

Review article

How best to teach CPR to schoolchildren: A systematic review[☆]

Nina Plant, Katherine Taylor*

Department of Anesthesiology and Pain Medicine, Hospital for Sick Children, Toronto, Canada

ARTICLE INFO

Article history:

Received 5 July 2012

Received in revised form

28 November 2012

Accepted 3 December 2012

Keywords:

CPR training

CPR education

Schoolchildren

ABSTRACT

Background: Training schoolchildren to perform cardiopulmonary resuscitation is one possible method of increasing bystander CPR rates. We reviewed available literature to identify what methods of training children have been successful.

Objectives and methods: This review sought to evaluate evidence addressing the following PICO question: (P) In schoolchildren, (I) what types of CPR, AED and first aid training (C) when compared to no training and to each other (O) lead to ability to perform life saving measures? Searches were conducted in Ovid MEDLINE (1946 – August 2012), Ovid EMBASE (1974 – August 2012) and Ebscohost Cinahl (1981 – August 2012). Database specific subject headings in all three databases (MeSH in MEDLINE, Emtree in EMBASE, Cinahl Headings) were selected for the concepts of cardiopulmonary resuscitation (CPR) and education. The combined results were then limited by age to include all school aged children. The search yielded 2620 articles. From titles, abstract and key words, 208 articles described CPR, AED and/or first aid training in schoolchildren and were eligible for review. These were obtained in full, were unavailable or not published in English. We reviewed articles for publication type and relevance. 48 studies were identified. One additional study was included as an extension of a study retrieved within the search.

Results: The studies found by the search were heterogeneous for study and training methodology. Findings regarding schoolchild age and physical factors, the role of practical training, use of self-instruction kits, use of computer based learning, reduced training time, trainer type, AED training are presented.

Conclusions: Evidence shows that cardiopulmonary training, delivered in various ways, is successful in a wide age range of children. While older children perform more successfully on testing, younger children are able to perform basic tasks well, including use of AEDs. Chest compression depth correlates with physical factors such as increasing weight, BMI and height. Instruction must include hands on practice to enable children to perform physical tasks. Repeated training improves performance and retention but the format and frequency of repeated training is yet to be fully determined. Types of training that may reduce the main obstacles to implementation of such training in schools include use of self-instruction kits, computer based learning and use of teacher and peer tutor trainers, but again, need further exploration. As starting points we recommend legislative and funded mandates to provide such training to schoolchildren, and production and use of a framework which will delineate longitudinal delivery of training over the school career. Further research should have some uniformity in terms of assessment methodology, look at longer outcomes, and ideally will evaluate areas that are currently poorly defined.

© 2013 Published by Elsevier Ireland Ltd.

1. Introduction

The American Heart Association (AHA) published an advisory statement in 2011 which recommended that cardiopulmonary resuscitation (CPR) training for schoolchildren be mandatory.¹ The ultimate aim of CPR training provision at school is to increase

the rate of bystander CPR and survival after out of hospital cardiac arrest (OHCA). The annual incidence of adult sudden OHCA in the US is estimated at 55/100,000 people and survival is less than 10% across the US and Europe.^{2,3} A cardiac arrest victim is 2–4 times more likely to survive a cardiac arrest with bystander CPR provision⁴ but rates of bystander CPR at cardiac arrests are consistently less than 20%.^{3,5}

Arguments for CPR training in schoolchildren include: training a large cohort of the population will, over time, increase the proportion of trained adults in the population; increasing awareness, interest and sense of importance of actions in OHCA to a wide audience early on in life^{6–8}; training provision at a time when learning is already the main activity⁹; provision of life-saving

[☆] A Spanish translated version of the abstract of this article appears as Appendix in the final online version at <http://dx.doi.org/10.1016/j.resuscitation.2012.12.008>.

* Corresponding author at: Hospital for Sick Children, 555 University Avenue, Toronto, ON M5G 1X8, Canada. Tel.: +1 416 813 7445; fax: +1 416 813 7543.

E-mail address: Katherine.taylor@sickkids.ca (K. Taylor).

knowledge and skills at a time of increased mobility outside of the home into public areas and increasing employment¹⁰; schoolchildren are likely to be sufficiently physically fit to provide CPR; potential automaticity of response in a cardiac arrest situation¹¹; distribution of education and training across cultural and social groups; increased self-esteem and introduction of ideas of responsibility with provision of help in emergency situations a 'normal' response¹²; exposure of information and training materials to a second tier of learners at home.

2. Methods

2.1. PICO question

This review sought to evaluate evidence addressing the PICO question: (P) In schoolchildren, (I) what types of CPR, AED and first aid training (C) when compared to no training and to each other (O) lead to ability to perform life saving measures?

