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Simulation and education

An effort to reduce chest compression pauses during automated external defibrillator use among laypeople: A randomized partially blinded controlled trial

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Abstract

Aim: To implement small methodological changes in basic life support (BLS) training to reduce unnecessary pauses during automated external defibrillator (AED) use.

Methods: One hundred and two university students with no BLS knowledge were randomly allocated into three groups (control and 2 experimental groups). Both experimental groups received a two-hour BLS training. While the contents were identical in both groups, in one of them the reduction of no-flow time was focused on (focused no-flow group). The control group did not receive any training. Finally, all of them were evaluated in the same out-of-hospital cardiac arrest simulated scenario. The primary endpoint was the compression fraction.

Results: Results from 78 participants were analysed (control group: 19; traditional group: 30; focused no-flow group: 29). The focused no-flow group achieved higher percentages of compression fraction (median: 56.0, interquartile rank (IQR): 53.5–58.5) than the traditional group (44.0, IQR: 42.0–47.0) and control group (52.0, IQR: 43.0–58.0) in the complete scenario. Participants from the control group performed compression-only cardiopulmonary resuscitation (CPR), while the other groups performed compression-ventilation CPR. CPR fraction was calculated, showing the fraction of time in which the participants were performing resuscitation manoeuvres. In this case, the focused no-flow group reached higher percentages of CPR fraction (77.6, IQR: 74.4–82.4) than the traditional group (61.9, IQR: 59.3–68.1) and the control group (52.0, IQR: 43.0–58.0).

Conclusions: Laypeople having automated external defibrillation training focused on acting in anticipation of the AED prompts contributed to a reduction in chest compression pauses during an OHCA simulated scenario.

Keywords: Basic life support, Education, Bystander, Resuscitation, Simulation, No-flow time

Introduction

Out-of-hospital cardiac arrest (OHCA) is a leading cause of death and disabilities in developed countries. In Europe, the EuReCa ONE project reaffirmed that OHCA is a major public health problem, reporting an incidence rate of 84 per 100,000 population.[1] The early treatment of OHCA, instigated by a bystander activating the chain of survival, is highlighted as a key lifesaving factor, since the probability of post-OHCA survival increases if casualties receive immediate life support, even more so if an automated external defibrillator (AED) is used.[2,3] While high-quality chest compressions provide organ perfusion during cardiac arrest, AED analyses the victim's heart rhythm and recommends delivering a shock in those cases where a shockable rhythm persists.[2,3]

The design of the AEDs allows laypeople, even children,[4] to use the device safely following the pre-programmed acoustic and visual instructions.[5] However, a recent simulation study among participants who were untrained in basic life support (BLS) showed that 12 out of 26 were not able to finish a simple OHCA scenario, mainly due to dif-

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Abbreviations: AED, Automated external defibrillator, BLS, Basic life support, CPR, Cardiopulmonary resuscitation, EMS, Emergency medical services, ERC, European Resuscitation Council, OHCA, Out-of-hospital cardiac arrest

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ficulties during AED use.[6] Therefore, although it is assumed that AEDs are designed to provide straightforward acoustic and visual prompts that can be followed intuitively and easily, it seems that some focused training would be needed to optimize defibrillation performances within the general population, linking defibrillation and chest compressions.[7]

European Resuscitation Council (ERC) Guidelines encourage as minimal as possible pauses in chest compressions,[2,3] since no-flow periods are correlated with poor outcomes.[8] However, in real life there are two moments while using the AED when compressions must be stopped: during rhythm analysis and while shocks are administered. At every other stage, rescuers should perform their high-quality chest compressions as continually as possible. Since AEDs are designed not only for trained people, but also for laypeople, AED prompts have been designed to be emitted carefully and slowly for better understanding, and resuscitation guidelines recommend that providers pay attention to AED voice prompts and follow them strictly. Unfortunately, this quest for clarity may also inadvertently result in increased compression pauses at precisely those moments when chest compressions must be performed: while the AED is charging, just after shocking, and after the rhythm analysis if shock is not recommended (Fig. 1).

