Review

Blended learning for accredited life support courses – A systematic review

M. Elgohary, F.S. Palazzo, J. Breckwoldt, A. Cheng, J. Pellegrino, S. Schnaubelt, R. Greiff, A. Lockey, on behalf of the Education, Implementation, Team Task Force of the International Liaison Committee on Resuscitation ILCOR

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 and advanced cardiac life support (ALS) in 2010. 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. 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.

Blended learning is defined as the integration of face-to-face and online instruction, with coherence between the online and face-to-face elements to ensure that they complement each other. 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...
We included all comparative studies (prospective and retrospective) that looked at the impact of a blended learning approach on educational and resource outcomes. Of these, 2,359 were excluded leaving 61 full text articles to be included for eligibility (see Fig. 1). In total, 22 studies were identified for inclusion comprising studies covering BLS ($n = 13$), ALS ($n = 8$), and Advanced Trauma Life Support (ATLS) ($n = 1$). Fourteen further studies concerning BLS were 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 included in the initial search.

### 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,

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. 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. 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.

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) 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).

### Study selection

The authors independently screened all titles and abstracts of potentially eligible studies. Discrepancies were discussed and resolved by a third party investigator. A total of 1,460 studies were excluded after screening of titles and abstracts. Of the remaining 305, full-text articles were screened for eligibility (see Fig. 1). In total, 22 studies were identified for inclusion comprising studies covering BLS ($n = 13$), ALS ($n = 8$), and Advanced Trauma Life Support (ATLS) ($n = 1$). Fourteen further studies concerning BLS were 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 included in the initial search.

### 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. Fourteen studies focused on BLS courses (thirteen randomised and one observational), and these are summarised in Table 1. A total of 2,745 participants were involved from a variety of backgrounds including nursing, healthcare students (medical, nursing, and dental),}
Some studies added online content to standardised face-to-face courses (ranging from fixed content videos to interactive online learning programmes), and some substituted didactic content with online content leaving an amended face-to-face element. Two studies covered infant BLS training only. The remaining twelve studies covered adult BLS training. All studies reported the proportion of participants who had previous training for baseline group characteristics. Only one study adjusted mean differences for this data. No studies reported outcomes specific to whether participants had previous training or not.

Eight studies (three randomised and five observational) 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 to substitution of didactic elements with online learning. One study addressed the pilot version of a blended learning course with a further study analysing the amended final blended learning product. Only one study looked at online learning as a substitute for didactic elements. Four studies reported the proportion of participants who had previous training for baseline group characteristics, although none reported outcomes specific to prior training.

