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Simulation and education

Combining video instruction followed by voice feedback in a self-learning station for acquisition of Basic Life Support skills: A randomised non-inferiority trial☆

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ABSTRACT

Introduction: Current computerised self-learning (SL) stations for Basic Life Support (BLS) are an alternative to instructor-led (IL) refresher training but are not intended for initial skill acquisition. We developed a SL station for initial skill acquisition and evaluated its efficacy.
Methods: In a non-inferiority trial, 120 pharmacy students were randomised to IL small group training or individual training in a SL station. In the IL group, instructors demonstrated the skills and provided feedback. In the SL group a shortened Mini Anne™ video, to acquire the skills, was followed by Resusci Anne Skills Station™ software (both Laerdal, Norway) with voice feedback for further refinement. Testing was performed individually, respecting a seven week interval after training for every student.
Results: One hundred and seventeen participants were assessed (three drop-outs). The proportion of students achieving a mean compression depth 40–50 mm was 24/56 (43%) IL vs. 31/61 (51%) SL and 39/56 (70%) IL vs. 48/61 (79%) SL for a mean compression depth ≥40 mm. Compression rate 80–120/min was achieved in 49/56 (88%) IL vs. 57/61 (93%) SL and any incomplete release (≥5 mm) was observed in 31/56 (55%) IL and 35/61 (57%) SL. Adequate mean ventilation volume (400–1000 ml) was achieved in 29/56 (52%) IL vs. 36/61 (59%) SL. Non-inferiority was confirmed for depth and although inconclusive, other areas came close to demonstrate it.
Conclusions: Compression skills acquired in a SL station combining video-instruction with training using voice feedback were not inferior to IL training.

1. Introduction

For initial acquisition of Basic Life Support (BLS) skills, the European Resuscitation Council (ERC) Guidelines 2005 recommend training in small instructor-led (IL) groups with hands-on practice.[1] Recent studies indicate that training with a video or an interactive CD can be an alternative to traditional IL courses.[2–8]

The Mini Anne™ Self Directed Learning CPR program (Laerdal, Norway) is an effective method using a video to acquire the core skills of CPR.[5,9] It uses a “practice-while-watching” technique with learners practising CPR on a personal manikin (Mini Anne™) while watching the skills being demonstrated on a video. On the other hand, the Resusci Anne (RA) Skills Station™ (Laerdal, Norway) has been shown a feasible strategy for BLS refresher training.[10–14] The RA Skills Station™ provides self-directed BLS skill training with concurrent voice feedback during training. In addition it enables automatic recording and storage of performance data.

The goal of the current study was to develop a self-learning (SL) station for initial skill acquisition. Because the RA Skills Station™ is designed for refresher training only, a modification to enable initial skill acquisition was required. We therefore combined a Mini Anne™ approach with the RA Skills Station™ sequentially in one SL session and compared this new SL method with IL training. Given the available evidence underpinning the efficacy of IL small group training, we adopted a non-inferiority research design.[1,15] We hypothesized that training in a computerised SL station would result in at least equal BLS skill mastery as compared to IL training.

2. Research methods

2.1. Participants

The Ethics Committee of Ghent University Hospital approved the study. During the academic year 2009–2010, after obtaining

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informed consent, 120 third year pharmacy students were randomly assigned to IL group training (maximum six students) or individual training in a SL station using an online Research Randomizer software tool (http://www.randomizer.org/). No exclusion criteria were applied before randomisation and no stratification was performed. Participation in the study was voluntary and the students were informed that non-participation would not influence their grades.

2.2. Research procedure

At Ghent University, CPR training is a mandatory part of the pharmacy student's curriculum, and consists of a lecture followed by an IL training session. To introduce SL in the curriculum, we intended to change the practical IL part of the course to computer-guided learning, while keeping the lecture (90 min) to provide background on the techniques of BLS and to motivate students for the practical training. After the lecture, a SL station was made available in a small room secured with a badge reader, accessible 24 h a day and seven days a week. During a 12-week study period each student could exercise for 1 h with the option to attend a second time.