With the hypothesis that BLS training focused on avoiding unnecessary pauses would improve chest compression continuity during AED use, we carried out an experimental simulation-based study with a control group (untrained participants) and two experimental groups (trained participants).

Methods

Ethics

This study followed the Helsinki Convention's ethical principles, and it was approved by the Bioethical Committee of the University of Santiago de Compostela.

Participants

A convenience sample of 102 University students was invited to participate (Faculty of Education Sciences, Santiago de Compostela, Spain). Only students that had not previously undergone any BLS training were included in the study. Written informed consent was obtained from all participants, which stated that their participation was voluntary and they could withdraw at any stage.

Study design

This longitudinal randomized controlled trial followed the CONSORT statement. The 102 participants were distributed randomly into three groups: a control group (36 participants) and two experimental groups (34 and 32 participants) (Fig. 2). All participants were evaluated in the same simulated OHCA scenario, those from the experimental groups after two hours of BLS training. The general contents and the duration of the training were the same in both groups. There were only small changes in the methodology, since one experimental group was specifically focused on the reduction of no-flow time (focused no-flow group). The control group did not receive any training at all.

Interventions – BLS training

BLS training was given to the experimental groups and lasted 2 h: 1 h of theoretical content and demonstrations; 1 h of hands-on CPR and AED use. The theoretical lesson started with a video which illustrated the differences between acting or not in the case of OHCA (https://www.youtube.com/watch?v=CWRjAs4epqw&ab_channel=F%C3%B8rstehj%C3%A6lp.com), delivering the message that small actions can make huge differences. The content taught in the first hour of the training addressed how to recognize and act in the case of OHCA and highlighted the importance of bystander CPR, and AED use. In addition, the instructor explained the steps of the BLS sequence while performing them on a manikin: checking safety, response and breathing, calling emergency medical services, sending for an AED, starting CPR, and using AED. The hands-on session addressed the steps of the BLS sequence, CPR (30:2) and AED use. The ratio instructor:student, student:manikin and student:AED were 1:5–6; 2:1 and 2:1 respectively. For CPR training a basic adult manikin torso was used (Laerdal ResusciAnne). The only feedback provided during training was auditive with an external metronome to give the chest compression rate throughout. The AED used during training sessions was AED Trainer XFT-120C+ (Portomédica). The training was provided by a BLS Instructor from the Spanish Resuscitation Council.

Although the contents were the same in both experimental groups, there were some differences in the methodology, which aimed to reduce the no-flow time in the focused no-flow time group. The traditional group was taught with the same messages stated in the guidelines:[2] "Follow the spoken (and/or visual) prompts from the AED; Push the shock button as prompted. Immediately restart CPR with 30 compressions. If no shock is indicated, immediately restart CPR with 30 compressions".

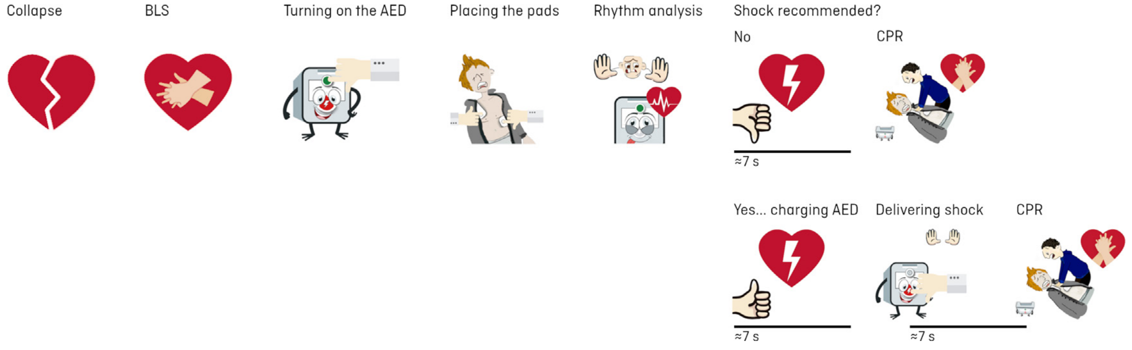

Fig. 1 – Sequence from cardiac arrest to AED use and moments when chest compressions must be performed. Times reported in the figure are extracted from Savastano et al.[11]

