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Review

Blended learning for accredited life support courses – A systematic review

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Abstract

Aim: To evaluate the effectiveness on educational and resource outcomes of blended compared to non-blended learning approaches for participants undertaking accredited life support courses.

Methods: This review was conducted in adherence with PRISMA standards. We searched EMBASE.com (including all journals listed in Medline), CINAHL and Cochrane from 1 January 2000 to 6 August 2021. Randomised and non-randomised studies were eligible for inclusion. Study screening, data extraction, risk of bias assessment (using RoB2 and ROBINS-I tools), and certainty of evidence evaluation (using GRADE) were all independently performed in duplicate. The systematic review was registered with PROSPERO (CRD42022274392).

Results: From 2,420 studies, we included data from 23 studies covering fourteen basic life support (BLS) with 2,745 participants, eight advanced cardiac life support (ALS) with 33,579 participants, and one Advanced Trauma Life Support (ATLS) with 92 participants. Blended learning is at least as effective as non-blended learning for participant satisfaction, knowledge, skills, and attitudes. There is potential for cost reduction and eventual net profit in using blended learning despite high set up costs. The certainty of evidence was very low due to a high risk of bias and inconsistency. Heterogeneity across studies precluded any meta-analysis.

Conclusion: Blended learning is at least as effective as non-blended learning for accredited BLS, ALS, and ATLS courses. Blended learning is associated with significant long term cost savings and thus provides a more efficient method of teaching. Further research is needed to investigate specific delivery methods and the effect of blended learning on other accredited life support courses.

Keywords: Blended learning, Hybrid learning, Healthcare, Health professions, Education, Systematic review, Life support, Accredited course

Introduction

Life support courses are designed to train healthcare professionals and the public in best practice across basic and advanced approaches to adult, paediatric, and newborn resuscitation. Traditionally, these courses have been delivered in a face-to-face format, with the first known blended learning courses being developed for basic life support (BLS) in 2006[1] and advanced cardiac life support (ALS) in 2010.[2] The ever-increasing demands upon clinical service delivery time have historically been a driver to reduce teaching and study leave time. As a result, there is a need for flexible, tailored, and timely methods of teaching which are also efficient and cost-effective.[3,4] A blended learning approach has the potential to deliver cost savings for both learners and teaching institutions when compared with conventional classroom learning whilst still maintaining face-to-face contact.[5–7].

Blended learning is defined as the integration of face-to-face and online instruction,[8] with coherence between the online and face-to-face elements to ensure that they complement each other.[9] It combines the advantages, but also the disadvantages, of both face-to-face and online approaches. Advantages include giving learners more control over the educational content to be engaged, the pace of learning, as well as flexibility around when and where learning

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takes place.[10,11] These online elements are usually, but not always, delivered prior to the face-to-face element, which then provides an opportunity for supervised hands-on practice in the skills required for resuscitation. A key disadvantage may be that simply adding an online module or replacing didactic content on a new platform may not improve student engagement.[12,13] It can also overwhelm the learner by adding complexity of material and therefore lead to lower confidence ratings.[14]

Learning in such formats may be better tailored to the learner, either in respect to different levels of pre-knowledge or for pace of learning.[11] More recently, the impact of the COVID-19 pandemic on the feasibility of face-to-face interactions and teaching has been profound, making the use of technology enhanced learning a necessity rather than an option.[15–18] It is important to understand what the true benefit of blended learning is on learning outcomes during resuscitation courses. This systematic review therefore aims to evaluate the impact of blended learning for accredited life support courses on educational outcomes and identify areas for future research.

Methods

The review was commissioned by the International Liaison Committee on Resuscitation (ILCOR) as part of a continuous evidence evaluation process. It was planned, conducted and reported in adherence with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards of quality for reporting meta-analyses.[19] The study protocol (see Appendix 1) was registered with PROSPERO on 20 August 2021 (registration number CRD42022274392). As this is a systematic review of previously published studies, no ethical approval or patient consent was required.

Research question

The *a priori* protocol utilised the PICO format (Population, Intervention, Control, Outcomes)[20] to formulate the research question: In participants undertaking an accredited life support course (P), does a blended learning approach (I), as opposed to a non-blended learning approach (stratified into subgroups of online only or face-to-face only) (C), affect the following outcomes: knowledge acquisition and retention (end of course, 6 months, 1 year), skills acquisition and retention (end of course, 6 months, 1 year), participant satisfaction (end of course), and resource outcomes (cost, time needed) (O).

We defined 'accredited life support course' as a structured course approved by a professional organisation (e.g., European Resuscitation Council (ERC), American Heart Association (AHA), St John Ambulance etc.). Tuition of life support skills delivered as part of a broader higher educational institutional curriculum was excluded from this definition unless a stand-alone accredited course had been used.

Study eligibility

We included all comparative studies (prospective and retrospective) for all accredited life support courses that looked at the impact of a blended learning approach on educational and resource outcomes. Publications from all years and all languages were to be included if there was an English abstract available. Studies involving unpublished results, trial protocols, commentaries, editorials, and reviews were excluded.

Data sources

We searched EMBASE.com (which includes all journals in Medline), CINAHL, Cochrane Reviews, and Cochrane Central Register of Controlled Trials (CENTRAL), with the last search date of 6 August 2021. The *a priori* protocol included no date limit, but as the concept of blended learning was not formally described until the early 2000s,[21] a decision was subsequently made to set the initial date from 1 January 2000. The search strategy, developed and run by an Information Specialist, is described in Appendix 2.

Study selection

The titles and abstracts of all potentially eligible studies were independently screened in duplicate for inclusion. The included studies were independently screened in more detail for eligibility in duplicate based upon set inclusion and exclusion criteria. Any disagreements between the reviewers were resolved by discussion. Included articles were also scrutinised for additional citations.

