WORKSHEET for Evidence-Based Review of Science for Emergency Cardiac Care

Worksheet author(s)

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Clinical question.

In laypersons and HCPs performing CPR, does the use of CPR feedback devices when compared to no device improves CPR skill acquisition, retention, and real life performance? (INTERVENTION)

Is this question addressing an intervention/therapy, prognosis or diagnosis? Intervention / therapy
State if this is a proposed new topic or revision of existing worksheet: Revision of existing worksheet

Conflict of interest specific to this question

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet?

Perkins:
Industry: None
Intellectual: Editor Resuscitation Journal; published papers relating to the use of feedback devices during CPR training including manikin feedback devices(Laerdal) and the CPREzy device(Allied Health). I have received research grants to investigate implementing quality of CPR into practice from the UK Department of Health National Institute of Health Research and Resuscitation Council (UK).

Yeung: No conflicts

Search strategy (including electronic databases searched).

Cochrane database of systematic reviews. – Resuscitation; basic life support

Ovid Medline (including Medline 1950- Aug 2009; EmBASE 1988 – Aug 2009) ("Prompt$" or "Feedback" as text words) AND ("Cardiopulmonary Resuscitation"[Mesh] OR "Heart Arrest"[Mesh])

The AHA Endnote library was searched using the terms feedback or prompt$ in abstracts.

- State inclusion and exclusion criteria

Inclusion: Studies describing the effect of audio or visual feedback on CPR skill acquisition, retention or performance
Exclusion: Studies where feedback / prompting is given following analysis of physiological signals e.g. coronary perfusion pressure; blood pressure; VF waveform.

- Number of articles/sources meeting criteria for further review:

This search identified 771 papers. After removal of duplicates, 600 titles were reviewed for relevance. From this 44 titles appeared relevant to the research question leading to detailed review of abstracts. Eight further articles were discarded at this phase leaving 36 articles for full review of which 31 were relevant. From the review of reference lists and review articles a further 8 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), five studies with retrospective controls in humans (LOE 3) and 21 animal / manikin (LOE 5) studies contained data supporting the use of feedback / prompt devices. Four LOE 5 studies were neutral. Eight LOE 5 studies provided opposing evidence (7 manikin; 1 case report)

Summary of evidence

Evidence Supporting Clinical Question

Good			**Abella 2007(E3)+** **Kramer-Johansen 2006 (E3) +**		**Choa 2008 (E3)*** **Dine 2008 (E3)+** **Elding 1998(E3)+** **Ertl 2007 (E3)*** **Handley 2003 (E3)+** **Oh 2008 (E3) #** ***Milander 1995 (E3) +*** **Perkins 2005 (E3) #** **Spooner 2007 (E1,E2) #** **Sutton 2007 (E1)*** **Wik 2001 (E1,E3)#** **Wik 2005 (E3)*** **Williamson 2005 (E1,E3)***
Fair		**Kern 1992 (E3)+**	**Chiang 2005 (E3) +** **Fletcher 2008 (E3) +** **Niles 2009 (E3) +**		**Beckers 2007 (E2,3) #** **Jantti 2009 (E3) +** **Monsieurs 2005 (E1,3) +** **Noordergraaf 2006 (E3)+** **Thomas 1995 (E3) +** **Wik 2002 (E1, E3)***
Poor		**Berg 1994(E3)+**			**Boyle 2002 (E3)*** **Lynch 2005 (E1)***
	1	**2**	**3**	**4**	**5**
			Level of evidence		

A = Return of spontaneous circulation
B = Survival of event
C = Survival to hospital discharge
D = Intact neurological survival
E = Other endpoint
Italics = Animal studies
E1 = skill acquisition; E2 = skill retention; E3 = skill performance;
* = Lay persons; # = Healthcare students; + = Healthcare professionals

Evidence Neutral to Clinical question

Good					**Bolle 2009 (E3) *** **Williamson 2005 (E1,E2)*** **Yang 2009 (E3)***
Fair					
Poor					**France 2006 (E3)+**
	1	**2**	**3**	**4**	**5**
			Level of evidence		