Since the RA Skills Station^{TM} was originally developed for refresher training, we needed to adapt it to teach initial skill acquisition. A step-by-step explanation and demonstration (Mini Anne^{TM}), in line with cognitive instructional design guidelines, was therefore introduced.[16,17] As such, the SL station included one computer showing an edited Mini Anne^{TM} video and a second computer running RA Skills Station software^{TM} version 2.0 connected to an "RA torso" manikin (Laerdal, Norway). The Mini Anne^{TM} video was edited by adding an introduction sequence (explaining the concept of the video and demonstrating the use of a face shield) and by removing repetitive sequences. The resulting video (duration 20 min) contained instruction and demonstration on the core CPR skills including compression, ventilation and combined CPR exercises.

After entering the room, participants first followed the edited Mini Anne^{TM} video, while practising on the RA manikin using a face shield. After completion, they were directed to login on the second computer providing visual and voice instructions during further training on the manikin. The Skills Station^{TM} exercises were presented in three parts: compressions, ventilations and full CPR. During the exercises, the computer provided concurrent voice feedback.

The computer registered performance of chest compression depth, rate, incomplete release and ventilation volume. The manikin's feedback as well as evaluation limits for compression rate and incomplete release was used as set by the manufacturer: rate 90–115/min, incomplete release $\geq$5 mm. For the feedback of CPR, cycles of 27–35 compressions and 1–4 ventilations were considered acceptable. For compression depth, our previous experiences with the SL station had shown that voice feedback using compression depth margins according to the guidelines induced learners to avoid deep compressions, leading to superficial compressions during retention testing.[18] We therefore applied an upper limit of 55 mm before the voice prompt "compressions to deep" was activated. The IL group was taught compression depth as usual, because we wanted this to serve as a true control without changing our standard way of teaching. For ventilation volume we selected a range of 400–1000 ml, because the chest of the manikin visibly rises after insufflation of 400 ml. The upper limit of 1000 ml was arbitrarily chosen.

Participants could repeat exercises but they were not obliged to take all exercises or to spend a minimum of time per exercise. After every exercise a score (automatically calculated by the Skills Station^{TM} software, according to the limits), accompanied by specific feedback was communicated on-screen to the participant. To pass the compression exercise 90 compressions were required with minimum 70% correct, for the ventilation exercise 12 ventilations were required with minimum 70% correct. For the combined CPR exercise 3 cycles of CPR were required with a minimum of 90 compressions (of which 70% correct) and a minimum of 6 ventilations (of which 70% correct).