2.2. Search strategy

Searches were conducted in Ovid MEDLINE (1946 – August 2012), Ovid EMBASE (1974 – August 2012) and Ebscohost Cinahl (1981 – August 2012). Database specific subject headings in all three databases (MeSH in MEDLINE, Emtree in EMBASE, Cinahl Headings) were selected for the concepts of cardiopulmonary resuscitation (CPR) and education. These subject headings were exploded, when applicable, to include narrower terms. Text word searches were also generated for the concept of CPR. All CPR terms (both subject headings and text words) were combined first using the Boolean "OR." All education terms were combined also using a Boolean "OR." These 2 sets of terms were then combined with the Boolean "AND." In the case of MEDLINE and Cinahl, CPR subject headings were also searched using the subheading "education" in order to capture different indexing practices. These results were then combined with the previous results using "OR." The combined results were then limited by age to include all school aged children. Relevant ages and "school" terms were also searched as text words and combined with the CPR and education results. In all databases, truncation symbols and adjacency commands were used in text word searches when appropriate, to capture variant endings of the search terms and variant spellings. No language or date restrictions were applied.

Articles describing CPR, AED and/or first aid training in schoolchildren were eligible for review. Titles, abstract and key words (where available) were reviewed for relevance by author NP and clearly irrelevant articles were discarded. Remaining articles that were available in English were sought in full and reviewed for publication type and relevance. Inclusion criteria: any study looking at provision of CPR, AED and first aid training to children of school age were included. Exclusion criteria: studies not looking exclusively at but including provision of such training to school age children, or where subjects were obviously attending higher education establishments, were excluded. Reference lists were not reviewed. One additional study was included as an extension of a study retrieved within the search.

2.3. Evidence appraisal

Studies were reviewed and classified by level of evidence according to SIGN guidelines¹³ (see [Supplementary Table 1](#)). Notable in studies performed prior to 1997, when research and scientific rigor was not equivalent to current standards, methodology descriptions are brief (standard at that time) and control selection methods are poor. While their data may be stronger, our level of

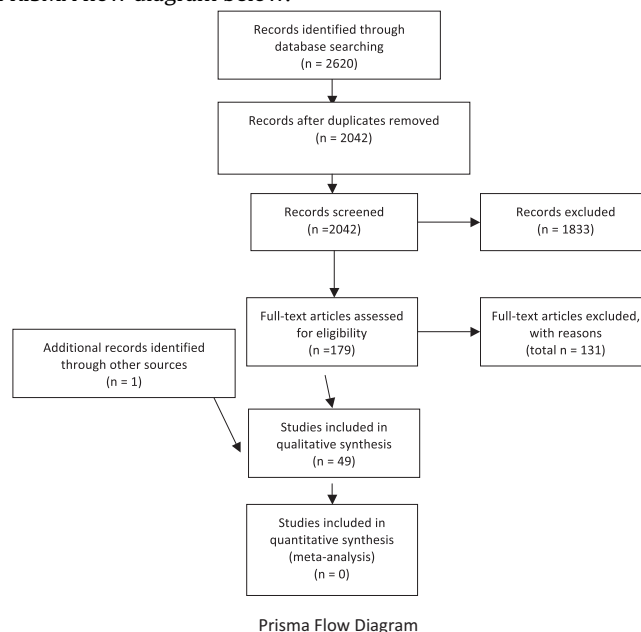
evidence scores err toward downgrading these papers for these reasons.

2.4. Data presentation

Numerical data are represented as originally presented in their parent publication.

3. Results

This search identified 2620 publications. After removal of 579 duplicates, 2041 publications were reviewed. Working from titles, abstracts or key words, 208 articles appeared relevant. 29 were unavailable in English. Of remaining articles, 48 were studies and fully reviewed. One additional study identified by and related to a search find was also included. This data is also presented in the PRISMA flow diagram below.



4. Study factors

Investigative methodology, training and reporting trends have varied and changed over the 50-year period in which relevant studies have been published, as mentioned above. In addition, the training objectives have had to keep pace with evolving life support recommendations.

5. Schoolchild factors

5.1. Schoolchild age

Studies assessing success of training courses demonstrate significant improvements in performance after training, compared to baseline, in children of all ages, from 4 to 20 years. While most studies have looked at training in teenagers, children of 4–5 years have been able to assess consciousness and breathing, remember the emergency number, give sufficient information by telephone, put a patient into recovery position and open the airway when tested 2 months after training.¹⁴ On assessment on the same tasks, performance of 6–7-year olds was 'excellent', and performance of CPR was deemed 'reasonable' to 'good'.¹² In another study of 6–7-year olds, which also included AED deployment, children performed significantly better than controls ($p < 0.001$).¹⁵ Authors also noted changes in empathic social behaviors.

Other investigators have trained children of a wider age range. Studies comparing children of different ages (8 versus 11 years, 12–20-year olds, and 11–15-year olds) found that older children (in higher school grades) perform better in testing than their younger counterparts for knowledge (MCQ ($p < 0.001$),¹⁶ and skills ($p = 0.01$),¹⁷ (pearson correlation 0.56, $p = 0.001$).¹⁸ Another group noted a trend toward better performance of discrete skills in older children.¹⁹

5.2. Physical factors

Child age and gender have been linked to ability to perform mouth to mouth ventilation (MMV), with older children, ($p = 0.0005$)²⁰, boys ($0 < 0.02$)²⁰ and children with a greater BMI ($r = 0.21$ $p = 0.01$)¹⁹ providing greater tidal volumes.

