	Laypersons (mostly high school students)	RCT	119	x	x	x	No difference in scenario score Cell phone prompt group took longer to complete scenario

Ventilation

Study	Device	Device type	Group	Design	n	Ventilation (Feedback vs control)			Other
						Rate	Volume	% correct	
Beckers 2007	CPR-Ezy	Prompt / Feedback	1st year medical students	Randomised crossover	202	x	x	43.2% vs 30.8% (p≤0.02)	X
Choa 2008	Cell phone	Prompt	CPR naïve Laypersons	RCT	44	x	No effect	x	Improved ventilation score
Ertl 2007	Multimedia PDA	Prompt	BLS trained lay persons	RCT	101	x	x	67.3% vs 42.3% participants (P=0.016)	OSCE score 21.9(2.7) vs 14.8 (3.5) P<0.01
Handley 2003	VAM incorporated in AED	Feedback	Nurses	RCT	36	No effect	No effect	13.9(SD13.0) vs 5.6(SD3.1)% P=0.004	X
Hostler 2005	VAM	Feedback	EMS staff	Randomised cross over	114	x	Attenuated decline in correct ventilations	Decreased fraction of correct ventilations	X
Monsieurs 2005	CAREvent® Public access resuscitator	Prompt	Nurses	RCT	152	6±1 vs 5±1 (P<0.001)	577±142 vs 743±279 (P=0.0002)	x	X

Oh 2008	Metronome	Prompt	Medical / nursing students	RCT	80	9.9±0.3 vs 7.4±1.8 (P<0.01)	x	x	X
Wik 2001	VAM	Feedback	Paramedic students	Before / after comparison	24	x	x	64% vs 2%	X
Wik 2002	VAM	Feedback	BLS trained laypersons	Before / after comparison	35	No effect	x	71%±27 vs 58%±30 (p≤0.01)	X
Wik 2005	VAM	Feedback	BLS trained laypersons	Before / after comparison 12 months after initial training	28	No effect	x	62(25) vs 9(20)% P<0.001	X
Williamson 2005	Heartstart AED	Prompt	Untrained laypersons	Randomised cross over	24	x	x	51.3(SD34.4) vs 15.3(SD32.8) P<0.001	X