Available online at www.sciencedirect.com

Resuscitation Plus

journal homepage: www.elsevier.com/locate/resuscitation-plus

Review

Outcomes of medical students training schoolchildren of ages 13–18 in cardiopulmonary resuscitation: A systematic review

Peitong Li[a,*], *Anita Milkovic*[a], *Peter Morley*[a,b], *Louisa Ng*[a]

Abstract

Background: Training schoolchildren in cardiopulmonary resuscitation (CPR) can increase the number of qualified people in the community, which in turn can improve survival rates of out-of-hospital cardiac arrests (OHCA). Medical students could be a valuable resource for providing the training. This systematic review aims to determine the outcomes of medical students providing CPR training to schoolchildren, aged 13–18 (who are thought to have the strength for effective chest compression), specifically CPR skills for both and non-technical skills such as communication and leadership for medical students.

Methods: A literature search of academic databases was conducted on 5 July 2023 using the following keywords: cardiopulmonary resuscitation, basic life support, medical students and high/middle/secondary school students. For the purpose of this review, "schoolchildren" refer to those aged 13–18. Studies were included where the primary focus was medical students teaching CPR to schoolchildren. The studies were critically appraised using the Medical Education Research Study Quality Instrument (MERSQI) tool and outcomes categorised by Kirkpatrick's Levels.

Results: Eleven studies were included, six randomised controlled trials and five cohort studies, with 1670 schoolchildren and 355 medical students as participants. Eight studies examined outcomes targeting schoolchildren, two examined outcomes for medical students and one examined both. Four of the eleven studies used validated outcome measures. Only outcomes at Kirkpatrick Level 1 and 2 were found, and all outcomes for both schoolchildren and medical students were positive. Schoolchildren showed improvements in theoretical and practical elements of CPR post-training, while medical students demonstrated improved professional practice skills such as leadership and mentorship as well as improvements in their own CPR skills post-teaching.

Conclusions: Schoolchildren can effectively acquire CPR skills through being trained by medical students, who themselves also benefit from improved CPR and professional practice skills after teaching. Further studies with robust methodology such as multi-site randomised controlled trials, the use of consistent and validated outcome measures, and the measurement of outcomes at higher Kirkpatrick levels to determine the impact on bystander CPR rates and community OHCA survival rates, are needed.

Keywords: Cardiopulmonary resuscitation, Basic life support, Medical students, Schoolchildren

Introduction

Cardiovascular mortality is often listed as one of the biggest leading causes of death worldwide, with out-of-hospital cardiac arrests (OHCA) affecting approximately 55 of every 100,000 adults per year.[1] Survival rates of OHCA have remained steady at 5–16% around the world over the past years[2]. Since many cardiac arrests occur in the community and are often witnessed by individuals within the proximity,[3] increasing the number of cardiopulmonary resuscitation (CPR) qualified community members can result in a higher chance of bystanders administering CPR, resulting in a two-fold increase in survival rate.[4] Training addresses the main barriers of bystander CPR: lack of knowledge, poor confidence[5] and fear of causing accidental harm.[6]

Incorporating mandatory training into the education curriculum for schoolchildren would increase CPR-trained individuals in the community.[7,8] Organisations such as the World Health Organisation and International Liaison Committee on Resuscitation have stated that schoolchildren can be effectively trained to provide CPR.[9,10] When CPR is not mandatory in schools, there is evidence that many people seek training to meet workplace requirements, or out of per-

* Corresponding author.
E-mail addresses: peitong.li@mh.org.au (P. Li), anita.milkovic@mh.org.au (A. Milkovic), pmorley@unimelb.edu.au (P. Morley), louisan@unimelb.edu.au (L. Ng).

https://doi.org/10.1016/j.resplu.2023.100463

2666-5204/© 2023 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

sonal interest indicating a significant societal interest in being skilled.[5] Andrews et al. identified that for individuals who have not undertaken training as part of their organisation, cost and access were the main barriers.[5] Introducing mandated CPR training in schools, as recommended by organisations such as the European Resuscitation Council (ERC) and American Heart Association, would therefore mitigate these barriers.[11,12]

The barriers of cost and access, however, are even more significant in large-scale training. In particular, it can be challenging to source large numbers of appropriately trained instructors. Whilst schoolteachers could be trained as instructors, their existing high workload limits the capacity of using them consistently as CPR instructors.[13] To reduce the demand for such CPR instructors, alternate educational tools and models have been trialled in schools, including online courses, app-based learning, peer assisted learning and teaching schoolteachers via the train-the-trainer model.[14–17] However, the lack of hands-on practice for app-based training resources restricts the effectiveness of training, which means that other alternatives should be sought. Some studies have successfully utilised qualified health professionals such as physicians, nurses and paramedics in teaching schoolchildren,[18–21] but the cost and availability of such instructors renders these teaching models unsustainable.

An alternate option is to involve medical students in CPR-instructor roles as a form of near-peer learning. Current literature suggests that medical students are as effective as physicians in teaching basic life support to schoolchildren,[22,23] with benefits thought to be bi-directional – children acquire CPR skills and confidence,[24–26] whilst medical students improve their own CPR skills[27,28] in addition to developing important soft skills such as teaching, mentorship and communication.[25,27,29]

There have been no systematic reviews conducted to date in this area – it would be useful to determine, in a comprehensive manner, the effectiveness of medical students teaching CPR to schoolchildren in terms of feasibility and knowledge transfer. It should be noted that since it is thought that older schoolchildren aged 13–18 are generally better able to provide chest compression to the adequate depth for effective CPR, this review therefore focuses on this subset of schoolchildren, and the phrase schoolchildren is used in this review to refer to schoolchildren only aged between 13 and 18. This review aims to identify existing evidence for the effectiveness of such educational interventions and to identify gaps in current knowledge. Such evidence may be useful for medical educators, researchers and policy makers when considering future school curriculums, as well as for future research.

Methods

This review was based on the Joanna Briggs Institute framework for systematic reviews, and written in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[30]

PICO(ST) was used to inform the search strategy:

- Population: Schoolchildren (recipients of intervention), and medical students (providers of intervention)
- Intervention: CPR training
- Comparison: No training or training conducted by other providers
- Outcomes: Knowledge, practice and professional skills, transfer of skills into the workplace, changes in organisational practice or direct benefits to patients
- Setting: Schools (for schoolchildren of ages 13–18 years)
- Timing: the search included studies from 1987 through to 2023

Data sources and search strategy

A database search of MEDLINE, EMBASE, EBMR, Scopus, CINAHL and EMCARE was conducted on 5 July 2023. Authors PL and AM developed the search strategy in conjunction with a university librarian with expertise in medical education. Keywords and search strings relevant to the topic were searched under the fields “Article Title” and “Abstract”, and where possible, medical subject headings (MeSH) were used. The following MeSH terms were included in the MEDLINE search: medical student, cardiopulmonary resuscitation, and schoolchildren (see Appendix 1 for full search). The search strategy employed for MEDLINE was adapted for the other databases. References of key articles were examined to identify further relevant publications. All years available in the databases were searched.

Study selection

Articles were included if medical students were the instructors and schoolchildren were the recipients of CPR teaching. These schoolchildren are typically in “high school”, “middle school” or “secondary school” depending on the schooling system.

Given that children below 13 years old are generally unable to provide chest compression to the adequate depth for effective CPR,[31] it was felt that if programs were to be introduced, resources should be focused on schoolchildren in the age bracket where effective chest compression could be provided. Mixed-learner studies with schoolchildren under 13 years of age were included if the majority (>75%) of the participants were above the age cut-off. In mixed instructor studies where the instructors were a mix of medical students and other types of professionals such as nurses or physicians, we included these studies if the results for medical students as instructors were reported separately. We included primary studies, published in English, where CPR training was the sole or predominant intervention. Outcomes could be for either medical students or schoolchildren or both. The reported outcomes were subsequently classified using Kirkpatrick’s four-level model of training evaluation (Table 1). Conference abstracts, opinion letters and editorials were excluded due to limited information. Articles were also excluded if involvement of medical students in CPR training was indirect (e.g. medical students training schoolteachers, who then trained schoolchildren).

Title and abstract review

Two reviewers (PL, AM) independently screened titles and abstracts for relevance, and full-text articles were then retrieved and screened for inclusion (Fig. 1). Any disagreements between the two reviewers were resolved by discussion with a third reviewer (LN). Multiple reports of the same study were collated and reported as a single study.

Data extraction

The following data were extracted from the included studies following the full-text review and entered into an Excel spreadsheet (by reviewer PL).

Table 1 – Kirkpatrick's levels for assessing educational outcomes.

