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Effect of mobile application- versus DVD-based CPR training on students' practical CPR skills and willingness to act: a cluster randomised study

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ABSTRACT

Objectives: The aim was to compare students´ practical CPR skills and willingness to perform bystander CPR, after a 30-minute mobile application (app)-based versus a 50-minute DVD-based training.

Settings: Seventh grade students in two Swedish municipalities.

Design: A cluster randomized trial. The classes were randomised to receive app- or DVD-based training. Willingness to act and CPR skills were assessed, directly after training and at six months, by using a questionnaire and a PC Skill Reporting System (total score 12-48). Training and measurements were performed from December 2013 to October 2014.

Participants: Sixty-three classes or 1232 seventh grade students (13-year old) were included in the study.

Primary and secondary outcome measures: Primary endpoint was the total score of the modified Cardiff test. The individual variables of the test and self-reported willingness to make a lifesaving intervention were secondary endpoints.

Results: The DVD-based group was superior to the app-based group in CPR skills; a total score of 36 (33-38) versus 33 (30-36) directly after training ($p<0.001$) and 33 (30-36) and 31 (28-34) at six months ($p<0.001$), respectively. At six months, the DVD-group performed significantly better in 8 out of 12 CPR skill components. Both groups improved compression depth from baseline to follow-up. If a friend suffered cardiac arrest 78% (DVD) versus 75% (app) would do compressions and ventilations, whereas only 31% (DVD) versus 32% (app) would perform standard CPR if the victim was a stranger.

Conclusions: At six months follow-up, the 50-minute DVD-based group showed superior CPR skills compared to the 30-minute app-based group. The groups did not differ in regard to willingness to make a lifesaving effort.

Strengths and limitations of this study

Largest randomised study to compare CPR training methods (mobile application versus DVD) in students.

The intervention was carried out in two major municipalities with schools from all socioeconomic areas and included 86% of eligible students.

Outcome measures of both practical CPR skills and willingness to act were evaluated directly after training and at six month.

The two CPR training methods differed in duration (30 vs 50 minutes) and thus we cannot differentiate between effects caused by type of training as opposed to duration of training.

INTRODUCTION

The incidence of out-of-hospital cardiac arrest (OHCA) in Sweden is approximately 54 per 100,000 persons per year,[1]. A majority of all OHCA occur at home, where the prognosis is poorer compared to cardiac arrests occurring at other locations in the community [2]. Early cardiopulmonary resuscitation (CPR) increases the chance of survival two to three times,[3-5]. Therefore, it is important that as many individuals as possible in the community acquire sufficient CPR skills.

The Swedish school curriculum specifies since 2011 that CPR skills are a core content in grade 7-9 (age 13-15),[6]. Each school decides how the education is offered; theoretical or practical, as one occasion or repeatedly. A statement from EuPSF, ERC, ILCOR and WFSA, approved by the WHO, recommend all schoolchildren CPR training every year from the age of 12,[7]. If all students receive practical CPR training in school, a large proportion of the population will have basic skills within a few decades. Such a situation could potentially increase CPR intervention of bystanders in OHCA and have significant impact on public health,[7-12].

Brief DVD-based courses are successful in teaching CPR-skills [12-16]. How short and simplified the training can be without negatively affecting students' skills and their willingness to act is, however, largely unknown [12]. There are plenty of different mobile applications (app), intended to spread how to perform CPR. An app is easily accessible and the format might appeal to young people. The aim of this study was to evaluate alternative CPR training method by comparing the practical CPR skills and the willingness to act in 13-year old students, directly after a 30-minute app-based or a 50-minute DVD-based training session, and at six months of follow-up. We hypothesised there is no difference between training methods in regard to teaching practical CPR skills, and if so the app-method is preferable due to less time and resources needed.

METHODS

Study population and design

In accordance with the Swedish school curriculum [6], the intervention was applied in grade 7 (13-year old students). Invitations to participate in the study were sent to the headmasters of all council schools in two municipalities (140,000 inhabitants). Eighteen of 24 schools agreed to participate. Four schools did not respond and two had CPR education only for grade 9. Prior to the study, students and their guardians obtained a letter with study information. Study participation of the individual students was completely voluntary and all participants gave an oral informed consent.

Inclusion criteria: seventh grade student in one of the participating schools. *Exclusion criteria*: student does not want to participate, student with a physical handicap that significantly limited the physical performance, classes of students with development disabilities (these classes are age-integrated and have fewer students per class).