Studies also demonstrate significant correlations between weight, BMI, height and gender on chest compression depth (CCD).^{18,19,21,22} One group identified a BMI > 15 in 9–18-year olds as the threshold above which adequate CCD could be provided.¹⁹ Another group identified a minimum weight of 50 kg to provide chest compressions of recommended depth.²³ In a 4-year longitudinal study the difference in CCD between children starting regular CPR training at 10 versus 13 years of age was significantly in favor of older children at 1 year ($p < 0.05$), but after 3 and 4 years (the younger children now 13–14 years old) those starting training earlier in life were performing significantly deeper compressions ($p < 0.05$).²⁴

The effect of factors including previous CPR training, social background, academic stress at school and gender has been variable.^{9,19,21,25–31}

6. Training factors

6.1. Effectiveness of CPR training in general

Traditional CPR training incorporates video and/or instructor demonstration, and hands-on manikin-based instruction and practice, accompanied by a manual. Testing is written and/or practical, although studies show poor correlation between the two in children.^{21,26,32}

Despite significant overall improvements after training, the quality of CPR on testing can still be poor. Despite good outcomes in other tested areas one study demonstrated that 29% of chest compressions by American children in grades 9–12 were 'effective'.³³ Another study found that, while significantly greater than untrained controls, less than 17% of trained children assessed airway, breathing or circulation during a basic life support testing scenario five months after training.³⁴ Older studies suggested that children performed discrete skills less well than continuous skills.^{35–37} Recent studies found deficiencies to be more balanced.^{26,38}

Of papers comparing children with adults, one found that high school students scored better on MCQ testing than police officers two months after training.²⁹ The second study compared 13–14-year olds against police cadets who scored higher on initial MCQ testing but worse than students a year later.³¹

6.2. The role of practical training

While standalone theoretical training could reduce time and resources needed, children receiving only theoretical training perform poorly on skills testing. Investigators showed no difference in skill testing between untrained controls and those who had trained online.³⁹ Another group found that children undertaking online and practical training outperformed an online training-only group with differences of 32–54% versus 57–74% in performing key CPR

actions.³³ Others found that 8–11-year olds receiving only theoretical training performed significantly less well on MCQ than those also receiving practical training ($p < 0.01$).¹⁶ Older studies also looked at this. In one study 55% of children receiving practical training passed the skills test versus 5% of those who had not.³⁵ In another study, schoolchildren either watched an instructional video or undertook teacher–instructor delivered training and manikin practice with pass rates of 37% versus 73% on skills testing.⁴⁰

6.3. Training type: compression to ventilation ratio

While guidelines include chest compressions and ventilations in CPR training, the provision of continuous chest compressions only (CCC) is an alternative approach that could increase willingness to initiate bystander CPR. Whether chest compressions delivered by children are more effective with different ratios of compressions to breaths is not yet clear (see [Supplementary Table 2](#)).

6.4. Self instruction kits

Studies reporting on performance of children and their adult relatives after distribution of self-instruction take-home kits to schoolchildren are summarized in [Supplementary Table 3](#). While children and adults show significant improvements in performance after training with the kit, adults provided more ventilations and chest compressions of adequate volume and depth. A further study provided self-instruction take-home kits to Italian 12th graders.⁴¹ When surveyed at 8 months, half of the children had used the kit at home for retraining.

An advantage of self-instruction kit training is that large numbers of children can be trained in this manner – over 54,000 in one Norwegian project.⁴² Another advantage is delivery of CPR training to adults or peers at home (a second tier). The Norwegian studies reported 2.9 and 3.8 persons trained per kit.^{42,43} The Italian study showed a multiplier effect of 1.77, significantly higher in girls ($p < 0.0001$).⁴¹ The Danish group reported a mean of 2.5 people using each kit and found a 2.9% increase in local bystander CPR rates, compared to the previous year (difference not significant).⁴⁴ Lorem et al. speculated that 12-year-old children were too young to fully engage their parents with the kit when parents performed significantly worse than their children.⁴² No study included a cost appraisal of their efforts, and the purchase cost of the self-instruction kits themselves may impede uptake by schools.

6.5. Computer based training (CBT)

Results of studies using CBT in CPR training in schoolchildren are summarized in [Table 1](#). Additionally, in studies looking at 'virtual world' (VW) or 'multiplayer online simulation' in 16–20-year olds, teenagers reported video gameplay from once a week to once a month and found the program easy to use and immersive,⁴⁵ suggesting that this could be an attractive training and/or retention tool to use in this age group.