Data collection

Data from each study were independently extracted by each reviewer and any conflicts were resolved by discussion to reach consensus. The data included course type, accrediting body, study design, date range, setting, prior training, outcome measures, control group description (online or face-to-face only), and blended learning approach used.

Analysis

Due to the substantial clinical and methodological heterogeneity of the studies identified following the search, it was deemed undesirable to perform any meta-analysis and therefore a narrative summary was provided. Risk of bias assessments were performed independently and in duplicate using the revised Cochrane risk-of-bias tool (RoB2)[22] for randomised trials, and ROBINS-I tool[23] for non-randomised studies. An assessment of certainty of evidence was made using Grading of Recommendations Assessment, Development and Evaluation (GRADE) methodology.[24]

Results

Study selection

The search identified 2,420 articles after removal of duplicates. Of these, 2,359 were excluded leaving 61 full text articles to be screened for eligibility (see Fig. 1). In total, 22 studies were identified for inclusion comprising studies covering BLS (n = 13),[1,25–36] ALS (n = 8),[2,37–43] and Advanced Trauma Life Support (ATLS) (n = 1).[44] One further study covering BLS was identified following the public consultation period for the ILCOR review (https://costr.ilcor.org/document/blended-learning-approach-for-life-support-education), that had not been identified in the initial search.[45]

Study characteristics

The studies were conducted between 2006 and 2021. Most studies used face-to-face only as the control group, with only two adult BLS studies having online learning only as a control group.[1,36]

Fourteen studies focused on BLS courses (thirteen randomised[1,25–34,36,45] and one observational[35]), and these are summarised in Table 1. A total of 2,745 participants were involved from a variety of backgrounds including nursing,[33] healthcare students (medical, nursing, and dental),[26,27,29,30,32,34,35,45] teenage stu-

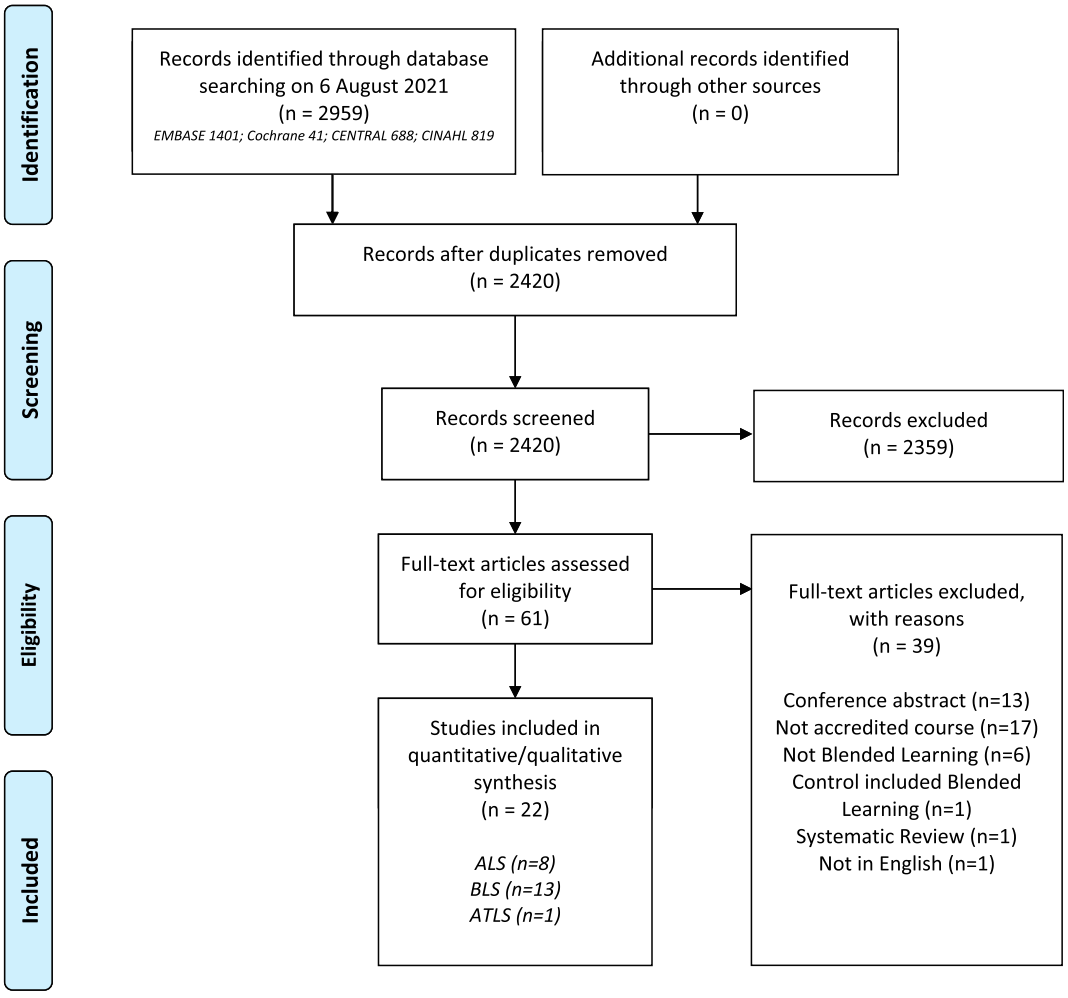

Fig. 1 – PRISMA Diagram.

dents,[1,36] parents of newborns,[25] and adult members of the public.[28,31] Some studies added online content to standardised face-to-face courses (ranging from fixed content videos to interactive online learning programmes),[1,25,32,34,36] and some substituted didactic content with online content leaving an amended face-to-face element.[26,28–31,33,35,45] Two studies covered infant BLS training only.[25,34] The remaining twelve studies covered adult BLS training.[1,26-33,35,36,45] All studies reported the proportion of participants who had previous training for baseline group characteristics. Only one study adjusted mean differences for this data.[1] No studies reported outcomes specific to whether participants had previous training or not.