One observational study focused on the ATLS course (see Table 3). 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 and three ALS 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). One study with 94 healthcare students assessed knowledge by self-assessment only and found a significant improvement in the blended learning group. One study with 383 high school students found higher scores in the intervention group, although no analysis was performed for statistical significance. 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 | 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 | 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 | 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 | BLS-AED | ERC | 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 | 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 | BLS-AED | ERC | RCT | Sep 2017–Aug 2018 | 89 Dental Students, Taiwan | None in last 3 years | Knowledge Skills | F2F | Online learning as substitute for didactic elements |
| Nakanishi 2017 | 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 | 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 | 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 | BLS | AHA | Cluster-controlled trial | 2003–2004 | 383 High School Students, USA | 66% control; 73% BL | Knowledge Skills | Online Skills Attitudes | F2F | Addition of F2F to online learning |
| Serwetnyk 2015 | BLS recert | AHA | RCT | Jul–Nov 2012 | 170 Nurses, USA | All had undertaken AHA BLS course previously | Knowledge Skills | F2F | Online learning as substitute for didactic elements |
| Shavit 2010 | Infant BLS | AHA | RCT | 2007–2008 | 34 Medical Students, Israel | No | Skills | F2F | Addition of online learning to F2F |
| Sopka 2012 | Adult BLS | ERC | Cohort | 2008–2009 | 202 Medical Students, Germany | No | Skills Attitudes | F2F | Online learning as substitute for didactic elements |
| Yeung 2017 | Adult BLS | RCUK | RCT | 2016 | 56 Secondary school children, UK | No | Skills Attitudes | F2F | 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.
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,1,25,34 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 BLS25 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 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     | ALS         | Hospital Universiti Sains | Non-RCT      | 2016–2017  | 96 doctors and paramedics, Malaysia | 40% (control) | Knowledge Skills Satisfaction | F2F Online learning as substitute for didactic elements |
| Chaves      | ALS         | Spanish Council for CPR | Non-RCT      | Unknown    | 110 medical residents, Spain | 76% (control) | Knowledge Skills Satisfaction | F2F Online learning as substitute for didactic elements |
| George      | ACLS        | Singapore First Aid Training | Observational | 2016       | Physicians, Spain | Not applicable | Costs | F2F Online learning as substitute for didactic elements |
| Ko          | ACLS        | American Heart Association | Cohort      | 2009       | 50 medical students, USA | Unknown | Knowledge Skills Satisfaction | F2F Online learning as substitute for didactic elements |
| Lockey      | ALS         | RCUK                   | RCT          | 2008–2009  | 2848 healthcare professionals, UK | Unknown | Knowledge Skills Satisfaction | F2F Online learning as substitute for didactic elements |
| Perkins     | ALS         | RCUK                   | RCT          | 2007       | 572 healthcare professionals, UK | Unknown | Knowledge Skills | F2F Interactive CD-ROM prior to F2F course |
| Perkins     | ALS         | RCUK                   | Randomised non-inferiority | 2008–2011 | 2733 healthcare professionals, UK/Australia | Yes | Knowledge Skills Satisfaction | F2F Online learning as substitute for didactic elements |
| Thorne      | 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        | 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.
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.26,30,32,35 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 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           | Low           | Low                                   | Low                  | Low                       | Low                               | Low     |
| Brannon 2009          | Low           | Low                                   | Concerns (a)         | Low                       | Low                               | Concerns|
| Castillo 2018         | Low           | Low                                   | Concerns (a)         | Concerns (b)              | Low                               | Concerns|
| Castillo 2019         | Low           | Low                                   | Low                  | Low                       | Low                               | Low     |
| Chien 2020            | Low           | Low                                   | Concerns (a)         | Low                       | Low                               | Concerns|
| Fernandez 2020        | Low           | Low                                   | Concerns (a)         | Low                       | Low                               | Concerns|
| Nakanishi, 2017       | Low           | Concerns (d)                          | Concerns (a)         | Low                       | Low                               | Concerns|
| Nishiyama, 2008       | Low           | High (d)                              | Low                  | Low                       | Low                               | High    |
| Nord, 2017            | Concerns (c)  | Concerns (d)                          | High (a)             | Concerns (b)              | Low                               | High    |
| Reder, 2006           | Low           | Concerns (d)                          | Concerns (a)         | Low                       | Low                               | Concerns|
| Serwetnyk, 2015       | Low           | Low                                   | Concerns (b)         | Low                       | Low                               | Concerns|
| Shavit 2010           | Concerns (c)  | Low                                   | Low                  | Low                       | Low                               | Concerns|
| Yeung 2017            | Low           | Low                                   | Low                  | Low                       | Low                               | Low     |
| Advanced Cardiac Life Support |
| Lockey, 2015          | Low           | Low                                   | Low                  | Low                       | Low                               | Low     |
| Perkins, 2010         | Low           | Low                                   | Low                  | Low                       | Low                               | Low     |
| Perkins, 2012         | Low           | Low                                   | Concerns (b)         | Low                       | Low                               | Concerns|

### 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 the reported results | Overall |
|-----------------------|-------------|-----------|---------------------------------|--------------------------------------|--------------|-------------------------|----------------------------------|---------|
| Basic Life Support     |             | Low       | Low                             | Low                                  | Low          | Moderate (a)            | Low                               | moderate |
| Advanced Cardiac Life Support |
| Abdulla, 2019         | Moderate (b)| Low       | Low                             | Low                                  | Low          | Moderate (a)            | Low                               | moderate |
| Chaves 2020           | Low         | Low       | Moderate (f)                    | Moderate (j)                         | Low          | Low                     | Low                               | moderate |
| George, 2016          | Low         | Low       | Low                             | Low                                  | Low          | Low                     | Low                               | low     |
| Ko, 2011              | Critical (g)| Low       | Low                             | Moderate (h)                         | Low          | Moderate (i)            | Low                               | critical |
| Thermo 2015           | Low         | Moderate (b)| Low                             | Serious (e)                          | Low          | Moderate (i)            | Low                               | serious |
| Advanced Trauma Life Support |
| Dyer 2021             | Serious (c)| Serious (d)| Low                             | Low                                  | Low          | Moderate (e)            | Low                               | serious |

