

Real-time visual feedback during training improves laypersons' CPR quality: a randomized controlled manikin study

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ABSTRACT

Objective: The chances of surviving an out-of-hospital cardiac arrest depend on early and high-quality cardiopulmonary resuscitation (CPR). Our aim is to verify whether the use of feedback devices during laypersons' CPR training improves chest compression quality.

Methods: Laypersons totalling 450 participating in Basic Life Support and Automated External Defibrillation (BLS/AED) courses were randomly divided into three groups: group No Feedback (NF) attended a course without any feedback, group Short Feedback (SF) a course with 1-minute training with real-time visual feedback, and group Long Feedback (LF) a course with 10-minute training with real-time visual feedback. At the end of each course, we recorded 1 minute of compression-only CPR. The primary end point was the difference in the percentage of compressions performed with correct depth.

Results: There was a significant improvement in the percentage of compressions with correct depth in the groups receiving feedback compared to the other (NF v. LF, $p = 0.022$; NF v. SF, $p = 0.005$). This improvement was also present in the percentage of compressions with a complete chest recoil (71.7% in NF, 86.6% in SF, and 88.8% in LF; $p < 0.001$), compressions with the correct hand position (93.2% in NF, 98.2% in SF, and 99.3% in LF; $p < 0.001$), and in the Total CPR Score (79.4% in NF, 90.2% in SF, and 92.5% in LF; $p < 0.001$). There were no significant differences for all of the parameters between group SF and group LF.

Conclusions: Real-time visual feedback improves laypersons' CPR quality, and we suggest its use in every BLS/AED course for laypersons because it can help achieve the goals emphasized by the International Liaison Committee on Resuscitation recommendations.

RÉSUMÉ

Objectif: Les chances de survie à la suite d'un arrêt cardiaque survenu dans la collectivité dépend de la rapidité des manœuvres de réanimation cardiorespiratoire (RCR) ainsi que de leur qualité. L'étude décrite ici visait à vérifier si l'utilisation de dispositifs de rétroaction durant la formation des profanes en la matière pouvait améliorer la qualité des compressions thoraciques.

Méthode: Ont participé à des cours de réanimation de base et de défibrillation 450 profanes en la matière, divisés au hasard en trois groupes : le premier a suivi le cours sans rétroaction (SR) aucune; le deuxième a suivi le cours avec une brève rétroaction (BR), soit 1 minute de formation avec une rétroaction visuelle en temps réel; et le troisième a suivi le cours avec une longue rétroaction (LR), soit 10 minutes de formation avec une rétroaction visuelle en temps réel. À la fin de chacun des cours, il y a eu enregistrement des compressions seules durant 1 min. Le principal critère d'évaluation était les différences de pourcentage quant aux compressions réalisées à la bonne profondeur.

Résultats: Une amélioration sensible du pourcentage des compressions réalisées à la bonne profondeur a été observée dans les groupes dans lesquels il y avait eu de la rétroaction comparativement à celui qui n'en avait pas reçu (SR contre [c.] LR : $p = 0,022$ et SR c. BR : $p = 0,005$). L'amélioration a aussi été relevée dans le pourcentage des compressions suivies d'une expansion complète de la cage thoracique (71,7 % dans SR; 86,6 % dans BR et 88,8 % dans LR; $p < 0,001$), dans le pourcentage des compressions effectuées avec les mains en bonne position (93,2 % dans SR; 98,2 % dans BR et 99,3 % dans LR; $p < 0,001$) ainsi que dans le *Total CPR score* (79,4 % dans SR; 90,2 % dans BR et 92,5 % dans LR; $p < 0,001$). Enfin, aucun des paramètres n'a connu d'écart important entre le groupe de la BR et le groupe de la LR.

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Conclusions: La rétroaction visuelle en temps réel améliore la qualité des manœuvres de RCR chez les profanes en la matière, et nous en recommandons l'usage dans tous les cours de réanimation de base et de défibrillation offerts aux personnes profanes en la matière, ce moyen pouvant aider à atteindre les objectifs sur lesquels on insistait dans les

recommandations de l'ILCOR (International Liaison Committee on Resuscitation).