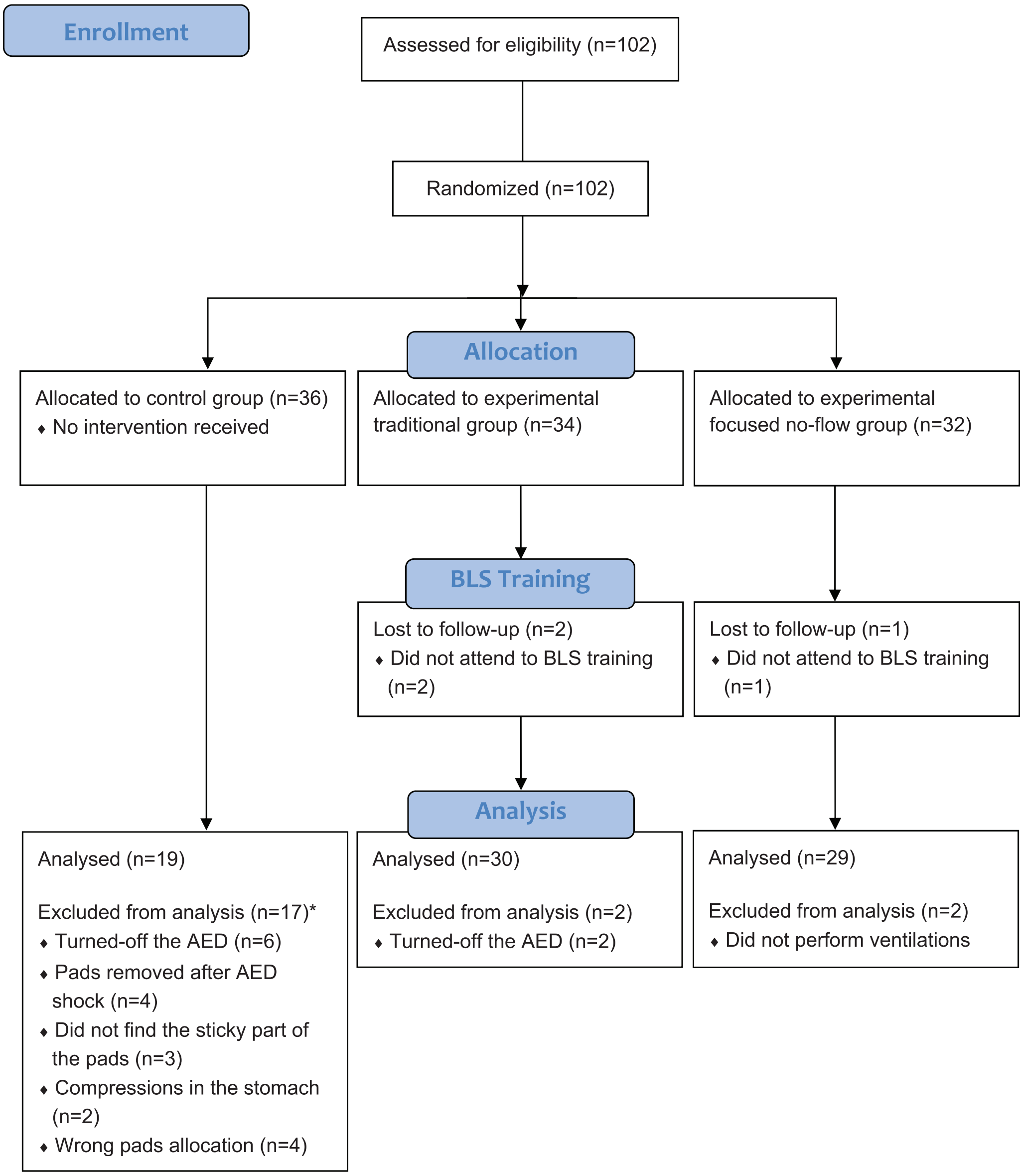

Fig. 2 – Flow diagram. *There were participants excluded from analysis due to more than one reason.