### Notes
- 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.
The remaining two studies found no significant difference in the attitudes of participants between control and intervention groups.\textsuperscript{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.\textsuperscript{27,33} The authors of one study\textsuperscript{27} performed a cost minimization analysis of the course previously described in their 2018 study.\textsuperscript{29} 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 €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.\textsuperscript{33} They did not include any cost savings from facility costs. The annual projected costs for the traditional course were €27,170 participants found that the intervention group now had significantly better results than the control group.\textsuperscript{43} The remaining four studies with a total of 828 participants found no significant difference in the skills assessment between the two groups at 7 months.\textsuperscript{2,37,38,40}

One study with 66 participants found no statistically significant difference in skills assessment between the two groups at 7 months.\textsuperscript{36}

**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).\textsuperscript{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\textsuperscript{27,43} there were significantly higher scores in the blended learning group, and in two studies with 2,843 participants\textsuperscript{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.\textsuperscript{2} One study with 66 participants assessed knowledge at 7 months using a validated MCQ.\textsuperscript{36} 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).\textsuperscript{2,37,38,40,42,43} The assessment methods varied between cardiac arrest simulation test results,\textsuperscript{2,37,42,43} checklists,\textsuperscript{38} and video analysis of the performance.\textsuperscript{43} 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.\textsuperscript{43} 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.\textsuperscript{43} The remaining four studies with a total of 828 participants found no significant difference in skills between the control and intervention groups.\textsuperscript{2,37,38,40}

One study with 66 participants found no statistically significant difference in skills assessment between the two groups at 7 months.\textsuperscript{36}

**ALS participant satisfaction**

Participant satisfaction was evaluated in five studies with a total of 3,676 participants.\textsuperscript{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.\textsuperscript{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, \( p = 0.01 \)).\textsuperscript{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.\textsuperscript{2}

Conversely, two studies found a preference for traditional courses.\textsuperscript{2,41} 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, \( p = 0.012 \)).\textsuperscript{36} 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.\textsuperscript{41} They also highly valued practical hands-on training that included simulation.

