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## Simulation and education

# Improving the cost-effectiveness of laypersons' paediatric basic life support skills training: A randomised non-inferiority study



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### Abstract

**Aim:** To compare dyad (training in pairs without an instructor) with resource-intensive instructor-led training for laypersons' paediatric resuscitation skills in a non-inferiority trial and examine cost-effectiveness of the training methods.

**Methods:** In this randomised parallel group non-inferiority trial, 155 dyad and 175 instructor-led laypersons were trained in Basic Life Support and Foreign Body Airway Obstruction Management. Dyads were given instructional videos, hands-on exercises and provided feedback to their partner for 50 min. Instructor-led laypersons trained in groups of six for two hours. Learning were assessed in scenarios immediately after training and, subsequently, at 14 days, 1, and 3 months. Pass rates, cost-effectiveness of producing a competent layperson (passing both tests), and non-inferiority were analysed.

**Results:** Sixty-eight (45.6%) dyad and 130 (74.3%) instructor-led laypersons passed the basic life support test ( $p < 0.001$ ). For Foreign Body Airway Obstruction Management 77 (54.2%) dyad and 130 (79.3%) for instructor-led laypersons passed ( $p < 0.001$ ). Skills decreased over three months for both groups. Forty-two (30.4%) dyad and ninety-eight (59.8%) for instructor-led laypersons were competent after training ( $p < 0.001$ ). The lower effectiveness of dyad training had reduced costs ( $p < 0.001$ ). For each 10,000 USD allocated to training, dyad training would result in 71 vs. 65 competent laypersons for instructor-led training. Non-inferiority of dyad training could not be established.

**Conclusion:** Instructor-led training was the most effective but also the most expensive training method, making it less cost-effective than dyad training. When the aim is to train for quantity rather than quality, dyad training would be the preferred choice of training method.

**Keywords:** Paediatric Basic Life Support, Training, Basic life support, Dyad training, Laypeople, Layperson, Foreign body airway obstruction, Hands-on, Manikin training, Cost-effectiveness, Hlr, Heart-lung rescue, Peer training, Education, Simulation, Pairs

*Abbreviations:* OHCA, Out-of-hospital cardiac arrest; FBAOM, Foreign Body Airway Obstruction Management; PBLs, Paediatric Basic Life Support; CI, Confidence interval.

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## Introduction

Survival of Out-of-Hospital Cardiac Arrest (OHCA) among children in Denmark remains low at 1.4% (<1 year) to 4.5% (1–5 years).<sup>1</sup> Survival with a favourable neurologic outcome increases with bystander Paediatric Basic Life Support (PBLs); however, only about half of the victims receive bystander PBLs.<sup>1–4</sup>

Intervention with appropriate Foreign Body Airway Obstruction Management (FBAOM) skills within minutes of an incident can prevent situations from deteriorating to cardiac arrests.<sup>5</sup> Consequently, both PBLs and FBAOM are life-saving first aid skills where the timing is critical. Trained laypersons are more likely than untrained laypersons to initiate bystander resuscitation attempts.<sup>6–8</sup> For laypersons to provide effective bystander PBLs and FBAOM, skills need to be learned in hands-on training courses.<sup>9,10</sup> Resuscitation skills have shown to decay in as little as three months.<sup>9</sup> Existing courses are often instructor-led and the required presence of an instructor makes training inflexible and increases costs.<sup>11</sup> Consequently, in order to train large groups, there is a need to develop training methods that are flexible and cost-effective.<sup>11,12</sup>

Dyad training occurs when learners work together in pairs to acquire skills and represents a low-cost alternative to traditional training courses.<sup>13</sup> The learners take turns performing the practical skills and serving as an observer who provides feedback.

Dyad training has been found to be effective in clinical skills training for novices when guided by video instructions,<sup>14,15</sup> and can improve trainee retention.<sup>16</sup> It represents an alternative to traditional skills training, which could prove to be efficient, feasible, flexible, and cost-effective.

The aim of this study was to compare dyad with instructor-led training for laypersons' paediatric resuscitation skills in a non-inferiority trial. Secondary objectives included cost-effectiveness, retention of skills, and confidence in performing lifesaving first aid for children.