Level 1: Reaction	**Level 1a**: Satisfaction reactions, commonly described as "liking of training".
	Level 1b: Utility reactions, which are self-perceived or self-assessed and include usefulness of the intervention, "ability to perform the job" and confidence
Level 2: Learning	**Level 2a**: Changes in attitudes or perceptions
	Level 2b: Post-intervention knowledge
	Level 2c: Behaviour or skill demonstration
Level 3: Transfer	**Level 3**: Transfer of attitudes or perceptions, knowledge, and skills into workplace
Level 4: Results	**Level 4a**: Changes in organisational practice including changes within the organisation or delivery of care
	Level 4b: Benefits to patients including improvement in the health outcomes and well-being of the patients

Note: Adapted from a meta-analysis of the relations among training criteria and a research article published by Yardley and Dornan on Medical Education.[44,45]

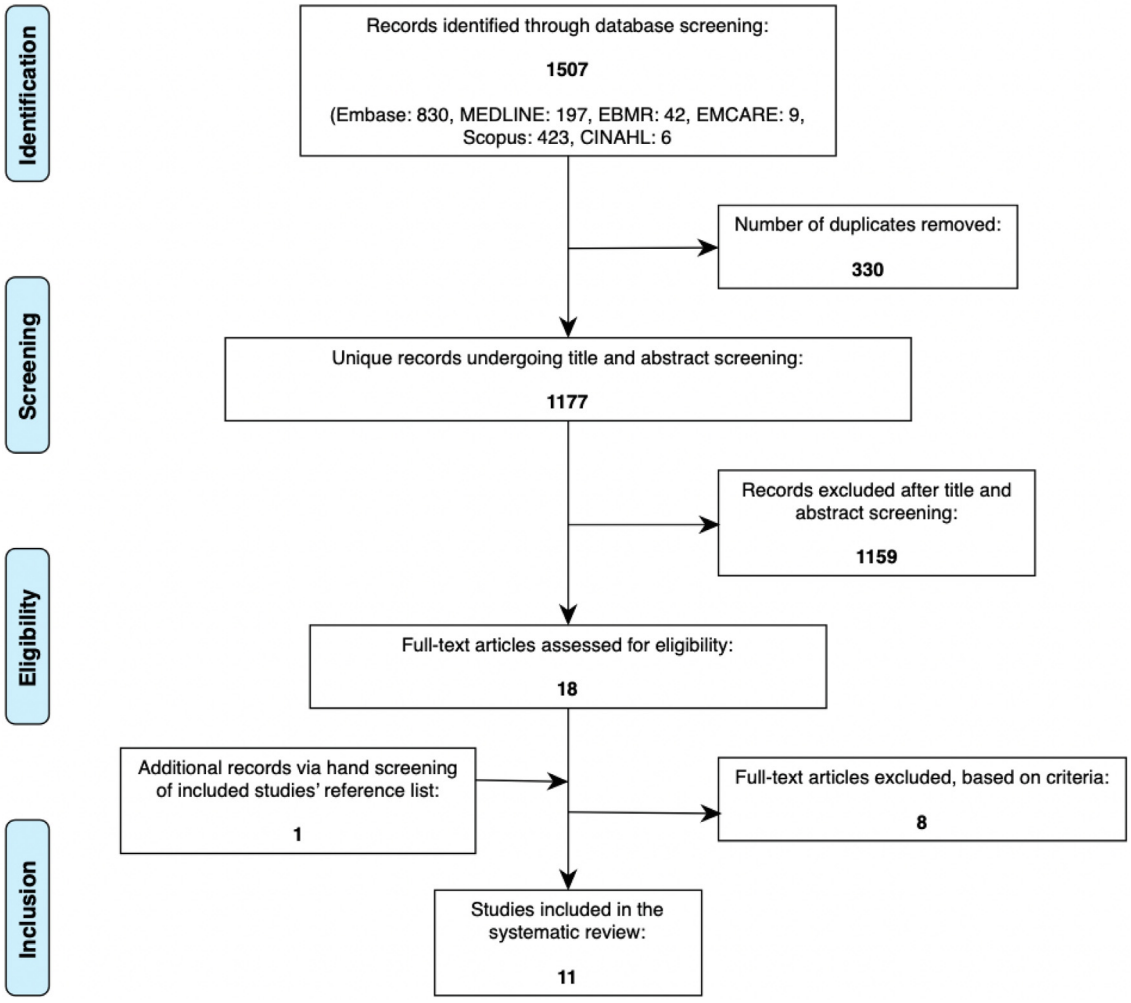

Fig. 1 – PRISMA Flow Diagram.

- Year of publication, country of study, study design
- Participants: numbers and year level of schoolchildren
- Description of the control and intervention
- Outcome measures, time points and results.

Extracted data was subsequently checked independently by a second reviewer (AM).

Critical appraisal

Included studies were critically appraised using the Medical Education Research Study Quality Instrument (MERSQI), a checklist commonly used to evaluate the methodological quality of experimental and observational studies in medical education.[32] Two reviewers (PL, LN) independently conducted this appraisal and resolved any disagreements through discussion. The MERSQI checklist has 10

criteria across 6 domains (study design, sampling, type of data, validity, data analysis and outcomes), with a total score range of 5–18. Total scores of the included papers are intended as a relative rather than absolute judgement of methodological quality, given the variability of study designs.[32]

For the purposes of this review, the terms CPR and Basic Life Support (BLS) were used interchangeably as is commonly seen in the reviewed literature. The choice of terminology reflected that of the included study being referenced.

Results

Characteristics of eligible studies

The full search identified 1507 citations, of which 19 were selected for full-text review (Fig. 1: PRISMA flow diagram). Of these 19, 8 studies were excluded due to insufficient information (abstracts or letters to editors). The remaining 11 studies [5 cohort studies, 6 randomised controlled trials (RCTs)] met the inclusion criteria (Table 2).

The included studies were spread geographically (7 from Europe, 2 from America, 2 from Asia), with a total participant number of 1,670 schoolchildren (all aged 13–17, and one study where less than 25% of the cohort was under 13)[24] and 355 medical students (across all year levels 1–5). Four RCTs compared the effectiveness in knowledge transfer of medical students as instructors with other groups of instructors, and two RCTs compared knowledge and skills for medical students conducting CPR training after being provided with different modalities of instruction themselves. The five cohort studies measured outcomes in CPR knowledge and skills gained by schoolchildren pre- and post-CPR training. Teaching involved face-to-face interactive classroom-sized group teaching by small groups of medical students delivered over either single or multiple sessions of 1–3 hours.

Outcomes were classified by Kirkpatrick's Levels. Where outcomes related to schoolchildren, eight studies measured confidence (Kirkpatrick Level 1b), knowledge (Kirkpatrick Level 2b) and skills (Kirkpatrick Level 2c) gained by the students post-training.[18,19,24,26,33–36] Two studies measured outcomes for medical students as CPR instructors, with the focus on professional practice skills (Kirkpatrick Level 2c) and CPR technical skills (Kirkpatrick Level 2c).[27,29] One study measured outcomes for both schoolchildren and medical students, namely confidence and theoretical knowledge in CPR (Kirkpatrick Levels 1b and 2b) for schoolchildren and confidence in professional practice outcomes (Kirkpatrick Level 1b) for medical students.[25]

Theoretical CPR knowledge tests, using multiple-choice or true/-false questions, was the most common outcome measure for schoolchildren. Practical CPR skills were measured using quantitative data for chest compression rate and depth with training mannequins, [18,19,33] however, one study used an observation-based psychomotor checklist.[34] Most outcome measures were self-developed, with only three validated outcome measures used (once each in three different studies): the Cardiff Test, a clinical teaching framework from the Stanford Faculty Development Program and an objective structured clinical examination.[18,27,29]

Quality of studies

The mean MERSQI score was 12.6 (range 9.5–16), with a standard deviation of 2.16 and median score of 12.5. Mean domain scores were highest for type of data (3/3) given the use of objective outcome measures across all studies, and lowest for data validity (0.91/3) due to the widespread use of self-developed outcome measurements which lacked psychometric validation. No study scored more than 1.5/3 for "outcomes" given the lack of measures at Kirkpatrick Levels 3 and 4. See Tables 3 and 4.

Outcomes for schoolchildren as recipients of CPR training from medical students

There were nine studies in which 1401 high school participants, aged 13–17 years, were trained in CPR by medical students.[18,19,24,26,33–36] The interventions were consistent; in that all schoolchildren received direct instruction from the medical students, despite some variability in the medical students' level of experience in teaching.