Eight studies (three randomised[2,41,42] and five observational[37–40,43]) focused on adult ALS courses (see Table 2). A total of 33,579 healthcare professionals and students were studied with interventions ranging from delivery of learning on a CD-ROM prior to a traditional course[2] to substitution of didactic elements with online learning.[37–43] One study addressed the pilot version of a blended learning course[42] with a further study analysing the amended final blended learning product.[43] Only one study looked at online learning as a substitute for didactic elements.[2] Four studies reported the proportion of participants who had previous training for baseline group characteristics, although none reported outcomes specific to prior training.[37,38,42,43]

One observational study focused on the ATLS course (see Table 3).[44] The intervention in this study, which included 92 physicians, was online learning as a substitute for didactic elements.

Risk of bias within studies and certainty of evidence

The risk of bias assessments are summarised in Tables 4 and 5. Only two BLS[27,45] and three ALS[2,39,41] studies were assessed to be low risk of bias. The main issues identified with the remaining studies related to missing outcome data (particularly for longer term retention outcomes), inadequate blinding of assessors, inadequate randomization, and unclear selection processes. The certainty of evidence was judged to be very low for all outcomes, downgraded for very serious risk of bias and inconsistency (see Appendix 3).

Basic life support (BLS)

BLS knowledge

Six adult BLS studies with a total of 1,695 participants assessed participants' knowledge post-intervention (see Table 6).[1,26,28,29,33,45] One study with 94 healthcare students assessed knowledge by self-assessment only and found a significant improvement in the blended learning group.[45] One study with 383 high school students found higher scores in the intervention group, although no analysis was performed for statistical significance.[1] Two studies with dental students and nurses with a total of 259 participants found a statisti-

Table 1 – Characteristics of BLS studies.

Study	Course type	Accrediting body	Study design	Date range	Setting	Prior training	Outcome measures	Control (F2F or online)	Blended learning description
Birkun 2019[45]	BLS-AED	Crimean Medical College	RCT	Nov–Dec 2018	94 medical and non-medical students, Crimea	32% control; 13% BL	Knowledge Skills	F2F	Online learning as substitute for didactic elements
Brannon 2009[25]	Infant BLS	University of Texas	RCT	Not stated	28 Parents of NICU patients, USA	None in last 2 years	Skills	F2F	Addition of online learning to F2F
Castillo 2018[26]	BLS-AED	ERC	RCT	One day in 2014	85 Nursing and Medical Students, Spain	None in last 3 years	Knowledge Skills	F2F	Online learning as substitute for didactic elements
Castillo 2019[27]	BLS-AED	ERC	Cost analysis based on previous RCT	One day in 2014	85 Nursing and Medical Students, Spain	None in last 3 years	Costs	F2F	Online learning as substitute for didactic elements
Chien 2020[28]	BLS-AED (CC-CPR)	AHA	RCT	2016–2017	736 Adult public, Taiwan	None in last year	Knowledge Skills	F2F	Online learning as substitute for didactic elements
Fernandez 2020[29]	BLS-AED	ERC	RCT	Sep 2017–Aug 2018	89 Dental Students, Spain	None in last 3 years	Knowledge Skills	F2F	Online learning as substitute for didactic elements
Nakanishi 2017[30]	Adult BLS	Japanese Red Cross (AHA Guidelines)	RCT	Unknown	95 Medical Students, Japan	61.8% control; 65.5% BL	Skills	F2F	Online learning as substitute for didactic elements
Nishiyama 2008[31]	BLS (CC-CPR)	Japanese Association for Acute Medicine	RCT	Aug–Dec 2006	183 Adult public, Japan	39.6% control; 37% BL	Skills	F2F	Online learning as substitute for didactic elements
Nord 2017[32]	BLS	Swedish CPR Council, ERC Guidelines	RCT	Dec 2013-Dec 2014	1232 13-year-old students, Sweden	Compressions: 26% control; 33% BL Ventilations: 19% control; 24% BL	Knowledge Skills Attitudes	F2F	Addition of online learning to F2F
Reder 2006[1]	BLS	AHA	Cluster-controlled trial	2003–2004	383 High School Students, USA	66% control; 73% BL	Knowledge Skills	Online	Addition of F2F to online learning
Serwetnyk 2015[33]	BLS recert	AHA	RCT	Jul-Nov 2012	170 Nurses, USA	All had undertaken AHA BLS course previously	Knowledge Skills Attitudes	F2F	Online learning as substitute for didactic elements
Shavit 2010[34]	Infant BLS	AHA	RCT	2007–2008	34 Medical Students, Israel	No	Skills	F2F	Addition of online learning to F2F
Sopka 2012[35]	Adult BLS	ERC	Cohort	2008–2009	202 Medical Students, Germany	No	Skills Attitudes	F2F	Online learning as substitute for didactic elements
Yeung 2017[36]	Adult BLS	RCUK	RCT	2016	56 Secondary school children, UK	No	Skills Attitudes	Group 1: F2F only Group 2: online only	Addition of F2F to online learning

BLS-AED = Basic Life Support with Automated External Defibrillator course, ERC = European Resuscitation Council, AHA = American Heart Association, RCUK = Resuscitation Council UK, RCT = Randomised Controlled Trial, BL = Blended Learning, F2F = face-to-face.

Table 2 – Characteristics of ALS studies.