## Methods

### Setting

The study was a non-inferiority blinded parallel group interventional study of the two training methods for FBAOM and PBLs skills: dyad training and instructor-led training. The study was exempt from ethical approval by the Ethical Committee of the Capital Region, Copenhagen, Denmark (journal no H-15010539). Approval from the Danish Data Protection Agency was obtained (CHR-2015-004 I-Suite no. 04223). The study was registered at [clinicaltrials.gov](http://clinicaltrials.gov) (Identifier: NCT03469154).

Participants were recruited from Danish daycare centres from December 2015 through June 2017 and was stopped due to limited funds.

Inclusion criteria were age above 18 years and employment at least 20 h per week in a setting that involves working with children less than seven years of age.

Exclusion criteria were health professional training (i.e. doctor, nurse, social-and health service helper) or any first aid training within one year.

Daycare centres in Denmark have responsibility for children ages 0–6 years old, thus, the training programmes were designed to teach skills appropriate for this age group. Both programmes involved training on children and infant resuscitation manikins (Little Junior™ and Baby Anne™, Laerdal, Stavanger, Norway). Course content followed the 2015 guidelines from the European resuscitation Council.<sup>5</sup>

### Interventions

The dyad training group participated in a PBLs and FBAOM skills training course which included both infant and children resuscitation skills with a maximum duration of 50 min. The course content and the different components of PBLs and FBAOM skills were presented using a computer programme with instructional videos. After each instructional video clip, the participants performed hands-on exercises on resuscitation manikins and took turns practicing and giving feedback. The total duration of the instructional video clips was approximately 20 min. Written instructions were provided to guide the feedback process which was intended to focus on observed actions in relation to the video instructions. The course duration was designed to allow each participant approximately 15 min of hands-on practice.

The instructor-led training group participated in a standardised course with the same content of PBLs and FBAOM skills. Courses included up to six participants and one instructor. The duration of the courses was two hours for a six-person course and was modified based on the number of participants to allow for approximately 15 min of hands-on practice per participant.

### Randomisation

Daycare managers informed employees about the study. Those willing to participate were randomised after receipt of each participant's name and email address in blocks of 12 to each of the two interventions (1:1). In addition, subgroups for retention testing were established, such that a total of 6 groups were created: dyad and instructor-led with 3 subgroups for each, including retention after 14 days, 1 month and 3 months. A flowchart of the randomisation process is shown in [Fig. 1](#). AH allocated the participants using [www.randomization.com](http://www.randomization.com).

After randomisation, participants received an email with a short description of their training method and instructions about how to book a training course using a personal login to a website ([www.redmitbarn.dk](http://www.redmitbarn.dk)). In addition, the email informed participants about optional learning resources, including text, quizzes, pictures and videos, that were freely available on the website.

Participants received two reminders to book a training course.