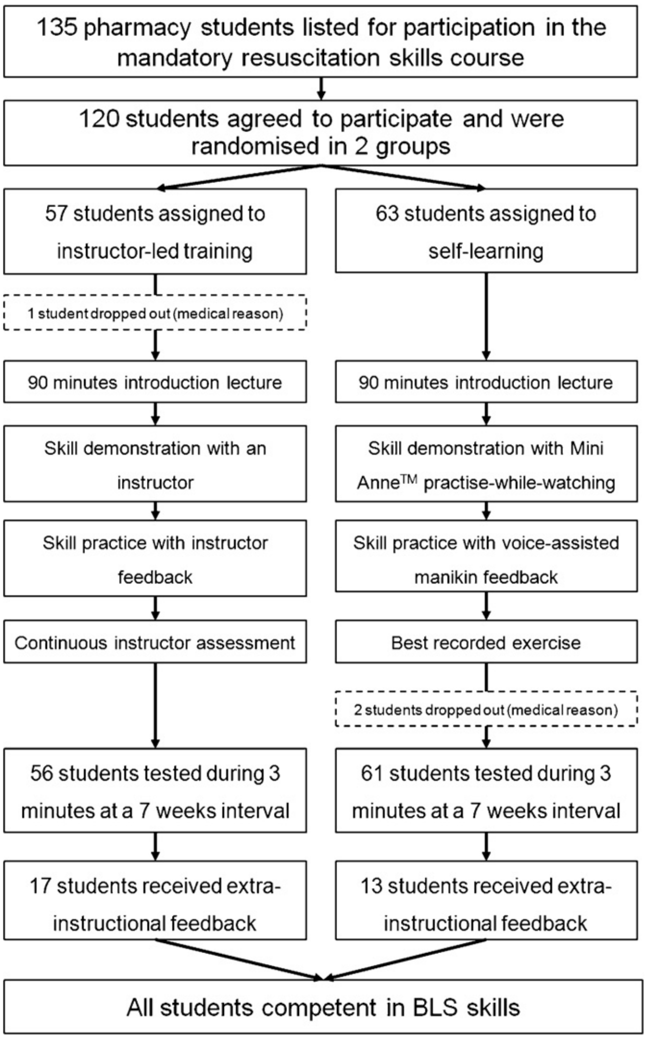

Fig. 1. Participants flow chart.

In the IL group, students attended a traditional BLS course where an ERC-certified BLS instructor trained them on a manikin in groups with a maximum of six participants. Each group session lasted no more than 90 min. The introduction to CPR was similar to the content of the Mini Anne^{TM} video used in the SL condition, followed by exercising on a "RA torso" manikin (Laerdal, Norway) without indicator lights, metronome or voice feedback. Individual instructor feedback was given, focussing on correct compression and ventilation techniques according to the ERC guidelines. Continuous performance assessment was carried out by the instructors with further practice and sufficient individual manikin exposure until every student was judged to be adequately trained (i.e. competent to perform BLS). No test was taken at the end of the course. The participant flow chart is shown in Fig. 1.

Respecting a seven week interval after initial training for every student, testing was done individually in a room with a RA manikin connected to a laptop computer equipped with the same RA Skills Station^{TM} software as during SL training, but with feedback disabled. An ERC BLS instructor welcomed the student and informed him that the test would consist of resuscitating a victim (i.e. the manikin) who just collapsed. No further information was given, except for the condition of the manikin, which was communicated after each appropriate assessment by the rescuer. The test protocol was consistent with the Utstein objective of "demonstrable lifesaving CPR on a manikin in a simulated scenario after the training course" and was similar to that used in other studies.[2–4,19] Participants were then given 3 min to perform CPR skills (without concurrent feedback). Skills were registered by the RA Skills Station™ software capturing data on compression depth and rate, on incomplete release and ventilation volume.[20] The instructor scored the participants overall performance as competent or not yet competent. After testing, "not yet competent" students were given extra-instructional feedback by the instructor with further practice in order to ensure skill mastery (i.e. "competent") in all students at the end of the study (Fig. 1).

2.3. Objectives and outcome measures

The trial was designed to determine whether the individual SL training method for initial skills acquisition was as effective (i.e. non-inferior) as conventional IL training. Four quality indicators related to BLS mastery were defined: compression depth, compression rate, incomplete release and ventilation volume.

Proportions in relation to the quality indicators were used as outcome measures to assess differences in BLS mastery: proportion of participants with mean compression depth 40–50 mm, proportion of participants with mean compression depth ≥40 mm, proportion of participants with mean compression rate 80–120/min, proportion of participants with any incomplete release (≥5 mm) and proportion of participants with mean ventilation volume 400–1000 ml.

For the outcome measures, the null hypothesis (H_0) stated that SL training was inferior to IL training measured seven weeks after training. To establish non-inferiority the upper limit of the 90% confidence interval (CI) needed to fall below the predefined non-inferiority margin. Comparing proportions, a difference of 10% was defined as non-inferior. Previous results from our research group reported a success rate for IL training of 56% for mean compression depth 40–50 mm, 62% for mean compression depth ≥40 mm, 70% for mean compression rate 80–120/min and 75% for mean ventilation volume 400–1000 ml.[21] A 46–50% rate of incomplete release is reported in literature.[22–24] This means that the 90% CI for the odds ratio for IL vs. SL training should not exceed 1.49 for compression depth 40–50 mm; 1.51 for compression depth ≥40 mm, 1.56 for mean compression rate 80–120/min and 1.62 for mean ventilation volume 400–1000 ml. For incomplete release, the lower limit of the 90% CI for the odds ratio should not fall below 0.67. In addition, for the SL group, performance at the end of training and seven weeks later was compared.