Three studies which assessed confidence of schoolchildren (Kirkpatrick Level 1b) in performing CPR post-training found positive results.[24–26] One of these three studies further measured schoolchildren's perceived willingness to perform CPR on certain people such as friends, family members and strangers,[26] and found a positive correlation between willingness to perform CPR and confidence post-training. Only one study conducted by Haseneder et al.. (2018) re-assessed confidence in performing CPR at a delayed time-point (9 months) post-training, which showed that whilst the schoolchildren's knowledge in CPR was retained, their confidence in performing CPR was not sustained.[24]

Seven studies compared post-intervention (immediate or within 2-weeks) (t_1) theoretical knowledge (Kirkpatrick Level 2b) with pre-intervention (t_0), and all showed statistically significant improvement.[19,24–26,33–35] Only two studies explored the retention of theoretical knowledge through follow-up assessments at 6–9 months post-intervention (t_2).[24,35] The findings were contradictory – one study showed that the schoolchildren had good retention of information after 9-months,[24] but the other found that retention was poor at 6-months post-intervention.[35] It was noted that the method of assessing knowledge retention differed. The assessment by Ribeiro et al. (2013) was conceptually more challenging and examined knowledge including the practical application such as CPR approach and sequence,[35] whereas the assessment by Haseneder et al. (2019) did not.[24]

Five studies examined CPR practical skills (Kirkpatrick Level 2c) post-training;[18,19,33,34,36] three measured chest compression rate and depth[18,19,33] and two reported on schoolchildren's approach/sequence of CPR during a scenario-based practical assessment.[18,36] All produced positive results immediately post-intervention and one study found that these skills were retained at 8-weeks post-training,[18] but another study showed that they had faded significantly by 6-months.[36]

Four studies found comparable effectiveness between medical student instructors and other instructors (physicians, nurses, teachers-in-training).[18,19,24,33] A cluster RCT found that schoolchildren scored better in theory immediately (p = 0.002) and after 9-months (p = 0.002) when taught by medical students compared with emergency physicians.[24] However, a cohort study by Dîrzu et al. (2017) found no difference when comparing schoolchildren taught by medical students versus residents and anaesthesia/intensive care specialists. It was also observed that schoolchildren trained by medical students delivered appropriate compression depth, but inappropriately high compression rates compared to those trained by senior physicians (p = 0.01).[19] A non-inferiority RCT by Cuijpers et al. (2016) showed that medical students did not produce worse outcomes for schoolchildren in knowledge or technical skills when com-

Table 2 – Summary of included studies.

Studies With Outcomes Targeted Towards Schoolchildren (Recipients of CPR Training)

Author Country (Year)	Study Design	Number of participants	Intervention	Control	Outcome Measures [Time points]	Results	Study authors' conclusions
Cuijpers et al[17] *Netherlands (2016)*	RCT (non-inferiority trial) (n=144)	Schoolchildren (13-16 years)	CPR training provided by either medical students (second-third year) or physical education student teachers during class. Schoolchildren were assigned to: - Registered nurses (n=12) - Medical students (n=17) - Physical education student teachers (n=15)	CPR training provided by a registered nurse during class	**Practical CPR skills** 1. CPR approach, CPR and AED sequence Schoolchildren's CPR skills were scored after a scenario-based setting in-person and through a videotape recording of the session by a qualified instructor. The assessment was via a form based on the Cardiff Test items relevant for the correct application of the European Resuscitation Council guidelines. A score of >80 % was considered to represent well-acquired CPR skills. 2. CPR technical skills Technical skills such as compression rate, compression depth and ventilation volume were registered by the manikin software during assessment. [Time points: immediately post-intervention (t_1); 8-weeks post-intervention (t_2)]	**Practical CPR skills** 1. CPR approach, CPR and AED sequence score: ($\bar{x}$ (95% CI)) t_1 t_2 • Overall: 67.0 (66.4-67.6); 65.5 (64.7-66.3) • Registered nurse: 66.2 (65.0-67.5); 64.8 (63.1-66.5) • PE student teacher: 66.1 (65.2-67.1); 64.6 (63.2-66.0) • Medical student: 68.3 (67.4-69.4); 65.5 (65.9-68.0) • Between groups comparison: p=0.003*; p=0.021 2. CPR technical skills Between groups comparison (chi-square): • compression rate: 3.69 p=0.16 • compression depth: 1.02 p=0.60 • ventilation volume: 1.25 p=0.54 ***[Kirkpatrick Level 2c]***	The medical student instructors were shown to be non-inferior to groups trained by registered nurses and physical education student teachers in: - CPR approach, CPR and AED sequences. - CPR technical skills, both immediately and 8-weeks post-intervention.
Haseneder et al[23] *Germany (2018)*	Cluster-RCT (n=460) - 10 classrooms (control) - 10 classrooms (intervention)	Female schoolchildren (10-17 years)	CPR training provided by medical students (final/penultimate year) (n=4); 90 min theoretical session + 90 min practical session	CPR training provided by emergency physicians (n=4); 90 min theoretical session + 90 min practical session	**CPR theoretical knowledge** 1. CPR knowledge 13 item multiple choice questionnaire administered as a test **Confidence in performing CPR** 2. Schoolchildren's self-confidence in performing CPR A scale consisting of 1-5 Likert-type items ranging from: strongly agree to strongly disagree [Time points: baseline (t_0); 1-week post-intervention (t_1); 9-months post-intervention (t_2)]	**CPR theoretical knowledge** 1. CPR knowledge score: ***All** participants* • t_0 vs t_1 : p=0.001* • t_1 vs t_2 : p=0.080 Statistically significant increase in CPR knowledge post-intervention. T_2 scores not significantly different compared with t_1 scores. *Comparison between instructor groups, medical students vs. emergency physicians ($\bar{x}$ (95% CI))* • t_1: 0.74 (0.28-1.20) p=0.002* • t_2: 0.77 (0.28-1.25) p=0.002* Score for knowledge was significantly higher for medical student-trained schoolchildren, compared to those trained by emergency physicians.	Compared to baseline, schoolchildren post-intervention scored higher in: - CPR knowledge. - Self-confidence in CPR. Schoolchildren 9-months post-training compared to 1-week post-training demonstrated: - Retention of CPR knowledge over time. - Decreased self-confidence in CPR. Training provided by medical students as compared to ED physicians resulted in: - A statistically significant greater increase in CPR knowledge. - No significant difference in self-confidence in CPR.

Studies With Outcomes Targeted Towards Schoolchildren (Recipients of CPR Training)

Author Country (Year)	Study Design	Number of participants	Intervention	Control	Outcome Measures [Time points]	Results	Study authors' conclusions
						Confidence in performing CPR 2. Self-confidence score *All participants* • t_0 / t_1 : p<0.001* • t_2 / t_1 : p<0.001* In both groups, self-confidence was significantly higher 1-week post-training compared with baseline. Self-confidence scores at t2 were significantly lower than at t1, but were still significantly higher compared with baseline. *Comparison between instructor groups, MS vs. EP* • t_0 : p=0.60 • t_1 : p=0.85 • t_2 : p=0.46 Score for self-confidence not significantly different between EP-trained and MS-trained students. ***[Kirkpatrick Level 1b; 2b]***	
Ribeiro et al[33] *Brazil (2013)*	Cohort study	- Two groups of schoolchildren from public high schools (n1a=24; n1b=57) - Two groups of schoolchildren from private high schools (n2a=89; n2b=32) All schoolchildren were 13-15 years old.	120 min CPR training session provided by medical students (year not provided) (n=3)	Not applicable	**CPR theoretical knowledge** 1. CPR knowledge Assessed through two versions of a questionnaire comprising of 25 multiple choice questions, addressing the following aspects: 1. General knowledge, 2. Sequence of procedures, and 3. Correct technique of administering each component. The two versions differed only in the order of the questions [Time points: baseline (t_0) - version 1; immediately post-intervention (t_1) - version 2; 6 months post-intervention (t_2) - version 1]	**CPR theoretical knowledge** *t_0 vs t_1* 1. General knowledge correct responses: $\bar{x}$ score (out of 7) *Public high school students vs. Private high school students* • Baseline: 3.04; 3.46 • Post intervention: 5.82; 6.06 *Public vs Private* • Baseline: p=0.01* • Post-intervention: p=0.15 2. Sequence of procedures correct responses: $\bar{x}$ score (out of 7) *Public high school students vs. Private high school students* • Baseline: 2.20; 2.39 • Post intervention: 5.47; 5.86 *Public vs Private* • Baseline: p=0.25 • Post-intervention: p=0.07 3. Correct technique of administering correct responses: $\bar{x}$ score (out of 11) *Public high school students vs. Private high school students* • Baseline: 3.53; 3.80 • Post intervention: 9.91; 9.80 *Public vs Private* • Baseline: p=0.22 • Post intervention: p=0.82	Schoolchildren's CPR theoretical knowledge improved immediately post-intervention but had reduced retention at 6 months. Private schoolchildren compared to public students had higher baseline general knowledge. No significant difference was found between private and public schoolchildren immediately post-intervention. Public schoolchildren compared to private students had poorer retention of knowledge 6-months post intervention, likely due to cultural factors. Teaching of CPR by medical students was effective in both the immediate and late retention of knowledge.