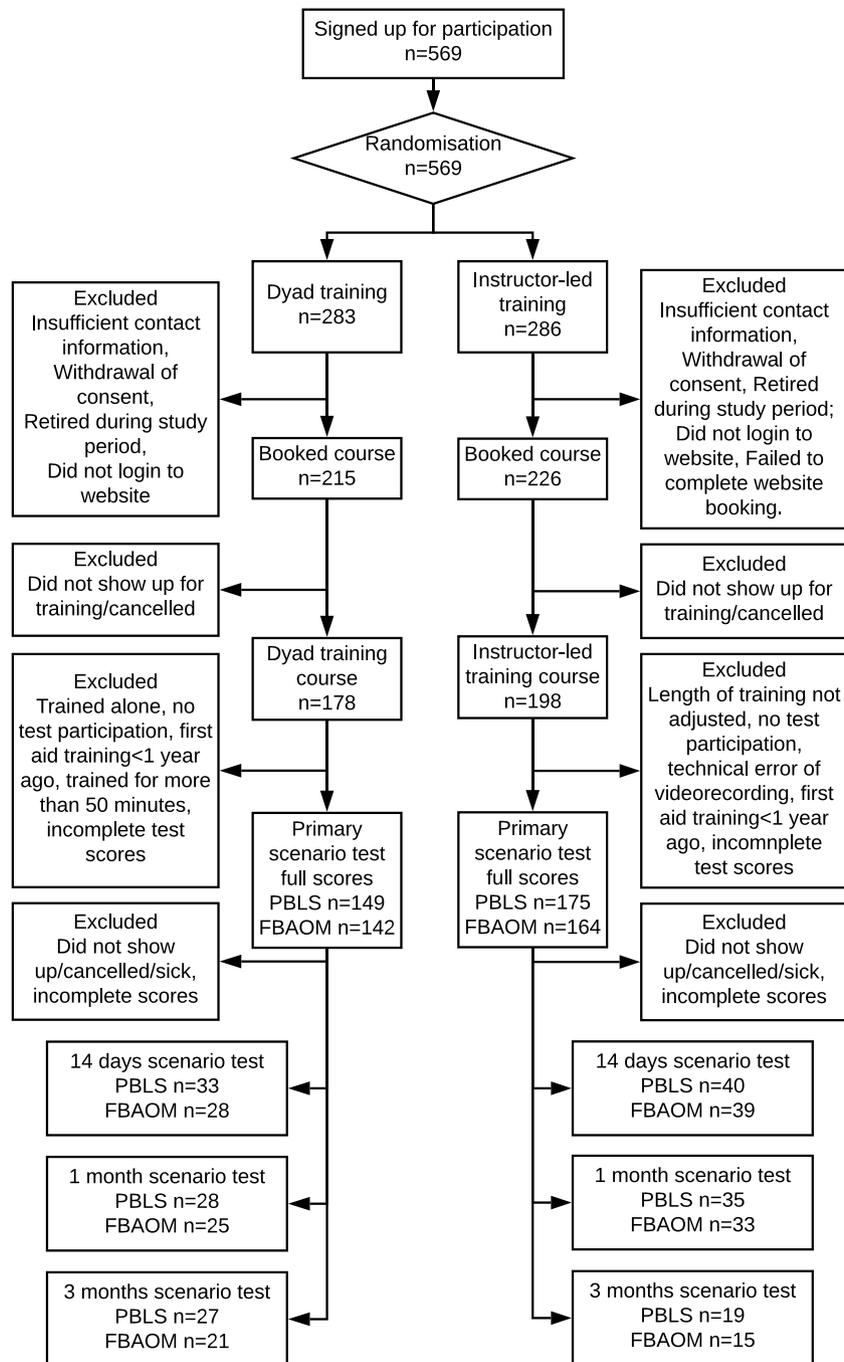
### Outcome measures

The primary outcome of PBLs and FBAOM skills was assessed with a primary standardised video-recorded scenario test, which participants completed immediately after training. Retention of skills was examined after 14 days, 1 month and 3 months with similar tests in which the scenario setting was changed slightly. The alterations did not impact the intended action (i.e. age of victim was changed from nine months to ten months and, consequently, the same skills were considered appropriate).

Scenario tests were rated using assessment instruments for laypersons' PBLs and FBAOM skills (Appendix Table 1). Validity evidence for the assessment interpretation was established in prior studies.<sup>17,18</sup>

Two blinded raters scored each of the video-recorded tests. All raters received 5-hour training about use of the assessment instrument. Only tests, where both raters scored all items, were included in the analysis. A summarised score of all individual items was calculated as a percentage of the maximum obtainable score for PBLs and FBAOM, separately. For both PBLs and FBAOM, the participant's score refers to the mean of the two raters' summarised scores.

The pass level was defined in a prior study as 74% and 55% of the maximum score for PBLs and FBAOM, respectively.<sup>17</sup> PBLs and



**Fig. 1 – Flowchart of the randomisation of participants and inclusion in the analysis.**

**A total of 178 and 198 participated in the training courses for dyad training and instructor-led training, respectively. Of these, 23 participants from the dyad training courses were excluded: Fifteen trained alone because of uneven numbers of participants showing up, four refused video-recordings, two provided information after the course that they trained first aid within one year, and two participants trained for more than the maximum of 50 min. In the instructor-led group 23 were excluded: The duration of the course was not adjusted to number of participants due to miscommunication for 13 participants. Six participants left before the test was conducted, two refused to be filmed, one had a technical error of the video-recording and one gave information at the course on first aid training within one year. No full scores were obtained for 11 FBAOM tests.**

**A total of 175 and 155 participants participated in the primary scenario test for instructor-led and dyad trained, respectively. For some of the tests the raters were unable to assess all items due to participants blocking the view, facilitators by human error did not follow the standardised protocol, or other situations where raters did not find it possible to assess all items. For dyad training six participants had missing full scores for PBLs and 13 for FBAOM. For instructor-led training 11 participants in FBAOM tests did not have a full score. For the retention analysis additional**

FBAOM scores for untrained laypersons, obtained in a prior study, were 47% of the maximum score for both sets of skills.<sup>17</sup>

Participants' confidence in practical lifesaving first aid skills for children was evaluated using a one-question questionnaire with a 5-point Likert scale (1: Very unconfident– 5: Very confident) before training, immediately following training, and after 14 days, one month or three months.