Study	Course type	Accrediting body	Study design	Date range	Setting	Prior training	Outcome measures	Control (F2F or online)	Blended learning description
Abdulla 2019[37]	ALS	Hospital Universiti Sains	Non-RCT	2016–2017	96 doctors and paramedics, Malaysia	40% (control) 10% (intervention)	Knowledge Skills Satisfaction	F2F	Online learning as substitute for didactic elements
Chaves 2020[38]	ALS	Spanish Council for CPR	Non-RCT	Unknown	110 medical residents, Spain	76% (control) 64% (intervention)	Knowledge Skills Satisfaction	F2F	Online learning as substitute for didactic elements
George 2018[39]	ACLS	Singapore First Aid Training	Observational	2016	Physicians, Spain	Not applicable	Costs	F2F	Online learning as substitute for didactic elements
Ko 2011[40]	ACLS	American Heart Association	Cohort	2009	50 medical students, USA	Unknown	Knowledge Skills Satisfaction	F2F	Online learning as substitute for didactic elements
Lockey 2015[41]	ALS	RCUK	RCT	2008–2009	2848 healthcare professionals, UK	Unknown	Attitudes	F2F	Online learning as substitute for didactic elements
Perkins 2010[2]	ALS	RCUK	RCT	2007	572 healthcare professionals, UK	Unknown	Knowledge Skills	F2F	Interactive CD-ROM prior to F2F course
Perkins 2012[42]	ALS	RCUK	Randomised non-inferiority	2008–2011	2733 healthcare professionals, UK/Australia	Yes	Knowledge Skills Satisfaction Costs	F2F	Online learning as substitute for didactic elements
Thorne 2015[43]	ALS	RCUK	Cohort	2013–2014	27,170 healthcare professionals, UK	Yes	Knowledge Skills	F2F	Online learning as substitute for didactic elements

ALS = Advanced Life Support, ACLS = Advanced Cardiac Life Support, RCT = Randomised Controlled Trial, RCUK = Resuscitation Council UK, F2F = face-to-face.

Table 3 – Characteristics of ATLS study.

Study	Course type	Accrediting body	Study design	Date range	Setting	Prior training	Outcome measures	Control (F2F or online)	Blended learning description
Dyer 2021[44]	ATLS	American College of Surgeons	Cohort	July 2019–Dec 2020	92 PGY1 Doctors, USA	Not stated	Knowledge Skills	F2F	Substitution of didactic elements with online learning

ATLS = Advanced Trauma Life Support, F2F = face-to-face, PGY1 = 1st year Postgraduate.

cally significant deterioration in post intervention knowledge scores and increased requirements for knowledge remediation.[29,33] The remaining two studies involving nursing and medical students and members of the public with a total of 959 participants found no significant difference between the control and intervention groups for knowledge acquisition.[26,28] Four of the studies also assessed knowledge retention between 2 and 12 months.[1,26,28,29] There was no significant difference between the groups at any time point.

BLS skills

Thirteen studies with a total of 2,741 participants assessed skills post-intervention (see Table 7).[1,25,26,28–36,45] Two of these studies with a total of 57 participants covered infant BLS training only,[25,34] and the remainder covered adult BLS.[1,26,28–33,35,36]One study with 123 medical and nursing students undertaking adult BLS found a statistically significant improvement in skills scores in the blended learning group.[26] One study with 108 medical students undertaking adult BLS found a statistically significant improvement in time to first compression, but a statistically significant decrease in total chest compressions.[30] One study with 81 school children learning adult BLS found a statistically significant benefit for chest compression depth for blended learning over online only using a gaming app.[36] One study with 34 medical students learning infant BLS found better performance in a range of components of BLS, although they did not perform an analysis for statistical significance.[34] The remainder of the studies with a total of 2,395 participants, including one study of infant BLS[25] and 8 studies of adult BLS,[1,28,29,31–33,35,45] found no significant difference between the intervention and control groups.

Eight adult BLS studies also assessed skills retention between 2 and 12 months.[1,26,28–30,32,35,36] One study with 383 high school students found that the intervention group had better skills retention at

Table 4 – Risk of Bias for Randomised Controlled Trials.

Study ID (Name, Year)	Randomisation	Deviation from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported results	Overall
Basic Life Support						
Birkun 2019[45]	Low	Low	Low	Low	Low	Low
Brannon 2009[25]	Low	Low	Concerns (a)	Low	Low	Concerns
Castillo 2018[26]	Low	Low	Concerns (a)	Concerns (b)	Low	Concerns
Castillo 2019[27]	Low	Low	Low	Low	Low	Low
Chien 2020[28]	Low	Low	Concerns (a)	Low	Low	Concerns
Fernandez 2020[29]	Low	Low	Concerns (a)	Low	Low	Concerns
Nakanishi, 2017[30]	Low	Concerns (d)	Concerns (a)	Low	Low	Concerns
Nishiyama, 2008[31]	Low	High (d)	Low	Low	Low	High
Nord, 2017[32]	Concerns (c)	Concerns (d)	High (a)	Concerns (b)	Low	High
Reder, 2006[1]	Low	Concerns (d)	Concerns (a)	Low	Low	Concerns
Serwetnyk, 2015[33]	Low	Low	High (a)	Concerns (b)	Low	High
Shavit 2010[34]	Concerns (c)	Low	Low	Low	Low	Concerns
Yeung 2017[36]	Low	Low	Low	Concerns (b)	Low	Concerns
Advanced Cardiac Life Support						
Lockey, 2015[41]	Low	Low	Low	Low	Low	Low
Perkins, 2010[2]	Low	Low	Low	Low	Low	Low
Perkins, 2012[42]	Low	Low	Low	Concerns (b)	Low	Concerns

a: missing data, b: assessors not blinded, c: inadequate randomisation, d: incomplete or variable exposure to intervention, e: participants not blinded.