Keywords: cardiac arrest, cardiopulmonary resuscitation, education, feedback devices, first responders, laypersons, training

INTRODUCTION

Nearly 1 in 1,000 people every year will succumb to an out-of-hospital cardiac arrest (OHCA)^{1,2} with a mean survival rate at hospital discharge of about 7%.^{3,4} The chance of survival following OHCA depends on the "chain of survival"⁵ concept as well as the steps taken in the first few minutes following the event. With better implementation of the links of this chain, cardiac arrest survival can be improved.⁶ Early and high quality cardiopulmonary resuscitation (CPR) has been shown to greatly improve the survival rate of cardiac arrest victims,^{7,8} as indicated by American Heart Association (AHA) guidelines changes from 2005 to date.⁹⁻¹¹ For this reason, the 2015 Guidelines for Cardiopulmonary Resuscitation stress the importance of performing high quality CPR immediately after a cardiac arrest. Both laypersons and health care providers, in fact, are recommended to compress the adult chest at a rate of at least 100 compressions per minute (not exceeding 120) with a compression depth of at least 5 cm (not exceeding 6 cm); rescuers should also allow complete chest recoil after each compression and attempt to minimize frequency and duration of interruptions in compressions.^{11,12} Many factors contribute to CPR quality: individual factors, training, awareness, technique, and rescuer fatigue¹³; however, data about laypersons' CPR quality are scarce. Furthermore, the International Liaison Committee on Resuscitation (ILCOR) 2010 recommendations, in the education knowledge gaps section, underlined the lack of a specific technique to optimize chest recoil,¹⁴ and this point remained unsolved in ILCOR 2015 recommendations.¹⁵ Instructor assessment of chest compression quality during training has been demonstrated to be not accurate enough.¹⁶ For this reason, in the last few years, many types of CPR feedback devices have been developed, and their use has been demonstrated to increase the quality of health care providers' CPR during both training¹⁷⁻²⁴ and in real-life cardiac arrest scenarios.²⁵ Recent evidence has also shown that

real-time audiovisual feedback used during a real cardiac arrest increases the survival rate and the chances of a favourable outcome following OHCA.^{26,27} Regarding laypersons, one study demonstrated that CPR quality is improved during the use of feedback devices²⁸; however, there are only a few non-randomized studies regarding the use of such devices during laypersons' training, and their results are controversial.²⁹⁻³¹ Moreover, the optimal duration of feedback device use is unknown.³²⁻³⁴ The aim of this study is to determine whether the use of a CPR feedback device improves laypersons' CPR quality after the completion of a training course and, secondarily, to determine whether final quality is related to how long the feedback device is used in training.

METHODS

Study design

We performed a randomized, controlled manikin study. Regarding the blinding method, participants and instructors knew the time spent using a feedback device for each participant, but the instructors did not know which were the study endpoints and the statistical analysis were blinded (statisticians did not know which group they were analysing). We submitted the study to a regional ethics committee for medical research that considered it exempt from evaluation, in accordance with Italian law, because the study did not include the use of drugs or medical devices, and it was not directly related to health and illness of the participants. We obtained a written consent for study participation from all participants.

Study setting and population

The study was conducted at the two IRC-Comunità Training Centers of the nonprofit associations Pavia nel Cuore (Via de Canistris 7, Pavia, Italy) and Robbio nel

Cuore (Via Mortara 5, Robbio, Pavia, Italy). Volunteers were recruited during our BLS/AED free courses; the courses were promoted by the local newspaper and on social networks (Facebook, Twitter). Laypersons over 18 years old with no previous training in CPR were eligible for randomization. Each participant was asked to supply demographic data (i.e., gender, age, weight, and height), and body mass index was also calculated for each participant. We informed all of the participants that we would have evaluated their performance for scientific purposes only. No identifying data were collected. Enrolment was conducted from March 2013 to September 2014, and a total of 450 participants were included in the study.

