FULL TITLE: **Acquiring basic life support skills in a self-learning station: video alone is not enough.**

RUNNING TITLE: **Basic life support skills acquisition in a self-learning station.**

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**Conflict of interest**

Laerdal (Stavanger, Norway) provided the manikin, the face shields and the Resusci Anne Skills Station™ licenses for the study. Laerdal has taken no part in designing the study, analysing the data or in writing or revising the manuscript. The authors received an unrestricted grant from the Laerdal Foundation.
ABSTRACT

Objectives
Since self-learning stations for cardiopulmonary resuscitation (CPR) were designed to refresh skills, we developed a self-learning station combining a video with computer exercises to learn CPR to novices. We assessed the efficacy of the different components and the impact of gender, height and weight on CPR acquisition.

Methods
One hundred and twenty-five pharmacy students were trained using learning-while-watching video instructions (Mini Anne™, Laerdal, Norway) followed by exercises with voice feedback (Resusci Anne Skills Station™, Laerdal, Norway). The proportion of students with adequate CPR skills was measured at baseline, after video training and after subsequent voice feedback training.

Results
Complete datasets were obtained for 104 students. After video training, compression depth ≥50mm was achieved in 36/104 students, compression rate 100-120/min in 77/104, ventilation volume 400-1000 ml in 44/104 and complete release <5mm in 40/104. Compared with baseline results, only rate (29/104 vs. 77/104) and ventilation volume (8/104 vs. 44/104) improved. After subsequent training with voice feedback the proportions were: compression depth 92/104, compression rate 77/104, ventilation volume 74/104 and complete release 58/104. Compared with the skill level after video training only compression rate did not further improve. Male gender was associated with better compression depth at baseline and after the video. After voice feedback exercises females improved compression depth to the level of males.

Conclusions
Although in a self-learning station video training can introduce CPR skills to novices, additional voice feedback exercises were needed to achieve acceptable CPR quality. Furthermore, voice feedback exercises are able to remove pre-training differences between genders.

**Key words:** Basic Life Support, Cardiopulmonary Resuscitation, Computer-assisted instruction, Education, Self-learning.
INTRODUCTION

International cardiopulmonary resuscitation (CPR) guidelines encourage short video/computer self-learning courses, with minimal or no instructor coaching.\textsuperscript{1} Various CPR self-learning programmes have been compared with instructor-led courses for training lay people and healthcare providers.\textsuperscript{2-14} Despite all efforts, general mastery of CPR skills remain disappointingly poor, establishing the need for the development of more effective training strategies.\textsuperscript{1,15-18} Since self-learning stations for CPR were initially designed for refreshing skills, we developed a self-learning station combining a Mini Anne\textsuperscript{TM} practice-while-watching video followed by voice feedback exercises (Resusci Anne Skills Station\textsuperscript{TM}, Laerdal, Norway) to teach CPR to novices.\textsuperscript{2}

In a previous study we showed that such a combined instructional strategy is non-inferior to instructor-led training for initial CPR skill acquisition in a self-learning station.\textsuperscript{2} Although this combined instructional self-learning strategy is still not superior for (re)training skills, it can be a valuable time-efficient alternative.\textsuperscript{2,19} Knowledge gaps, however, remain about the impact of each training component on skill acquisition in lay people.

In the present study we analysed the learning efficacy of the video-training component and the additional impact of subsequent voice feedback exercises on the acquisition of CPR skills. Since, according to the literature, male gender is associated with better quality of CPR, we additionally investigated the predictive value for success of potential co-variables such as gender, height and weight in relation to the target outcomes.\textsuperscript{20,21}
METHODS

At Ghent University CPR training is a mandatory part of the pharmacy student’s curriculum. A self-learning station, as described previously, was made available in a small room secured with a badge reader, accessible 24 hours a day, seven days a week. During a five-week study period each student was required to practice CPR for up to one hour. The students were informed that non-participation in the study would not influence their grades and the Ethics Committee of Ghent University Hospital approved the study. Students’ characteristics (age, gender, height and weight) were registered before the training.

