Simulation and education

E-learning in pediatric basic life support: A randomized controlled non-inferiority study

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Abstract

Objective: Dissemination of pediatric basic life support (PBLs) skills is recommended. E-learning is accessible and cost-effective, but it is currently unknown whether laypersons can learn PBLs through e-learning. The hypothesis of this study was to investigate whether e-learning PBLs is non-inferior to instructor-led training.

Study design: Participants were recruited among child-minders and parents of children aged 0–6 years. Participants were randomized to either 2-h instructor-led training or e-learning using an e-learning program (duration 17 min) including an inflatable manikin. After training, participants were assessed in a simulated pediatric cardiac arrest scenario. Tests were video recorded and PBLs skills were assessed independently by two assessors blinded to training method. Primary outcome was the pass rate of the PBLs test (≥8 of 15 skills adequately performed) with a pre-specified non-inferiority margin of 20%.

Results: In total 160 participants were randomized 1:1. E-learning was non-inferior to instructor-led training (difference in pass rate −4%: 95% CI −9.0% to 0.5%). Pass rates were 100% among instructor-led trained (n = 67) and 96% among e-learned (n = 71). E-learners median time spent on the e-learning program was 30 min (range: 15–120 min) and the median number of log-ons was 2 (range: 1–5). After the study, all participants felt that their skills had improved.

Conclusion: E-learning PBLs is non-inferior to instructor-led training among child-minders and parents with children aged 0–6 years, although the pass rate was 4% (95% CI −9.0% to 0.5%) lower with e-learning.

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1. Introduction

The incidence of cardiac arrest among infants (children below the age of 12 months) is 72 per 100,000 infant-years and account for approximately half of all cardiac arrests among children.1,2 Their survival is dismal at approximately 5%.2 Bystander cardiopulmonary resuscitation (CPR) improves survival after cardiac arrest.3,4 Despite the proven role of CPR in improving survival, most children suffering from cardiac arrest do not receive bystander CPR.2,4–6 To improve the quality of bystander CPR and increasing the overall survival, the International Liaison Committee on Resuscitation has identified education as a primary area of intervention.7

The need of a classroom setting, cost of instructors, and duration of resuscitation courses are barriers to dissemination of CPR skills. Lack of time and opportunity are frequent reasons for not having any CPR training.2,3 Hence, methods to make CPR training more accessible without significant loss of quality are crucial. E-learning as web-based distance learning has the advantages of being flexibly accessed, interactive, and cost-effective.8 Self-training with a video or accessible web-based training are known to be effective alternatives to instructor-led courses in adult basic life support.
Effective self-training pediatric basic life support (PBLs) with an e-learning program and a manikin may accordingly facilitate dissemination of PBLs skills, however the effectiveness of e-learning PBLs among laypersons is not well-described.

The aim of this study was to investigate whether e-learning PBLs is non-inferior to instructor-led training.

2. Methods

2.1. Study design

The study was a prospective, randomized non-inferiority study. We randomized participants to either a 2-h instructor-led PBLs course or self-training using an inflatable manikin and an e-learning program.

2.2. Participants

Laypersons were recruited among child-minders and parents of children aged 0–6 years in the municipality of Aarhus in January and February 2013. All subjects were recruited via posters in daycare centers and advertisement through BarneIntra (a web based communication platform). Participants were informed that they would be offered free PBLs training but randomly allocated to one of two training methods without further details of the teaching methods. The exclusion criteria were PBLs training within the previous 12 months or holding a life-support instructor certificate or health care professional degree (e.g. physician, nurse, and physiotherapist). No more than one person from any household was allowed to participate. The following demographics were recorded: gender, age, number of children, educational level, previous PBLs training, and whether the subject ever performed PBLs in real life.

In conformity with the Danish National Committee on Biomedical Research Ethics, no ethical review committee approval was required. Oral and written consent was obtained. Participants were asked to sign a written agreement not to disclose details about their training and assessment before the end of the study.