Study protocol

Participants were randomly divided into three groups (Group NF for no feedback, Group SF for short feedback, and Group LF for long feedback) with an allocation ratio of 1:1:1 with a randomization list created with Research Randomizer (Urbaniak G. C. & Plous S., Research Randomizer Version 4.0; www.randomizer.org) using permuted blocks of 6. A CONSORT diagram is displayed in Figure 1.

Each group attended one of three different types of 5-hour BLS/AED courses (Group NF attended Course NF, Group SF attended Course SF, and Group LF attended Course LF), and all performed according to the 2010 ILCOR recommendations. Every course consisted of 1 hour of theory and 4 hours of practice with an instructor:attendees:manikin ratio of 1:5:1 and

maximum ratio of 1:6:1. The only difference among the courses was the amount of time spent training with feedback, in particular, as follows:

- Course NF: simple BLS/AED course without any feedback
- Course SF: BLS/AED course with 1 minute of training with real-time visual feedback manikin
- Course LF: BLS/AED course with 10 minutes of training with real-time visual feedback manikin

The manikin used for the three courses was Laerdal Little Anne (Laerdal Medical, Inc., AS, Norway). The real-time visual feedback on compression depth, compression rate, chest recoil, and the correct hand position was provided by the Resusci Anne Wireless SkillReporter software, version 1.1.0.20 (Laerdal Medical, Inc., AS, Norway) connected to the Laerdal Resusci Anne Wireless SkillReporter manikin (Laerdal Medical, Inc., AS, Norway), as shown in Figure 2. At the end of each course, we recorded 1 minute of compression-only CPR using the same software and the same manikin, without visual feedback for the attendee. We chose the duration of 1 minute to minimize the deterioration of chest compression quality as a result of fatigue, according to the results from Nishiyama et al.³⁵ To avoid any difference in results, as a result of using different manikins, Group NF and Group SF used the Resusci Anne Wireless SkillReporter manikin without any feedback for 10 and 9 minutes, respectively, during the course. This was done to ensure that all groups used this type of manikin for the same amount of time.

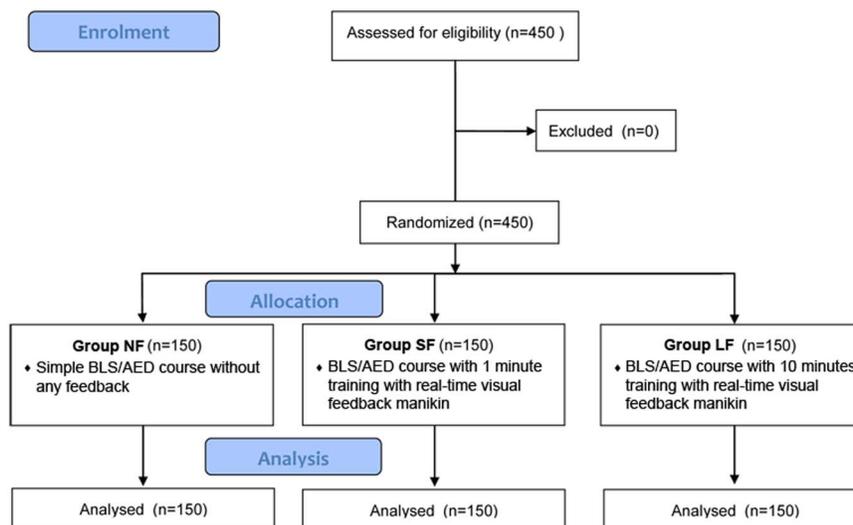


Figure 1. Flow chart of design and recruitment of participants according to 2010 CONSORT statement.