6.6. Brief training effectiveness

Brief interventions can result in focused success. 'Proficiency' in CPR skills was achieved by 87.5% of 12–14-year olds after a 50-min condensed training program.⁴⁶ After 20 min of training, 30% of 13–14-year olds performed continuous chest compressions at the correct rate, 45% with adequate compression depth and 31% with consistently correct hand placement.²² Another group taught 146 high school students CPR in 50 min and on assessment, students achieved a mean score of 17.8/20 for skill sequences, rates of 42% adequate CCD and 73.5% of correct hand placement and a

Table 1
Performance after computer based training (CBT).

Study country (subjects)	Testing	Control	CBT only	CBT + hands on	Traditional
US ³⁵ (784)	Written	54%	82%	87%	77%
	Key CPR actions	12–19%	32–54%	51–90%	53–95%
	Key AED actions	32–54%	81–95%	91–98%	92–100%
Australia ⁴⁰ (14)	Written	50%	62.5%	-	-
	Scenario testing	0–2/2*	1–2/2*		

* No significant difference (*p* value not given).

visible chest rise in two thirds of ventilations.⁴⁷ In groups looking at teaching ventilation skills, one found that after 10 min of training, 23% of 17-year olds provided breaths of optimal volume (700–1000 ml) with mean minute ventilation provision between 7.5 and 10.93 l/min⁴⁸ and another found that after 30 min of training, 81.5% of 10-year olds and all 14-year olds were able to successfully provide 5 ventilations²⁰.

6.7. Retention and retention strategies

Studies looking at 2 months up to 5 years retention show significant improvements on testing soon after training, then regression toward baseline.^{12,25,34,37,49,50}

Older (1976–1989) and newer studies (2007–2011) have looked at improving retention with repeated training. Of older studies, one trained 265 children and repeated training in half of them at 6 months. On testing several months after their last training session, performance of key skills in those receiving two sessions was significantly better ($p = 0.05$).¹⁷ In another, a 15-min nurse-led review, 6 months after initial training, led to improved knowledge scores from a mean of 46.5 to 64.2%.²⁵ Another study using a refresher video found no significant difference on skills testing compared to controls.³⁶

In a 4-year study, groups receiving annual or biannual training (repetition of the same training) were assessed annually (prior to repeat training and a minimum of 7 months after the last training session). There was no apparent advantage in biannual training, and the authors noted complaints of boredom at such frequent training and decreased motivation.²⁴

Small studies ($N = 24$ and $N = 16$) looked at the use of virtual world platforms (VW) in retraining 16–20-year olds at high school^{45,51} and found that self-efficacy (subjective assumption that one is able to perform a specific action⁵²) scores for CPR performance increased significantly post training ($p = 0.001$, $p = 0.023$).⁴⁵ On scenario testing, the intervention group did not perform significantly better than controls but adhered better to the newer guidelines used in retraining (baseline CPR training for intervention and control groups were based on older guidelines).⁵¹

6.8. Does trainer type make a difference?

Generally, CPR instructors have been healthcare professionals or schoolteachers. Overall the success of training delivery by one versus the other is not clear (see [Supplementary Table 4](#)). However, benefits of schoolteacher trainers include: less use of healthcare workers which may reduce cost and scheduling difficulties; use of professional educators to provide training (few healthcare instructors will have trained to teach children); teachers' training is a longer term investment as they will train successive student groups. Teachers are willing instructors as long as they receive appropriate training.⁵³ Students trained by higher-rated trainers performed 'significantly' better than those trained by low rated trainers (p -value not given).³⁵ Another potential instructor pool is medical students, who have instructed schoolchildren in a number of studies and who may also benefit from the process.^{28,54,55} One

study explored the use of peer tutors within a program to improve emergency preparedness amongst rural US agricultural communities. After 'First Aid for Rural Medical Emergencies (FARME)' and teach the trainer (TTT) training, 15–19-year-old students provided peer training to over 1000 students from other schools. On written testing, the peer tutors did not differ overall from controls that had received only FARME training, but did score significantly higher on anticipatory actions to prevent injuries ($p = 0.03$). Peer tutors reported increased confidence to teach, enjoyment of team-work and felt that they, as peer tutors, were best placed to 'connect' with young learners.⁵⁶ Another group found no difference in performance between groups with teacher instructors with or without additional 'peer tutors',⁹ and the peer tutors themselves were not assessed. An older study used medical student instructors to train schoolchildren (mean age 17 years) in CPR. They suggested that success was partly due to facilitation of teaching by similarity in age between instructors and learners.⁵⁵

6.9. AED training

Studies demonstrate how little training may be required for a child to successfully operate an AED. Fifteen 11–12-year olds, without prior training, were given verbal directions about electrode pads, and all used the AED to defibrillate the manikin with adequate pad placement, and a mean time of 90 s from entering the scenario to shock delivery.⁵⁷ This compared to EMTs receiving 6-monthly AED instruction taking a mean time to shock of 67 s. After being shown how to apply defibrillation pads, 9-year olds delivered a shock in a mock code in a mean time of 59.3 s, dropping to a mean time of 36.2 s following an instructor-led 2-min review.⁵⁸