Table 5 – Risk of Bias for non-Randomised Controlled Trials.

Study ID (Name, Year)	Confounding	Selection	Classification of intervention	Deviation from intended intervention	Missing data	Measurement of outcomes	Selection of reported results	**Overall**
Basic Life Support								
Sopka 2012[35]	Low	Low	Low	Low	Low	Moderate (a)	Low	moderate
Advanced Cardiac Life Support								
Abdulla, 2019[37]	Moderate (b)	Low	Low	Low	Low	Low	Low	moderate
Chaves 2020[38]	Low	Moderate (f)	Moderate (j)	Low	Low	Low	Low	moderate
George, 2018[39]	Low	Low	Low	Low	Low	Low	Low	low
Ko, 2011[40]	Critical (g)	Low	Low	Low	Moderate (h)	Low	Moderate (i)	critical
Thorne 2015[43]	Low	Moderate (b)	Low	Low	Low	Serious (e)	Low	serious
Advanced Trauma Life Support								
Dyer 2021[44]	Serious (c)	Serious (d)	Low	Low	Low	Moderate (e)	Low	serious

a: self-reported assessment could have been influenced by knowledge of intervention, b: participants selected intervention, c: courses run at different time periods, d: no analysis of baseline characteristics, e: no blinding of assessors, f: selection process unclear, g: intervention group had two-week placement in ED, h: missing data, i: no mention of written exam results before the mega code, j: intervention groups not fully defined.

2 months.[1] There was no analysis performed to assess for statistical significance. One study with 72 school children using a gaming app found, at 3 months, a statistically significant improvement in compression depth, but a statistically significant decrease in compression rate when blended learning was compared with online learning only.[36] Six studies of adult BLS studied skills retention at 6 months.[26,28,30,32,35,36] One study with 85 nursing and medical students found a statistically significant improvement in the blended learning group.[26] One study with 64 school children using a gaming app found a statistically significant improvement in compression depth when blended learning was compared with both face-to-face only and online learning only, but a statistically significant decrease in compression rate when blended learning was compared with online learning only.[36] The remainder of the studies with a total of 1,334 participants found no significant difference between the intervention and control groups.[28,30,32,35] One study with 53 dental students found no significant difference between the control and intervention groups at 9 months.[29] One study with 736 members of the public found no significant difference between the control and intervention groups at 12 months.[28].

BLS attitudes

Four adult BLS course studies assessed the change in attitudes of 1,685 participants.[32,33,35,36] One study with 432 school students found positive attitudes in both groups towards willingness to act, particularly if a friend had a cardiac arrest rather than a stranger.[32] At six months, the difference was more pronounced in the blended learning group. One study with 81 school students looking at a gaming approach to adult BLS training stated that there was a statistically significant improvement of attitudes in all groups post intervention.[36] The highest attitudinal score was in the gaming app only group. However, it was not stated how these improvements compared to each other.

Table 6 – Knowledge scores for BLS studies.

Study	Number Control vs Intervention Total	Control F2F only or Online Only	Intervention Blended Learning	P Value
BLS knowledge (post intervention)				
Birkun 2019[45]	55 vs 39 Total: 94	F2F: 4 (score out of 5)	4.3 (score out of 5)	<0.05
Castillo 2018[26]	66 vs 61 Total: 127	F2F: 8.36 (score out of 10)	8.44 (score out of 10)	0.41
Chien 2020[28]	416 vs 416 Total: 832	F2F: 89.22% (MCQ, 15 questions)	88.35% (MCQ, 15 questions)	0.19
Fernandez 2020[29]	45 vs 44 Total: 89	F2F: 8.6 (MCQ score out of 10)	8.1 (MCQ score out of 10)	0.013
Reder 2006[1]	213 vs 170 Total: 383	Online: 82% (MCQ, 10 questions)	87% (MCQ, 10 questions)	-
Serwetnyk 2015[33]	Control: 46 Intervention #1: 45 Intervention #2: 79 Total: 170	F2F: 2.2% needed remediation	#1: 4.7% needed remediation #2: 21.1% needed remediation	0.02
BLS knowledge retention (2 months)				
Reder 2006[1]	196 vs 160 Total: 356	Online: 81% (MCQ, 10 questions)	83% (MCQ, 10 questions)	-
BLS knowledge retention (6 months)				
Castillo 2018[26]	44 vs 41 Total: 85	F2F: 7.12 (score out of 10)	7.38 (score out of 10)	0.4
Chien 2020[28]	393 vs 385 Total: 778	F2F: 80.8% (MCQ, 15 questions)	80.29% (MCQ, 15 questions)	0.8
BLS knowledge retention (9 months)				
Fernandez 2020[29]	29 vs 24 Total: 53	F2F: 6.1 (MCQ score out of 10)	5.9 (MCQ score out of 10)	0.8
BLS knowledge retention (12 months)				
Chien 2020[28]	372 vs 364 Total: 736	F2F: 79.84% (MCQ, 15 questions)	78.36% (MCQ, 15 questions)	0.5

MCQ = Multiple Choice Questionnaire, BLS = Basic Life Support, F2F = face-to-face.

The remaining two studies found no significant difference in the attitudes of participants between control and intervention groups.[33,35]

BLS costs

Results from two studies showed that the blended learning course is superior to the traditional course in terms of cost reductions.[27,33] The authors of one study[27] performed a cost minimization analysis of the course previously described in their 2018 study.[26] They found that initial set up costs of a blended learning program resulted in a large unspecified net loss. There was however a net profit of €10,530 at 5 years in the blended learning group compared to a loss of €1,754 in the control group. In another study, the authors described cost savings due to course materials, instructor salary and backfill costs for participants.[33] They did not include any cost savings from facility costs. The annual projected costs for the traditional course were $482,351, as opposed to $293,341 for the blended learning course.