A = Return of spontaneous circulation
B = Survival of event
C = Survival to hospital discharge
D = Intact neurological survival
E = Other endpoint
Italics = Animal studies
E1 = skill acquisition; E2 = skill retention; E3 = skill performance
* = Lay persons; # = Healthcare students; + = Healthcare professionals

Evidence Opposing Clinical Question

Good					**Hostler 2005 (E3) +** **Isybe 2008 (E2)+** **Nishisaki 2009 (E3)+** **Perkins 2008 (E3)#** **van Berkom 2008 (E3)**

					Zanner 2007 (E3) *
Fair					**Cho 2009 (E4)** **Perkins 2005 (E4)**
Poor					
	1	**2**	**3**	**4**	**5**
Level of evidence					

A = Return of spontaneous circulation
B = Survival of event
C = Survival to hospital discharge
D = Intact neurological survival
E = Other endpoint
Italics = Animal studies

E1 = skill acquisition; E2 = skill retention; E3 = skill performance; E4 = CPR provider or patient injury
* = Lay persons; # = Healthcare students; + = Healthcare professionals

REVIEWER'S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK:

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 1). 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 (Wik 2001, 167) 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)(Williamson 2005, 140)
The effect of 20 minutes of VAM-facilitated refresher training (no instructor) was examined amongst 35 Basic Life Support (BLS) trained lay persons(Wik 2002, 273). 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 (Sutton 2007, 161) 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(Isbye 2008, 73) 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(Spooner 2007, 417) 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(Lynch 2005, 31). The individual contribution of the CPR feedback device cannot be separated from the effect of video self instruction.
Monsieurs et al (Monsieurs 2005, 45) 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(Isbye 2008, 73) 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 (Spooner 2007, 417)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 (Wik 2002, 273). 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 19 manikin studies(Beckers 2007, 100; Boyle 2002, 63; Choa 2008, 87; Dine 2008, 2817; Elding 1998, 169; Ertl 2007, 286; Handley 2003, 57; Hostler 2005, 53; Jantti 2009, 453; Monsieurs 2005, 45; Noordergraaf 2006, 241; Oh 2008, 273; Perkins 2005, 103; Thomas 1995, 155; Wik 2005, 391; Wik 2002, 273; Wik 2001, 167; Williamson 2005, 140; Zanner 2007, 487) and one study in animals(Milander 1995, 708). The studies are summarized in Table 2. Eight of these studies showed improved compression depth (Beckers 2007, 100; Dine 2008, 2817; Handley 2003, 57; Noordergraaf 2006, 241; Perkins 2005, 103; Wik 2005, 299; Wik 2002, 273; Wik 2001, 167)whilst one showed reduced depth(Oh 2008, 273). 8 studies showed improved compression rate(Beckers 2007, 100; Choa 2008, 87; Dine 2008, 2817; Milander 1995, 708; Monsieurs 2005, 45; Oh 2008, 273; Williamson 2005, 140) (2 additional studies showed reduced variability in compression rate(Boyle 2002, 63; Dine 2008, 2817)). The study in animals (Milander 1995, 708)found increased end-tidal CO2 in association with the increase in chest compressions brought about by prompting rescuers with a metronome. Six studies showed improvement in percentage of correct compressions(Boyle 2002, 63; Dine 2008, 2817; Elding 1998, 169; Monsieurs 2005, 45; Noordergraaf 2006, 241; Thomas 1995, 155). Mixed effects were seen on correct hand positioning (3 showed improved positioning(Boyle 2002, 63; Choa 2008, 87; Noordergraaf 2006, 241), 1 showed deterioration(Perkins 2005, 103)). Fewer studies investigated the impact on ventilation (n=11). Of these ten showed improved ventilation performance with feedback / prompt devices, (Beckers 2007, 100; Choa 2008, 87; Ertl 2007, 286; Handley 2003, 57; Monsieurs 2005, 45; Oh 2008, 273; Wik 2002, 273; Wik 2005, 27; Wik 2001, 167; Williamson 2005, 140) and one showed mixed changes. (Hostler 2005, 53)