2.4. Statistical methods

Differences in odds between both training conditions (IL and SL) for proportional BLS quality indicators were analysed by multiple logistic regression analysis, correcting for gender, height, weight and previous BLS training.[21,25] Non-inferiority criteria for the odds ratio for proportional BLS quality indicators were evaluated based on two-sided 90% CI instead of 95% CI for the purpose of a 1-sided test.[15] Performance at the end of training and after seven weeks in the SL group was compared using a McNemar test. Values are presented as counts (proportions) or means with standard deviation. Statistical analyses were performed using PASW® statistics 18 for Windows (SPSS Inc. Chicago, USA).

Table 1
Characteristics of students randomised to instructor-led (IL) or self-learning (SL) groups. Values represented as means (SD) or counts (proportions).

	IL (n = 57)	SL (n = 63)
Age (years)	21 (2)	21 (1)
Females	50 (88%)	44 (70%)
Height (cm)	170 (7)	173 (8)
Weight (kg)	61 (9)	64 (10)
Previous BLS training	9 (16%)	12 (19%)
Time since last training (months)	48 (31)	64 (30)

3. Results

3.1. Recruitment and baseline data

One hundred and twenty of 135 eligible students agreed to participate in the study and gave informed consent. The IL and the SL group respectively consisted of 88% and 70% female students and mean age was 21 years in both groups (Table 1). Twenty-one students, nine IL and 12 SL, reported previous BLS training. After randomisation, 56 students were trained in the IL condition (one student fell ill) and 63 in the SL condition. After seven weeks 56 IL and 61 SL students (two were ill) were tested (Fig. 1). After the retention test 17 IL and 13 SL students received extra instructional feedback and practice in order to become competent at the end of the course (Fig. 1).

3.2. Comparison of BLS quality between the two groups

After correction for gender, height, weight and previous BLS training, the adjusted two-sided 90% CI for the odds ratio of good mean compression depth 40–50 mm was (0.37–1.32) and therefore below the non-inferiority margin of 1.49, establishing non-inferiority (Table 2). Further, the adjusted proportion of students achieving a mean compression depth ≥40 mm was 9% higher in the IL condition. The odds ratio for good mean compression depth ≥40 mm was 0.73 and the corresponding 90% CI for the odds ratio (0.35–1.51) had the non-inferiority margin of 1.51 as its upper bound. The two-sided 90% CI for the odds ratio of good mean compression rate 80–120/min was (0.17–1.57) and therefore included the non-inferiority margin of 1.56. For incomplete release, with the lower bound of the 90% CI for the odds ratio (0.52–1.84) falling below the non-inferiority margin of 0.67 there was insufficient evidence to establish non-inferiority. The adjusted odds ratio for good mean ventilation volume 400–1000 ml was 0.85, in favour of the SL condition, and the upper bound of the corresponding 90% CI for the odds ratio (0.44–1.62) equalled the non-inferiority margin of 1.62.

3.3. Differences between end of training and retention data for SL group

In the SL station, the proportion of participants achieving a mean compression depth of 40–50 mm was 50/61 (82%) at the end of training and 31/61 (51%) after seven weeks ($P < 0.001$). For a depth ≥40 mm, this was 60/61 (98%) and 48/61 (79%), respectively ($P = 0.002$).

The proportion of participants achieving a mean compression rate 80–120/min was 61/61 (100%) at the end of training and 57/61 (93%) at seven weeks ($P = 0.13$). The proportions of participants with any incomplete release were similar after training 37/61 (61%) and at seven weeks 35/61 (57%) ($P = 0.84$). The proportion of participants with a ventilation volume 400–1000 ml was 60/61 (98%) and 36/61 (59%), respectively ($P < 0.001$). At the end of SL training, one student did not achieve adequate depth and another one did not achieve adequate ventilation volume. These two participants returned for a second training session.