The running costs per participant for the two training groups were calculated based on salary expenses for instructors and participants, as well as utility-related costs. Total expenses were recorded in Danish kroner (DKK) and converted to US dollars (USD) with an exchange rate of 1 USD = 6.35 DKK. The frequency of competent performers who passed both PBLs and FBAOM tests was calculated immediately after training. The training effect was related to cost by determining the incremental cost-effectiveness ratio (ICER).<sup>19</sup>

$$ICER = \frac{\Delta cost}{\Delta effect} = \frac{Mean\ cost\ of\ dyad\ training - Mean\ cost\ of\ instructorled\ training}{Dyads\ passing\ both\ tests\ (\%) - Instructorled\ passing\ both\ tests\ (\%)}$$

The number of trained and competent laypersons immediately after training was calculated per use of 10,000 USD of expenses, based on the running cost per participant for each training method.

### Statistics

A non-inferiority margin of 10% lower PBLs and FBAOM scores among dyad training participants was chosen, based on earlier findings.<sup>20–22</sup> Non-inferiority of dyad training to instructor-led training was examined with a two-sided 90% confidence interval (CI) for the ratio between the score among the participants in each type of training, corresponding to a one-sided t-test of ratios at alpha level 0.05. Thereby, non-inferiority of dyad training was concluded if the lower bound of the CI was above 0.9 (i.e. the 10% non-inferiority margin). If the CI did not include 1, participants for each type of training were concluded to differ.

Validity results for the skill assessment instruments were not established when the study was initiated. The sample size calculation was based on estimated binary pass frequencies of 80% in both groups and a power of 0.8, which resulted in 198 in each group. A subsequent validity study provided a continuous score that could measure increasing levels of skill,<sup>17</sup> and consequently, it was decided to use the PBLs and FBAOM scores.

To build bias-corrected CIs for the ICER, bootstrapping was used to generate 1000 resampled datasets based on the original dataset and calculate ICERs for each set. These were used to construct 95% confidence intervals.<sup>23</sup> CIs not including zero indicate significant differences in the cost and effect of training programmes at alpha 0.05.

Comparison of costs for dyad and instructor-led training was performed using independent samples t-test. Comparisons of PBLs and FBAOM scores with untrained laypersons, as well as ICER comparisons with no difference in cost, were analysed using one sample t-tests. Frequency comparisons were analysed using Yates corrected chi square test. Mann-Whitney *U* test for unrelated samples was used for comparisons between dyad and instructor-led participants

**Table 1 – Characteristics of participants.**

Type of training	Dyad	Instructor-led
Number	149	175
Female, n (%)	138 (93)	161 (92)
Age, years	44 (20–66)	47 (20–64)
Experience, years	15 (0–45)	16 (0–45)
Previous first aid training, n (%)	128 (86)	162 (93)
Time since training, Years	4 (1–30)	4 (1–32)

Data presented as n (%) and median (min–max).

for individual items in the PBLs and FBAOM assessments, as well as for confidence in performing lifesaving first aid for children. Changes in confidence over time were evaluated with Wilcoxon signed rank test for related samples. All analyses were based on an alpha of 0.05.

### Results

A total of 569 participants signed up for training. The flowchart (Fig. 1) illustrates the process from randomisation to inclusion in analysis. In total 376 participants participated in training. No difference was found between the proportion of signed up participants who participated in training and randomisation to either dyad or instructor-led training ( $X^2(1, N=569)=2.27, p=0.13$ ). After the primary test, 149 dyad training and 175 instructor-led participants received a full PBLs score, and 142 dyads and 164 instructor-led participants had a full FBAOM score. The remaining participants were lost to follow-up testing (Fig. 1). Table 1 presents the participants' characteristics.