At the beginning of the training an introduction video showing the correct use of a face shield was shown to every student, mentioning this would be mandatory for hygienic reasons. After this, and to establish baseline skill level an automated pre-test (T0) was taken, asking the students to try to resuscitate a cardiac arrest victim (Resusci Anne™ torso manikin, Laerdal, Norway) during a one-minute period. After the test, the students were trained in CPR using a combined learning strategy consisting of a practice-while-watching video (Mini Anne™, Laerdal, Norway) followed by computer exercises with concurrent voice feedback (Resusci Anne Skills Station™, Laerdal, Norway). Practising and testing was done on a full size manikin torso lying on the floor and using a face shield, while performance of chest compression depth, compression rate, complete release and ventilation volume was registered automatically. Feedback limits during training in the Skills Station™ were set as follows: for compressions at depth ≥50 mm (the physical upper compression limit of the manikin is 6 cm); for rate at 100-120/min; for ventilation limits at 400-1000 ml (because the chest of the manikin visibly rises after insufflation of at least 400 ml); for complete release at <5 mm.
To establish the impact of each training component, an automated three minutes test (without any feedback) was introduced after the practice-while-watching video (T1), as well as after the voice feedback exercises (T2; Fig. 1). Because separate compression quality indicators do not allow an overall pass or fail assessment in a SL station, we calculated a score combining compression depth, release and rate. To be able to provide effective CPR, we expected lay rescuers to achieve at least 70% of all compressions with correct depth and release as well as a rate between 100-120/min. In addition the outcome for this assessment score was explored using different pass levels. Students who did not achieve the expected competency level after the last test, were invited for additional instructor-facilitated training in the self-learning station.

**Objectives and outcome measures**

The primary aim of the study was to establish the impact of video learning and the additional impact of subsequent voice feedback exercises on four CPR quality indicators related to CPR mastery: compression depth, compression rate, complete release and ventilation volume.

Outcome measures included achievement of a mean compression depth ≥50 mm, a compression rate 100-120/min, a complete release (<5 mm) during all compressions and a mean ventilation volume 400-1000 ml. In addition, we also analysed how many students were able to achieve 70% or more compressions with a depth ≥50 mm, 70% or more compressions with complete release and 70% or more ventilations with a volume 400-1000ml.

**Statistical methods**
Regarding the proportional CPR quality indicators of both groups, performances at different stages of the training (T0, T1, T2) were compared. Confidence Intervals (CI) are reported for the differences between proportions. The use of a 95% Confidence Interval was chosen because it integrates sample size, effect difference and near significance of the findings all at once without the limitations imposed by a single P-value. For gender, CI’s are based on 2-sample tests for equality of proportions with continuity correction using software package R. For time, Wilson score CI for the difference between two correlated proportions were calculated using software package R (version 2.14.1).22

**RESULTS**

**Recruitment and baseline data**

During the academic year 2010-2011, 125 pharmacy students gave informed consent and were trained in a self-learning station. In the test procedures, a technical failure occurred during data registration of 21 students, resulting in incomplete data sets. There was no systematic variation to which subjects data were lost. Complete datasets were obtained from 104 students (Fig. 1). Student characteristics are described in Table 1. Subanalysis excluding all students with previous training did not show any significant differences in the results.

**Impact of the practice-while-watching video**

To analyse the learning efficacy of the video, the results of the one-minute pre-test (T0) were compared with the results from the first minute of the test after the video (T1). As shown in Table 2 the video only had a significant impact on compression
rate and ventilation skills. The proportion of students with adequate compression depth and complete release did not differ before and after the video (Table 2).