Three manikin based 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 (Choa 2008, 87; Ertl 2007, 286) or faster initiation of CPR(Choa 2008, 87) . whilst the third study showed that multi-media phone CPR instruction required more time to complete tasks than dispatcher assisted CPR(Zanner 2007, 487). Two further manikin studies used two way video communication in order for the dispatcher to review and comment on CPR real time in addition to providing dispatcher assisted instructions. One of these studies (which used high school students as the CPR provider) found this strategy reduced “hands off” time, but failed to reduce the time to first chest compression (Bolle 2009, 116). The other study (which used adults without recent BLS training) found improvements in compression depth and rate in association with video assisted dispatcher feedback but at the cost of delays in the time taken to start CPR and total instruction time (Yang 2009, 490). .

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 (Berg 1994, 35)and Kern(Kern 1992, 145) 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 (Chiang 2005, 297) 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 (Fletcher 2008, 127) 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(Abella 2007, 54). 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)(Kramer-Johansen 2006, 283). 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). Niles(Niles 2009, 553) examined the effect of introducing the Q-CPR system during the resuscitation of 20 paediatric (age 8-21) resuscitation attempts in a before / after cohort study. Use of the feedback/prompt system reduced the amount of leaning (residual force > 2.5 kg force) between chest compressions.

Device Risks and Limitations

There may be some limitations to the use of CPR feedback / prompt devices. Two LOE 5 manikin studies(Perkins 2009, 79) (Perkins 2009, 79) 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(Perkins 2009, 79). 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(van Berkom 2008, 66). A letter to the editor reports two cases where prolonged resuscitation attempts with the Q-CPR device were associated with skin and soft tissue damage to the patient.

Acknowledgements:
Reylon Meeks, Fang Goa, Dana Edelson and Jasmeet Soar contributed to a published systematic review on this topic which arose from this worksheet. (Yeung et al 2009 Resuscitation)

Citation List

Abella 2007

Abella BS, Edelson DP, Kim S et al. (2007) CPR quality improvement during in-hospital cardiac arrest using a real-time audiovisual feedback system. Resuscitation 73:54-61

LOE 3; quality good; supportive

LOE 3 – before /after study in humans; quality good

COI – authors supported by device manufacturer

Beckers 2007

Beckers SK, Skorning MH, Fries M, Bickenbach J, Beuerlein S, Derwall M, Kuhlen R, Rossaint R.
CPREzy improves performance of external chest compressions in simulated cardiac arrest.
Resuscitation. 2007 Jan;72(1):100-7. Epub 2006 Oct 31

LOE 5 (population = 1st year medical students); Quality fair, supportive

Summary: This pseudo-randomized controlled trial randomly assigned medical students to training with or without a CPREzy device during an instructor led BLS course. Initial testing immediately after training included use of the CPREzy device during skill testing in that group. Follow-up testing was split the two arms into four sub-groups. No details as to how these groups were assigned are provided.

The initial head to head comparison of training and testing with CPREzy compared to training and testing with no device showed that the use of CPREzy during skill performance led to significant improvements in ECC rate: (93.7% versus 19.8%, $P < 0.01$); ECC depth: (71.2% versus 34.1%, $P< 0.01$) and the correct depth of compression (71.2% versus 34.1%, $p \leq 0.01$). There were no significant differences in the number of incomplete releases between compressions ($p = 0.722$) and incorrect hand positioning ($p = 0.244$).

The study went on to test the effect of CPREzy guided training compared to standard training on skill acquisition by recalling students one week later (marked in paper as sub-groups 1b and 2b). Testing was performed without feedback from the device in both groups. Skill acquisition (% correct compression depth defined as 40-50mm) was superior in the CPREzy arm (72% vs 44%, $P<0.01$). There were no other significant differences in compression rate; release or position.