The study used a cluster randomized design,[17]. A randomization list was generated by an independent statistician and each of the sixty-three participating classes were randomly assigned to one of main interventions: app- or DVD-based education. In addition to the main intervention, some classes were randomized to various additional interventions, which were equally distributed in both groups. Ten classes

were randomly assigned to perform practical test only at six months. Thus, more students participated at the six-month retest (**Figure 1**). In the framework of this study, the additional interventions have not been analysed. Training and measurements were performed from December 2013 to October 2014.

CPR education

The CPR education was performed in accordance with the European Resuscitation Council (ERC) guidelines 2010,[18]. Training was given to the entire class together. Classes consisted of 14-29 students. The participants had access to an own training manikin, MiniAnne. Ten teachers were previous CPR-instructors and 19 teachers received a five-hour education to become CPR-instructors. All teachers obtained individual oral and written information to assure they were up to date with present CPR guidelines and training. The teachers acted as facilitator; they introduced the lesson, gave advice on the fly, answered questions and completed the course. For the app-based method, the students practised independently by using eight images with related text in a mobile application; introduction, checks responsiveness, open the airway, checks respiration, alarm, chest compressions, ventilations and CPR 30:2,[19]. For the DVD-based method, the whole class practised CPR and recovery position together, based on instructions from a 31-minute DVD. A total of 14 cycles of compressions and ventilations were carried out. The DVD and app are produced by the Swedish Resuscitation Council.

Assessment

Previous studies indicate that CPR skills can deteriorate already in 3-6 months,[12, 20]. In the present trial, CPR skills and willingness to act were evaluated directly after training and at six months, in order to assess both immediate and long-term effects of the education. The six month follow-up was carried out without prior notice.

Laerdal PC skill reporting system version 2.4, linked to resuscitation manikin ResusciAnne, was used to automatically measure quantitative data; compression-ventilation ratio, hand-position, compression depth, total number of compressions and ventilations, ventilation volume, hands-off time, compression rate and incomplete release. The participants' actions regarding check responsiveness, check respiration and call for help were assessed by direct observation of the investigator (AN). Collected data were recorded directly into a scoring sheet, which was a modified version of the validated Cardiff Test,[21]. A total score of 12-48 points was calculated.

The ERC guidelines recommend a compression depth of 50-60 mm,[18]. The PC Skill Reporter System measures up to 60 mm compression depth. To avoid that those who compress >60 mm obtain the highest score (6 points), highest score was given for an average compression depth of 50-59 mm. Those who compressed ≥60 mm received 5 points. We chose to retain the 6-point scale, as in previous studies,[22] even though no one could receive 3 points, which would corresponded to a >65 mm compression depth. All indicators of the scoring sheet are described in detail in the supplementary file 1. The tests were not filmed, because several students of a pre-study experienced filming as stressful,[23].

The duration of the practical test was 3 minutes. The optimal conduct was 30 seconds to check responsiveness, check respiration and call for help, followed by 2.5

minutes of CPR. During the CPR, participants were expected to perform at least 5 cycles of 30 compressions and 2 ventilations. The tests were conducted at the schools with one student at a time. The student was introduced to the test by the following story: “You see an adult, someone you know, who collapsed in front of you. There is no one more on site. Show how you would act in a real life situation”. Directly after the practical test, students received individual constructive feedback from the investigator for two minutes. The students then answered a fixed-response questionnaire, where questions were asked about background factors and willingness to act. A majority of students responded to the survey online and each question had to be answered in order to proceed to the next. Two of the questions allowed the student to add their own comments. Prior to our study, the comprehension of the questionnaire was tested and found satisfactory in a separate cohort of 175 students. The questionnaire is included in the supplementary file 2.

The investigator (AN) is a registered CPR instructor, experienced in the modified Cardiff test. The investigator was blinded to the allocated training method of the students.

Study outcome measures

Primary endpoint was the total score of the modified Cardiff test. The individual variables of the test and self-reported willingness to make a lifesaving intervention were secondary endpoints.

Statistical plan and analyses

Data are presented as proportion (percent) or median (interquartile range). Differences in proportions were analysed with Pearson chi-square test. Differences in continuous variables were assessed using Mann-Whitney U-test or Wilcoxon Signed Rank test for unpaired and paired comparisons, respectively. By calculating the (individual total score-12)/(maximum total score-12)*100, we received a measure of CPR quality in relation to optimal CPR. A p-value <0.05 was considered statistically significant.