**Impact of the voice feedback exercises**

To analyse the additional impact of the voice feedback, the results from the first minute of the test after the video exercise (T1) were compared with the results from the first minute of the test after the voice feedback exercises (T2) and a significant improvement was observed for all compression and ventilation outcome measures, except for compression rate (Table 2).

**Interaction effects of student characteristics**

For the student characteristics significant interactions with CPR quality indicators could be observed for gender, height and weight. Being taller or weighing more was in favour of deeper compression depth at T0 and related to gender (men being on average 13 cm taller and 13 kg heavier than women). No additional interactions were observed for height and weight. In relation to gender no significant interactions were found with respect to compression rate and mean ventilation volume 400-1000 ml.

For compression depth female students performed worse than male students at T0 and at T1 (Table 4). In both genders, the proportion of students with adequate depth did not improve significantly after the video training (T1). However, this proportion increased significantly after the voice feedback exercises in both male and female students, and resulted in no significant differences between male (89%) and female students (88%) at T2 (-1% [-14%,15%]). The same was observed for ≥70% of all compressions ≥50 mm (Table 4).
For the variables describing complete release significant interactions between gender were found at T0, as well as at T1 for the variable “≥70% of compressions with complete release”. In contrast to compression depth, the proportion of women who succeeded was larger than the proportion of men (Table 4). Again all significant interaction effects due to gender disappeared after the voice feedback exercises (T2) and for the variable “≥70% of compressions with complete release”. This was due to the fact that significantly more men achieved ≥70% complete release (from 41% to 81%: +41% [16%,56%]), whereas no significant increase was observed for women (from 83% to 88%: +5% [-4%,15%]; Table 4).

**Combined assessment score for compression skills**

Based on the combination of percentage compressions with a depth ≥50 mm and percentage compressions with complete release and compression rate between 100-120/min, a “pass 70” score resulted in approximately 60% overall success rate. Additionally different combined assessment score thresholds were explored and are shown in Table 3.

**DISCUSSION**

We analysed the learning efficacy of a practice-while-watching video and the additional impact of subsequent training with voice feedback exercises on CPR skills acquisition in a self-learning station. To assess the quality of CPR performance, reporting proportions of successful students provides more information than reporting improvements of (group) mean values. Therefore we analysed and reported the proportion of successful participants for each important CPR component against a
pre-defined pass level. In order to allow some comparison with other studies mean values were also reported in the manuscript.

The integration of a video-based approach in our combined learning strategy builds on the reported benefits of interactive video instruction on general performance of CPR.\(^3\)\(^4\)\(^5\)\(^6\)\(^7\)\(^8\)\(^9\)\(^10\)\(^11\) Four studies assessing the efficacy of video training only report group means or mean percentages\(^3\)\(^6\), five studies report (mean) proportions of compression and ventilations\(^7\)\(^8\)\(^9\)\(^10\)\(^11\), and three studies report proportions of participants achieving a specific target.\(^12\)\(^13\)\(^14\) A systematic review by Mäkinen et al. in 2007 concluded that explicit comparable outcomes are needed to assess the quality of CPR.\(^24\) All studies show a general improvement in attitude towards CPR and an improvement in skills compared to traditional learning, although in most cases performance of CPR skills was not adequate. Saraç et al. reported that video self-instruction even resulted in weaker CPR performance compared to instructor-led training.\(^25\) Bobrow et al. analysed the influence of watching an ultra-brief video, a brief video and a brief video combined with psychomotor skill practice in lay people and found that all video groups successfully achieved a median chest compression rate within the target (90-100/min).\(^5\) Median compression depth did not differ between video groups (ultra-brief video: 41 mm; brief video: 42 mm; brief video with practice: 48 mm) and was significantly greater compared to the control group (30 mm). Moreover addition of practice-while-watching did not improve performance. In the Bobrow study median group values were reported (using ERC 2005 guidelines), which does not indicate the proportions of successful students or the number of correct compressions. In our study the practice-while-watching video only had a positive impact on the proportion of successful students with good compression rate
and good mean ventilation volume 400-1000 ml, although the absolute proportion for the latter was still low (42%). Considerable improvement in compression rate during the practice-while-watching video training can be explained by the continuous presence of a metronome sound. Jäntti et al. reported that metronome guidance used during manikin CPR corrected chest compression rate in experienced rescuers, but did not affect chest compression depth or rescuer fatigue.²⁶ Chung et al. observed that the average compression depth was significantly lower in metronome-guided CPR with the rate set at 100/min.²⁷ In our study metronome-guided practice-while-watching was not associated with improved compression depth. This could mean that watching someone performing compressions on a video does not provide sufficient information regarding the required depth and release. Nevertheless, our video intervention might have had an impact on other CPR skills such as opening the airway and correct hand placement, but we did not assess these particular skills.

