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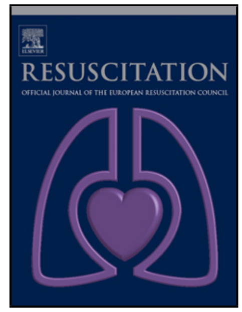

Spaced learning versus Massed learning in resuscitation – A systematic review

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Spaced learning versus Massed learning in resuscitation – A systematic review

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Abstract

AIM

Skill decay is a recognised problem in resuscitation training. Spaced learning has been proposed as an intervention to optimise resuscitation skill performance compared to traditional massed learning. A systematic review was performed to answer 'In learners taking resuscitation courses, does spaced learning compared to massed learning improve educational outcomes and clinical outcomes?'

METHODS

This systematic review followed the PRISMA guidelines. We searched bibliographic databases (Embase, MEDLINE and the Cochrane Library (CENTRAL)) from inception to 2 December 2019. Randomised controlled trials and non-randomised studies were eligible for inclusion. Two reviewers independently scrutinized studies for relevance, extracted data and assessed quality of studies. Risk of bias of studies and quality of evidence were assessed using RoB, ROBINS-I tool and GRADEpro respectively. Educational outcomes studied were skill retention and performance 1 year after completion of training; skill performance between completion of training and 1 year; and knowledge at course conclusion. Clinical outcomes were skill performance at actual resuscitation, patient survival to discharge with favourable neurological outcome. This systematic review was registered in PROSPERO (CRD42019150358).

RESULTS

From 2,042 references, we included data from 17 studies (13 randomised studies, 4 cohort studies) in courses with manikins and simulation in the narrative synthesis. Eight studies reported results from basic life support training (with or without automatic external defibrillator); three studies reported from paediatric life support training; five were in neonatal resuscitation and one study reported results from a bespoke emergency medicine course which included resuscitation teaching. Fifteen out of seventeen studies reported improved performance with the use of spaced learning. The overall certainty of evidence was rated as very low for all outcomes primarily due to a very serious risk of bias. Heterogeneity across studies precluded any meta-analyses. There was a lack of data on the effectiveness of spaced learning on skill acquisition compared to maintaining skill performance and/or preventing skill decay. There was also insufficient data to examine the effectiveness of spaced learning on laypeople compared to healthcare providers.

CONCLUSIONS

Despite the very low certainty of evidence this systematic review suggests that spaced learning can improve skill performance at 1 year post course conclusion and skill performance between course conclusion and 1 year. There is a lack of data from this educational intervention on skill performance in clinical resuscitation and patient survival at discharge with favourable neurological outcomes.

Keywords: Education; Training; Systematic Review

INTRODUCTION

Evidence suggests that knowledge and skills acquired during resuscitation training can decay significantly by 6 months to 1 year after training, with skills decay occurring faster than knowledge.[1, 2] The optimal method and retraining interval of resuscitation training is not currently known.[3] 'Spaced learning' is defined as 'a learning procedure in which practice periods for a particular task are separated by lengthy rest periods or lengthy periods of practicing different activities or studying other material, rather than occurring close together in time', whereas 'massed learning' involves 'a single period of learning procedure in which practice trials occur close together in time, either in a single lengthy session or in sessions separated by short intervals.'[4, 5] Formats employing spaced learning in resuscitation training are increasingly being developed with the aim of enhancing the educational impact and flexibility of teaching. The spaced learning principle, where the content can be distributed across different sessions or repeated, is supported by evidence from both the cognitive science and neuroscience literature. [6] Educational theoretical approaches align strongly with the advantages of spaced learning due to the additional time afforded to reflect and elaborate on the learning content between the learning sessions and memory consolidation effects by recall.[7-11] Within our review, we included the term 'booster' training which describes 'spaced practice after initial completion of training and is generally related to low-frequency tasks such as the provision of cardiopulmonary resuscitation (CPR).' [12] Booster training is used when the learner is still proficient, but competency begins to wane.[13]

The objective of this systematic review is to evaluate whether spaced learning improves educational and clinical outcomes compared to traditional massed learning in learners undertaking resuscitation training courses.

METHODS

The protocol for this systematic review was registered with PROSPERO (CRD42019150358) on 10 October 2019. Reporting of the systematic review was in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. [14] The review was commissioned by the International Liaison Committee on Resuscitation (ILCOR).

Search strategy and selection criteria

Bibliographic databases (PubMed, CINAHL, Embase, ERIC and the Cochrane Library (CENTRAL)) were searched from inception to 29 July 2019 using a combination of index terms and key words relating to the population, intervention and comparator. The search strategy was developed in conjunction with information specialists at St Michael's Hospital Health Sciences Library (see Supplementary Materials Appendix A for sample search strategy). Reference lists of relevant articles were checked for additional studies. No relevant ongoing studies were identified after a search of clinical trial registers (www.clinicaltrials.gov, www.isrctn.com and http://www.who.int/ictrp/en/). Endnote X9 (Clarivate Analytics) was used to store records and facilitate screening. The search was repeated on 2 December 2019 to identify any studies published after initial search and no studies were found.

Study selection

Studies were eligible for inclusion if they met the following pre-defined criteria:

1) Population: All learners taking resuscitation training courses (all course types and all age groups) and/or first aid courses.
2) Intervention: Training or retraining which is distributed over time ("spaced" learning).