Participants from the focused no-flow group were not instructed to “follow the spoken prompts from the AED”, but to act in anticipation of the AED’s prompts, and this was the sole difference between the focused no-flow group and the traditional group. Just after the rhythm analysis, the focused no-flow group was encouraged to start CPR immediately, since if the AED did not recommend shocking, CPR has to be started, whereas if another shock is recommended, the AED requires a further charge before shocking, which means that the rescuer has a brief timespan to deliver compressions until the AED is ready to shock. Finally, they were also urged to start CPR immediately after delivering the shock without waiting for any prompt from the AED.

BLS assessment

Participants were individually evaluated by means of a simple OHCA-simulated scenario (Fig. 3) immediately after the training. They were placed in front of a ResusciAnne manikin and told that a person had collapsed while passing a crosswalk. They were expected to complete the BLS protocol steps: 1) checking safety; 2) checking response; 3) opening the airway and checking breathing; 4) alerting the emergency medical services (EMS); 5) sending for an AED; 6) starting CPR; and 7) and using AED. An investigator provided an AED after 1 min of CPR, and it was programmed to recommend two shocks. Shocking was not recommended in the third analysis since in that scenario time the casualty would be presumed to be breathing.

Several interval times were registered from the beginning of the scenario to: 1) starting CPR; 2) providing AED to the participants; 3) first shock; 4) second shock; 5) end of the scenario. The BLS sequence was assessed by means of a questionnaire that was filled out during the simulation while observing the participant’s performance.[9] If the participants called the EMS, they were given dispatcher instructions according to EMS protocols.[10] If not, the investigator played the role of a bystander making the call and put

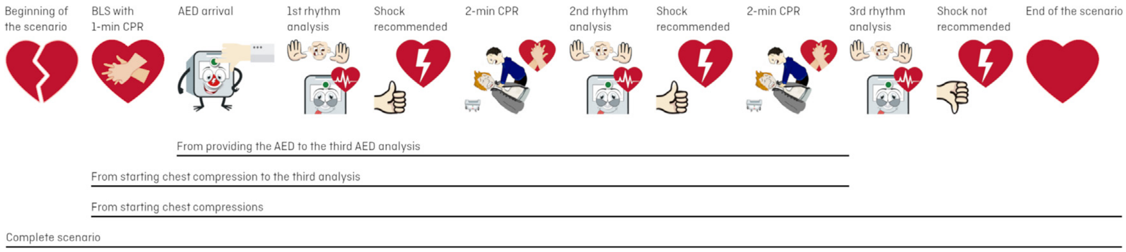

Fig. 3 – Steps of the basic life support assessment and intervals in which compression fraction was registered and analysed.

them in contact with the EMS. In this case, "*Calling EMS*" would be registered as "*not performed*", since only those actions performed on the initiative of the participants themselves were considered as "*performed*". Finally, it was also registered if participants checked breathing during AED analysis, while also noting their actions after the third analysis, in which AED did not recommend delivering a shock.

The quality of CPR was assessed with a ResusciAnne manikin, equipped with a Simpad SkillReporter able to provide feedback about compressions and ventilation quality. An AED trainer was also used (AED Trainer 2, Laerdal).

Partially blinded randomization

Randomization was performed electronically using Microsoft Excel to generate sequences of random numbers. Participants were allocated into the three groups described above without knowledge about the group in which they were part.

Outcomes

The primary outcome was the compression fraction defined as the proportion of time (in percentage) in which participants were performing compressions (Fig. 3): 1) in the complete scenario; 2) from starting chest compressions; 3) from starting chest compression to the third analysis; 4) from providing the AED to the third AED analysis.

The secondary outcome was the CPR fraction. Since experimental groups were instructed to perform compressions and ventilations, compression fraction does not reveal the whole time in which participants were performing CPR, just compressions. CPR fraction allows a normalised comparison between participants that performed both compressions and ventilations and those that only performed compressions, since it shows the fraction of time in which the participants were performing resuscitation manoeuvres, only compressions or compressions and ventilations.

Results from the BLS and CPR quality variables were registered as controls in order to verify that training only has an influence on no-flow time.