Subsequent training with voice feedback resulted in significant improvement of all CPR quality indicators, except compression rate, in the majority of students. With 85% of the students delivering ≥70% of their compressions ≥50 mm, 87% delivering ≥70% of all their compressions with complete release and 74% achieving a compression rate between 100-120/min this combined learning approach proved very effective and confirms previous results obtained for initial CPR skills acquisition in a self-learning station.² The acquisition of ventilation skills, which is generally poor, was shown to be satisfactory in 71% of the students achieving a good mean ventilation volume and having ≥70% of all ventilations between 400 and 1000 ml. The significant improvement of the quality indicators after the subsequent voice feedback exercises is attributed to voice prompting.²⁸⁻³¹ An earlier study of voice-
assisted manikin feedback found that subjects receiving voice feedback during a 3-minute period of CPR not only performed better, but also maintained that level of performance in the second period without the feedback.\textsuperscript{30} The generally good performance at the end of the current study may also be partly attributed to the fact that repeated testing, even within a same training session, may induce a learning effect and better retention of skills.\textsuperscript{32-34} An alternative explanation for good performance in our young population might be an age-related advantage in attention span and memory capacity.\textsuperscript{35} However even in a young population it is generally accepted that skill decay occurs within three to six months after initial training. This was confirmed in our results, where previous CPR training was present in 14\% of the pharmacy students with an average time of 39 months since last training, but no differences could be observed as compared to the group of lay students.

With regard to gender, previous manikin studies demonstrated that female rescuers achieved fewer compressions with adequate depth.\textsuperscript{20,21,36} Our study however, showed that after voice feedback exercises female rescuers can “catch up” with male rescuers regarding compression depth. These findings could be attributed to the fact that women have relatively less muscle strength, resulting in more shallow compressions and more complete release at the start compared to men.\textsuperscript{37,38} After voice feedback training women achieved deeper compressions and men achieved more complete release. Therefore, voice feedback exercises appear to be a good strategy to further train and improve students that lack adequate skills mastery at the start and after video training. In view of community CPR training programs this finding is important with regard to the choice of the training method.
Although an overall success rate of almost 60% students achieving at least 70% success for compression depth and release as well as a rate between 100-120/min does not seem very high, we believe it is a promising result for lay rescuers after a one-hour training in a SL station. Clearly a single training in a SL station may not be sufficient for every single learner and future research should therefore determine how to provide further training to the remaining unsuccessful students. Furthermore, when training professional rescuers, ventilation skills mastery should be included in the assessment.

Limitations
We conducted a prospective observational study without control group. The generally young age in our population of pharmacy students limits the generalisability of the results. Since we expected that most lay students would not know how to perform CPR a methodological choice of a one minute test at T0 was made. To allow comparison only the first minute of T1 and T2 could be analysed. Future research, however, should be performed with tests of equal duration (e.g. 2 minutes).