### 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\textsuperscript{15} | 55 vs 59 Total: 94 | F2F: 4 (score out of 5) | 4.3 (score out of 5) | <0.05    |
| Castillo 2018\textsuperscript{26} | 66 vs 61 Total: 127 | F2F: 8.36 (score out of 10) | 8.44 (score out of 10) | 0.41     |
| Chien 2020\textsuperscript{28} | 416 vs 416 Total: 832 | F2F: 89.22% (MCQ, 15 questions) | 88.35% (MCQ, 15 questions) | 0.19     |
| Fernandez 2020\textsuperscript{30} | 45 vs 44 Total: 89 | F2F: 8.6 (MCQ score out of 10) | 8.1 (MCQ score out of 10) | 0.013    |
| Reder 2006\textsuperscript{1} | 213 vs 170 Total: 383 | Online: 82% (MCQ, 10 questions) | 87% (MCQ, 10 questions) | -        |
| Serwetnyk 2015\textsuperscript{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\textsuperscript{1} | 196 vs 160 Total: 356 | Online: 81% (MCQ, 10 questions) | 83% (MCQ, 10 questions) | -        |
| **BLS knowledge retention (6 months)** |                                      |                                 |                               |          |
| Castillo 2018\textsuperscript{26} | 44 vs 41 Total: 85 | F2F: 7.12 (score out of 10) | 7.38 (score out of 10) | 0.4      |
| Chien 2020\textsuperscript{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\textsuperscript{30} | 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\textsuperscript{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.
| Study                  | Number Control vs Intervention Total | Control F2F only or Online Only | Intervention Blended Learning | P Value |
|-----------------------|-------------------------------------|---------------------------------|--------------------------------|---------|
| **BLS skills (post intervention)** |                                     |                                 |                                |         |
| Birkun 201915         | 55 vs 39 Total: 94                  | F2F: mean 31.6 ± 3.3            | Mean 32.0 ± 2.7                | 0.687   |
| Brannon 200925        | 13 vs 10 Total: 23                 | F2F: 9/13 pass                  | 10/10 pass                     | 0.081   |
| Castillo 201826       | 64 vs 59 Total: 123                | F2F: 7.70 (score out of 10)     | 8.15 (score out of 10)         | 0.02    |
| Chien 202029          | 416 vs 416 Total: 832              | F2F: 34.44 (score out of 40)    | 34.88 (score out of 40)        | 0.54    |
| Fernandez 202020      | 45 vs 44 Total: 89                 | F2F: 64%                        | 64.7%                          | 0.9     |
| Nakanishi 201730      | 54 vs 54 Total: 108                | F2F: 29.5 sec (time to 1st compression) | 34 sec (time to 1st compression) | 0.01    |
| Castillo 201826       | 64 vs 59 Total: 123                | F2F: 7.70 (score out of 10)     | 8.15 (score out of 10)         | 0.02    |
| Chien 202029          | 416 vs 416 Total: 832              | F2F: 34.44 (score out of 40)    | 34.88 (score out of 40)        | 0.54    |
| Fernandez 202020      | 45 vs 44 Total: 89                 | F2F: 64%                        | 64.7%                          | 0.9     |
| Nakanishi 201730      | 54 vs 54 Total: 108                | F2F: 29.5 sec (time to 1st compression) | 34 sec (time to 1st compression) | 0.01    |
| Castillo 201826       | 64 vs 59 Total: 123                | F2F: 7.70 (score out of 10)     | 8.15 (score out of 10)         | 0.02    |
| Chien 202029          | 416 vs 416 Total: 832              | F2F: 34.44 (score out of 40)    | 34.88 (score out of 40)        | 0.54    |
| Fernandez 202020      | 45 vs 44 Total: 89                 | F2F: 64%                        | 64.7%                          | 0.9     |
| Nakanishi 201730      | 54 vs 54 Total: 108                | F2F: 29.5 sec (time to 1st compression) | 34 sec (time to 1st compression) | 0.01    |
| Nishiyama 200831      | 95 vs 87 Total: 182                | F2F: 159 (post-training, chest compressions) | 161 (post-training, chest compressions) | 0.628   |
| Nord 201732           | 224 vs 208 Total: 432              | F2F: 34 (score out of 48)       | 34 (score out of 48)           | Non Significant |
| Reder 20061           | 213 vs 170 Total: 383              | Online: 79% (successful ventilation) | 81% (successful ventilations) | Not assessed |
| Serwetnyk 201533      | Control: 46 Intervention #1: 45 Intervention #2: 79 Total: 170 | F2F: 10.9% needed remediation | #1: 22.2% needed remediation | 0.347 |
| Shavit 201034         | 16 vs 18 Total: 34                 | F2F: 1.13/2 (assessing responsiveness) | 0.06/2 (airway opening) | Not assessed |
|                      |                                     | 1.06/2 (breathing technique)     | 0.68/2 (breathing technique)   |         |
|                      |                                     | 1.44/4 (chest compression technique) | 3.19/4 (chest compression technique) |         |
|                      |                                     | 2.81/3 (activating EMS)          | 3/3 (activating EMS)           |         |
|                      |                                     | 0.47/1 (resuming CPR)            | 0.97/1 (resuming CPR)          |         |
| Sopka 201235         | 95 vs 95 Total: 190                | F2F: 85.26% (>60% algorithm adherence) | 91.58% (>60% algorithm adherence) | 0.1787 |
| Yeung 201736         | Group 1 (F2F): 27 Group 2 (OL): 25 Group 3 (BL): 29 Total: 81 | Gp 1: 37.35, Gp 2: 26.44 (compression depth) | Gp 3: 42.09 (compression depth) | Depth |
|                      |                                     | Gp1: 116, Gp 2: 125.17 (compression rate) | Gp 3: 117.61 (compression rate) | Rate |
|                      |                                     | F2FvBL: 0.237 OLvBL: 0.0001 Rate F2FvBL: 0.277 OLvBL: 0.999 |
| BLS skills retention (2 months) |                                     | Online: 79% (successful ventilation) | 84% (successful ventilations) | Not assessed |
| Reder 20061           | 213 vs 170 Total: 383              | 80% (successful compressions)    | 84% (successful compressions) | Not assessed |
| BLS skills retention (3 months) |                                     | 84% (successful compressions)    | 84% (successful compressions) | Not assessed |
| Yeung 201736         | 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 3: 37.39 (compression depth) | Depth |
|                      |                                     | Gp 1: 113.75, Gp 2: 119.44 (compression rate) | Gp 3: 97.91 (compression rate) | Rate |
|                      |                                     | F2FvBL: 0.224 OLvBL: 0.013 Rate F2FvBL: 0.084 OLvBL: 0.043 |
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 ALS46 and neonatal resuscitation training47 has been associated with improved patient outcomes. ILCOR has recommended provision of this training48 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 affected44 and educators for all
A blended learning approach allows for theoretical and the institutions which support it, that there is no detriment to this provides evidence to reassure those trained through blended learning, to minimise the challenges presented. The current review types of life support education have moved toward using blended learning programmes, relating to the cost of pro-
gramme 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.