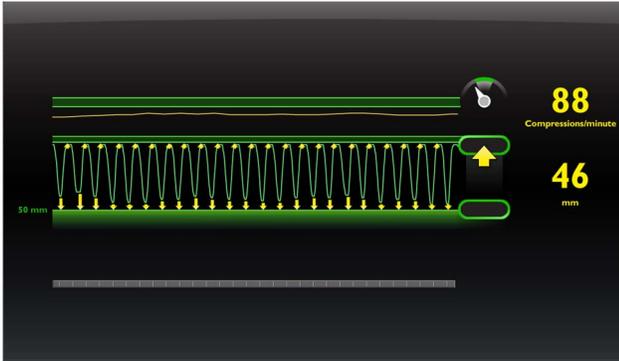


Figure 2. Screenshot representing the real-time visual given by the Resusci Anne Wireless SkillReporter software: the yellow arrows reveal inadequate depth or incomplete chest recoil, whilst, in the top, the compression rate is represented by both a number and a continuous line.

Measurements

For each participant, we analysed the percentage of compressions with correct depth (50 mm–60 mm), the percentage of correctly released compressions, the percentage of compressions with the correct hand position, the number of compressions, and the Total CPR Score. Total CPR Score is a comprehensive scoring algorithm developed by Laerdal in close collaboration with members of the AHA Emergency Cardiovascular Care Subcommittees and co-authors of the 2013 AHA Consensus Statement on CPR Quality. This score ranges from 0% to 100% and reflects the adherence to guidelines; the score decreases gradually as the performance deviates from the guidelines.

The primary end point was the difference in the percentage of compressions with correct depth (50 mm–60 mm) among the groups. Secondary end points were the differences in the percentage of correctly released compressions, in the percentage of compressions with correct hand position, in the compression rate, and in the Total CPR Score among the groups.

Data analysis

All data were entered in anonymous form into a database (Microsoft Excel 2010) and then analysed with SPSS 19.0 Windows version (SPSS Inc., Armonk, New York). We evaluated differences among the groups using the analysis of variance (ANOVA) with the Fisher's least significant difference (LSD) correction for the post-hoc comparison. All continuous variables are

expressed as means with their 95% confidence intervals. A p -value < 0.05 was defined as statistically significant. The sample size calculation was based on the comparison of the primary end point in the three groups; we did not perform earlier studies that would have been useful as a basis for a sample size calculation; therefore, based on previous studies,^{36–38} we wanted to adequately detect a mean paired difference of 0.7 times the standard deviation. Based on an $\alpha = 0.05$ and a power of 80%, a sample size of 37 study participants per group was needed. The enrolment of the participants was easier than expected, and we had no logistic problems in increasing the number of our study population. Therefore, we decided to reach the number of 450 participants to improve the power of our study. We also performed an analysis on the first 37 laypersons enrolled for each group (111 participants) to verify whether our primary end point was satisfied finding a statistically significant difference in the percentage of compressions with correct depth (overall $p = 0.017$). We performed all of the analyses shown in the results on the entire sample ($n = 450$).

RESULTS

Demographic characteristics of the population

We compared the demographic variables of the three groups to verify whether there were any differences that could influence the results. As shown in Table 1, there were no differences among the three groups.

ANOVA among the groups and Fisher's LSD post-hoc comparisons for the primary end point

We found a statistically significant difference among the three groups for the percentage of compressions with correct depth (overall $p = 0.012$), for the percentage of compressions with complete chest recoil (overall $p < 0.001$), for the percentage of compressions with correct hand position (overall $p < 0.001$), and for Total CPR Score (overall $p < 0.001$). We did not find any difference among the three groups for the compression rate (overall $p = 0.529$). The Fisher's LSD post-hoc comparisons among the three groups for the percentage of compressions with correct depth showed a statistically significant difference between groups NF and SF ($p = 0.005$) and between groups NF and LF

Table 1. Comparison of the demographic characteristics of the three groups

	Group NF (n = 150)	Group SF (n = 150)	Group LF (n = 150)	p values
Height (cm)	172.7 (95% CI, 171.3-174.1)	171.6 (95% CI, 170.4-173.2)	171.8 (95% CI, 170.1-173.1)	0.931
Age (years)	37 (95% CI, 34-39)	37 (95% CI, 34-38)	36 (95% CI, 35-38)	0.993
Weight (kg)	71 (95% CI, 68.8-73.2)	70.8 (95% CI, 68.8-73.1)	70.9 (95% CI, 68.9-72.8)	0.518
BMI (kg/cm ²)	23.7 (95% CI, 23.1-24.3)	24 (95% CI, 23.4-24.4)	23.9 (95% CI, 23.4-24.5)	0.755

CI = confidence interval; LF = long feedback; NF = no feedback; SF = short feedback.