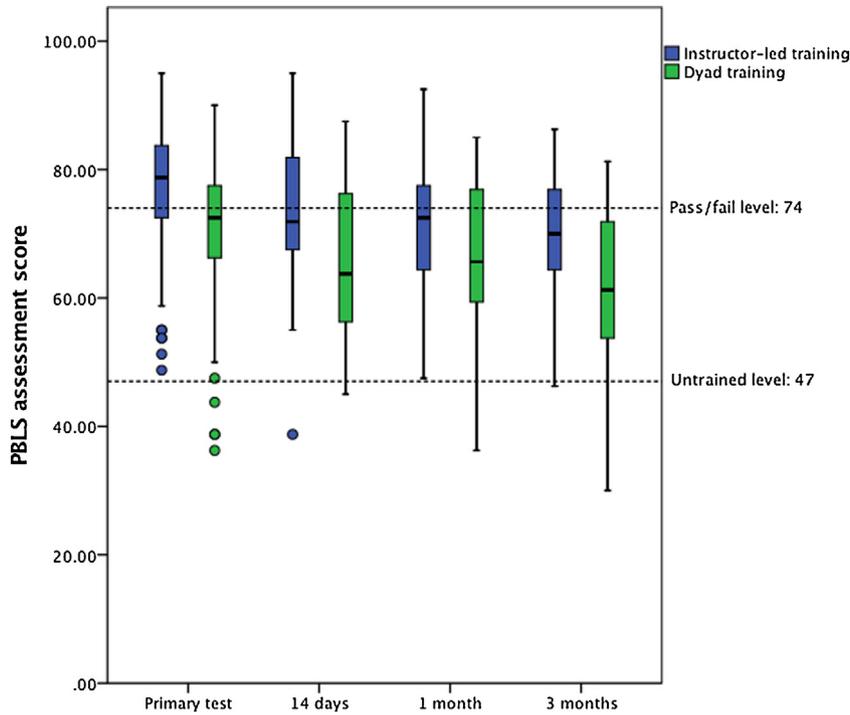
The distribution of PBLs and FBAOM scores for the primary test, after 14 days, one month and three months is shown in Figs. 2 and 3 and described in Appendix Table 3. For the primary test of PBLs skills, the dyad participants mean PBLs score was 70.9 compared with 77.5 for the instructor-led participants. The PBLs scores resulted in a pass rate of 45.6% ( $n=68$ ) for dyad participants compared with 74.3% ( $n=130$ ) in the instructor-led group ( $X^2(1, N=324)=26.60, p<0.001$ ). After three months, the PBLs scores were significantly higher than untrained laypersons for both dyad participants ( $t(26)=5.58, p<0.001$ ) and instructor-led participants ( $t(18)=9.57, p<0.001$ ).

The FBAOM mean score was 56.5 and 65.2 for dyad and instructor-led participants, respectively; and resulted in pass rates of 54.2% ( $n=77$ ) and 79.3% ( $n=130$ ) ( $X^2(1, N=306)=20.68, p<0.001$ ). After three months, The FBAOM scores demonstrated no significant difference as compared to those for untrained laypersons for both dyad participants ( $t(20)=0.763, p=0.45$ ) and instructor-led participants ( $t(14)=1.34, p=0.20$ ).

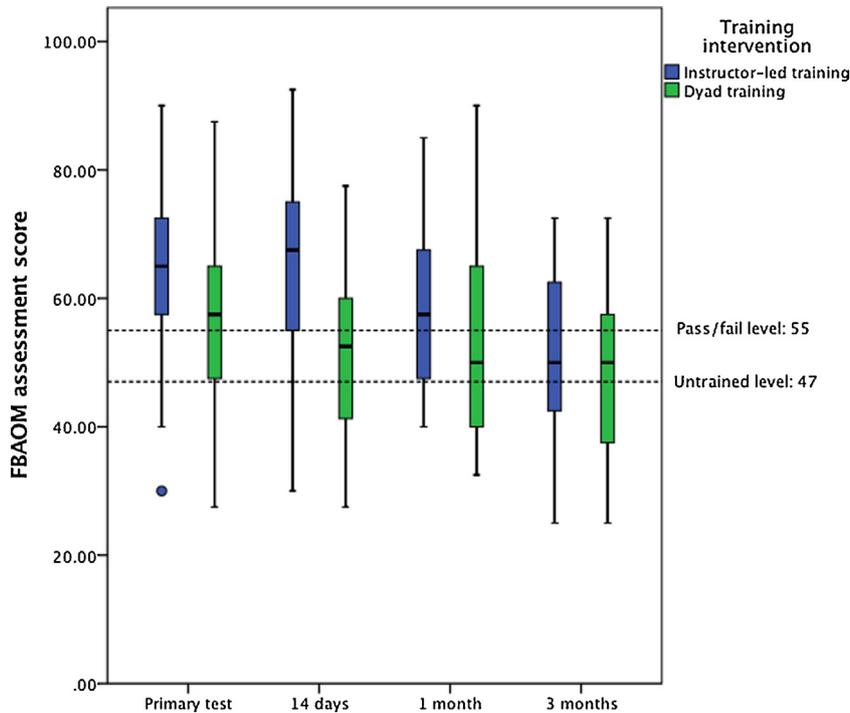
The non-inferiority analysis is shown in Fig. 4 (and Appendix Table 3). Non-inferiority of dyad training to instructor-led training could not be established (CIs lower bound below 0.9). The dyad participants had significantly lower scores than instructor-led participants (CIs below 1) for PBLs in the primary test, after 14 days and 3 months, and for FBAOM in the primary test and after 14 days.