Sample size calculations were based on data from a pre-study,[23]. In order to have a 90% power to detect a 2 point intergroup difference of the total score of the modified Cardiff test with a significance level of 0.05, an effective sample size of 194 students would be needed. Intraclass correlation coefficient (95% CI) was 0.20 (0.19, 0.21),[17, 24]. The design effect, caused by the cluster randomization, was 4.22. A number of 1061 and 1124 students performed the first and the second test, respectively. This corresponds to an effective sample size of 251 and 266, respectively, which is well above the 194 needed to reach a power of 90%.

Analyses were performed using IBM SPSS version 21 and STATA version 13.1.

RESULTS

Student sample

A total of 1426 students from 63 seventh grade classes in 18 schools were randomized to receive a 30-minute app-based or 50-minute DVD-based CPR training. At baseline 1232 students, corresponding to 86% of the eligible students, were included in the study. At six months 1124 of these students completed the

retest **(Figure 1)**. The students´ characteristics were similar in both intervention groups and are summarized in **Table 1.**

Table 1 Students´ characteristics.

	App (n=596)	DVD (n=636)	p-value
Male	285 (48)	294 (46)	NS
Previous compression training	192 (32)	171 (27)	NS
Previous ventilation training	158 (26)	113 (18)	<0.001
Previously experienced a cardiac arrest situation	19 (3)	21 (3)	NS

Values are presented as n (%). Differences in proportions between groups were analysed by Pearson chi-square test. NS, not significant.

CPR skills

The DVD-group performed significantly better in terms of total score at both time points; at baseline 36 (33-38) versus 33 (30-36) points (p<0.001) and at six months 33 (30-36) versus 31 (28-34) points (p<0.001). For individual variables, the DVD-group performed significantly better in six out of twelve immediately after training and eight out of twelve at six months. Results of the modified Cardiff-test are summarized in **Table 2.** Data on variables reflecting the quality of chest compressions are presented in **Table 3**. Of note, compression depth and hands-off time improved significantly from baseline to six months testing in both the DVD- and the app-group. Also, the DVD-group performed significantly better in terms of chest compressions with complete release.

Table 2 Assessment of CPR skills directly after app-based or DVD-based training (baseline) and at six months (retest).

	App, baseline (N=524)	DVD, baseline (N=537)	p-value	App, retest (N=549)	DVD, retest (N=575)	p-value
Checks responsiveness by talking						
2: Yes	241 (46)	354 (66)	<0.001	127 (23)	213 (37)	<0.001
1: No	283 (54)	183 (34)		422 (77)	362 (63)	
Checks responsiveness by shaking						
3: Yes	353 (67)	376 (70)	NS	164 (30)	219 (38)	0.004
2: No	169 (32)	160 (30)		385 (70)	356 (62)	
3: Potentially dangerous	2 (<1)	1 (<1)		0	0	
Open airway – chin lift, head tilt						
5: Perfect	6 (1)	23 (4)	<0.001	3 (1)	9 (2)	<0.001
4: Acceptable	46 (9)	110 (20)		9 (2)	17 (3)	
3: Attempted other	3 (<1)	1 (<1)		0	1 (<1)	
2: Only one element	130 (25)	186 (35)		18 (3)	73 (13)	
1: No	339 (65)	217 (40)		519 (94)	475 (83)	
Checks respiration – see, listen, feel						
2: Yes	388 (74)	396 (74)	NS	225 (41)	327 (57)	NS
1: No	136 (26)	141 (26)		324 (59)	248 (43)	
Call for help or dials 112						
2: Yes	396 (76)	431 (80)	NS	411 (75)	458 (80)	NS
1: No	128 (24)	106 (20)		138 (25)	117 (20)	
Compression/ventilation ratio						
4: 30:2 (28-32:2)	182 (35)	292 (54)	<0.001	165 (30)	233 (40)	<0.001