Statistical analysis

Compression fraction and CPR quality variables were expressed as a median with interquartile range (IQR). BLS sequence variables are shown as absolute with relative frequencies. Inter-group factor for continuous variables were analysed throughout Kruskal-Wallis test, and Mann-Whitney U Test for pairwise analysis. In the case of categorial variables, Chi-square statistic was performed.

Statistical analyses were performed with IBM SPSS Statistics v.25 for Macintosh. A significance level of $p < 0.05$ was considered for all analyses.

Results

Demographics

Data from 78 participants were analysed in the final study (Fig. 2). Two participants were excluded in both experimental groups for turning-off the AED during BLS assessment (traditional group: n = 2) or not performing ventilations (no-flow group: n = 2). Those participants that did not perform ventilations in the experimental groups were excluded. In the control group, 17 participants were excluded due to turning-off the AED, and/or removing the pads after shocking, and/or not finding the sticky part of the pads, and/or compressing in the stomach area and/or applying pads in the wrong place.

Fifty-five participants (70.5%) were female, with similar proportions across the three groups (control group: 13 (68.4%); traditional group: 21 (70.0%); focused no-flow group: 21 (72,4%)). The mean age was 21.4 ± 2.1 years (control group: 21.2 ± 0.9; traditional group: 20.6 ± 2.5; no-flow group: 22.2 ± 1.8). Participants from the control group needed more time to complete the OHCA simulated scenario (555 s, IQR: 520–592) compared to the traditional group (471 s, IQR: 459–482) and the no-flow group (449 s, IQR: 435–459) participants ($p < 0.001$).

Compression fraction

The compression fraction of the three groups is shown in Fig. 4 and Supplementary Table 1. Fig. 4 shows the results of four intervals of compression fraction as indicated in Fig. 3. Significant differences were found between the three groups in the four-time intervals ($p < 0.001$ in all analyses). Pairwise analysis showed differences between the focused no-flow and the traditional group. Participants from the focused no-flow group spent significantly more time performing compressions than those from the traditional group ($p < 0.001$ in all analyses). However, those differences were only seen between the no-flow group and control group in the interval time related to the whole scenario ($p = 0.021$). Comparing the traditional group versus the control group, untrained participants reached higher percentages of compression fraction ($p < 0.05$ in all analyses).

CPR fraction

All the participants from the control group performed compression-only CPR, while participants in the experimental groups performed compression:ventilation CPR, spending a median time of 91 s (IQR: 84–102) performing ventilations (traditional group: 90 s, IQR: 80–99; focused no-flow group: 96 s, IQR: 88–108; $p = 0.058$). The CPR fraction shows the fraction of time in which the participants were performing resuscitation manoeuvres. This allows better comparisons between participants who performed compression-only