The individual item score comparisons are illustrated in Fig. 5. For all items except PBLs "rescue breaths" ( $U=12739, p=0.57$ ), PBLs "Ventilations" ( $U=12850, P=0.58$ ), and FBAOM "Call for help"

**participants were lost to follow-up and incomplete item scores. This overall resulted in 182 participants (56%) in the PBLs retention analysis and did not differ between the dyad and instructor-led participants ( $X^2(1, N=324)=0.730; p=0.39$ ). For FBAOM 161 (53%) participated in the retention test and did not differ between dyad and instructor-led participants ( $X^2(1, N=306)=0.002; p=0.96$ ).**



**Fig. 2 – Boxplots of the PBLS scores at the different testing time by training group. The dotted lines are the passing score and the mean score of untrained laypersons.<sup>17</sup>**



**Fig. 3 – Boxplots of the FBAOM scores at the different testing time by training group. The dotted lines are the passing score and the mean score of untrained laypersons.<sup>17</sup>**

( $U = 12446$ ,  $p = 0.16$ ), instructor-led participants had significantly higher scores than dyad participants ( $p < 0.05$ ).

Confidence scores were higher after training compared with pre-training levels for both dyad ( $Z = -9.05$ ,  $p < 0.001$ ) and instructor-led

participants ( $Z = -10.22$ ,  $p < 0.001$ ). Confidence scores were higher for the instructor-led group compared with the dyad group immediately after training ( $U = 10060.5$ ,  $p < 0.001$ ), 14 days ( $U = 571.5$ ,  $p = 0.04$ ) and three months ( $U = 181.5$ ,  $p = 0.03$ ) (Appendix Table 3). Scores

declined over the three months but were still higher than pre-training levels for both instructor-led ( $Z=-3.35, p=0.001$ ) and dyad participants ( $Z=-3.89, p < 0.001$ ).

The estimation of running costs is shown in Appendix Table 4. The mean running cost per participant was 43 USD (95% CI: 43–43) and 92 USD (95% CI: 91–93) for dyad and instructor-led training, respectively ( $t(328) = 103.69, p < 0.001$ ).

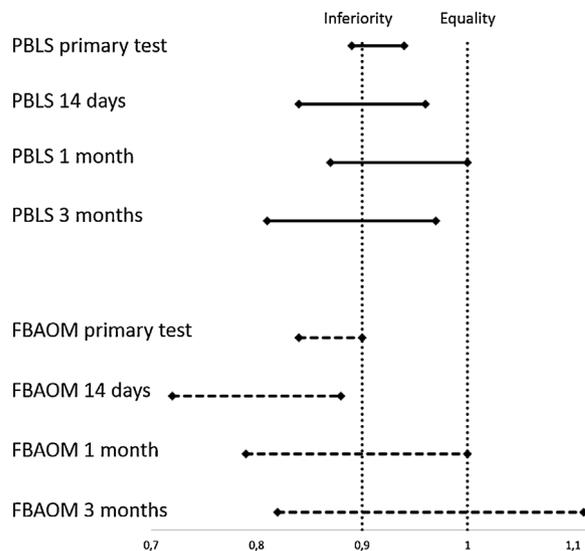
Out of 330 participants, 302 participants had both a FBAOM and PBLs score for the primary test. The frequency of competent participants (passing both tests) was 30.4% ( $n = 42$ ) and 59.8% ( $n = 98$ ) for dyad and instructor-led participants, respectively ( $\chi^2(1, N = 302) = 24.74, p < 0.001$ ).