Prior to training, 45% of 12–14-year-old children knew what an AED was. After training, 75.7% were able to perform all 7 critical CCC and AED skills.⁴⁶ Without any practical training, 81–95% of children receiving CBT-only performed key AED actions at testing.³³ Children of 6–7 years delivered simulated AED defibrillation after training and received a median score of 1 (excellent). The authors concluded that for these children, 'using an AED was as simple as using a TV remote control'.¹⁵

7. Discussion

Some areas in the world have been able to improve their outcomes after OHCA by implementation of community-wide campaigns including training of schoolchildren in CPR. The US community of Seattle and King County have one of the best OHCA survival rates in the world. CPR was initiated by bystanders in 52% of OHCA cases in 2011 with 21% overall survival. Of patients suffering OHCA in a shockable rhythm prior to EMS arrival, 45% survived. This compares to under 5% survival in other US states.⁵⁹ In this region, CPR training was expanded out to the community in the 1970s and the EMS continue to provide training to community groups including schoolchildren. They aim to provide CPR/AED training to students three times prior to graduation from high school.⁶⁰ In Stavanger, Norway, bystander CPR rates increased from 60%

(2001–2005) to 73% (2006–2008) attributed in part to training over 54,000 schoolchildren.^{42,61}

This review has identified that CPR, AED and first aid training is effective in children from the age of 4 years up to school leaving age, and that children may retain knowledge and skills years later. Younger children are able to perform consciousness assessment, call for help and give relevant details, put victims into the recovery position and operate an AED. They also absorb messages about empathy and helping those in distress. However, teenage children perform better in all areas and compare favorably with adults. Ability to perform adequate chest compressions and ventilations increases with age, weight, BMI and height with thresholds for success identified as a BMI over 15 and weight over 50 kg. Consensus on the appropriate age to start CPR training in schoolchildren has historically been from 10 to 11 years of age, based on intellectual ability and sufficient body mass to effectively provide chest compressions and ventilation^{7,53,62,63} but starting age-appropriate training earlier would deliver key messages, build a foundation and provide time for other training opportunities and reinforcement later in the school career.

On testing, there are clear differences between children who do and do not receive practical training in CPR and, as recommended in lay person CPR training,⁶⁴ the hands-on element is essential – arguably more so in children who may be more difficult to keep engaged. Evidence on how to improve retention of skills shows that repeated training improves performance. Optimal frequency of repeated training is not yet clear but biannual training, versus annual training, has not improved performance at yearly testing. The best format of revision training is not clear, but we need to use varying formats to keep the topic fresh and engaging. Increasing access to, and high levels of familiarity within this age-group with computer-based and online programs warrants further exploration for initial and revision training.

Studies looking at AED training in children show that children as young as 6 years can quickly deliver a shock with minimal training. No studies have discussed in depth whether we should, however, be encouraging this to happen in real life situations, and at what age we should encourage AED use, given the theoretical risk of harm to themselves.

Building a framework to outline what training should be delivered at what age would allow a longer-term view on how to deliver training throughout a child's school career. Longitudinal studies would help build the evidence for how best to deliver this training. Based on current evidence, training should start early with age-appropriate topics, regular reinforcement of key actions such as recognition and calling for help, and sequential introduction of more complex actions with increasing age (and size). Such a strategic framework would open discussions on logistics and funding. An existing American framework authored by a multidisciplinary taskforce, published by the US Maternal and Child Health Bureau, named BELS could provide a starting point.⁶⁵

In addition, moves to minimize complexity of training and to introduce non-technical skills (NTS) and strategies may help school-age children deliver care in a real-life situation.^{64,66} Of US students answering a survey, 86% had previously received training in CPR, and 106 had witnessed a cardiac arrest. Of these, 23% had got involved in the rescue attempt.⁶⁷ Providing strategies to communicate with emergency dispatchers, to engage adults rescuers at the scene, and to boost self-confidence would be valuable.

In reality, it is impossible to divorce CPR training in schoolchildren from cost, time and effort involved in implementation of teaching programs and in sustaining delivery. Potential options for overcoming these obstacles would be: reduce instructor time; use non-healthcare instructors; move learning out of school and into homes using self-instruction kits (with a secondary benefit of

increasing access to a second tier of learners); increase use of CBT; minimize training session time. Use of teacher instructors has not been shown to be inferior to use of healthcare instructors and teachers really are best placed to coordinate and deliver this training. Using volunteer community trainers would also reduce costs. The use of older schoolchildren as 'peer tutors' could benefit both age groups but has not been fully explored. Self-instruction kits have been used successfully to train large numbers of schoolchildren, and in part accounted for increased bystander CPR rates however a cost evaluation has not been performed and the initial outlay of cost in purchasing the kits may be prohibitive.