2.3. Randomization

Participants were randomly allocated to either training method when entering the study. Randomization sequence was computer generated by the senior author (BL) using www.graphpad.com/quickcalcs: 1:1 in block sizes of six. Enrollment and assignment of participants to their respective groups were undertaken by the lead investigator (LQK).

2.4. Two-hour PBLs instructor-led course

A 2-h PBLs instructor-led course was developed. Participants were instructed in single rescuer PBLs for infants (0–12 months) in accordance with the European Resuscitation Council (ERC) Guidelines for Resuscitation 2010: pediatric life support, using the 4-step teaching approach.21 In brief: the instructor first demonstrated PBLs, without any explanation (step 1), followed by a repeated demonstration with detailed explanation of each skill where participants observed and were allowed to ask questions (step 2). The participants now had to guide the instructor through the skill procedure while the instructor performed according to the instructions (step 3). Finally, all participants individually demonstrated the skill procedure and received feedback (step 4).

PBLs training was provided by three ERC BLS certified instructors. Instructor/participant ratio varied from 1:3 to 1:6. Laerdal Resusci® Baby Basic manikins (Laerdal Medical, Stavanger, Norway) were used. At course start, participants received written instructions on PBLs including information on resuscitation of children above 1 year.

2.5. E-learning program training group

The e-learning program included a 17-min video and covered single rescuer PBLs for infants (0–12 months). The video used the 4-step teaching approach and adhered to the ERC Guidelines for Resuscitation 2010: pediatric life support.21,22 The video had a short introduction encouraging e-learners to train with the manikin along with a short introduction to the use of the manikin. Subsequently, the video demonstrated PBLs, initially without explanation (step 1) followed by a demonstration with detailed explanation of each step (step 2). Following the second step, 10 multiple-choice questions enabling self-evaluation and active participation were inserted (step 3). The e-learning module provided feedback. The video concluded with a repetition of the initial demonstration of PBLs, the encouragement to train with the manikin (step 4), and a short summary. There were no limits placed on the e-learners use of the e-learning program (e.g. number of log-ons, time logged in) within the time-frame of the study. The e-learners could pause and skip in the e-learning module according to their preference. A manikin (MiniBaby® American Heart Association/American Academy of Pediatrics Infant CPR Anytime), written instructions identical to those given to the instructor-led group, and access to the e-learning module was provided for approximately 14 days prior to assessment.

2.6. Assessment and outcome measures

Participants were informed that there would be an evaluation of the course but no details about the formal assessment were given. The instructor-led candidates were assessed immediately after their course whereas the e-learned were scheduled for an assessment date. Skills in PBLs were assessed using a manikin (Laerdal Resusci® Baby Basic, Laerdal Medical, Stavanger, Norway). The subjects were given a standard scenario; “You are looking after an infant. The infant is suddenly quiet and motionless.” and asked to react as in a real-life setting. Assessments were video recorded and the subjects were asked to cease resuscitation efforts after four cycles of chest compressions and rescue breaths. The videos were evaluated independently by two assessors blinded to the intervention. The assessors were certified ERC BLS instructors. Each assessor conducted an independent evaluation and in case of disagreement, assessors reviewed the video together and came to an agreement.

Because of the lack of a uniform and validated method for evaluating PBLs training outcomes within the literature a skill checklist complying with the ERC Guidelines for Resuscitation 2010: pediatric life support21 was defined. The assessors used the skill checklist and rated 15 actions representing individual steps of the PBLs algorithm as adequately or inadequately performed (see supplement). The primary outcome measure was the overall pass rate. Passing required ≥8 of 15 skills rated as adequately performed.