($p = 0.022$), but not between groups SF and LF ($p = 0.601$) (Table 2).

DISCUSSION

Current evidences about the feedback devices

It has been well demonstrated that feedback devices improve health care providers' CPR quality during both training¹⁷⁻²⁴ and in real-life scenarios.²⁵ ILCOR 2015 recommendations pointed out the importance of high-quality CPR performed not only by health care providers but also by laypersons, who are often the first bystanders in the setting of OHCA.¹⁵ However, teaching high-quality CPR to laypersons is often a considerable challenge for an emergency medical services (EMS) medical director and BLS/AED course instructor, probably mainly because laypersons have had no experience of CPR prior to the course. Moreover, as demonstrated by Brennan et al.,¹⁶ it is difficult for the instructors to be accurate during an assessment of chest compression quality, and feedback devices can serve as a helpful tool. In literature, studies regarding the use of feedback devices by laypersons are scarce, and their results are controversial. Krasteva et al.²⁹ in 2011 and González-Salvado et al.³⁰ in 2016 demonstrated that these devices can help improve the CPR performance of laypersons while training on a manikin; their results, however, were not confirmed by Pavo et al.³¹ who showed that human feedback and feedback by audiovisual devices are equal in effectiveness. Therefore, the utility of feedback devices over human feedback in teaching CPR to laypersons is currently unclear, and there are no randomized studies on this topic. Our present study describes an

intervention that may improve the quality of CPR by layperson bystanders, which, in turn, may be a life-saving method for someone who experiences an OHCA.

Discussion of the study results

There was a statistically significant improvement in all of the parameters, except for compression rate, in the groups receiving real-time visual feedback during BLS/AED training compared to the group not receiving real-time visual feedback (see Table 2). Regarding compression rate, it is interesting to notice that it does not seem to be affected by the incorporation of real-time visual feedback because all of the groups, including the NF group, reached the compression rate suggested by the guidelines (i.e., between 100 and 120 per minute). It is possible that a standard BLS/AED course is sufficient to achieve the correct compression rate and that feedback is not necessary to improve this parameter. Our study showed no significant differences between Group SF and Group LF in all of the parameters. Regarding methodology, it is important to point out that only a small group of well-trained IRC-Comunità-certified BLS/AED instructors was involved in this study, and all of the BLS/AED courses were performed using the same methodology (i.e., same slides, same syllabus), in the same place (i.e., the headquarters of the two associations), and at the same time of the day (weekend mornings) to minimize any teaching bias. Furthermore, we chose the duration of 1 minute to verify CPR quality after the course because, according to our reference,³⁵ a longer duration (i.e., 4 minutes, which is the mean arrival time of BLS provider with AED in the United States) could tire the participants unnecessarily considering that the goal of the study was only to verify whether the use of

Table 2. Comparison of the percentage of compressions with correct depth, the percentage of compressions with complete chest recoil, the percentage of compressions with correct hand position, the compression rate, and Total CPR Score among the groups