Implementation and uptake within schools is still a wider issue. Without legislative mandate, uptake of CPR training in school programs is likely to be slow. A first aid scheme in Norway promoted by the Ministry of Health was rolled out in only 37% of target schools despite provision of textbooks, videos and teacher manuals.⁵² In particular, unfunded legislative mandates are unlikely to be fully realized. Estimates of the costs involved in the delivery of school-based CPR training are described elsewhere.^{1,67,68} Alternative funding options are public–private finance partnerships, e.g. the ACT Foundation in Canada who have helped deliver training to 1.8 million students by raising funds, involving local partners, and assisting schools to set up programs.⁶⁹ Again, a clear delivery strategy for training over the school career could help to gain funding and support from authorities and streamline the use of resources by sharing of equipment, trainers and implementation costs across schools. Other factors that would encourage schools include greater curricular time, and more certified instructors. Many teachers believed linking training with other school goals, such as health education and employment preparation, was extremely important.⁶⁷

8. Conclusion

Studies performed over a wide time period and looking at a variety of approaches to training schoolchildren in CPR and associated skills show that all training interventions are successful within a short time scale in increasing knowledge and skills of children when tested. Training should start at an early age and be repeated at regular intervals over the school career. Training interventions should be age-appropriate and practical and should both reinforce core ideas and sequentially introduce skills of greater complexity. Brevity, diversity of format and attention to cost and efficiency will promote interest from children and schools. A framework outlining the delivery of training would help educational establishments to coordinate, plan and implement such training. Legislative and funding mandates are key to achieving the goal of providing all schoolchildren with training and improving rates of bystander intervention at OHCA.

Conflict of interest statement

No funding was formally allocated to undertaking this review.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.resuscitation.2012.12.008>.

References

1. Cave DM, Aufderheide TP, Beeson J, et al. Importance and implementation of training in cardiopulmonary resuscitation and automated external defibrillation in schools: a science advisory from the American Heart Association. *Circulation* 2011;123:691–706.