3) Comparator: Training or retraining provided at one single time point ("massed" learning).
4) Outcomes: Educational outcomes (skill performance 1 year after course conclusion; skill performance between course conclusion and 1 year; knowledge at course conclusion) and clinical outcome (quality of performance in actual resuscitations; patient survival with favourable neurologic outcome)
5) Study Designs: Randomised controlled trials (RCTs) and non-randomised studies (non-randomised controlled trials, interrupted time series, controlled before-and-after studies, cohort studies) were eligible for inclusion. Unpublished studies (e.g., conference abstracts, trial protocols) were excluded.
6) Timeframe and language: All years and all languages were included as long as there was an English abstract.

Studies were selected by two reviewers (MJH/RG) independently by title screening and abstract. The full text of selected studies was retrieved and reviewed by two reviewers (MJH/RG) independently. Reasons for exclusion were documented.

Data Extraction and Quality Assessment

A standardised data extraction form was used to record information on study design, participant characteristics, sample size, description of spaced learning, and outcome measures by two reviewers independently (JY/MJH). Any disagreement surrounding the selection of a manuscript or data extraction was resolved either by consensus or arbitration by a third reviewer (RG). Two reviewers (JY/TD) assessed the risk of bias of individual studies independently, using the Cochrane Collaboration Risk of Bias 2 (RoB2) tool for randomised controlled trials [15] and the Risk Of Bias In Non-randomised Studies - of Interventions (ROBINS-I tool)[16] for non-randomised studies. Disagreements were resolved by discussion between the two reviewers.

Data analysis and synthesis

There was high heterogeneity among studies including clinical heterogeneity (such as type, format of intervention, methods of outcome assessments), and methodologic heterogeneity (outcome assessments, duration of follow-up, timing of assessment). We were unable to perform a meta-analysis and have conducted a narrative synthesis of the findings. For the same reason, we were unable to undertake planned *a priori* subgroup analyses comparing training outcomes from healthcare professionals and laypeople or skill acquisition/skill performance after first training and subsequent retraining.

The certainty of evidence was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system in GRADEpro Guideline Development Tool (Evidence Prime, Inc., McMaster University).[17, 18]

RESULTS

After removal of duplicates, the literature search yielded 2,042 unique references. After screening, 17 studies (13 randomised studies [19-31], 4 cohort studies [32-35]) fulfilled the eligibility criteria and were included in the qualitative synthesis. (Figure 1) Studies were conducted in North America (n=12), Europe (n=2), South East Asia (n=2) and Africa (n=1). The kappa value for identifying studies during initial screening was 0.94. Table 1 contains the characteristics of included studies. We classified the included studies into spaced learning (7 studies [19, 21-24, 32, 34]) and booster training (10 studies [20, 25-31, 33, 35]) groups. Of note, three studies appear to have reported different outcomes from the same cohort of participants.[25-27]

Of the seventeen studies, eight studies reported results from basic life support (BLS) training (with or without AED) [20, 21, 24-27, 31, 33]; three studies reported paediatric life support training [19, 22, 32]; five in neonatal resuscitation [23, 28-30, 35] and one study reported results from a bespoke emergency medicine course which included resuscitation training.[34] Twelve studies looked at courses of duration of less than 1 day [20, 24-33, 36] and 5 studies looked at courses of duration of 1 day or longer.[19, 22, 23, 34, 35]

Risk of bias for individual studies

Thirteen randomised studies had moderate to serious overall risk of bias due to lack of allocation concealment, blinding of outcome assessors and blinding of participants. [19-31] (Table 2a) Four non-randomised studies had either moderate (n=2) or serious (n=2) overall risk of bias.[32-35] The most common sources of bias were inadequate adjustment of confounding factors and participant selection. (Table 2b)

Certainty of evidence across studies

The overall certainty of evidence was very low across all outcomes, primarily due to risk of bias and inconsistency. GRADE summary tables are provided in Appendix B (Supplementary Materials).

Educational outcomes

Skill performance 1 year after course conclusion (critical outcome)

We identified very low certainty of evidence (downgraded for risk of bias, inconsistency and imprecision) from four randomised studies which all reported the use of spaced learning in BLS to evaluate the number of participants able to provide chest compression of adequate depth at 1 year. [20, 21, 27, 31] One study randomised 87 healthcare providers into receiving either massed learning BLS training (conventional recertification course) or spaced learning (monthly 2-min practice with real-time feedback). [21] The spaced learning group was asked to practice CPR for 2 minutes on manikins while receiving real-time CPR feedback, at least once per month. Control group participants were not asked to practice CPR during the study period. The study reported that more participants were able to perform chest compressions of adequate depth with spaced learning compared to massed learning. At 12 months testing, higher proportions of chest compressions from spaced learning group were rated 'excellent', defined as achieving at least 90% of all American Heart Association standards for chest compression depth, rate and recoil for each individual criterion, than in the massed learning group (control 6/41 (14.6%), intervention 25/46 (54.3%), $p < 0.001$, Odds Ratio (OR) 6.94 (95% Confidence Interval (CI) 2.45, 19.69)). This study also reported improvement in other quality of chest compressions measures with use of spaced learning: percentage of correct chest compression rate improved from 78.0 (95%CI 70.8, 85.1) to 92.7 (95%CI 86.0, 99.4); percentage of chest compressions with complete recoil from 86.5 (95%CI 81.6, 91.4) to 97.4 (95%CI 92.8, 100.0). Similar improvements were also reported in paediatric CPR parameters.