Four of the included studies analysed cost effectiveness. 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.

| Table 8 – Knowledge scores for ALS studies. |
|---------------------------------------------|
| Study                                      | Number Control vs Intervention Total | Control F2F only | Intervention Blended Learning | P Value |
|---------------------------------------------|--------------------------------------|------------------|-------------------------------|---------|
| Chaves 2020<sup>36</sup>                   | 48 vs 48 Total: 96                   | 70.6% (MCQ)      | 78.9% (MCQ)                   | <0.001  |
| Ko 2011<sup>10</sup>                       | 21 vs 29 Total: 50                   | 3.19 (checklist with 9 items) | 3.03 (checklist with 9 items) | 0.623   |
| Perkins 2010<sup>2</sup>                   | 285 vs 287 Total: 572               | 17.8 (checklist with 22 items) | 20 (checklist with 22 items) | 0.09    |
| Perkins 2012<sup>42</sup>                  | 1366 vs 1367 Total: 2733            | 80.2% (simulation test pass rate) | 74.5% (simulation test pass rate) | 0.002   |
| Thorne 2015<sup>43</sup>                   | 18,952 vs 8218 Total: 27,170        | 83.6% (simulation test pass rate) | 84.6% (simulation test pass rate) | 0.035   |
| Abdullah 2019<sup>7</sup>                  | 48 vs 48 Total: 96                   | 87.5% (simulation test pass rate) | 95.8% (simulation test pass rate) | 0.134   |
| Chaves 2020<sup>36</sup>                   | 52 vs 58 Total: 110                  | 3.19 (checklist with 9 items) | 3.03 (checklist with 9 items) | 0.623   |
| Ko 2011<sup>10</sup>                       | 21 vs 29 Total: 50                   | 3.19 (checklist with 9 items) | 3.03 (checklist with 9 items) | 0.623   |
| Perkins 2010<sup>2</sup>                   | 285 vs 287 Total: 572               | 17.8 (checklist with 22 items) | 20 (checklist with 22 items) | 0.09    |
| Perkins 2012<sup>42</sup>                  | 1366 vs 1367 Total: 2733            | 80.2% (simulation test pass rate) | 74.5% (simulation test pass rate) | 0.002   |
| Thorne 2015<sup>43</sup>                   | 18,952 vs 8218 Total: 27,170        | 83.6% (simulation test pass rate) | 84.6% (simulation test pass rate) | 0.035   |

| Table 9 – Skills scores for ALS studies. |
|------------------------------------------|
| Study                                      | Number Control vs Intervention Total | Control F2F only | Intervention Blended Learning | P Value |
|-------------------------------------------|--------------------------------------|------------------|-------------------------------|---------|
| ALSSkills (post intervention)             |                                       |                  |                               |         |
| Abdullah 2019<sup>7</sup>                | 48 vs 48 Total: 96                   | 87.5% (simulation test pass rate) | 95.8% (simulation test pass rate) | 0.134   |
| Ko 2011<sup>10</sup>                      | 21 vs 29 Total: 50                   | 17.8 (checklist with 22 items) | 20 (checklist with 22 items) | 0.09    |
| Perkins 2010<sup>2</sup>                  | 285 vs 287 Total: 572               | Not presented    | Not presented                 |         |
| Perkins 2012<sup>42</sup>                 | 1366 vs 1367 Total: 2733            | 80.2% (simulation test pass rate) | 74.5% (simulation test pass rate) | 0.002   |
| Thorne 2015<sup>43</sup>                  | 18,952 vs 8218 Total: 27,170        | 83.6% (simulation test pass rate) | 84.6% (simulation test pass rate) | 0.035   |
| Abdullah 2019<sup>7</sup>                | 48 vs 48 Total: 96                   | 38% satisfactory or excellent | 55% satisfactory or excellent | NS      |

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

**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 approach against a control group (face-to-face only<sup>2,25–45</sup> or online learning only<sup>1,36</sup>) but the structures of blended learning courses and the exact outcomes assessed differed greatly. Some studies added an online component which either lengthened<sup>1,2,25,32,34,36</sup> or maintained<sup>26-33,35,37–45</sup> 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.