2. Rea TD, Eisenberg MS, Sinibaldi G, White RD. Incidence of EMS-treated out-of-hospital cardiac arrest in the United States. *Resuscitation* 2004;63:17–24.
3. Vaillancourt C, Stiell IG. Cardiac arrest care and emergency medical services in Canada. *Can J Cardiol* 2004;20:1081.
4. Van Hoeyweghen RJ, Bossaert LL, Mullie A, et al. Quality and efficiency of bystander CPR. *Resuscitation* 1993;26:47–52.
5. Gallagher EJ, Lombardi G, Gennis P. Effectiveness of bystander cardiopulmonary resuscitation and survival following out-of-hospital cardiac arrest. *J Am Med Assoc* 1995;274:1922–5.
6. Lewis RM, Fulstow R, Smith GB. The teaching of cardiopulmonary resuscitation in schools in Hampshire. *Resuscitation* 1997;35:27–31.
7. Miro O, Jimenez-Fabrega X, Espigol G, et al. Teaching basic life support to 12–16 year olds in Barcelona schools: views of head teachers. *Resuscitation* 2006;70:107–16.
8. Kanstad BK, Nilsen SA, Fredriksen K. CPR knowledge and attitude to performing bystander CPR among secondary school students in Norway. *Resuscitation* 2011;82:1053–9.
9. Lester C, Donnelly P, Weston C. Is peer tutoring beneficial in the context of school resuscitation training? *Health Educ Res* 1997;12:347–54.
10. Topham CS. Emergency medical care training and adolescents. *Adolescence* 1982;17:901–4.
11. Lester CA, Weston CF, Donnelly PD, Assar D, Morgan MJ. The need for wider dissemination of CPR skills: are schools the answer? *Resuscitation* 1994;28:233–7.
12. Bollig G, Wahl HA, Svendsen MV. Primary school children are able to perform basic life-saving first aid measures. *Resuscitation* 2009;80:689–92.
13. Network SIG. Sign 50 a guideline developer's handbook; 2008.
14. Bollig G, Myklebust AG, Ostringen K. Effects of first aid training in the kindergarten – a pilot study. *Scand J Trauma Resusc Emerg Med* 2011;19:13.
15. Uray T, Lunzer A, Ochsenhofer A, et al. Feasibility of life-supporting first-aid (LSFA) training as a mandatory subject in primary schools. *Resuscitation* 2003;59:211–20.
16. Lubrano R, Romero S, Scoppi P, et al. How to become an under 11 rescuer: a practical method to teach first aid to primary schoolchildren. *Resuscitation* 2005;64:303–7.
17. Van Kerschaver E, Deloos HH, Moens GFG. The effectiveness of repeated cardiopulmonary resuscitation training in a school population. *Resuscitation* 1989;17:211–22.
18. Naqvi S, Siddiqi R, Hussain B, Batool H, Arshad H. School children training for basic life support. *J Coll Physicians Surg Pak* 2011;21:611–5.
19. Fleischhackl R, Nuernberger A, Sterz F, et al. School children sufficiently apply life supporting first aid: a prospective investigation. *Crit Care* 2009;13.
20. Sherif C, Erdös J, Sohm M, et al. Effectiveness of mouth-to-mouth resuscitation performed by young adolescents on a mannequin. *Am J Emerg Med* 2005;23:51–4.
21. Schultz A, Rosenblum E, Skipper B. Alyce annie: a new CPR home practice manikin. *J School Health* 1981;51:507–11.
22. Jones I, Whitfield R, Colquhoun M, Chamberlain D, Vetter N, Newcombe R. At what age can schoolchildren provide effective chest compressions? An observational study from the Heartstart UK Schools Training Programme. *BMJ* 2007;334:1201.
23. Uhm TH, Oh JK, Park JH, Yang SJ, Kim JH. Correlation between physical features of elementary school children and chest compression depth. *Hong Kong J Emerg Med* 2010;17:218–23.
24. Bohn A, Van Aken HK, Mollhoff T, et al. Teaching resuscitation in schools: annual tuition by trained teachers is effective starting at age 10. A four-year prospective cohort study. *Resuscitation* 2012;83:619–25.
25. Corne L, Rydant L, Lauwaert D, Bruynseels P. Teaching cardiopulmonary resuscitation basic life support to school-children. *Acta Anaesthesiol Belg* 1984;35(Suppl.):107–13.
26. Lester C, Donnelly P, Weston C, Morgan M. Teaching schoolchildren cardiopulmonary resuscitation. *Resuscitation* 1996;31:33–8.
27. Frederick K, Bixby E, Orzel MN, Stewart-Brown S, Willett K. Will changing the emphasis from 'pulseless' to 'no signs of circulation' improve the recall scores for effective life support skills in children? *Resuscitation* 2002;55:255–61.
28. Toner P, Connolly M, Laverty L, McGrath P, Connolly D, McCluskey DR. Teaching basic life support to school children using medical students and teachers in a 'peer-training' model – results of the 'ABC for life' programme. *Resuscitation* 2007;75:169–75.
29. Rosafio T, Cichella C, Vetrugno L, Ballone E, Orlandi P, Scesi M. Chain of survival: differences in early access and early CPR between policemen and high-school students. *Resuscitation* 2001;49:25–31.
30. Jimenez-Fabrega X, Escalada-Roig X, Miro O, et al. Comparison between exclusively school teacher-based and mixed school teacher and healthcare provider-based programme on basic cardiopulmonary resuscitation for secondary schools. *Emerg Med J* 2009;26:648–52.
31. Jimenez-Fabrega X, Escalada-Roig X, Sanchez M, et al. Results achieved by emergency physicians in teaching basic cardiopulmonary resuscitation to secondary school students. *Eur J Emerg Med* 2009;16:139–44.
32. Parashar AK. Effective planned teaching programme on knowledge & practice of basic life support among students in Mangalore. *Nurs J India* 2010;101:40–1.
33. Reder S, Cummings P, Quan L. Comparison of three instructional methods for teaching cardiopulmonary resuscitation and use of an automatic external defibrillator to high school students. *Resuscitation* 2006;69:443–53.
34. Frederick K, Bixby E, Orzel MN, Stewart-Brown S, Willett K. An evaluation of the effectiveness of the injury minimization programme for schools (IMPS). *Injury Prevent* 2000;6:92–5.
35. Vanderschmidt H, Burnap TK, Thwaites JK. Evaluation of a cardiopulmonary resuscitation course for secondary schools. *Med Care* 1975;13:763–74.
36. Vanderschmidt H, Burnap TK, Thwaites JK. Evaluation of a cardiopulmonary resuscitation course for secondary schools retention study. *Med Care* 1976;14:181–4.
37. Moore PJ, Plotnikoff RC, Preston GD. A study of school students' long term retention of expired air resuscitation knowledge and skills. *Resuscitation* 1992;24:17–25.