3: Other	299 (57)	230 (43)		319 (58)	304 (53)	
2: Compressions only	43 (8)	15 (3)		65 (12)	38 (7)	
1: Ventilations only	0	0		0	0	
Hand-position during compression						
4: Correct	50 (10)	68 (13)	NS	29 (5)	25 (4)	NS
3: Other wrong	312 (60)	333 (62)		250 (46)	299 (52)	
2: Too low	162 (31)	136 (25)		270 (49)	251 (44)	
1: Not attempted	0	0		0	0	
Average compression depth						
6: 50-59 mm	100 (19)	114 (21)	NS	183 (33)	224 (39)	0.031
5: ≥ 60 mm	5 (1)	2 (<1)		8 (2)	15 (3)	
4: 35-49 mm	255 (49)	271 (50)		239 (44)	242 (42)	
3:	0	0		0	0	
2: 1-34 mm	164 (31)	150 (28)		119 (22)	93 (16)	
1: Not attempted	0	0		0	0	
Total compression counted						
6: 140-190	179 (34)	240 (45)	<0.001	186 (34)	211 (37)	0.013
5: ≥ 191	266 (51)	223 (42)		253 (46)	285 (50)	
4: 121-139	29 (6)	42 (8)		51 (9)	37 (6)	
3: 81-120	36 (7)	19 (4)		43 (8)	38 (7)	
2: 1-80	14 (3)	13 (2)		16 (3)	4 (1)	
1: Not attempted	0	0		0	0	
Average ventilation volume						
5: 500-600 ml	27 (5)	31 (6)	<0.001	19 (4)	22 (4)	<0.001
4: 1-499 ml	43 (8)	59 (11)		50 (9)	49 (8)	
3: ≥ 601 ml	207 (40)	357 (66)		188 (34)	262 (46)	
2: 0 ml	204 (39)	75 (14)		225 (41)	204 (36)	
1: Not attempted	43 (8)	15 (3)		67 (12)	38 (7)	
Total ventilation counted						
5: 8-12	117 (22)	249 (46)	<0.001	98 (18)	139 (24)	0.001
4: 1-7	112 (21)	130 (24)		81 (15)	94 (16)	
3: ≥ 13	48 (9)	68 (13)		78 (14)	100 (17)	
2: 0	204 (39)	75 (14)		225 (41)	204 (36)	
1: Not attempted	43 (8)	15 (3)		67 (12)	38 (7)	
Total "hands-off" time						
4: 0-60 s	122 (23)	56 (10)	<0.001	196 (36)	164 (28)	0.018
3: 61-90 s	302 (58)	355 (66)		278 (51)	339 (59)	
2: 91-135 s	97 (18)	117 (22)		71 (13)	71 (12)	
1: 136-180 s	3 (1)	9 (2)		4 (1)	1 (<1)	
Total score	33 (30-36)	36 (33-38)	<0.001	31 (28-34)	33.0 (30-36)	<0.001

Results are presented as n (%) or median (25^{th}-75^{th} percentile). Differences in proportions between groups were analysed by Pearson chi-square test. Differences in continuous variables between groups were analysed by Mann-Whitney U test. P-values <0.05 were considered statistically significant. NS, not significant. The table lists the variable's best option at the top. All numbers are rounded to the nearest evenly integer.

Table 3 Chest compression data of the app- and the DVD-group.

	App directly after training (N=524)	DVD directly after training (N=537)	p-value	App at retest (N=549)	DVD at retest (N=575)	p-value
CC depth (mm)	41 (32-48)	42 (33-48)	NS	45 (36-52)*	47 (39-54)*	0.002
CC rate (n/min)	113 (91-131)	112 (100-124)	NS	102 (80-119)*	105 (89-119)*	0.013
CC rate 100-120/min	149 (28)	232 (43)	<0.001	166 (30)	217 (38)	0.008
CC with complete release	387 (74)	446 (83)	<0.001	416 (76)	476 (83)	0.004
Total hands-off time (s)	74 (61-86)	80 (71-90)	<0.001	68 (55-81)*	70 (58-81)*	NS

Values are presented as median (25^{th}-75^{th} percentile) or n (%). Differences in proportions were analysed by Pearson chi-square test. Differences between groups were analysed by Mann-Whitney U test. Differences between baseline and retest were analysed by Wilcoxon signed ranks test, where * indicates p<0.001. CC, chest compression; NS, not significant.

Willingness to act

For all variables reflecting willingness to act and potential obstacles, we found no significant differences between the DVD- and the app-group. At six months follow-up 81% in the DVD- and 78% in the app-group were more confident to act compared to prior to training. Also, students considered themselves to have enough knowledge to do chest compressions (91% in DVD- and 92% in app-group) and to do rescue breaths (74% in DVD- and 70% in app-group). Six students described situations where they had made a lifesaving intervention within 6 months after training. As shown in **Figure 2**, there was a huge difference in willingness to intervene in an OHCA situation of a friend compared to a situation involving a stranger ($p<0.001$). Fear to do harm (8% in DVD- and 7% in app-group) and fear of touching a stranger (6% in DVD- and 5% in app-group) are the two most common reasons for not wanting to perform chest compressions. Fear of disease transmission (8% in DVD- and 11% in app-group) and to touch a stranger (10% in DVD- and 8% in app-group) are the two most common reasons given for not wanting to perform ventilations on a stranger.