In booster training, three RCTs (n=790) reported that more participants were able to provide chest compression of an adequate depth compared to no booster training.[20, 27, 31] One RCT compared CPR booster training with no booster training in CPR-certified intensive care nurses. Participants were asked to practice skills on a manikin without feedback, and were randomised to booster training with different frequency (monthly, one session every 3 months, one session every 6 months) or to an annual update with no booster training (control).[20] For the primary outcome of CPR performance at 12 months, this study reported improved chest compression performance across all booster groups compared with the control group; with monthly booster training providing the best skill performance but also the highest attrition rate (only 26/56, 46% of participants completed the 1 year study). Participants who trained monthly had a significantly higher rate of 'excellent' CPR performance (15/26, 58%) than those in all other groups (12/46, 26% in the 3-month group, $p = 0.008$; 10/47, 21% in the 6-month group, $p = 0.002$; and 7/48, 15% in the 12-month group, $p < 0.001$). In a second study, Oermann et al also reported improved CPR performance in 541 BLS trained nursing students who received brief monthly BLS practice sessions compared to no monthly practice.[27] In the booster training group (240 participants), a mean of 59.2% (Standard deviation (SD) 36.6) of compressions were performed to an adequate depth and no skill decay was seen over 12 months. In contrast, the control group (301 participants) had a significant loss of ability to compress with an adequate depth at 12 months (mean 36.5mm SD 7.7) and only a mean of 36.5% (SD 33.6) of compressions with an adequate depth ($p=0.004$). Students in the booster training group also provided a significantly higher mean percentage of ventilations with an adequate volume (booster 52.2% SD 30.9 vs control 38.5% SD 36.1, $p<0.001$) and a significantly larger mean ventilation volume (booster 565.4ml (SD 147.8) vs control 430.7ml (SD 231.7), $p<0.0001$). In a third study, 112 laypeople were randomised to training with a 45 minute DVD program in compression only CPR with and without 15 minute booster training at 6 months [31]. At 12 months testing, the number of total chest compressions performed was significantly higher in the booster group (57 participants) than in the control group (55 participants) (booster mean 182.0 SD 41.7 vs control mean 142.0 SD 59.1, $p < 0.001$). The number of appropriate chest compressions (with depth>50mm, correct hand position, complete recoil) performed was significantly higher in the booster group than in the control group (booster mean 68.9 SD 72.3 vs control mean 36.3 SD 50.8, $p = 0.009$). Time without chest compressions was also significantly shorter in the booster group (booster mean 16.1 SD 2.1 seconds (s) vs no booster 26.9 SD 3.7 s, $p < 0.001$). There were no significant differences in time to first chest compression and AED operations between the two groups.

Skill performance between course conclusion and 1 year (critical outcome)

We identified very low certainty of evidence (downgraded for risk of bias and imprecision) from two RCTs (n=201) for the number of participants able to perform chest compressions with adequate depth at 6 months. [21, 27] In a randomised trial 87 healthcare professionals were randomised to spaced learning (self-directed monthly 2-min practice with real-time feedback) or massed learning (conventional recertification course with instructor feedback) for their annual paediatric BLS training.[21] At 3 month testing, there was improvement in the mean percentage of chest compressions of adequate depth which was sustained with little decay over the 12 month study period in the spaced learning group (baseline mean % 56.7 95%CI 44.6, 68.7; 3 months 84.2 95%CI 74.9, 93.6; 6 months 83.2 95%CI 74.4, 92.1; 9 months 82.2 95%CI 73.5, 91.0; 12 months 81.2 95%CI 72.3, 90.2). Similar improvements were also seen in mean % of chest compressions with correct rate and mean % of chest compressions with complete chest recoil. In contrast, the control group showed no improvement at 3 months and chest compression quality further declined over a 12 month period. As the intervention group was also exposed to real-time feedback, it is possible that the improvement shown in skill testing may be a result of the use of real-time feedback as well as spaced learning. Similar improvement in chest compression performance with booster training was also reported by a second study. [27] Six hundred and six nursing students who previously completed an instructor-led BLS course were recruited and randomised to either brief monthly practice (booster training) or no practice (control group). In the booster training group, students' mean compression depths were within the accepted range (between 38 and 51 mm), with no significant loss over the 12 months study period. The mean compression depths ranged from 38.6 (SD = 6.7) mm at 3 months to 40.3 (SD = 6.6) mm at 12 months and 39.9 (SD = 5.9) mm following booster training. In contrast, the control group had significant skill decay in chest compression depth; the mean depth at 9 months was 39.6mm (SD 6.8) and at 12 months was 36.5mm (SD 7.7, $p = 0.004$). With booster training, students improved their ability to ventilate with an adequate volume (6 months mean ventilation volume 514.0 mL (SD = 208.4), 12 months mean ventilation volume was 620.7 mL (SD = 211.0)). In the control group, the mean ventilation volumes remained less than the recommended minimum (500ml) throughout the 12 months.