Quality – fair. RCT using manikins. No details regarding randomization or concealment. Although participants initially randomized, it is unclear if stratification into 4 groups for follow-up testing was randomized or not and the numbers in each group range from 36-57 suggesting un-even allocations or high loss to follow-up.

Berg 1994

Berg RA, Sanders AB, Milander M et al. (1994) Efficacy of audio-prompted rate guidance in improving resuscitator performance of cardiopulmonary resuscitation on children. Acad Emerg Med 1:35-40

LOE 2 – supportive; quality poor

No COI

Bolle 2009

Bolle, S. R., Scholl, J.Gilbert, M. (2009). "Can video mobile phones improve CPR quality when used for dispatcher assistance during simulated cardiac arrest?" Acta Anaesthesiol Scand **53**(1): 116.

LOE 5; quality good

LOE 5 manikin study; quality good (randomized controlled trial)

No COI

Boyle 2002

Boyle AJ, Wilson AM, Connelly K, McGuigan L, Wilson J, Whitbourn R. Improvement in timing and effectiveness of external cardiac compressions with a new non-invasive device: the CPR-Ezy. Resuscitation. 2002 Jul;54(1):63-7.

LOE 5 – not directly comparing to an instructor; Quality – Poor (before-after comparison)

Quality – before and after comparison; cross over effects therefore possible. Non-blinded

No COI

Cho 2009

Cho, G. C. (2009). "Skin and soft tissue damage caused by use of feedback-sensor during chest compressions." Resuscitation **80**(5): 600;

LOE 5 ; Quality – fair

Case report of two patients sustaining soft tissue and skin injuries in association with an accelerometer device used during prolonged resuscitation attempts.

No COI

Chiang 2005

Chiang WC, Chen WJ, Chen SY et al. (2005) Better adherence to the guidelines during cardiopulmonary resuscitation through the provision of audio-prompts. Resuscitation 64:297-301

LOE 3; quality fair

In the first stage from 1 September to 30 November 2003, three major discrepancies were identified between clinical CPR practice and the current guidelines. These included an inadequate number of chest compressions per minute, unnecessary hands-off periods, and intubation attempt times longer than 20 s without re-oxygenation by a bag-valve-mask (BVM). In the second stage, we attempted to improve these deficiencies in CPR practice by the audio-prompt methods. Two instruments were employed to remind the operators: the first was an audiotape recorded from a metronome at 100 bleeps/min, and the other was a siren that sounded once every 20 s

LOE 3 – before /after study in humans; quality fair

No COI

Dine 2008

LOE 5, quality good, supportive

COI: Investigators and study supported by device manufacturer (Q-CPR)

Elding 1998

Elding C, Baskett P, Hughes A (1998) The study of the effectiveness of chest compressions using the CPR-plus. Resuscitation 36:169-173

LOE 5: Quality – good; supportive

Quality – not blinded; details of process of randomisation un-clear; No evidence of cross over effects

No comment about funding source or conflict of interest

Ertl 2007

Ertl, L. and F. Christ (2007). "Significant improvement of the quality of bystander first aid using an expert system with a mobile multimedia device." Resuscitation 74: 286-95.

LOE 5, quality good, supportive

No COI

Fletcher 2008

Fletcher D, Galloway R, Chamberlain D et al. (2008) Basics in advanced life support: a role for download audit and metronomes. Resuscitation 78:127-134

LOE 3, quality good. supportive

No COI

France 2006

France J, Wilson S, Whitton N (2006) Auditory and visual prompts during cardiopulmonary resuscitation in the emergency department. Emerg Med J 23:160-161

LOE 5; Quality poor; neutral

No COI

Handley 2003

Handley AJ, Handley SA (2003) Improving CPR performance using an audible feedback system suitable for incorporation into an automated external defibrillator. Resuscitation 57:57-62

LOE 5 ; quality good; supportive

No COI

Hostler 2005

Hostler D, Guimond G, Callaway C (2005) A comparison of CPR delivery with various compression-to-ventilation ratios during two-rescuer CPR. Resuscitation 65:325-328

LOE 5; quality good; supportive (ventilation) and neutral (compression);

COI – study supported by research grant from device manufacturer

Isbye 2008

Isbye, D. L., P. Hoiby, et al. (2008). "Voice advisory manikin versus instructor facilitated training in cardiopulmonary resuscitation." Resuscitation **79**(1): 73-81.