Acceptable adequacy of chest compressions required a chest compression rate of 90–130 per minute, a judgment of a chest compression depth of one third or more of the thorax anterior–posterior diameter, and 28–32 compressions per compression cycle along with proper hand placement. Rescue breaths were deemed adequate when a slight rise of the thorax was visible and only two ventilations were attempted. Parameters on chest compressions and rescue breaths were calculated from three cycles of CPR. The initial 5 rescue breaths were deemed adequate when a slight rise of the thorax was visible and 4–6 ventilations only were given. Very excessive rescue breaths were deemed inadequate.

Before participation and after assessment, the participants completed a questionnaire evaluating their self-confidence and comfort.

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level as BLS providers on a Likert-scale. E-learners reported number of log-ons and time spent e-learning. The original intention was to extract number of log-ons and time spent online from the e-learning program; however we were unable to extract meaningful data due to a web page programming error.

2.7. Statistical analysis

To estimate the number of participants, we performed a sample size calculation on the primary outcome using a binomial test calculator. We assumed a pass rate of 80% in both groups and pre-specified a 20% non-inferiority margin, a 5% two-sided significance level, 80% power, and a 1:1 sample size ratio. The 20% non-inferiority margin has been used in a previous study on e-learning resuscitation. In total, 63 participants were needed in each group. Anticipating drop-out, the sample size was increased to 80 participants in each group. Only, the primary outcome measure was assessed for non-inferiority. Data are reported according to the CONSORT guidelines.

Since the primary outcome data did not meet requirements for binomial distribution calculations, we used Fishers exact test as a hypothesis test. Subsequently, we used a binomial test calculator to calculate the 95% confidence interval (CI). For the remaining categorical variables, we used Fishers exact test. Continues variables were analyzed using Mann–Whitney U test. Calculations were conducted using GraphPad Prism (GraphPad Software Version 6, La Jolla, CA, USA). A P-value <0.05 was considered statistically significant.

3. Results

We recruited 160 participants (Fig. 1). The number of participants lost was 13 versus 5 comparing instructor-led trained and e-learners. Participant baseline demographics are shown in Table 1. No adverse events occurred during the study.

E-learning was non-inferior to instructor-led training (difference -4%; 95% CI -9.05). Pass rates were 100% among instructor-led trained and 96% among e-learners (Fig. 2).

Median time with access to the e-learning module was 14 days (range: 12–19 days). According to self-reported data, the median time spent on the e-learning program was 30 min (range: 15–120 min) and the median number of log-ons was 2 (one log-on: n=34, two log-ons: n=26, three log-ons: n=7, four log-ons: n=2, five log-ons: n=2). According to internet site logs, e-learners median time from last log-on prior to assessment was 1 day (range: 0–7 days).

The results of the analysis of the 15 individual skill steps are presented in Table 2. Individual skill performance by

### Table 1: Baseline demographics.

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Instructor-led training</th>
<th>E-learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>34 (27–59) a</td>
<td>37 (26–53)</td>
</tr>
<tr>
<td>Sex (female)</td>
<td>58 (86.6%)</td>
<td>51 (71.8%)</td>
</tr>
<tr>
<td>Children (yes)</td>
<td>67 (100.0%)</td>
<td>69 (97.0%)</td>
</tr>
<tr>
<td>Level of education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>State school</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>High school</td>
<td>3 (4.5%)</td>
<td>3 (4.2%)</td>
</tr>
<tr>
<td>Vocational education</td>
<td>4 (6.0%)</td>
<td>5 (7.0%)</td>
</tr>
<tr>
<td>Short further education (&lt;2 years)</td>
<td>5 (7.5%)</td>
<td>8 (11.3%)</td>
</tr>
<tr>
<td>Medium long further education (2–4 years)</td>
<td>20 (29.9%)</td>
<td>21 (29.6%)</td>
</tr>
<tr>
<td>Long further education (&gt;4 years)</td>
<td>35 (52.2%)</td>
<td>34 (47.9%)</td>
</tr>
</tbody>
</table>

Data are median (range) or n (%).

a Missing data on age for n = 2.