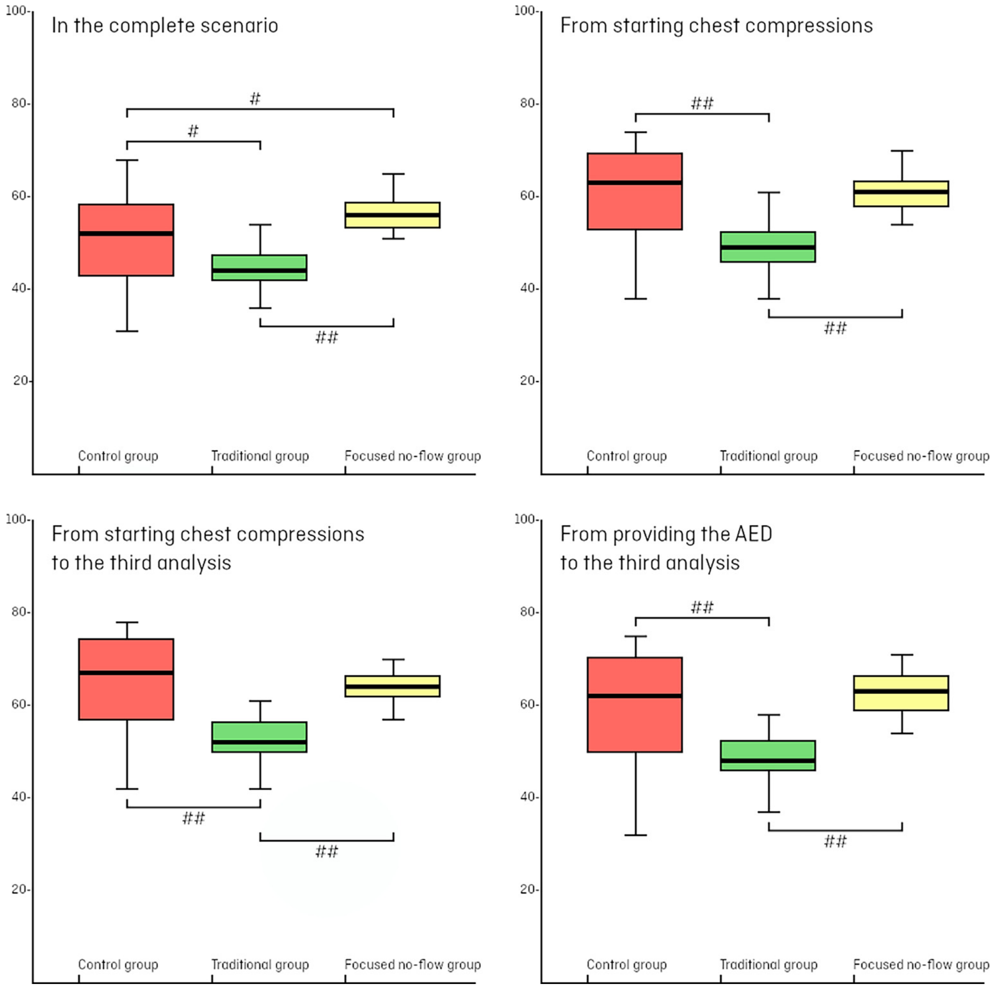

Fig. 4 – Compression fraction. $^{\#}p < 0.05$; $^{\#\#}p < 0.001$.

CPR (control group) and compression-ventilation CPR (experimental groups) (Fig. 5 and Supplementary Table 2). The CPR fraction was higher than the compression fraction in both experimental groups. Focused no-flow participants reached the highest index of CPR fraction in the four interval times analysed compared with the other two groups ($p < 0.001$ in all analyses). Although Fig. 5 shows better results of CPR fraction in the traditional group compared to the control group, the only significant differences were observed during the whole scenario interval time ($p = 0.017$).

Basic life support sequence and CPR

Variables related to BLS and CPR quality were registered to ascertain that the differences in the training methodology only had an influence on the primary outcomes: compression fraction/pauses. In this regard, results from the BLS sequence and CPR quality are shown in Supplementary Tables 3 and 4 respectively. No differences were found in any BLS variable between the traditional and the focused no-flow group, while proficiency was significantly better in the experimental groups compared to the control group. Regarding CPR quality, the control (517, IQR: 368–589) and the focused no-flow group (481, IQR: 453–508) performed more compressions than the traditional group (398, IQR: 369–456). Both experimental groups compressed deeper (traditional group; 52 mm, IQR: 44–57; focused no-flow group: 46 mm, IQR: 42–55) than the control group (33 mm, IQR: 26–46) with no differences between them (traditional vs. focused no-flow), and no differences were observed between the three groups in terms of compression rate and hand position.

Discussion

Our results showed that, in an OHCA simulated scenario, compression pauses can be reduced during AED use when the instructor encourages the students to act in anticipation of the standard AED prompts. This was especially important in two specific moments: immediately after rhythm analysis and immediately after shocking.