Table 2
Results seven weeks after training.

	IL ($n = 56$)	SL ($n = 61$)						
	Number of participants (%)	Number of participants (%)	Non inferiority margin[a]	Unadjusted odds ratio (90% CI)	Result	Adjusted[b] odds ratio (90% CI)	Result	*P*-value
Mean compression depth 40–50 mm	24 (43)	31 (51)	1.49	0.73 (0.39;1.34)	Non inferior	0.70 (0.37;1.32)	Non inferior	0.35
Mean compression depth ≥40 mm	39 (70)	48 (79)	1.51	0.62 (0.31;1.25)	Non inferior	0.73 (0.35;1.51)	Inconcl.	0.48
Mean compression rate 80–120/min	49 (88)	57 (93)	1.56	0.49 (0.17;1.45)	Non inferior	0.51 (0.17;1.57)	Inconcl.	0.33
Any incomplete release ≥5 mm	31 (55)	35 (57)	0.67	0.92 (0.50;1.70)	Inconcl.	0.97 (0.52;1.84)	Inconcl.	0.94
Mean ventilation volume 400–1000 ml	29 (52)	36 (59)	1.62	0.75 (0.40;1.38)	Non inferior	0.85 (0.44;1.62)	Inconcl.	0.67

Inconcl. = inconclusive.
[a] To establish non-inferiority the upper limit of the 90% CI needed to fall below the predefined non-inferiority margin, for any incomplete release the lower limit of the 90% confidence interval for the odds ratio should not fall below 0.67.
[b] Adjusted for gender, height, weight and previous BLS training.

4. Discussion

We developed a novel approach to acquire BLS skills in a SL station by combining a practice-while-watching technique with exercises using concurrent individualised feedback. The results demonstrate non-inferiority for the proportion of students reaching a compression depth between 40 and 50 mm. For the other proportions, formally, the test results were inconclusive but came very close to demonstrate it.

The concept of this method is that new skills are demonstrated by a virtual instructor while the student practises individually, followed by refinement of skills by concurrent voice feedback and textual feedback after every exercise, while performance is constantly registered. With a 98% success rate for compression and ventilation skills at the end of training (with voice feedback enabled), this new training method proved highly effective in a population with 17% previous BLS training. This also explains the fact that only two non-successful participants of the SL group had to return for a second training session.

Kardong-Edgren et al. are the only who studied training with voice feedback in combination with another learning method.[26] They compared a self-directed e-learning course for cognitive learning (the American Heart Association's HeartCode™ program) followed by psychomotor skills refinement, using a voice assisted manikin (Laerdal, Norway) with IL training in nursing students with previous BLS training. They reported that, immediately after training, 53% of all students' compressions had adequate depth (38–51 mm) and 46% of all bag-valve-mask ventilations had adequate volume (500–800 ml). Comparing their results with our data is difficult for two reasons. Our results at the end of training in the SL group were obtained with voice guidance and their population had a higher percentage of previously trained participants (92% vs. 17% in our sample).

Using only the Mini Anne™ video self-instruction method, Nielsen et al. reported adequate compression depth (40–50 mm) after 3.5–4 months in 30% and 78% (≥40 mm) of nursing students.[27] Their results may have been influenced by a pre-test which may have induced a learning effect.[28,29] Our higher percentage (51%) of students achieving depth 40–50 mm may be due to a shorter retention interval.[4] Another difference is that, in the Nielsen study, the Mini Anne™ was used during group-training with facilitators present which may also have resulted in an improved learning outcome due to instructor and peer facilitation. Facilitation by instructors and peers was also present in the study by Einspruch et al. who compared a traditional IL BLS course with a 20 min video self-instruction program used in three self-training groups (self-training alone, self-training with instructor facilitation, and self-training with peer facilitation).[4] The three self-learning groups were reported together, leading to proportions of adults (between the ages of 40 and 50 years and without CPR training for the past five years) achieving compressions with adequate depth (≥38 mm) of 38% during initial performance and 48% in a two-month retention test.[4] For self-training alone and considering compressions of ≥40 mm as adequate, our data shows better acquisition (98%) and retention (79%) at seven weeks. Perhaps our results at retention could even be underestimated in comparison to other studies that used a lower limit of 38 mm for adequate compression depth.[4–6,10–13,19,26]