Studies With Outcomes Targeted Towards Schoolchildren (Recipients of CPR Training)

Author Country (Year)	Study Design	Number of participants	Intervention	Control	Outcome Measures [Time points]	Results	Study authors' conclusions
						Overall, no significant difference in CPR theoretical knowledge was found between public and private schoolchildren post-intervention. t_2 : 6-months' post-intervention: $\bar{x}$ score (% correct) • Public: 70.6 • Private: 77.6 • Public vs Private: p<0.01* Private school students had a significantly higher difference in knowledge retention at 6-months post-intervention. ***[Kirkpatrick Level 2b]***	
Dîrzu et al[31] * *Romania (2016)*	Cohort study	Schoolchildren (15 years old) (n=97)	Both a theoretical and practical CPR training session provided by medical students (third-fourth year) (n=4)	Not applicable	**CPR theoretical knowledge** 1. Theoretical knowledge Multiple choice questionnaire [Time points: baseline (t_0); 2-weeks post-intervention (t_1)] **Practical CPR skills** 2. Practical CPR skills Evaluated with a Resusci Anne mannequin with a SkillReporter device attached. Skills were also noted on paper by an evaluator. [Practical skills were only assessed post-intervention at t_1]	**CPR theoretical knowledge** 1. Theoretical knowledge score: $\bar{x}$ (SD) • t_0 : 39.52 (12.37) p=0.366 • t_1 : 78.48 (8.07) p=0.021* There was a statistically significant increase in correct test responses post-intervention. **Practical CPR skills** 2. Practical CPR skills from recorded data at t_1 : $\bar{x}$ (SD) • Compression rate (100-120 min^{-1} ideal): 134.7 (14.09) p=0.99 • Compression depth (38-51 mm ideal): 39.06 (8.16) p=0.34 ***[Kirkpatrick Level 2b; 2c]***	Schoolchildren's theoretical knowledge post-intervention compared to their baseline improved with teaching from medical students. Their technical skills analysed by automated and independent evaluators were found to be in an acceptable range.
Dîrzu et al[18] * *Romania (2017)*	RCT (non-inferiority trial)	Schoolchildren (15 years old) (n=296) Assigned to three groups: - Medical students - Residents - Anaesthesia / intensive care specialists	Both a theoretical and practical CPR training session provided by medical students (third-fourth year) (n=4)	Both a theoretical and practical CPR training session provided by: - Residents (n=4) - Specialists (n=4)	**CPR theoretical knowledge** 1. Theoretical knowledge Multiple choice questionnaire conceived by an independent evaluator [Time points: baseline (t_0); 2-weeks post-intervention (t_1)] **Practical CPR skills** 2. Practical CPR skills Evaluated with a Resusci Anne mannequin with a SkillReporter device attached [Practical skills were only assessed post-intervention at t_1]	**CPR theoretical knowledge** 1. Theoretical knowledge: $\bar{x}$ % score (SD) *% score at t_0 ; % score at t_1 :* • Medical students group: 39.5 (12.4); 78.5 (8.9) • Residents group: 40.7 (11.5); 78.5 (7.4) • Specialist group: 39.2 (10.8); 76.8 (10.7) • Groups comparison: n/a; p=0.819 A significant increase in % correct responses was observed in all groups post-intervention. There was no statistically significant difference between the groups. **Practical CPR skills** 2. Practical CPR skills from automatic recording: $\bar{x}$ (SD) *Compression rate (min^{-1}); Compression depth (cm)* • Medical students group: 134.7 (14.1); 39.1 (8.2) • Residents group: 137.9 (15.9); 40.5 (9.7) • Specialist group: 126.3 (19.3); 38.1 (8.2) • p value: p<0.001*; p=0.277 Schoolchildren from both the medical students and residents groups demonstrated statistically significant difference in compression rates, but no statistically significant difference in compression depth across all three groups. ***[Kirkpatrick Level 2b; 2c]***	Theoretical knowledge and practical CPR skills determined by an MCQ test and automated evaluation respectively showed comparable results in all groups. Outcomes of schoolchildren receiving CPR training from medical students was not inferior to residents or specialists conducting the teaching.

Studies With Outcomes Targeted Towards Schoolchildren (Recipients of CPR Training)

Author Country (Year)	Study Design	Number of participants	Intervention	Control	Outcome Measures [Time points]	Results	Study authors' conclusions
***Isa et al*[32]** *Malaysia (2019)*	RCT	Schoolchildren (16 years old) (n=44) Assigned to: - Schoolteachers - Medical students	Both a theoretical and practical CPR training session provided by schoolteachers (n=5)	Both a theoretical and practical CPR training session provided by medical students (year not provided) (n=5)	**CPR theoretical knowledge** 1. CPR knowledge Participants given a series of 9 questions pertaining to CPR **Practical CPR skills** 2. Practical CPR skills - psychomotor assessment Psychomotor skills checklist [Time points: baseline (t_0); immediately post-intervention (t_1); 3-months post-intervention (t_2)]	CPR theoretical knowledge 1. CPR knowledge *Difference in change of knowledge score* • schoolteacher group: median +3 (IQR 1) • medical student group: median +2 (IQR 2) The difference in outcome between the schoolteacher and medical student group was statistically insignificant. Practical CPR skills 2. Practical CPR skills - psychomotor assessment *Difference in change of psychomotor skills at baseline vs. post training* • schoolteacher group: +5 (IQR 2) • medical student group: +7 (IQR 3) $p < 0.001$* The difference in psychomotor skills score improvement between the schoolteacher and medical student groups was statistically significant. ***[Kirkpatrick Level 2b; 2c]***	Both schoolteachers and medical students could effectively train schoolchildren effectively in performing CPR.
Mowbray et al[34] Scotland (1987)	Cohort study	Schoolchildren (17 years old) (n=40)	150 min of CPR training provided by medical students (first year) (n=10)	Not applicable	**Practical CPR skills** 1. CPR technical skills Schoolchildren were assessed in their ability to perform mouth-to-mouth ventilation and chest compressions based on American Heart Association guidelines. Assessments were conducted by members of the Anaesthetics Department. [Time points: immediately post-intervention (t_1); 6-months post intervention (t_2)]	Practical CPR skills 1. CPR technical skills t1: all schoolchildren were found to be proficient in basic CPR. t2: 17 out of 40 schoolchildren were reassessed; only 47% were found to be proficient in basic CPR. 8/40 schoolchildren could perform mouth-to-mouth ventilation and chest compressions satisfactorily ***[Kirkpatrick Level 2c]***	All schoolchildren were able to perform basic CPR immediately after training. Although the first-year medical students had minimal medical knowledge, they acquired CPR skills quickly and were able to successfully instruct the schoolchildren.
***Yeow et al*[25]** *Vietnam (2021)*	Cohort study	Schoolchildren (16 years old) (n=118)	CPR training provided by medical students (age and number of participants not provided), involving both theoretical and practical components	Not applicable	**CPR theoretical knowledge** 1. CPR knowledge Participants given a 14-question test pertaining to CPR. Questions were set by the study team with the instructors based on course content. **Confidence in performing CPR** 2. Schoolchildren's self-confidence and willingness in performing CPR Participants were asked to rate their confidence and willingness to	**CPR theoretical knowledge** 1. CPR knowledge score: *Knowledge score (out of 14) at time points* • t_0 : 6.5 • t_1 : 13 ($p<0.001$*) • t_2 : 10 ($p<0.001$*) There was a statistically significant improve in CPR knowledge post-intervention, which was retained 3-months post-intervention.	A CPR course ran by medical students resulted in statistically significant increase in schoolchildren's knowledge, confidence and willingness in performing CPR on family members, friends as well as bystanders.