There were three small studies (2 randomised and one cohort study) describing spaced learning in paediatric advanced life support.[19, 22, 32] The first randomised study randomised 36 healthcare professionals to either six 30-minute modular paediatric advanced life support taught over 6 months (spaced learning) or 1 day standard paediatric advanced life support recertification course (control). [22] CPR performance was assessed with a clinical performance score made up of 21 items with a maximum score of 42 (each item rated as 0 = not performed; 1 = performed inappropriately or not in a timely manner; and 2 = performed correctly and in a timely manner). At course conclusion, clinical performance scores in the 17 participants in the spaced learning group improved (baseline 16.3±4.1 to post training 22.4±3.9) compared with scores in the control group (19 participants) (baseline 14.3±4.7 to post training 14.9±4.4, $p = 0.006$). The second study randomised 48 emergency medical services (EMS) providers to either spaced (26 participants, four weekly sessions) or massed learning (22 participants, two sequential days).[19] At 3 months, practical skills of participants were assessed using global skills rating scale (GRS) score based on 4 point Likert scale (1=very poor, 4 = excellent). Infant and adult chest compressions were similar in both groups but bag valve mask ventilation (BVM) and intraosseous insertion (IO) performance was superior in the spaced learning group (spaced learning group BVM score mean 2.2 (SD 7), $p = 0.005$, IO score mean 3.1 (SD 0.5), $p = 0.04$; massed learning group BVM score mean 1.8 (SD 0.5), $p = 0.98$) IO score mean 2.7 (SD 0.2), $p = 0.98$). In the third study, the same research group recruited 45 medical students to a paediatric resuscitation course in either a spaced (23 participants) or massed format (22 participants) in a cohort study. [32] Four weeks following course completion, participants were tested with a knowledge exam and their ability to perform bag-valve mask ventilation, intra-osseous insertion and chest compressions. The study found no significant difference in knowledge and overall skill performance but fewer critical procedural steps were missed by the spaced learning group.

There were eight studies identified that reported booster training. Sullivan at al randomised 66 nurses into four BLS training groups: massed training (control, 18 participants) and three booster training groups that participated in 15 minute in-situ in-hospital cardiac arrest training sessions every two (2M, 15 participants), three (3M, 16 participants) or six months (6M, 17 participants)[24]. The study found that more frequent training was associated with a decreased median time (in seconds) to starting compressions (control: 33 (IQR 25–40) vs training every 6 months: 21 (IQR 15–26) vs training every 3 months: 14 (IQR 10–20) vs training every 2 months: 13 (IQR 9–20); $p < 0.001$). More frequent training was also associated with decreased median time (in seconds) to defibrillation (control: 157 (IQR 140–254) vs. training every 6 months: 138 (IQR 107–158) vs training every 3 months: 115 (IQR 101–119) vs training every 2 months: 109 (IQR 98–129); $p < 0.001$). In a randomised study of 605 BLS trained nursing students comparing monthly booster CPR training with no booster training, the booster training group had superior compression performance (% correct mean chest compressions: booster group (302 participants) mean % 49.2 (SD 33.2) vs control (303 participants) mean % 39.7 (SD 34.8), $p=0.003$). [25] The booster training group also had better ventilation skills (% correct ventilations: booster group mean % 48.0 (SD 32.3) vs control group mean % 36.7 (SD 33.7), $p<0.0001$). In a separate report from the same study, the authors conducted a post-course survey in 357 out of a cohort of 605 participants. [26] A higher percentage of students in the booster training group reported immediately post-training being “confident” or “very confident” in their ability to perform CPR than the control group after their training (booster group, 95%, 157 of 165 respondents, vs. control, 78%, 137 out of 176 respondents, $p=0.003$). There was no discernible difference in the proportion of student satisfaction (booster training, 93%, 153 of 165 respondents vs control group 90%, 156 of 179 respondents, p-0.23). O’Donnell and colleagues also compared monthly booster or a single booster at 3 months with no booster training in 100 nursing students undertaking BLS courses.[33] At 6 months, they found improved knowledge test results, including recognition of arrest, opening airway and initiation of CPR, in the booster training groups compared to the control (no booster training) group (mean knowledge test score monthly practice group 11.5 out of 14, 3 monthly practice group 10.68 out of 14, no practice group 9.50 out of 14, $p=0.05$). The study did not demonstrate a difference in practical performance between the three groups at 6 months.

Repeated booster practice was tested in four studies in neonatal resuscitation. In a study in Honduras, 49 neonatal hospital providers who were trained in a Help Babies Breathe 1 day (8 hour) workshop were randomised to once monthly practice for 6 months versus three consecutive practices at 3, 5 and 6 months. [23] Repeated monthly practice resulted in improvements and maintenance of performance with participants in the monthly practice group scoring a mean of 1.3 points (SE 0.42) higher in objective structured clinical evaluations (OSCE). They were also 2.9 times more likely to pass on the first attempt than those who practiced less frequently. Also in neonatal resuscitation, Ernst et al randomised 110 students training in neonatal intubation to massed learning with no booster training (control), once weekly booster training or one week of 4 consecutive day's booster training. [28] After 6 weeks, students were assessed with video-based scenarios and booster training was associated with an improved neonatal intubation performance. In comparing scores in equipment selection and preparation, the median preparation score (maximum 11) for the weekly group (32 participants, median 9 IQR 8.0-9.5), and consecutive day (37 participants, median 8.0 IQR 7.5-9.0) groups were significantly higher than the control group (41 participants, median 7.0 IQR 6.0-8.0, p<0.001). The median performance score (maximum 8) was also significantly higher in weekly (median 7.0 IQR 6.5-7.5) and consecutive day (median 7.0 IQR 6.0-7.5) groups compared to the control group (median 5.5 IQR 4.0-6.0, p<0.001). Bender et al conducted a randomised controlled trial comparing booster training 9 months after a neonatal resuscitation training program with no booster training (control). [30] At 15 months testing, the booster group (23 participants) scored significantly higher in procedural scores than the control group (27 participants) (71.6/107 versus 64.4/107, p=0.02) but no difference in knowledge scores was found. Cepada Brito randomised 25 neonatal intensive care staff members in a neonatal resuscitation program to monthly booster training (7 participants), one booster every 3 months (7 participants) or one booster every 6 months (11 participants). [29] The study did not find any statistical difference in CPR performance at 6 months across the three groups.