Funding

This systematic review, including the services of Jenny Ring (Information Specialist), was funded by the International Liaison Committee on Resuscitation (ILCOR).

CRediT authorship contribution statement

M. Elgohary: Investigation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization. F.S. Palazzo: Investigation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization. J. Breckwoldt: Conceptualization, Methodology, Validation, Investigation, Formal analysis, Data curation, Writing – review & editing, Visualization. J. Pellegrino: Conceptualization, Methodology, Validation, Investigation, Formal analysis, Data curation, Writing – review & editing, Visualization. A. Cheng: Conceptualization, Methodology, Validation, Investigation, Formal analysis, Data curation, Writing – review & editing, Visualization. S. Schnaubelt: Conceptualization, Methodology, Validation, Investigation, Formal analysis, Data curation, Writing – review & editing, Visualization. R. Greif: Conceptualization, Methodology, Validation, Investigation, Formal analysis, Data curation, Writing – review & editing, Visualization. A. Lockey: Conceptualization, Methodology, Validation, Investigation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration.

Acknowledgement

The authors would like to thank Jenny Ring (Information Specialist) for her help with this review.

The following ILCOR Education Implementation and Teams (EIT) Taskforce members are acknowledged as collaborators on this review: Farhan Bhanji, Janet Bray, Joanthan P Duff, Kathryn Eastwood, Elaine Gilfoyle, Ming-Ju Hsieh, Kasper G Lauridsen, Yiqun Lin, Tasuku Matsuyama, Kevin Nation, Catherine Patocka, Taylor Sawyer, Chih-Wei Yang, Joyce Yeung, and Judith Finn. We would like to thank Peter Morley (Chair ILCOR Science Advisory Committee) for his valuable contributions.

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.

Author details

on behalf of the Education, Implementation, Team Task Force of the International Liaison Committee on Resuscitation ILCOR *Emergency Department, Calderdale & Huddersfield NHS Trust, Halifax, UK Indian University Hospital of Zurich, Zurich, Switzerland *Departments of Pediatrics and Emergency Medicine, University of Calgary, Alberta, Canada *University of Akron, OH, United States *Department of Emergency Medicine, Medical University of Vienna, Vienna, Austria *Department of Anaesthesiology and Pain Medicine, Bern University Hospital, University of Bern, Bern, Switzerland *School of Medicine, Sigmund Freud University, Vienna, Austria *School of Human and Health Sciences, University of Huddersfield, Huddersfield, UK