**Fig. 2.** Primary outcome. Error bars indicate 2-sided 95% CIs. The dashed line at \( x = \Delta \) indicates the non-inferiority margin of 20%; the gray area to the right of \( x = \Delta \) indicated non-inferiority.

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instructor-led trained tended to be better (statistically significant in 4 of 15, all clustered in the first part of the performance).

When comparing instructor-led trained and e-learned, no significant differences in chest compressions delivered per compression cycle (range: 24–35 versus 15–38), chest compression rate (median: 113 min⁻¹, 25% percentile: 105 min⁻¹, 75% percentile: 125 min⁻¹ versus median: 112 min⁻¹, 25% percentile: 92 min⁻¹, 75% percentile: 129 min⁻¹), or number of initial rescue breaths (median: 5, range: 3–9 versus median: 5, range: 2–9) were observed (Fig. 3).

After the study, all participants felt that their skills had improved. Overall there was progress in the participants’ self-confidence and comfort level as PBLS providers in both groups (see supplement).

### 4. Discussion

The main finding of this study is that e-learning PBLS is non-inferior to instructor-led training. Our study suggests that more instructor-led trained than e-learned participants are lost to training or test. Both instructor-led training and e-learning improve participant’s self-confidence and comfort level as PBLS providers.

Only a few studies have been published on e-learning of PBLS. E-learning improved the ability to perform PBLS and pediatric advanced life support among medical students, doctors and nurses. In these studies, PBLS skills were assessed before and after e-learning, but no comparison of e-learning to instructor-led (control) or other training was performed.

Parents and nurses learned PBLS better using a voice advisory manikin when compared to instructor-led training. Self-directed PBLS learning among parents and nurses using either video alone or video combined with both textbook and instructor-supported training was not statistically different from instructor-led training regarding acquisition of skills. In these studies, self-training tended to improve skills in PBLS.

In one study, self-training using a video was less effective than instructor-led training for parents of high risk infants. In this study, the time spent training, the duration and content of the instruction video, and whether a manikin was used was not described. It is therefore difficult to elaborate on reasons for self-training being less efficient than instructor-led training. Less time spent training in the self-training group, details related to the instruction video, and the lack of a manikin may explain the differences.

Our findings are in accordance with studies on e-learning of adult BLS. A non-randomized pilot study comparing e-learning and instructor-led BLS training with automated external resuscitation (AED) among nurses demonstrated a significant and equal increase in resuscitation knowledge and skills in both groups. A study among laypersons showed that it may be possible to achieve reasonable adult BLS and AED skills using a micro-simulation web-based program, even without practice on a manikin, although the results may have been biased by the exclusion of two participants who never accessed the e-learning program. Contrary, among high school students, an online course in adult CPR (without any hands-on practice) compared to no resuscitation training improved knowledge of adult BLS significantly without improving performance of adult BLS skills. These results suggest that hands-on training is effective and is an important part of skill training.

In our study, passing the skill assessment required ≥8 of 15 skills rated as adequately performed. Thus participants could pass
without performing critical steps of the PBLS algorithm correctly. As presented in Table 2, however, this was not the case. In both groups, participants performed ‘gives 5 rescue breaths’, ‘call 1-1-2’, ‘sufficient chest compressions’, ‘sufficient rescue breaths’, and ‘CPR (30:2) without interruptions until the EMS arrives’ equally well. Raising the bar for number of passed skills may entail failing participants, who performed the critical steps of the PBLS skills correctly and would be able to make a difference in a real life situation. Interestingly, the four skills that were performed slightly better by the instructor-led than the e-learned were all clustered among the first steps in the PBLS algorithm. This might reflect a lack in the e-learning program or a prioritization of the skills by the e-learned.