Knowledge at course conclusion (important outcome)

We found very low certainty evidence (downgraded for risk of bias and imprecision) from three cohort studies.[19, 33, 34] Two studies [19, 34] examined spaced learning and one study [33] looked at booster training. Breckwoldt and colleagues designed an emergency medicine intensive course and compared the knowledge of 156 students for a course delivered over 5 half-days with afternoon as private time or self-directed learning (spaced learning), compared with a course delivered over 3 full days (massed learning). [34] At course conclusion, participants were assessed by a video case-based key-feature knowledge test. Participants from the spaced group reached a mean score of 14.8 out of 22 points (SD 2.0), compared to a mean score of 13.7 (SD 2.0) in the massed learning group (p = 0.002). In a randomised controlled trial, Patocka et al randomised 72 EMS providers to spaced learning (four 3.5hr sessions over 1 month) or massed learning (two sequential 7hr days). Forty-eight participants completed the training and were tested with a 33-question standardized Paediatric Advanced Life Support Multiple Choice Question (MCQ) test at post-training and 3-months post-course. [19] Participants from the spaced learning group maintained their MCQ score between course conclusion and 3 months post course (26 participants, post course 30.3 SD 0.5 vs 3-months 29.7 SD 0.5, P= 0.39) compared with a significant decay seen in the massed learning group (22 participants, post course 31.1 SD 0.5 vs 3-months 29.6 SD 0.5, p= 0.04). In an observational study, O'Donnell divided BLS trained nursing students into 3 groups: monthly booster training (33 participants), one booster training every 3 months (34 participants) and no booster training (33 participants) and tested them at 6 months.[33] There was high number of dropouts across all groups with only 44 participants completing theory testing and 60 participants completing practical tests. The study found a higher mean test score (maximum 14) in theoretical knowledge in the booster training groups compared with the no booster training group at 6 months (monthly practice mean score 11.5 out of 14, 3 monthly practice 10.68 out of 14, no practice 9.50 out of 14, p=0.05).

Clinical outcomes

Our review did not identify any relevant studies for the important outcomes of quality of clinical performance in actual resuscitation or patient survival to hospital discharge with favourable neurological outcome.

There was however, indirect evidence from one observational study for the impact of booster training on delivery room management of the newborn. [35] This study assessed the impact of frequent brief (3–5 minute weekly) on-site simulation training sessions on newborn management in the delivery room and the potential impact on 24-hour neonatal mortality. One hundred and seventeen healthcare workers were trained. Before and after data was collection from pre-implementation observations from February 2010 to January 2011 and post-implementation from February 2011 to January 2012. The number of stimulated neonates increased from 712 (14.5%) to 785 (16.3%) (p = 0.016), those suctioned increased from 634 (13.0%) to 762 (15.8%) (p ≤ 0.0005). Mortality at 24-hours decreased from 11.1/1000 to 7.2/1000 (p = 0.040).

DISCUSSION

Our review found growing evidence suggesting that spaced learning can improve skill retention (performance 1 year after course conclusion), skill performance (performance between course completion and 1 year) and knowledge at course completion. A related systematic review was conducted in 2010 by ILCOR on resuscitation course duration in basic life support training which concluded that it was reasonable to consider shortening the duration of traditional instructor-led basic life support courses (EIT-029A).[37] A second review into whether non-traditional scheduling formats such as random scheduling or modular courses, as opposed to traditional scheduling, was unable to recommend a particular course format (EIT-020).[37] This review identified only very low certainty evidence to support spaced learning in resuscitation education, which was derived mainly from basic life support, paediatric and neonatal life support courses. Whilst we did not find any studies in adult advanced life support training or first aid training, it is not unreasonable to postulate that spaced learning may offer similar benefits seen in other courses.