REFERENCES

1. Reder S, Cummings P, Quan L. Comparison of three instructional methods for teaching cardiopulmonary resuscitation and use of an automatic external defibrillator to high school students. Resuscitation 2006;69:443–53.
2. Perkins GD, Fullerton JN, Davis-Gomez N, et al. The effect of pre-course e-learning prior to advanced life support training: a randomised controlled trial. Resuscitation 2010;81:877–81.
3. Dunleavy G, Nikolaou CK, Nifakos S, Atun R, Law GCY, Tudor Car L. Mobile Digital Education for Health Professions: Systematic Review and Meta-Analysis by the Digital Health Education Collaboration. J Med Internet Res 2019:21.
4. Milanese SF, Grimmer-Somers K, Sourvis T, Innes-Walker K, Chipchase LS. Is a blended learning approach effective for learning in allied health clinicians? Phys Therapy Rev 2014;19:86–93.
5. Graham CR. Blended learning systems. Handb Blend Learn 2006:3–21.
6. Harding A, Kaczynski D, Wood L. Evaluation of blended learning: analysis of qualitative data. Paper presented at: Proceedings of The Australian Conference on Science and Mathematics Education (formerly UniServe Science Conference), 2012.
7. Gibbons AS, Fairweather PG. Computer-based instruction: Design and development. Educ Technol 1998.
8. Graham CR. Emerging practice and research in blended learning. Handb Distance Educ 2013;3:333–50.
9. Nortvig A-M, Petersen AK, Balle SH. A Literature Review of the Factors Influencing E-Learning and Blended Learning in Relation to Learning Outcome, Student Satisfaction and Engagement. Electron J e-Learn 2018;16:46–55.
10. Phillips J, Wiesbauer F. The flipped classroom in medical education: A new standard in teaching. Trends Anaesthesia Crit Care 2022.
11. Tolks D, Schäfer C, Raupach T, et al. An introduction to the inverted/ flipped classroom model in education and advanced training in medicine and in the healthcare professions. GMS J Med Educ 2016;33.
12. Garrison DR, Kanuka H. Blended learning: Uncovering its transformative potential in higher education. Internet High Educ 2004;7:95–105.
13. River J, Currie J, Crawford T, Bethivas V, Randall S. A systematic review examining the effectiveness of blending technology with team-based learning. Nurse Educ Today 2016;45:185–92.
14. Nacca N, Holliday J, Ko PY. Randomized trial of a novel ACLS teaching tool: does it improve student performance? Western J Emerg Med 2014;15:913.
15. Gordon M, Patricio M, Horne L, et al. Developments in medical education in response to the COVID-19 pandemic: A rapid BEME systematic review: BEME Guide No. 63. Med Teacher 2020;1–14.
16. Kent F, George J, Lindley J, Brock T. Virtual workshops to preserve interprofessional collaboration when physical distancing. Med Educ 2020;54:661–2.
17. Theoret C, Ming X. Our education, our concerns: The impact on medical student education of COVID-19. Med Educ 2020;54:591–2.
18. Tsang ACO, Lee PWP, Chen JY, Leung GKK. From bedside to website: a neurological clinical teaching experience. Med Educ 2020;54:660.
19. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Syst Rev 2021;10:89.
20. Richardson WS, Wilson MC, Nishikawa J, Hayward RS. The well-built clinical question: a key to evidence-based decisions. ACP J Club 1995;123:A12–3.
21. Voss R. Blended learning: What is it and where might it take us. Sloan-C View 2003;2:2–6.
22. Sterne JA, Savovic J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ 2019;366.
23. Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ 2016;355.
24. Schümermann H. The GRADE handbook. Cochrane Collab 2013.
25. Brannon TS, White LA, Kilcrease JN, Richard LD, Spillers JG, Phelps CL. Use of instructional video to prepare parents for learning infant cardiopulmonary resuscitation. Paper presented at: Baylor University Medical Center Proceedings, 2009.
26. Castillo J, Gallart A, Rodríguez E, Castillo J, Gomar C. Basic life support and external defibrillation competences after instruction and at 6 months comparing face-to-face and blended training. Randomis Trial Nurse Educ Today 2018;65:232–8.
27. Castillo J, Gomar C, Rodríguez E, Trapero M, Gallart A. Cost minimization analysis for basic life support. Resuscitation 2019;134:127–32.
28. Chien C-Y, Fang S-Y, Tsai L-H, et al. Traditional versus blended CPR training program: A randomized controlled non-inferiority study. Sci Rep 2020;10:1–8.
29. de Balanzó Fernández X, Ferrés-Amat E. Standard basic life support training of the European Resuscitation Council versus blended training: a randomized trial of a new teaching method. Emergencias: revista de la Sociedad Española de Medicina de Emergencias 2020;32:45–8.
30. Nakamichi T, Goto T, Kobuchi T, Kimura T, Hayashi H, Tokuda Y. The effects of flipped learning for bystander cardiopulmonary resuscitation on undergraduate medical students. Int J Med Educ 2017;8:430.