Studies With Outcomes Targeted Towards Schoolchildren (Recipients of CPR Training)

Author Country (Year)	Study Design	Number of participants	Intervention	Control	Outcome Measures [Time points]	Results	Study authors' conclusions
					perform CPR on a Likert scale of 1-5, with 1 being the least confident/willing and 5 being the most confident/willing. The following were assessed: a. Confidence in performing CPR, b. Willingness to perform chest compressions, and c. Willingness to perform mouth-to-mouth ventilation [Time points: baseline (t_0); immediately post-intervention (t_1); 3-months post-intervention (t_2)]	**Confidence in performing CPR** 2. Self-confidence and willingness score/rating *a. Confidence in performing CPR* • t_0 / t_1 : p<0.001* • t_0 / t_2 : p<0.001* • t_1 / t_2 : p=0.597 *b. Willingness to perform chest compressions* • t_0 / t_1 : p<0.001* • t_0 / t_2 : p=0.003* • t_1 / t_2 : p=0.001* *c. Willingness to perform mouth-to-mouth ventilation* • t_0 / t_1 : p<0.001* • t_0 / t_2 : p<0.001* • t_1 / t_2 : p=1.000 Willingness and confidence in performing CPR on strangers increased immediately post-intervention, and remained high at 3-months post intervention. ***[Kirkpatrick Level 1b; 2b]***	

Studies With Outcomes Targeted Towards Medical Students (CPR Instructors)

Author Country (Year)	Study Design	Participants (sample size)	Intervention	Control	Outcome Measures (Time points)	Results	Study authors' conclusions
***Beck et al*[28]** *Germany (2016)*	RCT	Medical students (final year) (n=80) - Control group (n=25) - Intervention group (n=28) - Dropouts (n=27) Schoolchildren (7th-8th grade); participant number unknown.	Medical students as part of the intervention course participated in a CPR-instructor course which included the following: 1. A 4-hour preparatory seminar 2. CPR-teaching session at a high school	Medical students in the control group had the assessment of CPR- and teaching-skills first, and the intervention followed afterwards.	**Professional practice skills** 1. Effectiveness of teaching Structured assessment across 2 stations using a 10-item standardised checklist based on the modified Stanford Faculty Development Program's clinical teaching framework, looking at 4 domains: a. teacher-group interaction, b. structure, c. learner-centred teaching, and d. presentation style. **Practical CPR skills** 2. CPR-skills A single station, structured assessment using a 15-item structured assessment checklist supported by a feedback-device included in a high-fidelity mannequin. [Time point: 3-weeks post-intervention (t_1)]	**Professional practice skills** 1.Effectiveness of teaching in domains: mean difference between intervention & control (95% CI) *Teacher-group interaction* • 0.43 (0.13-0.74) p=0.005* • 0.67 (0.37-0.98) p<0.001* *Structure* • 0.52 (0.21-0.82) p=0.001* *Learner-centred teaching* • 0.34 (0.03-0.65) p=0.031* *Presentation style* • 0.41 (0.10-0.72) p=0.009* Medical students from the CPR instructor course demonstrated statistically significantly higher scores in effectiveness of teaching compared to control. **Practical CPR skills** 2. CPR-skills pass rate: $\bar{x}$ (95% CI) • Control group: 8% (0-18%) • Intervention group: 43% (26-61%) • Group comparison: p=0.007* Medical students from the CPR instructor course scored higher in CPR skills compared to control. **[Kirkpatrick Level 2c]**	The intervention group compared to the control group scored higher in: - Effectiveness of teaching. - CPR skills.
***Breckwoldt et al*[26]** *Germany (2007)*	RCT	Medical students (5th year) (n=198) - Control group (n=60) - BLS vehicle group (n=64) - BLS teaching group (n=75) Schoolchildren (14-16 years old); participant number unknown.	10 hours of conventional university CPR training Plus an alternative use of BLS skills: - Accompany an emergency medical services (EMS) BLS ambulance for a day - Teach BLS in high school	15 hours of conventional university BLS training	**Practical CPR skills** 1. BLS skills Structured Clinical examination in BLS based on the checklist used by the European Resuscitation Council. [Time point: 1-4 weeks post-intervention (t_1)] **CPR theoretical knowledge** 2. Theoretical knowledge 30 open questions written test; not formally validated [Time point: 1-4 weeks post-intervention (t_1)]	**Practical CPR skills** 1. BLS-skills pass rate: Median (Q1, Q3) • Control: 78.8% (69.2, 84.6) • EMS: 76.9% (69.2, 88.5) • BLS teaching: 84.6% (76.9, 90.0) - Control / EMS: no significant difference - BLS teaching / Control: p=0.015* - BLS teaching / EMS: p=0.010* **CPR theoretical knowledge** 2. Theoretical knowledge pass rate: Median (Q1, Q3) Control: 67.2% (59.8, 72.7) EMS: 63.2% (57.2, 72.9) BLS teaching: 66.0% (59.8, 72.4) Group comparisons: p=0.779 **[Kirkpatrick Level 2c]**	The teaching group compared to the control group scored higher in BLS skills. There was no difference between groups in theoretical knowledge.

Studies With Outcomes Targeted Towards Both Schoolchildren And Medical Students

Author Country (Year)	Study Design	Participants (sample size)	Intervention	Control	Outcome Measures (Time points)	Results	Study authors' conclusions
***Kalluri et al*[24]** *USA (2018)*	Cohort study	Medical students (first year) (n_1 = 12) (n_2 = 18) Schoolchildren (ages unknown) (n_1 = 58) (n_2 = 211) n_1 = pilot semester n_2 = 2 year intervention	1. 3-hour training session for medical students 2. 60 min PumpStart (CPR) session provided by medical students Same intervention across both groups of schoolchildren and medical students	Not applicable	**Medical students - Professional Practice skills** *Confidence levels in:* 1. Communication and mentorship 2. Leadership, career & professional development 3. Commitment to service learning Rank agreement with statements on a survey ranging from 1 to 5 (1=strongly disagree; 5=strongly agree) [Time points: baseline (t_0); immediately post-intervention (t_1)] **Schoolchildren - CPR theoretical knowledge** 1. CPR technique MCQs provided in a survey [Time points: baseline (t_0); immediately post-intervention (t_1)] **Schoolchildren - Confidence in performing CPR** 2. Comfort levels in performing CPR Questions scaled from 1-4 in a survey Scale ranging from not comfortable to very comfortable [Time points: baseline (t_0); immediately post-intervention (t_1)]	**Medical students - Professional Practice skills** 1. Communication and mentorship: $\bar{x}$ *Communication* — *Mentorship* • t_0 : 3.2 / 5 — • t_0 : 4.4 / 5 • t_1 : 4.6 / 5 — • t_1 : 4.8 / 5 p=0.004* — p=0.02* 2. Leadership, career & professional development: $\bar{x}$ • t_0 : 3.8 / 5 • t_1 : 4.6 / 5 p=0.01* 3. Commitment to service learning: $\bar{x}$ • t_0 : 4.2 / 5 • t_1 : 4.8 / 5 p=0.01* Medical students self-rated higher in confidence in all domains of professional practice skills. **Schoolchildren - CPR theoretical knowledge** 1. CPR technique score: $\bar{x}$ (n_1 pilot; n_2 all) • t_0 : 30% ; 37% • t_1 : 82% ; 89% - n_1 : p<0.0001* - n_2 : p<0.0001* **Confidence in performing CPR** 2. Change in comfort levels in performing CPR from baseline to post intervention: % of sample (n_1 pilot; n_2 all) • Increase: 61%; 72% • No change: 33%; 22% • Decrease: 5%; 6% **[Kirkpatrick Level 1b and 2b for schoolchildren; Level 1b for medical students]**	**Medical students** Medical students post intervention compared to baseline showed higher confidence in: - Communication and mentorship. - Leadership, career & professional development. - Commitment to service learning. **Schoolchildren** Post-intervention, compared to baseline, schoolchildren scored higher in: - CPR technique theory. Majority of schoolchildren post-intervention compared to baseline scored higher in: - Confidence in performing CPR.

RCT = Randomised control trial; CPR = cardiopulmonary resuscitation; BLS = basic life support; * = significance level $p < 0.05$; Diff = difference; CI = confidence interval; Q1, Q3 = interquartile range; AED = automated external defibrillator; Dîrzu et al* = insufficient information to determine if studies overlap

Table 3 – MERSQI[a] Domain and Item Scores for Included Studies.

Scale Items	Subscale (points awarded if present)	Studies assessing outcomes for schoolchildren								Studies assessing outcomes for medical students		Study assessing outcomes for both
MERSQI [a]	Total score (maximum 18)	Cuijpers[17] (2016)	Haseneder[23] (2018)	Ribeiro[33] (2013)	Dîrzu[31] (2016)	Dîrzu[18] (2017)	Isa[32] (2019)	Yeow[25] (2021)	Mowbray[34] (1987)	Beck[28] (2016)	Breckwoldt[26] (2007)	Kalluri[24] (2018)
Study design (maximum 3)	Single-group cross-sectional/post-test only (1)								1			
	Single-group pre-/post-test (1.5)				1.5			1.5				1.5
	Non-randomised two-group (2)			2								
	Randomised controlled trial (3)	3	3			3	3			3	3	
Sampling: institutions, *n* (maximum 1.5)	1 (0.5)		0.5		0.5	0.5	0.5	0.5	0.5	0.5	0.5	
	2 (1)	1										
	> 2 (1.5)			1.5								1.5
Sampling: response rate (maximum 1.5)	< 50% or not reported (0.5)											
	50-74% (1)				1					1		
	≥ 75% (1.5)	1.5	1.5	1.5		1.5	1.5	1.5	1.5		1.5	1.5
Type of data: outcome assessment (maximum 3)	Subjective (1)											
	Objective (3)	3	3	3	3	3	3	3	3	3	3	3
Validity evidence (maximum 3)	Not applicable (0)	-	-	-	-	-	-	-	-	-	-	-
	Content (1)	1	0	1	0	0	0	0	0	1	1	0
	Internal structure (1)	1	0	0	0	0	0	0	0	1	1	0
	Relations to other variables (1)	1	0	0	0	0	0	0	0	1	1	0
Data analysis: appropriate (maximum 1)	Inappropriate (0)											
	Appropriate (1)	1	1	1	1	1	1	1	1	1	1	1
Data analysis: sophistication (maximum 2)	Descriptive (1)						1		1			
	Beyond descriptive analysis (2)	2	2	2	2	2		2		2	2	2
Outcome (maximum 3)	Satisfaction, attitudes, perceptions (1)							1				
	Knowledge, skills (1.5)	1.5	1.5	1.5	1.5	1.5	1.5		1.5	1.5	1.5	1.5
	Behaviours (2)											
	Patient/healthcare outcomes (3)											
	TOTAL	16	12.5	13.5	10.5	12.5	11.5	10.5	9.5	15	15.5	12