Whilst our review focused mainly on technical skill performance associated with improved patient outcomes, two included studies reported conflicting results on human factors in spaced learning. [22, 30] In a study of booster training versus no booster training in the neonatal resuscitation program, participants were assessed using Global Team Competency Scales and delivery room performance at follow-up. [30] Participants in the booster group scored higher on Teamwork Behaviours Assessment Instrument (booster group 18.8 out of 25 versus no booster 16.2 out of 25, p=0.02) that correlated well with procedural skills (r = 0.86). In contrast, a randomised study comparing six 30-minute modular paediatric advanced life support taught over 6 months (spaced learning) and 1 day standard paediatric advised life support recertification course (control) did not find any improvement in team behaviour scores (mean Behavioural Assessment Tool score spaced learning 2.8 SD 3.6 vs control 3.0 SD 4.0, p = 0.69) despite improved clinical performance. [22]

We classified the included studies broadly into spaced learning and booster training groups but they were highly heterogeneous. The included studies included only participants from single centre and majority had small numbers of participants (<250 participants). The format, duration and frequency of spaced learning and booster training varied from instructor-led training, hands on practice, to self-directed learning with or without feedback. It is unclear whether different formats of training will impact on the effectiveness of spaced learning. For example, there is evidence that the addition of testing may improve skills learning compared to no testing.[38, 39] It was beyond the remit of our review to inspect the optimal format of spaced learning or to analyse the effect of different retraining intervals. Any educational intervention should be designed to deliver the learning objectives specific to a course and it is unlikely that one specific format, design or duration would fit all resuscitation courses.

While some may argue there is potential increase in costs or resource use required for faculty, equipment and learners to implement spaced learning, there is some evidence that spaced learning may actually lead to cost savings.[20, 36] Cost and resources were not specifically reported by included studies but one study reported a shorter duration in training and testing in a spaced PALS course than in the standard PALS course (spaced learning 8hrs vs massed learning 12.5hrs).[22] A potential drawback of spaced learning is the apparent drop out in the number of participants seen in some of the included studies. One example is Andersen's study where participants were randomised to a different frequency of booster training.[20] Two hundred and forty-four participants were randomised but only 167 completed the training (31.6% drop outs) with some participants no longer interested, left their position at the hospital or not able to complete all training sessions. In a second study, 72 participants were randomised to spaced and massed learning groups but scheduling conflicts meant that only 49 participants were able to complete training over the 3 month study period (31.9% drop outs).[19] Participation in spaced learning requires ongoing motivation to stay in the course. Thought should be given to ways of overcoming the challenge of engaging participants in the repeated, effortful practice of spaced learning.

Limitations

Due to the high heterogeneity in included studies we were unable to conduct any meta-analyses. There was a lack of data on the impact of spaced learning on the quality of performance in actual resuscitations and a lack of data on the impact of spaced learning on patient survival with favourable neurological outcome. Whilst there was some limited data on infant mortality at 24 hours post-delivery in spaced learning in delivery room management,[35] there is no data on survival to hospital discharge or long-term survival in neonates.

The majority of studies focused on skill retention and or retraining, and only one study described novice participants who acquired new knowledge and skills. [34] There was no meaningful data to allow us to examine the effectiveness of spaced learning on skill acquisition compared to maintaining skill performance and/or preventing skill decay.

There was also insufficient data to examine the effectiveness of spaced learning on laypeople compared to healthcare providers.

CONCLUSIONS

Very low certainty evidence suggests that spaced learning may be associated with improved educational outcomes compared to massed learning in resuscitation courses at 1 year and from course conclusion to 1 year post training. There was no data on skill performance during clinical resuscitation or patient survival with favourable neurological outcomes.

Joyce Yeung: Conceptualization; Data curation; Formal analysis; Methodology; Project administration; Software; Writing - original draft. Therese Djarv; Data curation; Formal analysis. Ming Ju Hsieh: Data curation; Formal analysis. Taylor Sawyer: Data curation; Writing - original draft. Andrew Lockey: Supervision; Writing - review & editing. Judith Finn: Methodology; Supervision; Validation; Writing - review & editing. Robert Greif: Conceptualization; Supervision; Validation; Writing - review & editing

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Joyce Yeung as Expert Systematic Reviewer.

David Lightfoot as Information Services, St Michael's Hospital.

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CONFLICTS OF INTEREST

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CONFLICTS OF INTEREST

No conflict of interests declared.