Advanced cardiac life support (ALS)

ALS knowledge

Five studies with a total of 30,681 participants assessed participants' knowledge at the end of the course using a validated post-course MCQ test (see Table 8).[2,37,38,42,43] Four of the studies used online lectures as a substitute for the theoretical classes. In two studies with 27,266 participants[37,43] there were significantly higher scores in the blended learning group, and in two studies with 2,843 participants[38,42] there was no significant difference between the groups. One study with 572 participants that used CD-ROM learning material as an additive to the conventional course material showed no significant differences between the two groups.[2] One study with 66 participants assessed knowledge at 7 months using a validated MCQ.[38] The score results were not significantly different between the blended and traditional group.

ALS skills

Six studies with a total of 30,731 participants assessed participants' skills at the end of the course (see Table 9).[2,37,38,40,42,43] The assessment methods varied between cardiac arrest simulation test results,[2,37,42,43] checklists,[38] and video analysis of the performance.[40] One pilot study for the Resuscitation Council UK (RCUK) e-ALS course of 2,733 participants found that the control group scored significantly better than the intervention group.[42] However, the same authors then made adjustments to the course and the subsequent observational study of the revised version with 27,170 participants found that the intervention group now had significantly better results than the control group.[43] The remaining four studies with a total of 828 participants found no significant difference in skills between the control and intervention groups.[2,37,38,40] One study with 66 participants found no statistically significant difference in skills assessment between the two groups at 7 months.[38]

ALS participant satisfaction

Participant satisfaction was evaluated in five studies with a total of 3,676 participants.[2,37,38,40,41] In a study with 96 doctors and paramedics, 96% agreed that viewing the videos was essential, 58% felt that online learning could replace face-to-face teaching, while 85% believed that online learning should be used as adjunct to conventional instructor teaching.[37] In a study with 59 medical students, a significant difference was found between the groups with the intervention group feeling better prepared to participate in a real-life resuscitation attempt (6.6 vs 7.73, $p = 0.01$).[40] In a study with 572 healthcare professionals, over 70% of participants felt that a pre-course interactive CD-ROM improved their understanding of key ALS learning points.[2]

Conversely, two studies found a preference for traditional courses.[38,41] In a study with 110 medical students, the scores for level of satisfaction were significantly better for the control group (3.58 vs 3.30, $p = 0.012$).[38] In a study of the pilot RCUK e-ALS course, participants consistently scored content delivered face-to-face over the same content delivered over the e-learning platform.[41] They also highly valued practical hands-on training that included simulation.

Table 7 – Skills scores for BLS studies.

Study	Number Control vs Intervention Total	Control F2F only or Online Only	Intervention Blended Learning	P Value
BLS skills (post intervention)				
Birkun 2019[45]	55 vs 39 Total: 94	F2F: mean 31.6 ± 3.3	Mean 32.0 ± 2.7	0.687
Brannon 2009[25]	13 vs 10 Total: 23	F2F: 9/13 pass	10/10 pass	0.081
Castillo 2018[26]	64 vs 59 Total: 123	F2F: 7.70 (score out of 10)	8.15 (score out of 10)	0.02
Chien 2020[28]	416 vs 416 Total: 832	F2F: 34.44 (score out of 40)	34.88 (score out of 40)	0.54
Fernandez 2020[29]	45 vs 44 Total: 89	F2F: 64%	64.7%	0.9
Nakanishi 2017[30]	54 vs 54 Total: 108	F2F: 29.5 sec (time to 1st compression) 120 (total chest compressions)	34 sec (time to 1st compression) 101 (total chest compressions)	0.01 0.005
Nishiyama 2008[31]	95 vs 87 Total: 182	F2F: 159 (post-training, chest compressions)	161 (post-training, chest compressions)	0.628
Nord 2017[32]	224 vs 208 Total: 432	F2F: 34 (score out of 48)	34 (score out of 48)	Non Significant
Reder 2006[1]	213 vs 170 Total: 383	Online: 79% (successful ventilation) 80% (successful compressions)	81% (successful ventilations) 81% (successful compressions)	Not assessed
Serwetnyk 2015[33]	Control: 46 Intervention #1: 45 Intervention #2: 79 Total: 170	F2F: 10.9% needed remediation	#1: 22.2% needed remediation #2: 17.7% needed remediation	0.347
Shavit 2010[34]	16 vs 18 Total: 34	F2F: 1.13/2 (assessing responsiveness) 0.06/2 (airway opening) 1.06/2 (breathing technique) 1.84/4 (chest compression technique) 2.81/3 (activating EMS) 0.47/1 (resuming CPR)	1.69/2 (assessing responsiveness) 0.06/2 (airway opening) 1.86/2 (breathing technique) 3.19/4 (chest compression technique) 3/3 (activating EMS) 0.97/1 (resuming CPR)	Not assessed
Sopka 2012[35]	95 vs 95 Total: 190	F2F: 85.26% (>60% algorithm adherence)	91.58% (>60% algorithm adherence)	0.1787
Yeung 2017[36]	Group 1 (F2F): 27 Group 2 (OL): 25 Group 3 (BL): 29 Total: 81	Gp 1: 37.35, Gp 2: 26.44 (compression depth) Gp1: 116, Gp 2: 125.17 (compression rate)	Gp 3: 42.09 (compression depth) Gp 3: 117.61 (compression rate)	Depth F2FvBL: 0.237 OLvBL: 0.0001 Rate F2FvBL: 0.277 OLvBL: 0.999
BLS skills retention (2 months)				
Reder 2006[1]	213 vs 170 Total: 383	Online: 79% (successful ventilation) 80% (successful compressions)	84% (successful ventilations) 84% (successful compressions)	Not assessed
BLS skills retention (3 months)				
Yeung 2017[36]	Group 1 (F2F): 22 Group 2 (OL): 24 Group 3 (BL): 26 Total: 72	Gp 1: 32.35, Gp 2:30.44 (compression depth) Gp 1: 113.75, Gp 2: 119.44 (compression rate)	Gp 3: 37.39 (compression depth) Gp 3: 97.91(compression rate)	Depth F2FvBL: 0.224 OLvBL: 0.013 Rate F2FvBL: 0.084 OLvBL: 0.043