Compression pauses must be minimized in cases of OHCA.[3] However, prompts from AEDs instruct users to stop chest compressions both during rhythm analysis and shocking. This means that, even with correct performance, there will always be some kind of compression pauses. A study that aimed to compare the performance assessments of commercially available Automatic External Defibrillators reported that AEDs spend 9.7 s for rhythm analysis, 6.9 s for charging, and give a post-shock pause (time elapsing from the shock delivery to the instruction to resume CPR) of 6.7 s.[11] Since shorter pre- and post-shock pauses were associated with higher

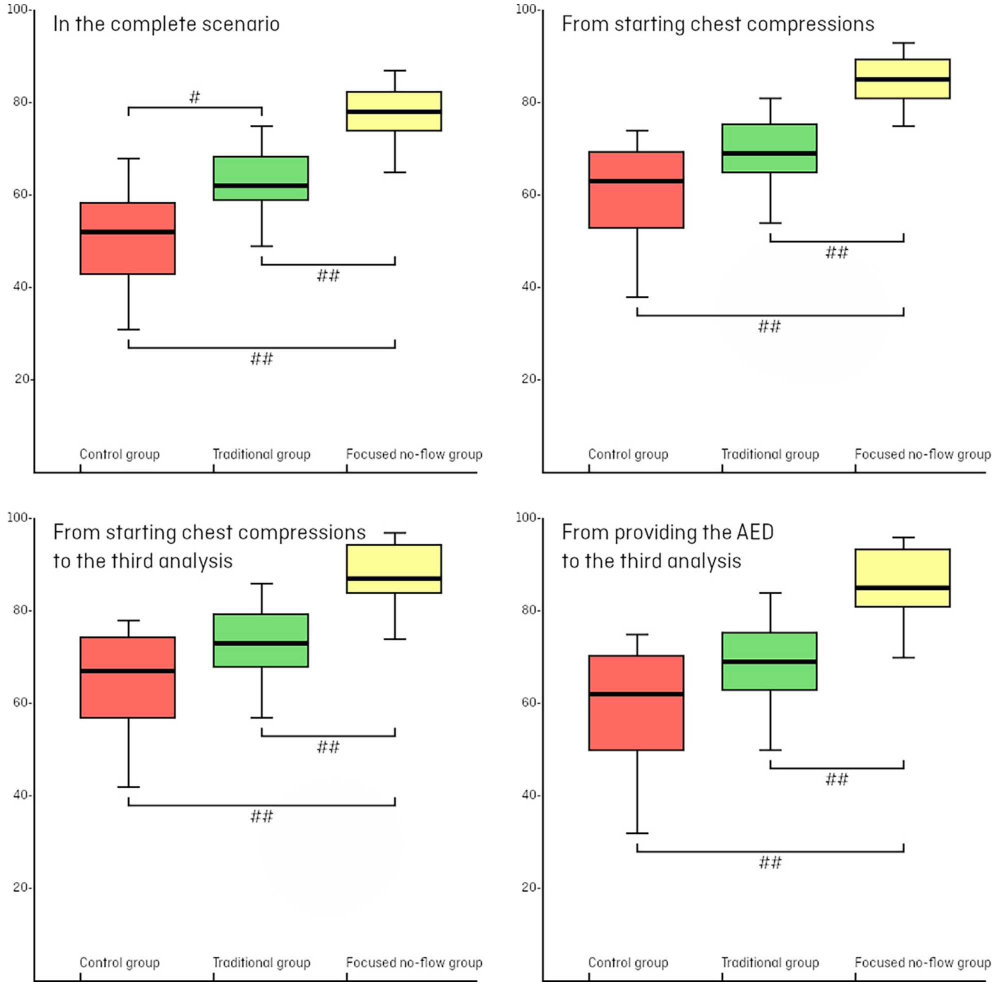

Fig. 5 – Cardiopulmonary resuscitation fraction. $^{\#}p < 0.05$; $^{\#\#}p < 0.001$.

odds of OHCA survival,[12] previous research has been trying to reduce pre- and post-shock pauses in different ways: with modifications of AED prompts,[13] rhythm analysis during CPR[14–18] or charging the AED during ongoing CPR.[18,19] In our study, with an alternative simple complementary approach to the problem, the attention was not focused on the AED, but on the rescuers.

Participants from the focused no-flow group devoted more time performing chest compressions than the traditional group, with differences of more than 12% of compression fraction in all the sequences analysed in our OHCA simulated scenario. This means that the focused no-flow group was performing chest compressions for, at least, 7 s per minute (12%) more than the traditional group. Taking into account that pre-shock pauses <10 s and peri-shock pauses <20 s were associated with significantly higher odds of survival and positive neurological outcomes,[12] our results may have some educational and eventually clinical relevance. In fact, while the traditional group achieved a compression fraction significantly lower than the control group, the focused no-flow group was able to reach higher compression fraction figures in the complete scenario, even performing compressions and ventilations.