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LEGENDS TO FIGURES

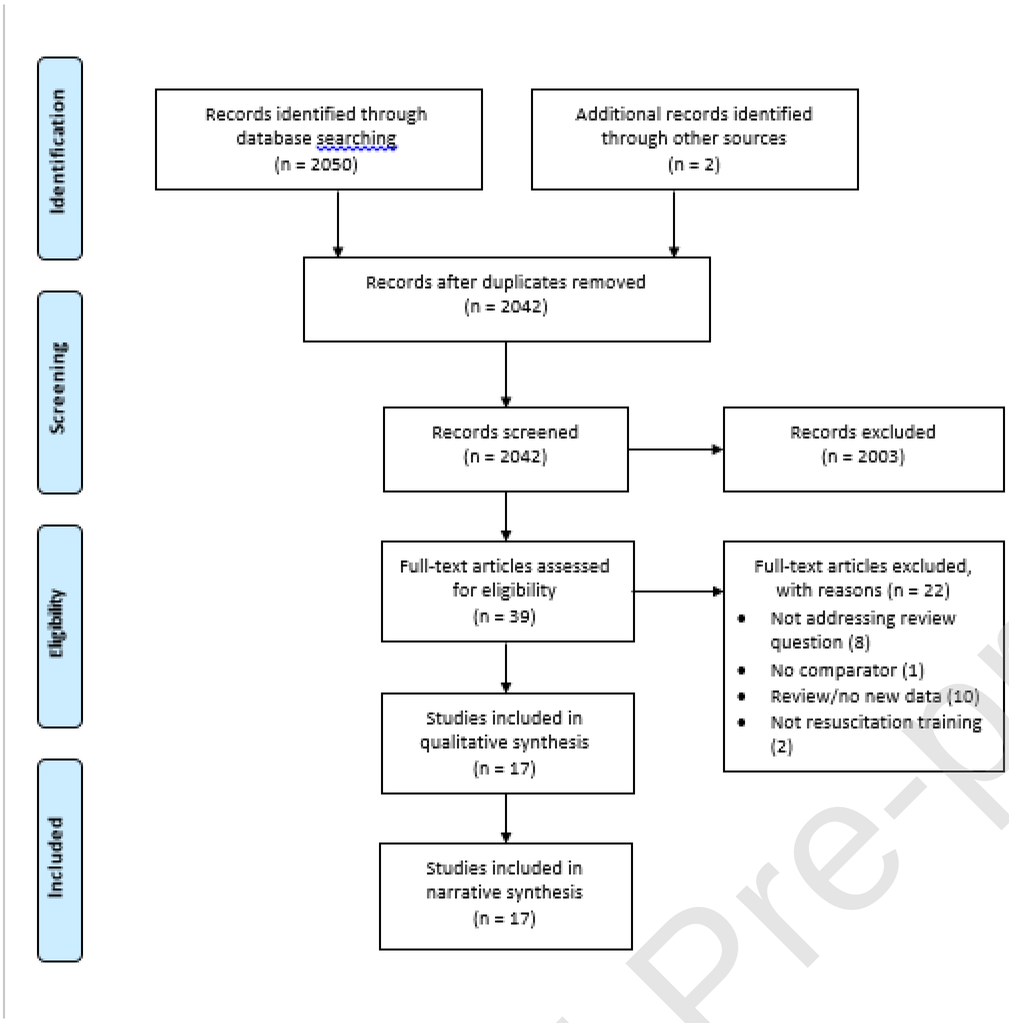

Figure 1. PRISMA Diagram

Table 1a Characteristics of included studies 'Spaced learning'

Author Year Country	Study design	Student	Number of students	Course/Skills taught	Intervention	Control	Primary outcome(s)
Patocka 2019 Canada	Single-blinded RCT	Trained EMS providers (EMT or paramedics)	48	AHA/Heart and Stroke Foundation of Canada 2010 PALS curriculum	Spaced course (four 3.5 -h weekly sessions over 1 month)	Massed course (two sequential 7-h days)	Global rating scale (GRS) score for the four individual procedural skills (adult and infant CC, infan BVM and IO) immediately after course and 3 months later
Lin 2018 Canada	RCT	Trained Healthcare providers working in the ED	87	Just-in-time CPR training; AHA BLS course	Distributed training at least once a month with real-time feedback without limited practicing time (AHA Resuscitation Quality Improvement (RQI) program)	Standard AHA BLS course 4.5 hours course	"Excellent CPR"(defined as achieving at least 90% of all AHA standards for CC depth, rate and recoil for each individual criterion.) after one year
Patocka 2015 Canada	Prospective cohort	Third-year medical students	45	5 hours Pediatric Resuscitation course based on PALS	4 weekly 1.25 hour sessions(each with one week spacing interval)	Single 5-hour session	Performance on the Multiple Choice Examination, knowledge assessment and procedural skill global rating scores. 4 weeks following the completion of the last session
Kurosawa 2014 Japan	Prospective randomized single-blind trial	Trained PICU-nurses, respiratory therapists, and nurse practitioners.	40	PALS recertification course, based on American Heart Association (AHA) PALS recertification training	Simulation-based modular PALS recertification training (reconstructed into six 30-min sessions conducted monthly) and two 15-minute AED/CPR demonstration sessions, and up to 60 minutes for the written evaluation for a total of 4.5 hours	standard 1-day simulation-based PALS recertification course 7.5 hours	Skill performance measured by a validated Clinical Performance Tool immediately after training
Tabangin 2018 Honduras	RCT	Clinic and hospital providers (doctors and nurses)	37	Helping Babies Breathe (HBB)	monthly practice for 6 months after initial training	three consecutive practices at 3, 5 and 6 months	Observed Structure Clinica Examination score immediately after training at 3 and 6 months
Sullivan 2015 USA	RCT	Trained nurses	66	CPR and defibrillation for IHCA	15 min in-situ IHCA training sessions every two (2M), three (3M) or six months (6M)	Standard AHA BLS course 4.5 hours course	Time elapsed from call for help to; (1) initiation of chest compressions and (2) successful defibrillation in IHCA 6 months after initial training
Breckwoldt 2016 Switzerland	quasi-experimental study	5th year medical student	156	Students' procedural knowledge within intensive course in emergency medicine	26 teaching hours in 4.5 days	26 teaching hours in 3.0 days	the difference in overall key-feature test score within 8 days after training

Table 1b Characteristics of included studies with 'Booster training'