Cost and effect were lower for dyad training compared with instructor-led training for all bootstrap samples and the original dataset. The ICER, therefore, represents the reduced cost per percentage point the frequency of competent laypersons decreased. The ICER was 1.68 USD (95% CI 1.22–2.66) per percentage-point.

Our results indicate that for each 10,000 USD spent, 233 (95% CI 232–235) laypersons can be trained by the dyad training method and 71 will be competent (passing both PBLs and FBAOM tests) after the training. For instructor-led training, 109 (95% CI 108–110) can be trained resulting in 65 competent laypersons.

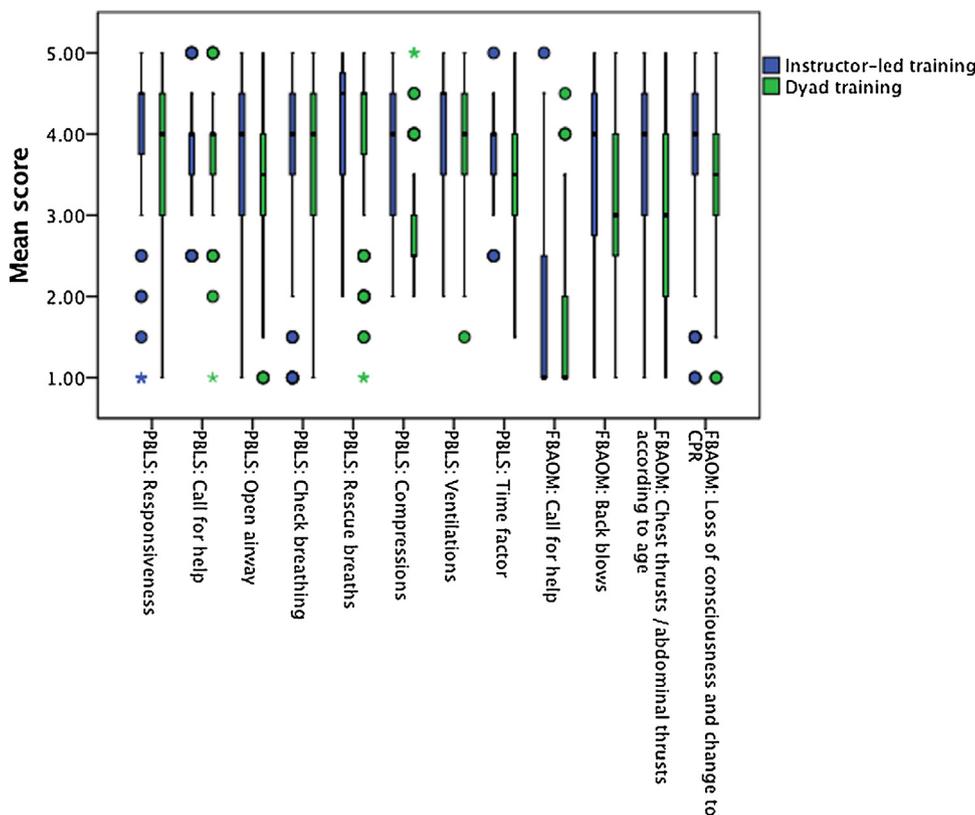
### Discussion

Dyad training was compared with instructor-led training for learning outcomes and cost-effectiveness. Dyad participants'



**Fig. 4 – Non-inferiority plots of dyad/instructor-led ratios of PBLs and FBAOM scores.**

The non-inferiority margin is 10%, which corresponds to a ratio of 0.9. The graph illustrates the 90% confidence intervals of PBLs and FBAOM score ratios. Confidence intervals above 0.9 indicate non-inferiority (alpha 0.05). Confidence intervals not including 1 indicate scores are not equal for dyad and instructor-led participants (alpha 0.1).