Conclusions
Although in a self-learning station video training may be useful to introduce new skills, additional voice feedback exercises are needed to achieve acceptable CPR quality. Furthermore voice feedback exercises are able to remove pre-training differences between genders. A self-learning station building on this one-hour combined teaching strategy may be a valuable alternative to an instructor-led course.
ACKNOWLEDGEMENTS

We are grateful to the management of Ghent University Hospital, to the IT department for computer support, to Charlotte Vankeirsbilck and Lien Yde for administrative support and to all the students who participated in the study. The Flash™ module was programmed by Uniweb bvba (Strombeek-Bever, Belgium) and was embedded in the existing Resusci Anne Skills Station™ software with the help of Laerdal Sophus programmers (Laerdal, Sweden).
References


FIGURE LEGEND

Figure 1: Participant flow chart
Table 1: Characteristics of students (n=104).

Values represented as means (SD) or counts (proportions).

<table>
<thead>
<tr>
<th></th>
<th>Males (n=27)</th>
<th>Females (n=77)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>21 (1)</td>
<td>21 (1)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>182 (7)</td>
<td>169 (5)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>74 (9)</td>
<td>61 (8)</td>
</tr>
<tr>
<td>Previous BLS training</td>
<td>4 (15%)</td>
<td>10 (13%)</td>
</tr>
<tr>
<td>Time since last training</td>
<td>31 (81)</td>
<td>42 (35)</td>
</tr>
<tr>
<td></td>
<td>(months) (n=14)</td>
<td></td>
</tr>
</tbody>
</table>
Table 2: Results of one minute CPR at baseline, after video training and after voice-feedback training (n=104).

<table>
<thead>
<tr>
<th></th>
<th>Pre-test (T0)</th>
<th>Test after video exercise (T1)</th>
<th>Test after voice feedback exercise (T2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of participants</td>
<td>Number of participants</td>
<td>Difference T0-T1</td>
</tr>
<tr>
<td></td>
<td>n/N (% [95% CI])</td>
<td>n/N (% [95% CI])</td>
<td>(%) [95% CI]</td>
</tr>
<tr>
<td>Mean compression depth ≥50 mm</td>
<td>30/104 (29%) [21%,38%]</td>
<td>36/104 (35%) [26%,44%]</td>
<td>6% [-2%,14%]</td>
</tr>
<tr>
<td>≥70% of compressions ≥50 mm</td>
<td>26/104 (25%) [18%,34%]</td>
<td>29/104 (28%) [20%,37%]</td>
<td>3% [-5%,11%]</td>
</tr>
<tr>
<td>Compression rate 100-120/min</td>
<td>29/104 (28%) [20%,37%]</td>
<td>77/104 (74%) [65%,82%]</td>
<td>46% [33%,57%]</td>
</tr>
<tr>
<td>Mean ventilation volume 400-1000 ml</td>
<td>8/104 (8%) [4%,14%]</td>
<td>44/104 (42%) [33%,52%]</td>
<td>34% [24%,45%]</td>
</tr>
<tr>
<td>≥70% of ventilations 400-1000 ml</td>
<td>6/104 (6%) [3%,12%]</td>
<td>44/104 (42%) [33%,52%]</td>
<td>36% [26%,46%]</td>
</tr>
<tr>
<td>All compressions with complete release &lt;5 mm</td>
<td>44/104 (42%) [33%,52%]</td>
<td>40/104 (39%) [30%,48%]</td>
<td>-3% [-16%,8%]</td>
</tr>
<tr>
<td>≥70% of compressions with complete release &lt;5 mm</td>
<td>74/104 (71%) [62%,79%]</td>
<td>75/104 (72%) [63%,80%]</td>
<td>-1% [-9%,7%]</td>
</tr>
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</table>
Table 3: Composite pass scores for compression skills using different thresholds (n=104).