LOE 5, quality good; neutral (E1, E3); opposing (E2)

COI – 1st author received research grants from device manufacturer

Jantti 2009

Jantti, H., Silfvast, T., Turpeinen, A., Kiviniemi, V.Uusaro, A. (2009). "Influence of chest compression rate guidance on the quality of cardiopulmonary resuscitation performed on manikins." Resuscitation 80(4): 453.

LOE 5; quality fair; supportive

LOE 5 – manikin study; quality fair (before and after comparison rather than RCT)

No COI

Kern 1992

Kern KB, Sanders AB, Raife J et al. (1992) A study of chest compression rates during cardiopulmonary resuscitation in humans: the importance of rate-directed chest compressions. Arch Intern Med 152:145-149

LOE 2; supportive, quality fair

Interventional study in adults in cardiac arrest. Comparators – std CPR; metronome guided (rate 80 +120). Patients acted as own controls. Improved ETCO2 in metronome group (highest in 120 rate group).

No COI

Kramer-Johansen 2006

Kramer-Johansen J, Myklebust H, Wik L et al. (2006) Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: a prospective interventional study. Resuscitation 71:283-292

COI – study supported by research grant from device manufacturer

Lynch 2005

Lynch B, Einspruch EL, Nichol G et al. (2005) Effectiveness of a 30-min CPR self-instruction program for lay responders: a controlled randomized study. Resuscitation 67:31-43

LOE 5; Quality – Poor, supportive (E1), neutral (E2,E3)

Summary: Adults (age 40-70) laypersons, without CPR training in the previous 5 years, were randomized to one of 5 groups. 3 groups received video self instruction (video; inflatable manikin and CPRcoach (which gives audio feedback on ECC rate and depth) either alone; with instructor facilitation or peer facilitation; instructor delivered training (4 hours) or control (no training). There were no differences between the 3 self instruction groups so their data were pooled for analysis.

A higher proportion of participants in the VSI group were judged to have demonstrated adequate overall performance compared to the instructor group (40% vs 59%, P=0.014). The mean percentage correct ventilations (defined as ventilation > 700ml on Laerdal manikin sensor) were also higher in the VSI group (39% vs 87%, P=0.031). There were no significant differences in other comparisons (sequence; hand placement; compression depth. Comparisons with the un-trained control group are not considered relevant to this worksheet.

The study does not separate the effects from audio-visual feedback from video self instruction, so the individual contribution of audio-visual feedback is not examined hence LOE 5.

Quality – poor. No sample size estimate but power probably OK based on similar studies of this size. No details of randomization process or concealment are provided. The paper does not state whether participants were randomized to groups of a 1:1 or other basis. The primary and secondary outcomes are not defined a priori. The number of participants in each group appears to vary between outcome measures, without any clear explanation as to the reasoning behind this.

COI The study received financial support from the AHA and Laerdal Medical

Milander 1995

Milander MM, Hiscok PS, Sanders AB et al. (1995) Chest compression and ventilation rates during cardiopulmonary resuscitation: the effects of audible tone guidance. Acad.Emerg.Med. 2:708-713

LOE 2, quality fair, supportive

Summary: Translational research study which involved observing CPR quality in real life and then effect of CPR audible tone guided CPR in laboratory on pigs (before / after comparison). CPR quality (compression rate) ETCO2 improved (minimal effect on coronary perfusion pressure) with audible tone guidance.