Table 7 (continued)

Study	Number Control vs Intervention Total	Control F2F only or Online Only	Intervention Blended Learning	P Value
BLS skills retention (6 months)				
Castillo 2018[26]	44 vs 41 Total: 85	F2F: 6.1 (score out of 10)	7.44 (score out of 10)	0.008
Chien 2020[28]	393 vs 385 Total: 778	F2F: 29.96 (score out of 40)	30.01 (score out of 40)	0.95
Nakanishi 2017[30]	50 vs 45 Total: 95	F2F: 33 sec (time to 1st compression) 101.5 (total chest compressions)	31 sec (time to 1st compression) 104 (total chest compressions)	0.73 0.75
Nord 2017[32]	213 vs 186 Total: 399	F2F: 32 (score out of 48)	33 (score out of 48)	NS
Sopka 2012[35]	30 vs 32 Total: 62	F2F: 82.33% (>60% algorithm adherence)	81.25% (>60% algorithm adherence)	0.9330
Yeung 2017[36]	Group 1 (F2F): 19 Group 2 (OL): 21 Group 3 (BL): 24 Total: 64	Gp 1: 32.50, Gp 2: 32.56 (compression depth) Gp 1: 113.95, Gp 2: 115.72 (compression rate)	Gp 3: 41.96 (compression depth) Gp 3: 100.13 (compression rate)	Depth F2FvBL: 0.009 OLvBL: 0.001 Rate F2FvBL: 0.075 OLvBL: 0.024
BLS skills retention (9 months)				
Fernandez 2020[29]	29 vs 24 Total: 53	F2F: 50.9%	52.3%	0.6
BLS skills retention (12 months)				
Chien 2020[28]	372 vs 364 Total: 736	F2F: 27.93 (score out of 40)	28.36 (score out of 40)	0.82

F2F = face-to-face, BL = Blended Learning, OL = Online Learning, BLS = Basic Life Support.

ALS costs

Results from two studies showed that the blended learning course is superior to the traditional course in terms of cost reductions.[39,42] A study from Singapore showed 61% of savings over 5 years if blended ALS courses were to be used instead of a traditional approach.[39] The estimated annual costs to conduct ALS courses via blended learning and traditionally were S$43,467 and S$72,793, respectively. Furthermore, a study of the RCUK e-ALS course reported total costs per participant as $438 for blended learning and $935 for traditional learning.[42]

Advanced Trauma Life Support (ATLS)

One study with 92 doctors in the United States found that a blended learning approach for ATLS is better in terms of knowledge outcomes at the end of the course (control 30.84 vs intervention 32.42, $p = 0.049$).[44] Overall pass rates were better (89% vs 68% for the control group) but there was no specific description of the breakdown of skills performance as opposed to knowledge outcomes in determining the final result so a conclusion about skills training cannot be made.

Discussion

The findings of this review suggest that blended learning is at least as effective as traditional instructor-led teaching for educational outcomes in a range of accredited life support courses. Combined with the lower ongoing costs for learners and stakeholders, the evidence suggests that a blended learning approach is a more efficient means of delivery for life support education. This is of particular significance as the provision of accredited ALS[46] and neonatal resuscitation training[47] has been associated with improved patient outcomes. ILCOR has recommended provision of this training[48] and ERC has recommended further research to identify the potential benefits of a blended learning approach across all course modalities for laypeople and healthcare professionals.[49]

The move to online or blended learning in medical education is not a new development and is supported by the literature identified in this review. A systematic review of 56 studies found that blended learning for health professionals appears to have a consistent positive effect in comparison with no intervention, and to be more effective than or equivalent to non-blended instruction for knowledge acquisition.[50] A similar review in 2019 of 93 studies concluded that online digital education and blended learning may be equivalent to self-directed/face-to-face learning for training practicing doctors.[51] They identified studies that showed better outcomes in the intervention groups however the review itself showed very low quality of evidence overall. A relatable review from 2018 of twenty randomised controlled trials focused on resuscitation training and found that blended learning can be considered for future digital resuscitation training.[52] Unfortunately, the evidence was inadequate to suggest the use of digital resuscitation training for improving knowledge and skills at that stage. Recently, a systematic review of the effectiveness of blended learning in basic life support training among nursing students (including studies of approaches that were not accredited) concluded that using blended learning may be useful in increasing knowledge and skills acquisition.[53]

The importance of this review has become self-evident during the COVID-19 pandemic. Medical education, and specifically on-site resuscitation courses, have been affected[54] and educators for all

Table 8 – Knowledge scores for ALS studies.

Study	Number Control vs Intervention Total	Control F2F only	Intervention Blended Learning	P Value
ALS knowledge (post intervention)				
Abdullah 2019[37]	48 vs 48 Total: 96	70.6% (MCQ)	78.9% (MCQ)	<0.001
Chaves 2020[38]	52 vs 58 Total: 110	21.94 (MCQ, 25 questions)	21.84 (MCQ, 25 questions)	0.787
Perkins 2010[2]	285 vs 287 Total: 572	101.9 (MCQ, 120 marks)	101.4 (MCQ, 120 marks)	0.7
Perkins 2012[42]	1366 vs 1367 Total: 2733	88.96% (MCQ)	89.54% (MCQ)	0.054
Thorne 2015[43]	18,952 vs 8218 Total: 27,170	87.4% (MCQ)	87.9% (MCQ)	<0.001
ALS knowledge retention (7 months)				
Chaves 2020[38]	37 vs 29 Total: 66	20.14 (MCQ, 25 questions)	20.72 (MCQ, 25 questions)	0.310

MCQ = Multiple Choice Questionnaire, ALS = Advanced Life Support, F2F = face-to-face.