**Fig. 5 – Distribution of scores for the individual items by training group.**

Items were compared across the two groups using Mann-Whitney U test. There were significant differences ( $p < 0.05$ ) between the two groups for all items except PBLs “Rescue breaths” ( $p = 0.57$ ), PBLs “Ventilations” ( $P = 0.58$ ), and FBAOM “Call for help” ( $p = 0.16$ ).

performances were not equal to instructor-led participants, who had higher pass rates for both PBLS and FBAOM. Non-inferiority of dyad training could not be established. The cost-effectiveness analysis found that despite the decreased effectiveness of dyad training, it is associated with significantly lower cost as compared with instructor-led training.

Both groups had low item scores for FBOM call for help (Fig. 5), which may be due to the test design that may not have demonstrated these skills well. This was also found in a previous study.<sup>17</sup> Alternative explanations could be that less attention was given to these skills in both the dyad and instructor-led courses.

Despite being less effective, dyad training resulted in increased numbers of competent laypersons for the same amount of expenses spent. These findings suggest that on a population-based level, dyad training should be favoured over instructor-led training. This approach will result in increased numbers of competent laypersons and, thereby, improve the likelihood that one is present during a rare case of paediatric OHCA. In contrast, health care professionals are limited in numbers and it is important that each individual develops a high level of skill in resuscitation, as they have a higher likelihood of encountering cardiac arrests. For this population a more expensive and effective instructor-led training may be preferable.

The dyad training yielded greater than three times more trained people per 10,000 USD of associated expenses; however, some of these participants may not be fully competent (did not pass the test). Nonetheless, these individuals possess some skills that could make a difference in real resuscitation attempts. Although it is less effective than instructor-led training, dyad training still led to improvements in participants' confidence, which may help them to apply their skills,<sup>24</sup> increase their willingness to act, and improve survival through increased bystander PBLS provision rates.<sup>6,8</sup> Evaluating training outcomes may, therefore, not only be related to training efficacy, but also how to spend training resources best to increase survival from OHCA.

Pass rates for instructor-led participants (74.3%) was markedly higher than dyad participants (45.6%). The dyad training pass rate seems comparable to other short duration resuscitation courses which have found pass rates of 21%–43%.<sup>25–27</sup> The instructor-led pass rates are high, which may reflect highly motivated daycare employees participating in focussed training courses designed for their needs. Furthermore, even the poorer performing dyad participants achieved pass rates similar to other short duration courses. The benefits of training together may be increased motivation and shared responsibility for learning that may be beneficial for retraining purposes.<sup>13</sup> The dyad training may support a more team-based approach that could improve real resuscitation attempts.<sup>28</sup>

### Strengths and limitations

The strengths of this study are the design, use of assessment instruments with established validity, and the high number of participants compared with other training studies on paediatric basic life support.<sup>21,29,30</sup> The inclusion of costs provides insight which will help the decision-making process regarding which educational method to choose.<sup>12</sup>

Tests inherently induce a learning effect known as the testing effect.<sup>31</sup> Testing both groups balanced the effect of testing. The retention assessments were distributed on three different groups. Hence, retention test represents learning from the primary course

only. However, testing may still be beneficial for learning, especially when formative feedback is provided.<sup>9,17,32</sup>

Due to the study design and logistical challenges, participants were gathered on certain dates and times, which required an online booking system. After the first email was sent, 22% (n = 128) of participants failed to book a course and, thus, were lost to subsequent follow-up (flowchart Fig. 1). Nonetheless, among the participants who booked a course, the completion rate was 85% (n = 376) (Fig. 1). Dropout rates did not differ between the two groups, which suggests that participants would have been willing to participate in either type of training. Implementation of the same course for all employees at a single daycare centre could ease the booking process and enhance learning as many employees request training in their own daycare centre with known colleagues.

A clustering effect for participants on each unique instructor and dyad course may be present but adjustment for such was not possible in the analysis.

About half of the participants did not complete the retention test (Fig. 1), which limits interpretation. However the findings match decay of skills found in other studies.<sup>9</sup> Reasons for the dropout rates may be participants having no incitement to participate as training was completed. Logistic challenges may also have impaired the participation.

## Conclusions

Instructor-led training was most effective, had the greatest impact on confidence, and was the most expensive training method. It was less cost-effective than the less expensive, but also less effective dyad training method. Both skills and confidence declined over time. Non-inferiority of dyad training to instructor-led training could not be established. When the aim is to train for quantity rather than quality, the more cost-effective dyad training approach should be the preferred choice of training method.

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## Conflicts of interest

None of the authors had any conflicts of interest to report.

## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.resuscitation.2019.02.032>.

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