31. Nishiyama C, Iwami T, Kawamura T, et al. Effectiveness of simplified chest compression-only CPR training for the general public: a randomized controlled trial. Resuscitation 2008;79:90–6.
32. Nord A, Svensson L, Claesson A, et al. The effect of a national web course “Help-Brain-Heart” as a supplemental learning tool before CPR training: a cluster randomised trial. Scand J Trauma Resusc Emerg Med 2017;25:1–10.
33. Serwetnyk TM, Filmore K, VonBacho S, et al. Comparison of online and traditional basic life support renewal training methods for registered professional nurses. J Nurses Prof Dev 2015;31:E1–E10.
34. Shavit I, Peled S, Steiner IP, et al. Comparison of Outcomes of Two Skills-teaching Methods on Lay-rescuers’ Acquisition of Infant Basic Life Support Skills. Acad Emerg Med 2010;17:979–86.
35. Sopka S, Biermann H, Rossaint R, et al. Evaluation of a newly developed media-supported 4-step approach for basic life support training. Scand J Trauma Resusc Emerg Med 2012;20:1–9.
36. Yeung J, Kovic I, Vidacic M, et al. The school Lifesavers study—A randomised controlled trial comparing the impact of Lifesaver only, face-to-face training only, and Lifesaver with face-to-face training on CPR knowledge, skills and attitudes in UK school children. Resuscitation 2017;120:138–45.
37. Anthira Abdulla A, Nor J, Maladas J, et al. E-learning in advanced cardiac life support: Outcome and attitude among healthcare professionals. Hong Kong J Emerg Med 2019; 102490791985666.
38. Chaves J, Lorca-Marín AA, Delgado-Algarra EJ. Methodology of Specialist Physicians Training: From Traditional to e-Learning. Int J Environ Res Public Health 2020;17:7681.
39. George PP, Ooi CK, Leong E, Jarbrink K, Car J, Lockwood C. Return on investment in blended advanced cardiac life support training compared to face-to-face training in Singapore. Proc Singapore Healthcare 2018;27:234–42.
40. Ko PY, Scott JM, Mihai A, Grant WD. Comparison of a modified longitudinal simulation-based advanced cardiovascular life support to a traditional advanced cardiovascular life support curriculum in third-year medical students. Teach Learn Med 2011;23:324–30.
41. Lockey AS, Dyal L, Kimani PK, et al. Electronic learning in advanced resuscitation training: The perspective of the candidate. Resuscitation 2015;97:48–54.
42. Perkins GD, Kimani PK, Bullock I, et al. Improving the efficiency of advanced life support training: a randomized, controlled trial. Ann Intern Med 2012;157:19–28.
43. Thorne C, Lockey A, Bullock I, Hampshire S, Begum-Ali S, Perkins G. E-learning in advanced life support—an evaluation by the Resuscitation Council (UK). Resuscitation 2015;90;79–84.
44. Dyer L, Lieren A, Brannick M, Lunde JR, Whakter F. Advanced Trauma Life Support Course Delivery: Comparison of Outcomes From Modifications During Covid-19. Cureus 2021;13.
45. Birkin A, Altukhova I, Perova E, Frolova L, Abbulfayev L. Blended Distance-classroom Training as an Alternative to the Traditional Classroom Training in Basic Cardiopulmonary Resuscitation and Automated External Defibrillation. Russian Skillsosovskiy Journal “Emergency Medical Care” 2019:8:145–51.
46. Lockey A, Lin Y, Cheng A. Impact of adult advanced cardiac life support course participation on patient outcomes—A systematic review and meta-analysis. Resuscitation 2018;129:48–54.
47. Patel A, Khatib MN, Kurhe K, Bhargava S, Bang A. Impact of neonatal resuscitation trainings on neonatal and perinatal mortality: a systematic review and meta-analysis. BMJ Paediatr Open 2017;1.
48. Greif R, Bhanji F, Bigham B, et al. 2020 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations: Education, Implementation, and Teams. Resuscitation 2020;156:A188–239.
49. Greif R, Lockey A, Breckwoldt J, et al. European Resuscitation Council Guidelines 2021. Education for resuscitation. Resuscitation 2021;161:389–407.
50. Liu Q, Peng W, Zhang F, Hu R, Li Y, Yan W. The Effectiveness of Blended Learning in Health Professions: Systematic Review and Meta-Analysis. J Med Internet Res 2016;18.

51. George PP, Zhabenko O, Kyaw BM, et al. Online digital education for postregistration training of medical doctors: systematic review by the Digital Health Education Collaboration. J Med Internet Res 2019;21.

52. Lau Y, Nyoe RSS, Wong SN, Ab Hamid ZB, Leong BS, Lau ST. Effectiveness of digital resuscitation training in improving knowledge and skills: A systematic review and meta-analysis of randomised controlled trials. Resuscitation 2018;131:14–23.

53. Mulyadi M, Lea B-O, Malara RT, Bidjuni HJ. The effectiveness of blended learning in basic life support training among nursing students: A systematic review. KnE Life Sci 2021:402–14.

54. Ehilawa P, Thompson F, Ahmed R, et al. Impact of COVID-19 pandemic on postgraduate medical education—a survey of UK trainees. Future Healthc J 2021;8:24–5.

55. Papapanou M, Routsi E, Tsamakis K, et al. Medical education challenges and innovations during COVID-19 pandemic. Postgrad Med J 2021.