	Group			p-values			
	Group NF (n = 150)	Group SF (n = 150)	Group LF (n = 150)	ANOVA overall	Group NF v. Group SF ^a	Group NF v. Group LF ^a	Group SF v. Group LF ^a
Percentage (%) of compressions with correct depth	66.6 (95% CI, 60.1-73.1)	77.8 (95% CI, 72.8-82.8)	75.7 (95% CI, 70.7-80.8)	0.012	0.005	0.022	0.601
Percentage (%) of compressions with complete chest recoil	71.7 (95% CI, 66.2-77.2)	86.6 (95% CI, 82.4-90.8)	88.8 (95% CI, 85.6-92.2)	<0.001			
Percentage (%) of compressions with correct hand position	93.2 (95% CI, 89.7-96.6)	98.2 (95% CI, 96.7-99.8)	99.3 (95% CI, 98.6-100)	<0.001			
Compression rate (per minute)	119 (95% CI, 117-121)	117 (95% CI, 116-119)	118 (95% CI, 116-119)	0.592			
Total CPR Score (%)	79.4 (95% CI, 75.5-83.2)	90.2 (95% CI, 87.8-92.5)	92.5 (95% CI, 91-94)	<0.001			

ANOVA = analysis of variance; CI = confidence interval; LF = long feedback; NF = no feedback; SF = short feedback.
^aLSD corrected p-values are given.

feedback devices could improve CPR quality after a course. Given that the main difference among the courses was the use of feedback devices and how long they were used for, we infer that the differences in CPR performance among the three groups are the result of the real-time visual feedback. According to our results, we can also assume that just 1 minute per participant of real-time visual feedback is sufficient to improve CPR quality and, in the majority of the participants, to achieve the values established by the guidelines.

We think that many elements could be responsible for this improvement; real-time visual feedback allows laypersons not only to comprehend what the parameters established by the guidelines actually are, but also how to leverage their physical potential to achieve them. We also believe that participants could consider real-time visual feedback a challenge, motivating them to improve their performance and, therefore, reach the correct cut-off values. Moreover, one of our most interesting results is that this type of feedback considerably improves the percentage of compressions performed with complete chest recoil, filling in one of the knowledge gaps established by ILCOR 2010 recommendations,¹⁴ which remained unsolved in the ILCOR 2015 recommendations.¹⁵ Another point favouring these devices is that they are simple to use and that they do not require any specific skills other than those that a BLS/AED instructor already has besides basic knowledge of the software provided with the manikin.

In summary, our study is the largest randomized controlled manikin study regarding the use of real-time visual feedback during CPR training for laypersons carried out to date. Our results show that the use of such devices during BLS/AED courses improves the majority of measurable parameters of CPR and, therefore, the capability of laypersons to reach a high-quality CPR at the end of the course. This could have wide-ranging implications for EMS medical directors, BLS/AED course instructors, and coordinators involved in training laypersons in CPR who might consider to incorporate at least 1 minute of real-time visual feedback for all of the participants in their classes (if this technology is available) to help attendees achieve the goals emphasized by ILCOR 2015 recommendations.

Nonetheless, further investigations into the use of feedback in retraining and into the long-term efficacy of using such devices during CPR training are required.

If further studies confirm that this CPR quality improvement is retained 6 months and 1 year after a course, this intervention could be a simple and inexpensive way to improve bystander chest compression quality, which subsequently may lead to an improvement in OHCA survival, if widely adopted.

STUDY LIMITATIONS

The principal limitation of this study is that it was conducted using manikins; there is no direct evidence that the use of real-time visual feedback during CPR courses for laypersons improves patient outcome after OHCA. Nonetheless, it has been proved that high-quality CPR improves the survival rate of cardiac arrest victims,⁷ and that training of health care providers with feedback devices improves survival rates after OHCA.^{23,24} We can therefore assume that better training of laypersons using feedback devices may positively affect survival rates after OHCA.

Another weakness of our study is that we did not collect long-term follow-up data about the participants' CPR quality over the subsequent weeks to months. Further investigations are required to estimate the permanence of the effect of such devices during CPR training.

CONCLUSION

The use of real-time visual feedback in BLS/AED courses for laypersons improves the CPR quality of the participants and their adherence to guidelines. In particular, 1 minute of real-time visual feedback seems to be sufficient for laypersons to reach a better CPR quality. Although further study is needed, it is reasonable to consider the use of feedback devices in all BLS/AED courses for laypersons.

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Competing interests: None declared.

SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit <http://dx.doi.org/10.1017/cem.2016.410>

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