No COI

Monsieurs 2005

Monsieurs KG, De Regge M, Vogels C, Calle PA (2005) Improved basic life support performance by ward nurses using the CAREvent Public Access Resuscitator (PAR) in a simulated setting. Resuscitation 67:45-50

LOE 5; quality fair , supportive

Summary: Evaluation of CPR performance before and after CPR update training (different groups). Update group randomized to standard CPR training using pocket mask or PAR (public access resuscitator). The PAR device provides positive pressure ventilation (2) followed by 15 audible beeps to signal chest compression rate. Groups tested with and without PAR in randomized order (detail not completely clear). Study showed improved CPR performance after training with PAR group out performing standard CPR group both with and without the PAR device in operation.

No COI.

Noordergraaf 2006

Noordergraaf GJ, Drinkwaard BW, van Berkom PF et al. (2006) The quality of chest compressions by trained personnel: the effect of feedback, via the CPREzy, in a randomized controlled trial using a manikin model. Resuscitation 69:241-252

Level of evidence 5; quality fair; supportive

Reported as a "randomised" study of medical, nursing and support staff "forced" to participate in comparison of CPREzy versus standard CPR on a manikin. No details of randomisation process provided although allocation appears to have been 1:1. Unclear if CPREzy arm received additional tuition on device prior to testing.

COI – none stated

Niles 2009

Niles, D., Nysaether, J., Sutton, R., Nishisaki, A., Abella, B. S., Arbogast, K., Maltese, M. R., Berg, R. A., Helfaer, M.Nadkarni, V. (2009). "Leaning is common during in-hospital pediatric CPR, and decreased with automated corrective feedback." Resuscitation 80(5): 553.

Level of evidence 3; quality fair; supportive

Quality fair – 20 patients generated 40,000 data points. Statistical analysis did not correct for lack of independence between results

COI – grant support from device manufacturer; one of the authors an employee of the device manufacturer

Nishisaki 2009

Nishisaki, A., Nysaether, J., Sutton, R., Maltese, M., Niles, D., Donoghue, A., Bishnoi, R., Helfaer, M., Perkins, G. D., Berg, R., Arbogast, K.Nadkarni, V. (2009). "Effect of mattress deflection on CPR quality assessment for older children and adolescents." Resuscitation 80(5): 540.

LOE 5; quality good

COI – research group have received grant support from device manufacturer

Perkins 2005

Perkins GD, Augre C, Rogers H, Allan M, Thickett DR (2005) CPREzy: an evaluation during simulated cardiac arrest on a hospital bed. Resuscitation 64:103-108

Level of evidence 5; quality good

Summary: Randomised control cross over trial using CPREzy device amongst medical students. Study demonstrated improvements in some aspects of chest compression quality (depth) but not all (hand position worse). Participants found CPRezy caused greater fatigue than standard CPR and was associated with wrist pain in 95%. One medical student sustained an injury to their hand with the device.

Quality – good. Adequate sample size and randomisation process. 7 day "wash out" period to reduce cross over effects

Conflict of interest: Study received financial support from manufacturer although statement indicates that design, conduct, analysis and reporting were independent from sponsor. The worksheet author was a co-author on this paper.

Perkins 2009

Perkins, G. D., Kocierz, L., Smith, S. C., McCulloch, R. A.Davies, R. P. (2009). "Compression feedback devices over estimate chest compression depth when performed on a bed." Resuscitation **80**(1): 79.

LOE 5; quality good; opposing

COI – worksheet author was a coapplicant

Spooner 2007

Spooner BB, Fallaha JF, Kocierz L, Smith CM, Smith SC, Perkins GD. An evaluation of objective feedback in basic life support (BLS) training. Resuscitation. 2007 Jun;73(3):417-24. Epub 2007 Feb 1.