[a]Medical Education Research Study Quality Instrument

pared to registered nurses and physical education teachers-in-training.[18]

Outcomes for medical students teaching CPR

There were three studies (2 RCTs and 1 cohort study) that measured outcomes relating to medical students.[25,27,29] Of these, two measured their CPR skills post-instruction (Kirkpatrick Level 2c)[27,29] and two measured outcomes for professional practice (Kirkpatrick Levels 1b and 2c).[25,29] Medical students in all three studies received CPR training as a baseline. They then participated in a specially tailored CPR instructor course in two of the three studies,[25,29] in which the medical students were taught BLS theory and practical skills by qualified instructors.

The CPR skills of medical students after teaching CPR to schoolchildren was evaluated in two RCTs involving a total of 239 medical students.[27,29] Both studies assessed medical students' performance in a practical setting 3–4 weeks post-intervention.[27,29] The RCT conducted by Beck et al. (2016) showed that medical students who had had the opportunity to teach CPR to schoolchildren performed better in their CPR practical assessment, compared to those who have not.[29] Similar findings were reported by Breckwoldt et al. (2017), in which medical students who had taught CPR to schoolchildren demonstrated significantly improved CPR skills compared with those who had participated in a conventional university-level BLS course, or those who had been attached to an emergency medical service ambulance crew for 24 hours.[27]

Two studies assessed professional practice skills outcomes of medical students teaching CPR to schoolchildren.[25,29] The cohort study conducted by Kalluri et al. (2018) examined medical students' confidence in their professional practice skills (Kirkpatrick Level 1b) in the following areas: communication and mentorship, leadership, career and professional development, and commitment to service learning and found significant improvement in all areas.[25] The RCT by Breckwoldt et al. (2007), however, measured the objective teaching skills of medical students post-intervention (i.e. after they had already taught schoolchildren) by rotating them through two structured assessment stations where they taught a small group of schoolchildren the use of a cervical collar and mask ventilation. The stations were manned by blinded outcome assessors (a physician or medical student).[29] The structured assessments used a standardised checklist based on 4 domains: teacher-group interaction (encourages class discussion), structure (clear objectives and explanations), learner-centred teaching (friendly and shows genuine interest towards their schoolchildren), and presentation style (energetic and dynamic, interesting style). Medical students who had previously taught CPR scored significantly higher across all four teaching domains in the cervical collar assessment station. In the mask ventilation station, statistically

Table 4 – MERSQI Domain and Item Scores for Included Studies – Mean Values.

Domain	Item	Studies	Score		Mean (SD)	
		n (%)	Item	Maximum Domain	Item	Domain
Study Design						2.32 (0.81)
1. Study Design				3	2.32 (0.81)	
	Single group cross-sectional or single group post-test only	1 (9.1%)	1			
	Single group pre- and post-test	3 (27.3%)	1.5			
	Non-randomised, 2 group	1 (9.1%)	2			
	Randomised controlled experiment	6 (54.5%)	3			
Sampling						2.14 (0.50)
2. Institutions				1.5	0.73 (0.41)	
	Single institution	8 (72.7%)	0.5			
	Two institutions	1 (9.1%)	1			
	More than 2 institutions	2 (81.2%)	1.5			
3. Response Rate				1.5	1.41 (0.20)	
	< 50% or not reported	0 (0.0%)	n/a			
	50-74%	2 (18.2%)	0.5			
	≥ 75%	9 (81.8%)	1			
Type of Data			1.5			3.00 (0.00)
4. Type of Data				3	3.00 (0.00)	
	Assessment by study subject	0 (0.0%)	1			
	Objective measurement	11 (100.0%)	3			
Validity of Evaluation Instruments' Scores						0.91 (1.38)
	Not applicable	0 (0.0%)	n/a			
5. Content				1	0.36 (0.50)	
	Not reported	7 (63.6%)	0			
	Reported	4 (36.4%)	1			
6. Internal Structure				1	0.27 (0.47)	
	Not reported	8 (72.7%)	0			
	Reported	3 (27.3%)	1			
7. Relationships to other variables				1	0.27 (0.47)	
	Not reported	8 (72.7%)	0			
	Reported	3 (27.3%)	1			
Data Analysis						2.82 (0.40)
8. Appropriateness of Analysis				1	1.00 (0.00)	
	Data analysis inappropriate for study design or type of data	0 (0.0%)	0			
	Data analysis appropriate for study design or type of data	11 (100.0%)	1			
9. Sophistication of Analysis				2	1.82 (0.40)	
	Descriptive analysis only	2 (18.2%)	1			
	Beyond descriptive analysis	9 (81.8%)	2			
Outcome						1.45 (0.15)
10. Outcome				3	1.45 (0.15)	
	Satisfaction, attitudes, perceptions	1 (9.1%)	1			
	Knowledge, skills	10 (90.9%)	1.5			
	Behaviours	0 (0.0%)	2			
	Patient/healthcare outcomes	0 (0.0%)	3			
TOTAL				**18**		**12.64 (2.16)**

significant higher scores were limited to the teacher-group interaction domain.[29]

Discussion

There were a total of 11 studies included in this review which assessed outcomes of medical students training schoolchildren in CPR. Of these, nine studies assessed effectiveness of medical students teaching schoolchildren CPR and showed positive short-term outcomes across Kirkpatrick Levels 1b, 2b and 2c.[18,19,24–26,33–36] Four of the nine studies had delayed timepoints and found that skills were not retained in the longer-term.[24,35] Positive effects were found for the three studies examining outcomes for medical students across Kirkpatrick Levels 1b and 2c.[25,27,29] Delayed outcomes measuring long term retention of skills and confidence in medical students were not measured.

This review has shown that schoolchildren of grade 7 (13 years old) and above can be trained to perform CPR by medical students. At that age (grade 7 and above), in addition to having the intelligence and cognitive capacity to understand the importance of timely CPR in the context of cardiac arrests, schoolchildren also have the physical capability to produce effective chest compressions on adults.[31,37] Large-scale resuscitation training in schools will increase the number of BLS-trained individuals within the community,[7] but it is further possible that training school children may influence their relatives at home to undergo training themselves.[38]

Although it is clear that schoolchildren demonstrate an improvement in CPR skills immediately after training, outcomes on longer-term retention were varied. Two studies that measured theoretical knowledge 6–9 months post-instruction showed conflicting findings on retention.[24,35] Whilst the conflicting results could have been attributed to the assessment method itself, it could also have been affected by a wide variety of factors thought to influence the retention of knowledge, including but not limited to the modality of the delivered instruction, time spent conducting hands-on practice, as well as cultural factors such as socioeconomic background.[35] As one of the recognised barriers preventing bystanders from administering CPR is a lack of knowledge,[5] it is likely that refresher training is needed for retention. In line with evidence that found no difference in BLS knowledge and skills retention after annual or biannual retraining,[7] the Australian Resuscitation Council currently recommends annual refresher courses for CPR.[39] Similarly, the European Resuscitation Council recommends "frequent retraining between two and twelve months".[11]

The finding of positive outcomes in terms of the medical students' own CPR theoretical knowledge, practical skills and improvement in professional practice skills[25,27,29] is consistent with the concept that "the best way to learn is to teach" and similar findings have been demonstrated in other studies where medical students participate in BLS-instructor courses.[27,29] This concept is illustrated well through the RCT conducted by Breckwoldt et al. (2007), where medical students who taught CPR in a classroom setting to schoolchildren demonstrated significantly higher scores in BLS skills compared to a separate group of medical students who shadowed emergency medical services as part of their intervention.[27]

Although medical students were found overall to be effective instructors of CPR, it was interesting that Dîrzu et al. (2017) noted that errors in compression rate were more prominent amongst schoolchildren trained by medical students and junior physicians, compared to those trained by senior physicians.[19] This is a common finding when laypeople are taught since traditional teaching of CPR to laypeople has always followed the philosophy of taking a "push hard and fast" approach, which was taught to ensure that a minimum of 100 compressions per minute was achieved.[40] It is also worth noting that previous iterations of international resuscitation council guidelines stated a minimum compression rate, which likely affected the outcomes of compression rates being too high.[19,40,41] Current recommendations have a clear maximum of 120 compressions per minute. Although the medical students, similar to the specialist physicians, would have themselves been instructed based on international guidelines for the recommended compression rate of 100–120 per minute,[11,42] it is possible that the experience of the specialist physicians might have increased their mindfulness regarding maximum compression rates which influenced their teaching.