Einspruch et al. additionally reported proportions of participants achieving adequate ventilations (≥700 ml) of 61% immediately after training and 41% after 2 months.[4] Our data show better acquisition (98%) and retention (59%) at seven weeks for good mean ventilation, but we used a lower margin of 400 ml.

Improved performance of our SL group at retention testing could be explained by the refinement of skills using concurrent voice feedback.[10,26] An alternative explanation for our good results might be age-related differences in attention span and memory capacity.[30] The mean age of the participants in the present study was 21 years, potentially resulting in better acquisition of skills, although Braslow et al. found that participants over 40 year performed compressions comparable to younger participants.[3] Finally, our study population consisted of pharmacy students who may have more motivation than the general population.

Taking into account ERC 2005 guidelines, the proportion of students achieving complete release, adequate mean compression depth and mean ventilation volume after seven weeks remained unsatisfactory in both conditions. This confirms previous research documenting poor retention of skills after both IL and self-directed or voice assisted manikin learning.[2,9,11,31] As an alternative to evaluate the student's compressions as adequate, all compressions ≥40 mm were considered as adequate (therefore including compressions of more than 50 mm). This analysis seems justified because deeper compression depths are in line with ILCOR 2005 treatment recommendations stating that it is reasonable for lay rescuers and healthcare providers to compress the sternum by "at least 4–5 cm".[32] Additionally, the ERC 2010 guidelines now recommend a compression depth of "at least 5 cm".[33]

Of the SL group 98% had a depth ≥40 mm after initial learning. After seven weeks this was 70% for IL vs. 79% for SL. The unsuccessful students needed extra-instructional feedback in order to become competent (Fig. 1). Therefore, we conclude that a single training session (IL or SL) was insufficient to retain BLS skills. Repetitive training and testing may be essential to consolidate new skills.[31]

Participants were not tested immediately after training because our standard course for pharmacy students used continuous assessment and not end-of-course assessment. Therefore decline in skills could not be analysed in the IL group. Pre-training testing (to control for potential BLS mastery differences before the intervention) and testing at the end of training (to assess the effect of the intervention) should be encouraged in future studies. However, testing on its own, may induce a learning effect and better retention.[27–29,31] A post hoc power analysis resulted in a power of 0.31 for compression depth 40–50 mm, 0.32 for compression depth ≥40 mm, 0.34 for rate 80–120/min, 0.29 for any incomplete release (≥5 mm) and 0.36 for ventilation volume 400–1000 ml. We therefore cannot rule out a Type-II error as the reason for some results being statistically inconclusive. We have studied skills after seven weeks and therefore conclusions on longer-term retention cannot be drawn. Also the use of a lecture before training limits the generalizability of the results. ERC 2010 guidelines are encouraging short video/computer self-instruction courses, with minimal or no instructor coaching, combined with hands-on practice as an effective alternative to instructor-led BLS courses, but several knowledge gaps need to be addressed.[34] This includes the contribution of each self-learning component (Mini Anne video, RA Skills Station) and additional mediating variables that play a role in learning performance (time on task, self-efficacy, cognitive load and quality and quantity of feedback).

5. Conclusions

Based on the proportion of students achieving adequate compression depth, skills acquired in a SL station combining video-instruction with training using voice feedback were not inferior to IL training. This study provides evidence supporting the use of a SL station for initial BLS skill acquisition.

Conflict of interest statement

Laerdal Medical (Stavanger, Norway) supported the study by providing the manikin, the face shields and the RA Skills Station™ software for the duration of the study. Laerdal Medical has taken no part in designing the study, analysing data or writing of the manuscript. The authors have received a grant from the Laerdal Foundation to conduct further research in this area.

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