LOE 5 (population = 1st year medical students); Quality fair

Summary: This randomized controlled cross over trial investigated whether the addition of audio/visual feedback from a resuscitation manikin improved initial skill acquisition and skill retention compared to instructor only feedback. The manikins gave basic visual feedback on compression depth, hand position, release, ventilation volume, flow and rate and audio feedback on rate (metronome). Testing (with feedback turned off) was undertaken immediately after training (initial testing) and 6 weeks later (recall testing). At initial testing skill acquisition were significantly greater in the manikin feedback group (compression depth 39.96(5.9) vs 36.7 (7.4), P=0.018); % correct ECC (58(38) vs 40(37), P=0.023); ventilation flow rate 1371(493) vs 1174(404), P=0.023). There were no differences in acquisition of skill sequence between groups, compression rate; tidal volume or % correct rescue breaths.

No details on randomization or concealment.30% drop out between initial testing and follow-up, although evenly distributed between the two arms and follow-up testing not directly relevant to this worksheet.

This study was supported by the Resuscitation Council (UK). The worksheet reviewer was a co-author on this paper.

Sutton 2007

Sutton RM, Donoghue A, Myklebust H, Srikantan S, Byrne A, Priest M, Zoltani Z, Helfaer MA, Nadkarni V.
The voice advisory manikin (VAM): an innovative approach to pediatric lay provider basic life support skill education.
Resuscitation. 2007 Oct;75(1):161-8. Epub 2007 Apr 25

LOE 1; Quality – Good; Supportive

Summary: This study was a randomized controlled trial. Parents and lay care providers of hospitalized children were randomized to receive a scripted didactic pediatric CPR demonstration (including video) followed by either 20 minutes practice using an automated manikin (VAM system – set for audio and visual feedback) or instructor (1:1 ratio). The quality of CPR was then measured on a manikin immediately after training. The primary outcome of the study was % correct compressions and ventilations. Participants that failed to achieve >70% correct ECC + ventilations were re-trained using the same method and then re-tested. The study demonstrated improved CPR skill acquisition n the VAM arm (% correct CC 47.8(16.6) vs 26.6(17.7), P<0.001; % correct ventilations 5.3(2.1) vs 2.7(2.5), P<0.001) and lower error rates. These differences persisted after retraining.

No details of the sample size was derived are included. No details of randomization process or concealment were provided. 1 participant was randomized but not included in the data analysis as they were unable to perform the skill. The secondary outcomes were averaged from either 1 or 2 practice sessions. As only poorly performing participants were re-trained (higher proportion in the instructor arm) these results are potentially biased.

The study was funded by Endowed Funding from the Chair of Pediatric Critical Care Medicine at the Childrens Hospital Philadepphila; the research group have received grant support from the device manufacturer

van Berkom 2008

van Berkom PF, Noordergraaf GJ, Scheffer GJ, Noordergraaf A (2008) Does use of the CPREzy involve more work than CPR without feedback? Resuscitation 78:66-70

Level of evidence 5; quality good; Opposing
Summary: Laboratory study on manikins demonstrating that rescuer fatigue associated with CPREzy is due in part to extra work required to compress the spring in the CPREzy device.

Conflict of interest: CPREzy device donated by manufacturer. No other conflicts.

Wik 2001

Wik L, Thowsen J, Steen PA (2001) An automated voice advisory manikin system for training in basic life support without an instructor. A novel approach to CPR training. Resuscitation 50:167-172

Summary – randomised controlled cross over trial of audible CPR prompt device or no prompts amongst paramedic students (3 mins CPR, 2 min rest during cross over; 3 min CPR). Improved ventilation and compression parameters found in group that started with no feedback before progressing to feedback. No difference found in other groups – implying that in short term device not needed to maintain good quality CPR after initial guidance.

No COI stated

Wik 2002

Wik L, Myklebust H, Auestad BH, Steen PA (2002) Retention of basic life support skills 6 months after training with an automated voice advisory manikin system without instructor involvement. Resuscitation 52:273-279

LOE 5, quality fair (non randomised, own controls), supportive

Summary: Sequential study investigating the utility of voice prompts from a manikin to improve CPR performance amongst trained lay persons. The study also looked at the impact of refresher training although this is not directly relevant to this worksheet. Study found that CPR prompt device improved skill acquisition (improved ECC and ventilations - both with and without using device during testing). The study did not directly test the effect of voice prompts during training on retention of skills. However during retention testing compression and ventilation parameters improved when prompts were activated during actual testing.