Not surprisingly, all of the 11 included studies in this review were found to have examined outcomes at Kirkpatrick Levels 1 and 2, with no reports on the higher levels at 3 (transfer of skills into the workplace) and 4 (changes in organisational practice or direct benefits to patients). This is likely related to ease of data collection at Kirkpatrick Levels 1 and 2, as well as the complex logistics and confounders present with measuring outcomes within the community required in this context for Kirkpatrick Levels 3 and 4. Ultimately, positive outcomes at Levels 3 and 4 corresponding to an increase in bystander action in response to OHCAs within a population as a direct result of CPR education and training instigated by high schools would provide a strong evidence-base to support the investment in effort that would be required for such large-scale training.

No studies have directly compared the outcomes of teaching between different medical student year levels, but it appears that the effectiveness of teaching was not dependent on the seniority of the medical students. All year levels of medical students were represented within the studies in this review, with participants in their first year of medical school[25,36] through to final year.[24,29] There was insufficient data to make a direct comparison of the effectiveness of teaching between year levels. The lack of difference in the effectiveness is likely because CPR is a standalone skill for medical students, and is often taught independently to other skills which a medical student might acquire during their medical degree.

Limitations

The limitations of this review include: Firstly, a cut off for minimum age of schoolchildren was applied, hence results are not generalisable to primary school students. Secondly, whilst most of the studies were RCTs, the results should be interpreted in the context of the small number of included studies and their methodological weaknesses. Assessment timepoints were often short-term and sample sizes of both medical and schoolchildren were small. Included studies were varied in their reporting of the specific details of CPR training provided to both the medical students, and to the schoolchildren. The heterogeneity amongst studies reduced the ability to make direct comparisons between studies or to perform a meta-analysis of results. Studies can also be subject to publication bias. Finally, whilst MERSQI is commonly used as a tool for the critical appraisal of education-related studies, it has limitations such as the lack of items on blinding and the comparability of cohorts which are important components of risk of bias assessments. In addition, this study was not registered in PROSPERO prior to the commencement of our search.

Implications for educators and policy makers

In terms of implications for educators, despite the lack of evidence at Kirkpatrick Levels 3 and 4, the findings of this review support the idea that schoolchildren can be effectively trained in CPR and hence, by extension, the incorporation of CPR training into the curriculum for schoolchildren in high school (Grade 7–12). In 2015, the Kids Save Lives initiative was endorsed by the World Health Organisation, in which recommendations were made for schools to provide two hours of CPR training annually worldwide,[9] further supported by the International Liaison Committee for Resuscitation in a statement made in 2023.[10] This recommendation has been taken up to varying extent by different countries. The ERC guidelines state that *all* schoolchildren should routinely receive CPR training each year.[11] In Norway, CPR training in schools is well established in the national curriculum, ultimately resulting in the country leading in OHCA survival rates internationally.[43,44] Similarly, in Denmark, an increase in OHCA survival was significantly associated with a concomitant increase in bystander CPR.[45]

The high school curriculum for Victoria, Australia suggests that CPR training should be introduced at a year 9–10 level in health and physical education classes. However, the optional nature of this training limits widespread adoption.[46,47] In addition to compulsory CPR training in high school, yearly refresher sessions consistent with current recommendations by the Australian Resuscitation Council for civilian first aiders should be considered.[39] Further, partnerships between high schools and medical students should be considered to facilitate the involvement of medical students in these teaching programs. Medical students can mitigate the cost and availability issues of instructors, provide role modelling to schoolchildren, benefit themselves from the teaching they perform and deliver an important service to the community. Although not strictly within the scope of this review, considerations could also be given to partnerships with groups other than medical students, such as physiotherapy or nursing students.

Whilst this review demonstrates that medical students are capable of providing adequate CPR training for schoolchildren, this is dependent on the medical students themselves having sound knowledge and skills. In this context, it is important to consider the current evidence that many final year medical students have been found to have suboptimal knowledge of cardiac arrest and CPR.[48] In the included studies, medical students participants had been specifically provided with additional training, ranging from a 3-hour training session in both CPR and education, to 10-hours of university-level BLS along with a shadowing shift with an emergency medical services ambulance.[25,27,29] Therefore, for successful implementation of such programs, further work is likely required and the European Resuscitation Council recently proposed several suggestions to improving BLS knowledge such as mandatory CPR courses targeted at first-year undergraduates.[49]

Acknowledging that the high workload of schoolteachers in countries like the USA may limit their ability to fit additional CPR training into their pre-existing curriculum,[13] having CPR-qualified teachers would help provide BLS training to a greater number of schoolchildren. The availability of medical students and universities may differ from region to region, but the demand for CPR training would remain consistent among schoolchildren in high school. Therefore, role of medical students in teaching CPR in school should be a support, and not alternative to the schoolteachers, should the time and resources permit.

Further research should consider robust methodology with adequately powered multi-site randomised controlled trials, consistent use of validated outcome measures, longer-term assessment timepoints and statistical analysis for significant differences and effect sizes. The optimal training methods also remain unclear, as well as optimal retraining intervals. The impact of CPR education programs in schools on community CPR rates and subsequent OHCA survival rates should be examined given this is ultimate goal of such interventions.

Conclusion

All studies in this review have shown that schoolchildren, of ages 13–18 years, can effectively acquire the theoretical and practical skills for basic life support (BLS) through being trained by medical students. The medical students themselves also have positive outcomes in terms of their own CPR skills and their professional practice skills.

CRediT authorship contribution statement

Peitong Li: Formal analysis, Validation, Writing – original draft. **Anita Milkovic:** Formal analysis, Writing – review & editing. **Peter Morley:** Conceptualization. **Louisa Ng:** Supervision, Validation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank Dr. Brett Vaughan for his peer review. Many thanks also to Vesna Birkic for her assistance with the development of the search strategy.

Appendix 1. Search strategies

Search strategy for MEDLINE, Embase, MEDLINE, EBM Reviews, EMCARE

1. (medical adj2 (student* or undergraduate* or graduate* or trainee*)).mp.
2. ((student or trainee) adj doctor*).mp.
3. exp Students, Medical/
4. exp Education, Medical/ or exp Clinical Competence/
5. 1 or 2 or 3 or 4
6. exp Cardiopulmonary Resuscitation/ or exp Resuscitation/
7. (cardiopulmonary resuscitation or CPR or basic life support or BLS).mp.
8. (cardiopulmonary adj3 resuscitation).mp.
9. exp Out-of-Hospital Cardiac Arrest/ or Heart Arrest/
10. 6 or 7 or 8 or 9
11. ((high or middle or secondary) adj3 school#).mp.
12. (school student# not medical school).mp.

13. exp Schools/ or exp Adolescent/
14. 11 or 12 or 13
15. 5 and 10 and 14

Search strategy for scopus

((TITLE-ABS-KEY (medical W/2 (student* OR undergraduate* OR graduate* OR trainee*))) OR (TITLE-ABS-KEY ((student OR trainee) W/1 doctor*)) OR (INDEXTERMS ("Students, Medical")) OR (INDEXTERMS ("Education, Medical") OR INDEXTERMS ("Clinical Competence"))) AND ((INDEXTERMS ("Cardiopulmonary Resuscitation" OR cpr)) OR (TITLE-ABS-KEY ("cardiopulmonary resuscitation" OR "basic life support" OR bls)) OR (TITLE-ABS-KEY (cardiopulmonary W/3 resuscitation)) OR (INDEXTERMS ("Out-of-Hospital Cardiac Arrest") OR INDEXTERMS (resuscitation) OR INDEXTERMS ("Heart Arrest"))) AND ((TITLE-ABS-KEY ((high OR middle OR secondary) W/3 school?)) OR (TITLE-ABS-KEY ("school student")) OR (INDEXTERMS (schools) OR INDEXTERMS (adolescent))).