<table>
<thead>
<tr>
<th></th>
<th>Pre-test (T0)</th>
<th>Test after video exercise (T1)</th>
<th>Test after voice feedback exercise (T2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of participants (%)</td>
<td>Number of participants (%)</td>
<td>Number of participants (%)</td>
</tr>
<tr>
<td>Pass 100</td>
<td>2 (2)</td>
<td>4 (4)</td>
<td>18 (17)</td>
</tr>
<tr>
<td>Pass 90</td>
<td>4 (4)</td>
<td>11 (11)</td>
<td>44 (42)</td>
</tr>
<tr>
<td>Pass 80</td>
<td>5 (5)</td>
<td>13 (13)</td>
<td>52 (50)</td>
</tr>
<tr>
<td>Pass 70*</td>
<td>6 (6)</td>
<td>15 (14)</td>
<td>59 (57)</td>
</tr>
<tr>
<td>Pass 60</td>
<td>6 (6)</td>
<td>18 (17)</td>
<td>67 (64)</td>
</tr>
<tr>
<td>Pass 50</td>
<td>9 (8)</td>
<td>19 (18)</td>
<td>68 (65)</td>
</tr>
</tbody>
</table>

* Pass 70: ≥70% of all compressions ≥50 mm and ≥70% of all compressions with complete release and compression rate between 100-120/min.
Table 4: Mean compression depth and complete release by gender and time (n=104).

<table>
<thead>
<tr>
<th></th>
<th>Pre-test (T0)</th>
<th>Test after video exercise (T1)</th>
<th>Test after voice feedback exercise (T2)</th>
<th>Pre-test (T0)</th>
<th>Test after video exercise (T1)</th>
<th>Test after voice feedback exercise (T2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of participants</td>
<td>n/N (%), [95% CI]</td>
<td>n/N (%), [95% CI]</td>
<td>n/N (%), [95% CI]</td>
<td>n/N (%), [95% CI]</td>
<td>n/N (%), [95% CI]</td>
<td>n/N (%), [95% CI]</td>
</tr>
<tr>
<td>Probability success</td>
<td>15/27 (56%)</td>
<td>24/27 (90%)</td>
<td>13/27 (48%)</td>
<td>14/27 (52%)</td>
<td>24/17 (89%)</td>
<td></td>
</tr>
<tr>
<td>males</td>
<td>[37%,72%]</td>
<td>[72%,96%]</td>
<td>[31%,66%]</td>
<td>[34%,69%]</td>
<td>[72%, 96%]</td>
<td></td>
</tr>
<tr>
<td>Probability success</td>
<td>15/77 (19%)</td>
<td>21/77 (27%)</td>
<td>68/77 (88%)</td>
<td>13/77 (17%)</td>
<td>15/77 (20%)</td>
<td>64/77 (83%)</td>
</tr>
<tr>
<td>females</td>
<td>[12%,30%]</td>
<td>[19%,38%]</td>
<td>[79%,94%]</td>
<td>[10%,27%]</td>
<td>[12%,30%]</td>
<td>[73%, 90%]</td>
</tr>
<tr>
<td>Probability success</td>
<td>6/27 (22%)</td>
<td>9/27 (33%)</td>
<td>15/27 (56%)</td>
<td>11/27 (41%)</td>
<td>11/27 (41%)</td>
<td>22/27 (82%)</td>
</tr>
<tr>
<td>males</td>
<td>[11%,41%]</td>
<td>[19%, 52%]</td>
<td>[37%,72%]</td>
<td>[25%,59%]</td>
<td>[25%,59%]</td>
<td>[41%]</td>
</tr>
<tr>
<td>Probability success</td>
<td>38/77 (49%)</td>
<td>31/77 (40%)</td>
<td>43/77 (56%)</td>
<td>63/77 (82%)</td>
<td>64/77 (83%)</td>
<td>68/77 (88%)</td>
</tr>
<tr>
<td>females</td>
<td>[39%,60%]</td>
<td>[30%,51%]</td>
<td>[45%,66%]</td>
<td>[72%,89%]</td>
<td>[73%,90%]</td>
<td>[79%,94%]</td>
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