Author Year Country	Study design	Student	Number of students	Course/Skills taught	Intervention	Control	Primary outcome(s)
Ernst 2014 USA	RCT	3rd year medical students	110	neonatal intubation	Weekly (practice once/week for four consecutive weeks), or consecutive day (practice once/day for four consecutive days).	standard (control; no practice sessions),	Equipment selection (preparation score), procedural skill steps (procedure score), lengtl of intubation attempts (i seconds), and the numbe of attempts at 6 weeks
Montgomery * 2012 USA	RCT	Nursing students	606	BLS	6 min of monthly practice on a voice advisory manikin after initial training	no practice after initial training	Survey related to CPR confidence, initial course length, and satisfaction a 1 year
Kardong-Edgren* 2012 USA	RCT	Nursing students	606	BLS	6 min of monthly practice on a voice advisory manikin after initial training	no practice after initial training	Correctly performed compressions; Correctly performed ventilations a 12 months
O'Donnell 1993 UK	RCT	Trained nurses	100	CPR	Group 1: monthly refresher sessions, Group 2: a single refresher at 3 months	Group 3: no refresher training	Knowledge test and pass rate for the skill test 6 months after initial training
Anderson 2019 Canada	RCT	Trained healthcare professionals- ICU, Theatre, ED, ward nurses	244	AHA's Resuscitation Quality Improvement (RQI) program	Workplace-based CPR training at different intervals: Group1- monthly. Group2- 3months. Group3 - 6 months.	Workplace-based CPR training at different intervals: every 12 months	Proportion of participant performed 'Excellent' CP at the 12-month
Cepeda Brito 2017 USA	Single-blinded, randomized longitudinal study	Trained staff from neonatal intensive care unit	25	NRP	Booster/Refresher training at 1-month and 3-monthly intervals	One refresher training at 6-month	Effective chest compressions rate (>90 compressions/min, >1/3 anteroposterior chest wa diameter, full recoil, interruptions <1.5 seconds. Tested at 6 months
Oermann* 2011 USA	RCT	Nursing students	606	BLS	6 min of monthly practice on a voice advisory manikin after initial training	no practice after initial training	Compression rate and depth, percent of compressions performec with adequate depth, percentage with correct hand placement, ventilation rate and volume, and percentage ventilations with adequa volume. Randomly selected to be tested eve 3 months up to 1 year
Mduma 2015 Africa	Before and After study	midwives, nurse students, operating nurses, and doctors	Number of students not reported. 4894 deliveries before, 4814 post interventio n	NRP	Frequent brief (3–5 min weekly) on-site Help Baby Breathe (HBB) simulation training on newborn resuscitation practices in the delivery room	No booster	Delivery room management of newborn and 24-h neonatal outcomes (normal, admitted to a neonatal area, death, or stillbirths Observed by research assistants.
Bender 2014 USA	RCT	Residents (NICU and non-NICU)	50	NRP	booster simulation 7 to 10 months after NRP.	No booster	Video recordings independently assessed procedural skill and teamwork behaviour at 15months

Nishiyama 2015 Japan	RCT	University employees and students (non-healthcare)	112	BLS	15min refresher course 6 months after initial 45min training	Initial 45min BLS training. No refresher	The number of appropriate chest compressions during a 2-min test period at 12 months

*same study with different outcomes reported.

Table 2a Risk of bias – randomised study

Study ID	Random sequence generation - selection bias	Allocation concealment - selection bias	Blinding of outcome assessment - detection bias	Blinding of participants - performance bias	Incomplete outcome data - attrition bias	Selective reporting - reporting bias	Other bias
Patocka 2019	Low risk	Unclear risk	Unclear risk	High risk	Low risk	Unclear risk	Unclear risk
Anderson 2019	Low risk	Low risk	High risk	High risk	High risk	Unclear risk	Unclear risk
Lin 2018	Low risk	Low risk	High risk	High risk	Low risk	Unclear risk	Low risk
Kurosawa 2014	Unclear risk	Unclear risk	Low risk	High risk	Low risk	Low risk	Low risk
Tabangin 2018	Unclear risk	Unclear risk	Unclear risk	High risk	High risk	Unclear risk	Unclear risk
Sullivan 2015	Low risk	Low risk	High risk	High risk	Low risk	Unclear risk	Low risk
Oermann 2011	Unclear risk	High risk	High risk	High risk	High risk	Unclear risk	Unclear risk
Ernst 2014	Unclear risk	High risk	Low risk	High risk	Low risk	Unclear risk	Low risk
Montgomery 2012	Unclear risk	High risk	Unclear risk	High risk	High risk	Unclear risk	High risk
Kardong-Edgren 2012	Unclear risk	High risk	High risk	High risk	Low risk	Unclear risk	Unclear risk
Cepeda Brito 2017	Low risk	High risk	High risk	High risk	Low risk	Unclear risk	Low risk
Bender 2014	Low risk	High risk	High risk	High risk	Low risk	Unclear risk	Low risk
Nishiyama 2015	Low risk	Low risk	High risk	High risk	High risk	Unclear risk	Low risk

Table 2b Risk of bias – non randomised studies

Study ID	Bias due to confounding	Bias in participant selection	Bias in classification of intervention	Bias in deviation from intervention	Bias from missing data	Bias from measuring outcomes	Bias from selected reporting of results	Overall bias
Patocka 2015	Moderate	Serious	Low	Low	Low	Low	Low	Moderate
O'Donnell 1993	Low	Serious	Low	Low	Serious	Serious	Serious	Serious
Breckwoldt 2016	Moderate	Serious	Low	Low	Moderate	Low	Low	Serious
Mduma 2015	Moderate	Serious	Low	Low	Low	Low	Low	Moderate