Search strategy for CINAHL

(((medical N2 (student* OR undergraduate* OR graduate* OR trainee*))) OR (((student OR trainee) W1 doctor*)) OR (MH "Students, Medical"+) OR ((MH "Education, Medical"+) OR (MH "Clinical Competence"+)))
((MH "Cardiopulmonary Resuscitation"+) OR (("cardiopulmonary resuscitation" OR CPR OR "basic life support" OR BLS)) OR (cardiopulmonary N3 resuscitation) OR ((MH "Out-of-Hospital Cardiac Arrest"+) OR (MH Resuscitation+) OR (MH "Heart Arrest")))
((((high OR middle OR secondary) N3 school?)) OR ("school student") OR ((MH Schools+) OR (MH Adolescent+)))
1 AND 2 AND 3

Author details

[a]*Melbourne Medical School, The University of Melbourne, Parkville, Victoria 3010, Australia* [b]*Department of Intensive Care, Royal Melbourne Hospital, 300 Grattan Street, Victoria 3050, Australia*

REFERENCES

1. Berdowski J, Berg RA, Tijssen JG, Koster RW. Global incidences of out-of-hospital cardiac arrest and survival rates: Systematic review of 67 prospective studies. Resuscitation 2010;81:1479–87.
2. Nishiyama C, Kiguchi T, Okubo M, et al. Three-year trends in out-of-hospital cardiac arrest across the world: second report from the International Liaison Committee on Resuscitation (ILCOR). Resuscitation 2023;109757.
3. Berdowski J, de Beus MF, Blom M, et al. Exercise-related out-of-hospital cardiac arrest in the general population: incidence and prognosis. Eur Heart J 2013;34:3616–23.
4. Weston CF, Wilson RJ, Jones SD. Predicting survival from out-of-hospital cardiac arrest: a multivariate analysis. Resuscitation 1997;34:27–34.
5. Andrews T, Price L, Mills B, Holmes L. Young adults' perception of mandatory CPR training in Australian high schools: a qualitative investigation. Austr J Paramed 2018;15.
6. Hoang BH, Dao XD, Nakahara S, Sakamoto T. The need for improving access to emergency care through community involvement in low- and middle-income countries: A case study of cardiac arrest in Hanoi. Vietnam Emerg Med Australas 2018;30:867–9.
7. Bohn A, Lukas RP, Breckwoldt J, Bottiger BW, Van Aken H. 'Kids save lives': why schoolchildren should train in cardiopulmonary resuscitation. Curr Opin Crit Care 2015;21:220–5.
8. Sasson C, Rogers MA, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. Circ Cardiovasc Qual Outcomes 2010;3:63–81.
9. Bottiger BW, Van Aken H. Kids save lives–Training school children in cardiopulmonary resuscitation worldwide is now endorsed by the World Health Organization (WHO). Resuscitation 2015;94:A5–7.
10. Schroeder DC, Semeraro F, Greif R, et al. KIDS SAVE LIVES: Basic life support education for schoolchildren: A narrative review and scientific statement from the International Liaison Committee on Resuscitation. Resuscitation 2023;188 109772.
11. Perkins GD, Graesner JT, Semeraro F, et al. European Resuscitation Council Guidelines 2021: Executive summary. Resuscitation 2021;161:1–60.
12. Merchant RM, Topjian AA, Panchal AR, et al. Part 1: Executive Summary: 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation 2020;142:S337–57.
13. Hoyme DB, Atkins DL. Implementing cardiopulmonary resuscitation training programs in high schools: Iowa's experience. J Pediatr 2017;181:172–176.e3.
14. Napp A, Kosan J, Hoffend C, et al. Implementation of basic life support training for school children: Online education for potential instructors? Results of a cluster randomised, controlled, non-inferiority trial. Resuscitation 2020;152:141–8.
15. Doucet L, Lammens R, Hendrickx S, Dewolf P. App-based learning as an alternative for instructors in teaching basic life support to school children: a randomized control trial. Acta Clin Belg 2019;74:317–25.
16. Choi HS, Lee DH, Kim CW, Kim SE, Oh JH. Peer-assisted learning to train high-school students to perform basic life-support. World J Emerg Med 2015;6:186–90.
17. 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.
18. Cuijpers PJ, Bookelman G, Kicken W, de Vries W, Gorgels AP. Medical students and physical education students as CPR instructors: an appropriate solution to the CPR-instructor shortage in secondary schools? Neth Heart J 2016;24:456–61.
19. Dîrzu DS, Hagău N, Boț T, Fărcaș L, Copotoiu SM. Training in cardiopulmonary resuscitation provided by medical students, residents and specialists: A non-inferiority trial. Hong Kong J Emerg Med 2017;25:20–6.
20. 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.
21. 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.
22. Harvey PR, Higenbottam CV, Owen A, Hulme J, Bion JF. Peer-led training and assessment in basic life support for healthcare students: synthesis of literature review and fifteen years practical experience. Resuscitation 2012;83:894–9.
23. Beck S, Issleib M, Daubmann A, Zollner C. Peer education for BLS-training in schools? Results of a randomized-controlled, noninferiority trial. Resuscitation 2015;94:85–90.
24. Haseneder R, Skrzypczak M, Haller B, et al. Impact of instructor professional background and interim retesting on knowledge and self-confidence of schoolchildren after basic life support training: a cluster randomised longitudinal study. Emerg Med J 2019;36:239–44.

25. Kalluri NS, Knopov A, Kue R. A service-learning initiative to teach hands-only CPR to high school students: PumpStart. J Educ 2018;198:240–6.
26. Yeow MWX, Ng JYX, Nguyen VH, et al. Knowledge and attitudes of Vietnamese high school students towards cardiopulmonary resuscitation: Results from a pilot student-led cross-country bystander training workshop. Proc Singapore Healthcare 2021;30:302–8.
27. 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.
28. Ten Cate O, Durning S. Peer teaching in medical education: twelve reasons to move from theory to practice. Med Teach 2007;29:591–9.
29. Beck S, Meier-Klages V, Michaelis M, et al. Teaching school children basic life support improves teaching and basic life support skills of medical students: a randomised, controlled trial. Resuscitation 2016;108:1–7.
30. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ 2009;339 b2535.
31. 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.
32. Cook DA, Reed DA. Appraising the quality of medical education research methods: the Medical Education Research Study Quality Instrument and the Newcastle-Ottawa Scale-Education. Acad Med 2015;90:1067–76.
33. Dîrzu D, Hagău N, Bot T, Fărcaş L, Copotoiu S-M. The effectiveness of using medical students for training high school students in cardiopulmonary resuscitation. Acta Medica Marisiensis 2016:62.
34. Isa MH. Comparing teachers and medical students as trainers of cardiopulmonary resuscitation (CPR) among secondary school students. Med Health 2019;14:180–8.
35. Ribeiro LG, Germano R, Menezes PL, Schmidt A, Pazin-Filho A. Medical students teaching cardiopulmonary resuscitation to middle school Brazilian students. Arq Bras Cardiol 2013;101:328–35.
36. Mowbray A, McCulloch WJD, Conn AG, Spence AA. Teaching of cardiopulmonary resuscitation by medical students. Med Educ 1987;21:285–7.
37. Fleischhackl R, Nuernberger A, Sterz F, et al. School children sufficiently apply life supporting first aid: a prospective investigation. Crit Care 2009;13:R127.
38. 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.
39. Australian Resuscitation Council. ANZCOR Guideline 10.1 – Basic Life Support (BLS) Training: The ARC Guidelines; 2014 [Available from: https://resus.org.au/the-arc-guidelines/.
40. Palatnik A, Szulewski M. New CPR guidelines: Push hard, push fast. Nursing 2020 Crit Care 2006;1(2).
41. Haig S. Push hard and fast (but not too fast). Resuscitation 2012;83:1307–8.
42. Australian Resuscitation Council. ANZCOR Guideline 8 – Cardiopulmonary Resuscitation (CPR): The ARC Guidelines; 2014 [Available from: https://resus.org.au/the-arc-guidelines/].
43. 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.
44. The L. Out-of-hospital cardiac arrest: a unique medical emergency. Lancet 2018;391:911.
45. Wissenberg M, Lippert FK, Folke F, et al. Association of national initiatives to improve cardiac arrest management with rates of bystander intervention and patient survival after out-of-hospital cardiac arrest. J Am Med Assoc 2013;310:1377–84.
46. Victorian Curriculum and Assessment Authority. Health and Physical Education Levels 9 and 10: VCHPEP144: Victorian State Government; [Available from: https://victoriancurriculum.vcaa.vic.edu.au/health-and-physical-education/curriculum/f-10#level=9-10].
47. Bray J, Acworth J, Page G, et al. Aussie KIDS SAVE LIVES: A position statement from the Australian Resuscitation Council and supported by stakeholders. Emerg Med Australas 2021;33:944–6.
48. Baldi E, Contri E, Bailoni A, et al. Final-year medical students' knowledge of cardiac arrest and CPR: We must do more! Int J Cardiol 2019;296:76–80.
49. Baldi E, Savastano S, Contri E, et al. Mandatory cardiopulmonary resuscitation competencies for undergraduate healthcare students in Europe: A European Resuscitation Council guidance note. Eur J Anaesthesiol 2020;37:839–41.