38. Younas S, Raynes A, Morton S, Mackway-Jones K. An evaluation of the effectiveness of the opportunities for resuscitation and citizen safety (ORCS) defibrillator training programme designed for older school children. *Resuscitation* 2006;71:222–8.
39. Teague G, Riley RH. Online resuscitation training. Does it improve high school students' ability to perform cardiopulmonary resuscitation in a simulated environment? *Resuscitation* 2006;71:352–7.
40. Lind B. Teaching mouth-to-mouth resuscitation in primary schools. *Acta Anaesthesiol Scand Suppl* 1961;(Suppl. 9):63–81 [Acta Anaesthesiol Scand. 2007;51:1044–50].
41. Corrado G, Rovelli E, Beretta S, Santarone M, Ferrari G. Cardiopulmonary resuscitation training in high-school adolescents by distributing personal manikins. The Como-Cuore experience in the area of Como, Italy. *J Cardiovasc Med (Hagerstown)* 2011;12:249–54.
42. Lorem T, Palm A, Wik L. Impact of a self-instruction CPR kit on 7th graders' and adults' skills and CPR performance. *Resuscitation* 2008;79:103–8.
43. Lorem T, Steen PA, Wik L. High school students as ambassadors of CPR – a model for reaching the most appropriate target population? *Resuscitation* 2010;81:78–81.
44. Isbye DL, Rasmussen LS, Ringsted C, Lippert FK. Disseminating cardiopulmonary resuscitation training by distributing 35,000 personal manikins among school children. *Circulation* 2007;116:1380–5.
45. Youngblood P, Hedman L, Creutzfeldt J, et al. Virtual worlds for teaching the new CPR to high school students. *Stud Health Technol Inform* 2007;125:515–9.
46. Kelley J, Richman PB, Ewy GA, Clark L, Bulloch B, Bobrow BJ. Eighth grade students become proficient at CPR and use of an AED following a condensed training programme. *Resuscitation* 2006;71:229–36.
47. Kim SE, Lee SJ, Noh H, Lee DH, Kim CW. Is there any difference in cardiopulmonary resuscitation performance according to different instructional models of cardiopulmonary resuscitation education for junior and senior high school students? *Hong Kong J Emerg Med* 2011;18:375–82.
48. Paal P, Falk M, Sumann G, et al. Comparison of mouth-to-mouth, mouth-to-mask and mouth-to-face-shield ventilation by lay persons. *Resuscitation* 2006;70:117–23.
49. Plotnikoff R, Moore PJ. Retention of cardiopulmonary resuscitation knowledge and skills by 11- and 12-year-old children. *Med J Aust* 1989;150:296–302.
50. Connolly M, Toner P, Connolly D, McCluskey DR. The 'ABC for life' programme – teaching basic life support in schools. *Resuscitation* 2007;72:270–9.
51. Creutzfeldt J, Hedman L, Medin C, Stengard K, Fellander-Tsai L. Retention of knowledge after repeated virtual world CPR training in high school students. *Stud Health Technol Inform* 2009;142:59–61.
52. Engeland A, Roysamb E, Smedslund G, Sogaard AJ. Effects of first-aid training in junior high schools. *Inj Control Saf Promot* 2002;9:99–106.
53. McCluskey D, Moore P, Campbell S, Topping A. Teaching CPR in secondary education: the opinions of head teachers in one region of the UK. *Resuscitation* 2010;81:1601.
54. Breckwoldt J, Beetz D, Schnitzer L, Waskow C, Arntz HR, Weimann J. Medical students teaching basic life support to school children as a required element of medical education: a randomised controlled study comparing three different approaches to fifth year medical training in emergency medicine. *Resuscitation* 2007;74:158–65.
55. Mowbray A, McCulloch WJ, Conn AG, Spence AA. Teaching of cardiopulmonary resuscitation by medical students. *Med Educ* 1987;21:285–7.
56. Carruth AK, Pryor S, Cormier C, Bateman A, Matzke B, Gilmore K. Evaluation of a school-based train-the-trainer intervention program to teach first aid and risk reduction among high school students. *J Sch Health* 2010;80:453–60.
57. Gundry JW, Comess KA, DeRook FA, Jorgenson D, Bardy GH. Comparison of naive sixth-grade children with trained professionals in the use of an automated external defibrillator. *Circulation* 1999;100:1703–7.
58. Lawson L, March J. Automated external defibrillation by very young, untrained children. *Prehosp Emerg Care* 2002;6:295–8.
59. Division of Emergency Medical Services. Annual report to the King County Council. Public Health – Seattle & King County; 2012.
60. Kingcounty.gov. Cardiopulmonary resuscitation (CPR) education [online]. Available at: <http://www.kingcounty.gov/healthservices/health/ems/community/cpredu.aspx>; 2011 [accessed 23.09.12].
61. Lindner TW, Søreide E, Nilsen OB, Torunn MW, Lossius HM. Good outcome in every fourth resuscitation attempt is achievable – an Utstein template report from the Stavanger region. *Resuscitation* 2011;82:1508–13.
62. Eisenburger P, Safar P. Life supporting first aid training of the public – review and recommendations. *Resuscitation* 1999;41:3–18.
63. Lafferty C, Larsen PD, Galletly D. Resuscitation teaching in New Zealand schools. *N Z Med J* 2003;116:U582.
64. Soar J, Mancini ME, Bhanji F, et al. Part 12: Education, implementation, and teams: 2010 international consensus on cardiopulmonary resuscitation

- and emergency cardiovascular care science with treatment recommendations. *Resuscitation* 2010;81:e288–332.
65. (1999) MCHB. Basic emergency lifesaving skills (BELS): A framework for teaching emergency lifesaving skills to children and adolescents; 2003.
 66. Chehardy P, Doherty A, Dracup K, et al. Cardiopulmonary resuscitation and emergency cardiovascular care. Education. *Ann Emerg Med* 2001;37:S49–59.
 67. Reder S, Quan L. Cardiopulmonary resuscitation training in Washington state public high schools. *Resuscitation* 2003;56:283–8.
 68. Hazinski MF, Markenson D, Neish S, et al. Response to cardiac arrest and selected life-threatening medical emergencies: the medical emergency response plan for schools. A statement for healthcare providers, policy-makers, school administrators, and community leaders. *Pediatrics* 2004;113:155–68.
 69. Actfoundation.ca ACT [online]. Advanced coronary treatment foundation; 2012. Available at: <http://www.actfoundation.ca> [accessed 09.04.12].