COI Participants were employees of the manufacturer. Study was funded by the manufacturer of the manikin.

Wik 2005

Wik L, Myklebust H, Auestad BH, Steen PA (2005) Twelve-month retention of CPR skills with automatic correcting verbal feedback. Resuscitation 66:27-30

Primary objective of study was to investigate impact of refresher training on CPR performance whilst audio-visual feedback was provided during testing. Outcomes relevant to this worksheet were improved ventilation and chest compression performance (with feedback) 12 months after initial training and testing (without feedback).

COI Participants were employees of the manufacturer. Study was funded by the manufacturer of the manikin.

Williamson 2005

Williamson LJ, Larsen PD, Tzeng YC, Galletly DC (2005) Effect of automatic external defibrillator audio prompts on cardiopulmonary resuscitation performance. Emerg Med J 22:140-143

LOE 5; quality good. Supportive (untrained providers) and neutral (trained providers)

Summary: Two phase study. Phase one was a randomised controlled cross over trial of no feedback and feedback using audiovisual prompts in CPR naive lay persons. Following phase one, participants received CPR training. Eight weeks later participants returned for phase 2 – a randomised cross over trial with / without the feedback device. Phase 1 found that feedback was associated with improved chest compression rate, number of compressions, ventilation rate and number of correct ventilations. There was no difference in CPR quality in group with feedback initially when tested without feedback, implying that training with feedback improved skill acquisition. Phase two found no difference in performance with/without use of device. Conclusion – use of a CPR prompt device during actual simulated resuscitation performance improves

No COI

Yang 2009

Yang, C. W., Wang, H. C., Chiang, W. C., Hsu, C. W., Chang, W. T., Yen, Z. S., Ko, P. C., Ma, M. H., Chen, S. C.Chang, S. C. (2009). "Interactive video instruction improves the quality of dispatcher-assisted chest compression-only cardiopulmonary resuscitation in simulated cardiac arrests." Crit Care Med **37**(2): 490.

LOE 5; quality good; supportive

LOE 5 manikin study; quality good (RCT) ; supportive

No COI stated

Table 1 : 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% ($p \leq 0.01$)	93.7% vs 19.8% ($p \leq 0.01$)	x	71.9% vs 43.6% ($p \leq 0.01$)	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 comparis	24	92% vs 32% ($p=0.002$)	No effect	x	x	x	x

				on							
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	Parame	Before/	24	x	x	64% vs 2%	x	x	x

			dic students	after comparison				(p=0.002)			
Wik 2002	VAM	Feedback	Lay person	Before/ After comparison	A= 35 R= 30	No effect	X	71%±27 vs 58%±30 (p≤0.01)	No effect	x	58%±27 vs 18%±26 (p≤0.01)

Table 2: 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% participants correct (P=0.001)	64% vs 29% (P=0.005)	X
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	Feedback	Nurses	RCT	36	56.0%±32.2vs	No effect	x	Reduced shallow

	incorporated in AED					11.4±20.7% P<0.00005			compressions
Hostler 2005	VAM	Feedback	EMS staff	Randomised cross over	114	No effect	x	No effect	X
Jantti 2009	Metronome	Prompt	ICU nurses	Before / after	44	No effect	137±18 vs 98±2 (P<0.001)	No effect	Reduced no flow time
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 40±9mm (p=0.0001)	No effect	94% vs 64% (P=0.0001)	Improved hand position
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	No effect	X	X

						($p \leq 0.05$)			
Wik 2005	VAM	Feedback	BLS trained laypersons	Before / after comparison 12 months after initial training	28	87±9 vs 32±33% P<0.008	No effect	x	x
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	28	No effect	x	62(25) vs 9(20)% P<0.001	X

				training					
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