Pre-shock pauses depend on the AED's technical specifications and the rescuer's ability to perform chest compressions just after the analysis and just before shocking. Nevertheless, post-shock pauses only reflect the rescuers' behaviour, depending on whether they limit their intervention to following the prompts, or they actively anticipate what their next actions should be. We observed that, in the traditional group, although the participants were instructed to "*Immediately restart CPR with 30 compressions*" after shocking, they remained waiting for the prompt from the AED. In the focused no-flow group, feedback was continually provided about the need to anticipate the required actions and therefore act before the AED commands. This was the sole difference between both groups, while the methodology remained otherwise identical, with an optimal ratio of instructor:student 1:6,[20] demonstrations, explanations and opportunities for repetition.

There were no differences found in terms of CPR quality and BLS sequence performance in both experimental groups, which illustrates the effect of the groups' methodological differences on the primary and secondary outcomes. However, the focused no-flow group compressed slightly less deeply than the traditional group (not significant). Both experimental groups were trained without any kind of visual feedback for compression depth, only the corrections from the instructor, and visual feedback is generally considered useful in order to maintain an appropriate compression depth.[3,21] In addition, the focused no-flow group was performing compressions for significantly longer than the traditional group, and the effect of physical fatigue on compression depth has been widely studied.[2,21] Although the focused no-flow group compressed 4 mm under the 50 mm recommended, some clinical trials have shown that even compression depths just under 50 mm are associated with maximum survival rates.[22]

Although significant resources have been invested in improving AED prompts and algorithms,[6,13–19] the practical truth is that training people in the correct way may lead to a more significant reduction of compression pauses. Participants from the control group may be the best example of this. AED has been designed to be used by everybody (public access defibrillation), with simple straightforward messages to ensure a shock when used by a heterogeneous group of lay rescuers.[23] However, in our sample, 17 participants had to be excluded from the control group due to different reasons related to inappropriate AED use, which reveals the need for instructor-lead training for laypeople despite the ease of use of this apparatus.[6,7]

Limitations

Our study used a convenience sample, and it was carried out in simulated conditions; in real life situations the stress, psychological pressure, or even fear of using an AED might have a negative impact on the results. The randomization was partially blinded, which could introduce a bias that should be considered when interpreting results. In addition, we did not use real AED, so pre-shock pauses might be slightly different compared to those in the real apparatus. Furthermore, taking into account previous studies, it is clear that analysis and charging time or post-shock pauses can fluctuate among different models.[11] Nevertheless, we used different AED for training and BLS assessment for minimising bias and exploring the differences between groups regardless of the type of AED. Finally, several sub-groups of students were trained; thus, from a pedagogic perspective, psychological variables such as motivation, enthusiasm and emotional intelligence of both students and instructors might vary between the different lessons and could lead to some bias. In this regard, the fact that the variables related to BLS and CPR quality remained equal between both experimental groups might suggest that this limitation was minimised.

Conclusions

Providing laypeople with automated external defibrillation training focused on acting in anticipation of the AED prompts achieved a reduction in chest compression pauses during an OHCA simulated scenario. Several participants had to be excluded from the control group due to inappropriate AED use, a fact that highlights the flawed design of AED prompts and the consequent need to train laypeople for adequate AED performance.

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CRediT authorship contribution statement

Cristian Abelairas-Gómez: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization, Supervision. **Aida Carballo-Fazanes:** Methodology, Investigation, Writing – review & editing. **Santiago Martínez-Isasi:** Investigation, Funding acquisition. **Sergio López-García:** Investigation. **Antonio Rodríguez-Núñez:** Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Cristian Abelairas-Gómez is member of the ERC BLS Science and Education Committee and member of the Education, Implementation and Teams ILCOR Task Force. Antonio Rodríguez-Núñez is member of the Pediatric Life Support ILCOR Task Force.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2023.100393.

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