When the number of skills deemed necessary to pass was increased from 8 through 15 of 15, e-learning was not non-inferior to instructor-led training. Furthermore, e-learning was inferior to instructor-led training when the number of skills deemed necessary to pass was 9 through 14, but not when 8 or 15 (see supplement). The number of correctly performed skills was 11.7 versus 10.5 (P < 0.001) among the instructor-led trained and the e-learned, respectively (see supplement).

Determining a non-inferiority margin may be difficult and a relevant non-inferiority margin depends on the question at hand. In this study, the margin was 20%. The study examined two different strategies for training PBLS providers. E-learning supports wider dissemination at lower costs and this may compensate for a wider non-inferiority margin. A margin of 20% has previously been used in a similar study. Following the design and determination of the non-inferiority margin of 20% in this study, other studies have been published using a non-inferiority margin of 10%. The use of e-learning in this study would also have reached non-inferiority to instructor-led training (95% CI: 9.0-10.5) using a 10% margin, although this would significantly have increased the estimated study sample size. Based on recently published papers and our results a non-inferiority margin of 10% might be considered for future studies.

In our study, approximately three times as many instructor-led trained e-learned participants were lost to training or test. This was in spite of a great effort during the study to prevent loss of participants, i.e., participants were rescheduled to different courses in case of no-show. This indicates that people, even though volunteering, have difficulties showing up for scheduled resuscitation courses supporting the need of a more flexible and accessible solution which e-learning can provide. On the other hand, it can be challenging to ensure whether people complete e-learning. Possibly, electronic surveillance and reminders send by e-mail or short message service to participants who have not started or completed e-learning may improve course completion. A short follow-up session including an assessment, as reported here, or an electronic assessment may ensure this.

In addition to the convenience, e-learning may contribute to the dissemination of resuscitation skills. Two studies on self-training CPR among parents found that the parents shared their self-instructional material (a DVD and an inflatable manikin) with other caregivers. Such dissemination of hands-on CPR skills is perhaps more difficult with instructor-led training.

Most children suffering from out-of-hospital cardiac arrest do not receive bystander CPR. Barriers for bystander CPR include fear of performing CPR incorrectly and uncertainty about how to perform CPR. In addition, resuscitation of an infant is often perceived as more stressful than resuscitation of an adult. Improvements in self-confidence in providing CPR are of importance when selecting training method. We found an increased self-confidence and comfort level as PBLS providers among both instructor-led trained and e-learned participants. Similarly, two studies among parents of high risk infants showed that the comfort level increased significantly after 6 and 12 months of access to a CPR self-instructional kit. Self-training, therefore, seems to be a promising method to increase self-confidence.

Our study has a number of limitations. First, for the purpose of sample size calculation we assumed a pass rate of 80% in both groups but pass rates were much higher. Second, a few participants were excluded from the study after randomization because of infant CPR training within 12 months, although this should have precluded inclusion according to the exclusion criteria. Third, e-learners median time from last log-on prior to assessment was 1 day (range: 0–7 days) whereas the instructor-led trained underwent assessment immediately after their training. This could bias the result in favor of the instructor-led group; however, this strengthens our finding that e-learning is non-inferior to instructor-led training. Fourth, and also to the disadvantage of the e-learners, the manikin trained with in the instructor-led group was used for testing in both groups. Fifth, participants were unaware that their skills were to be assessed. This could affect the attention toward the training negatively in both groups. Whether this effect might differ between groups is uncertain. Sixth, although we asked participants not to disclose information on training method and test, we cannot exclude that participant’s shared information across groups. Finally, participants were aged 26–59 years and the majority was educated. It is unknown whether our findings can be extrapolated to younger or older and less educated individuals.

5. Conclusion

E-learning PBLS is non-inferior to instructor-led training among child-minders and parents with children aged 0–6 years, although the pass rate was 4% (95% CI: 9.0-10.5) lower with e-learning. Both e-learning and instructor-led training improved self-evaluated confidence and comfort level as PBLS provider.

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Conflict of interest statement

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2015.01.030.
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