Table 9 – Skills scores for ALS studies.

Study	Number Control vs Intervention Total	Control F2F only	Intervention Blended Learning	P Value
ALS skills (post intervention)				
Abdullah 2019[37]	48 vs 48 Total: 96	87.5% (simulation test pass rate)	95.8% (simulation test pass rate)	0.134
Chaves 2020[38]	52 vs 58 Total: 110	3.19 (checklist with 9 items)	3.03 (checklist with 9 items)	0.623
Ko 2011[40]	21 vs 29 Total: 50	17.8 (checklist with 22 items)	20 (checklist with 22 items)	0.09
Perkins 2010[2]	285 vs 287 Total: 572	Not presented	Not presented	0.8
Perkins 2012[42]	1366 vs 1367 Total: 2733	80.2% (simulation test pass rate)	74.5% (simulation test pass rate)	0.002
Thorne 2015[43]	18,952 vs 8218 Total: 27,170	83.6% (simulation test pass rate)	84.6% (simulation test pass rate)	0.035
ALS skills retention (7 months)				
Chaves 2020[38]	37 vs 29 Total: 66	38% satisfactory or excellent	55% satisfactory or excellent	NS

ALS = Advanced Life Support.

types of life support education have moved toward using blended learning to minimise the challenges presented.[55] The current review provides evidence to reassure those trained through blended learning, and the institutions which support it, that there is no detriment to this approach.

Four of the included studies analysed cost effectiveness.[27,33,39,42] A blended learning approach allows for theoretical aspects of the course material to be viewed online, reducing the overall in-person course length. This in turn reduces the time needed away from the clinical environment for both participants and faculty. Furthermore, a reduction in course length allows instructors to run more courses, and thus increase the number of participants they can train over time, which in turn enables an increase in revenue. The cost analysis studies reported substantial set up costs in developing the blended learning programmes, relating to the cost of programme developers, online support, ongoing data management, and web development. These set up costs were offset however by significant ongoing cost reductions to both learners and stakeholders by using a blended learning approach. These savings relate to faculty, catering and facility cost reductions because of the reduced face-to-face time needed. These studies demonstrated that a net profit can be made from a transition toward blended learning. In combination with the equivalent educational course outcomes, this supports a treatment effect in favour of a blended learning approach.

Blended learning may improve accessibility to those in remote locations, in times of pandemic, and for participants otherwise unable to commit to attending a full-length traditional course. Conversely, this approach may not be feasible in all settings. Low resource settings may not be able to provide online access and may therefore prefer to utilise the traditional face-to-face teaching approach. The set-up costs may be prohibitive for those in low resource environments, although the lower costs of a blended learning approach may be preferable if the set-up costs have been absorbed elsewhere. Finally, moving aspects of these courses online may act as a barrier to those who are not computer literate.

To the best our knowledge, our review is the first to conclude that a blended learning approach is at least as effective compared to traditional courses for a broad range of participants in the specific setting of accredited life support courses. The paucity of evidence identified in this review about outcomes stratified by previous training highlights an area that merits further analysis. However, the findings are important as they will inform future life support course design and ultimately improve learning and potentially patient outcomes.

Limitations and future research

Due to a lack of consistency of settings, duration of training and varying study designs there is substantial heterogeneity in both the BLS and ALS sub-groups. Hence, it was not feasible to perform any meta-analysis. All included studies assessed a blended learning group against a control group (face-to-face only[2,25–45] or online learning only[1,36]), but the structures of blended learning courses and the exact outcomes assessed differed greatly. Some studies added an online component which either lengthened[1,2,25,32,34,36] or maintained[26-31,33,35,37–45] the duration of the course. The nature of the online learning element was also different across the studies. Finally, the skills assessment in each study varied which added to the heterogeneity of the evidence.

It was not in the scope of this review to assess the effect of blended learning on patient outcomes. Further research is required in this area. There is also a paucity of evidence comparing a blended

learning approach with online learning only, as most studies used face-to-face as the control group. In addition, further research is needed to establish which elements and sequences of instructional delivery are associated with better educational outcomes. Finally, it is important to understand if a blended learning approach leads to better outcomes with certain sub-groups (e.g., first time or recertifying). The published evidence only covers three accredited life support courses, and further research is needed for other courses. Despite this, we feel that it is not unreasonable to assume that blended learning may offer similar outcomes in similar courses.

Conclusion

A blended learning approach to life support education is at least as effective as traditional face-to-face training regarding educational outcomes. There is evidence from accredited basic and advanced life support courses that a blended learning approach is associated with significant ongoing cost savings, although set-up costs to the accrediting organization may be substantial. Further research is needed to identify specific instructional delivery variants associated with better outcomes, and also the effect of a blended learning approach for other accredited life support courses.

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CRediT authorship contribution statement

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Conflicts of Interest

This systematic review was part of the ILCOR continuous evidence evaluation process, which is guided by a rigorous conflict of interest policy (see www.ilcor.org). Andrew Lockey is President of Resuscitation Council UK. Adam Cheng is ILCOR EIT Taskforce Vice-Chair, Robert Greif is ERC Director of Guidelines and ILCOR EIT Taskforce Chair. None of the other authors declared a conflict of interest.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2022.100240.

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