According to the questionnaire at six months, 31% of the students in the app-group had looked at the app one or several times after the training session and 26% had shown it to another person.

DISCUSSION

The main findings of the present study are two-fold. Firstly, a 50-minute DVD-based training method was superior to a 30-minute app-based education in terms of teaching practical CPR skills to seventh grade students. Secondly, there was no significant difference in willingness to act between the app- and DVD-group. The study was carried out in schools from all socioeconomic areas and included 86% of eligible students, strengthening the generalisability of our findings.

The total score of the modified Cardiff-test differed significantly by 2-3 points between the app- and DVD-group at both occasions. The importance of this difference is unclear, since the size of a clinically relevant difference has yet to be established. The largest differences in favour of the DVD-based method were found for the following components: check responsiveness by talking, open airway, compression/ventilation ratio and ventilation. Three of these variables can be related; if students fail to create an open airway, they will fail with the ventilations, which result in the students making repeated attempts and thus losing the correct compression/ventilation ratio. Indeed, several studies have shown that a large proportion of participants after CPR training have limited knowledge on how to correctly perform rescue breath,[22, 25-26]. The cause of the differences observed between the app- and DVD-group in this study is unknown. The present study was not designed to explain the cause of any potential differences. However, we speculate that the moving instruction at the DVD in combination with repeated training seems to be a strength of the DVD-based method. An advantage with the app-method is that it can provide support in acute situations, is available also after training has been completed, with the opportunity to repeat and to share with others.

Future studies are needed to explain why there are differences in DVD- as compared to app-methods.

In our study, practical CPR skills were significantly reduced from measurement directly after training to six months in both groups, which is similar to other studies,[12, 20]. In evaluating the CPR skills of the participants, we consider the results of the six months test to be of most importance, since these results reflect the long-term knowledge of the students. At six months, the DVD-group obtained 58% (33 points) and the app-group 53% (31 points) of the maximum score, which is comparable with results of previous studies where seventh grade students performed 50% and adults 57-61% of the total score at 3-4 months after training,[22, 25].

At the 6 months retest, both groups performed 4-5 mm deeper compressions compared to baseline. Previous studies show significant correlations between age, weight, height and compression depth,[20, 27-29]. However, in our study it is unlikely that the strength of the students improved so much during 6 months as to explain the improved compression depth. Interestingly, similar results were observed in a pre-study, despite the retest being carried out after only 3 months,[23]. The oral feedback received by the students after the first test might have helped them to perform deeper chest compressions at the retest. Also, we cannot exclude the fact that the students at the retest were more familiar with the test doll and thus performed better. The proportion of students, who applied incorrect hand-position was high in both groups (at retest; 96% versus 95%). Previous studies, using diverse definitions, indicate a large variation (13-90%) regarding correct hand-position,[22, 25, 27, 29-30]. Isby et al argues that the definition of "incorrect hand-position" is important when results are compared,[25]. The poor hand-positioning in our study could possibly be explained by the fact that the compression place on MiniAnne, used during training, is “marked” and thus the students might not reflect on correct hand-positioning. At the test situation, however, the ResuciAnne has a "whole chest-skin" without marking.

Students generally have a positive attitude towards CPR training,[12, 29, 31-33]. Practical training reduces concern to make mistakes, increases self-reported confidence and willingness to intervene,[31,34-35]. In our study, there was no significant difference in willingness to act between the app- and DVD-group. However, we found a huge difference in willingness to intervene in a cardiac arrest situation of a friend compared to a situation involving a stranger. This is in accordance with previous studies,[31, 34, 36] and needs to be considered when designing educations. Common reasons for not starting CPR include lack of CPR knowledge and fear of not being able to do CPR correctly,[31, 34,36-37]. In our study, fear to do harm was one of the most common reasons for not wanting to perform chest compressions on a stranger. In CPR training, it is important to emphasize that "laypeople cannot do anything wrong – the only wrong thing would be to do nothing",[7]. A common barrier for ventilation was fear of disease transmission. Therefore, it is important to emphasize that the risk of disease transmission during CPR intervention is very low,[38-39].

Clinical implication

The present study indicates that a DVD-based CPR training method might be preferable when teaching seventh grade students, although the clinical relevance of

a 2-3 point difference is unclear. Further studies are needed to identify optimal and alternative teaching methods.

Study limitations

Firstly, we cannot exclude that the duration of the training (30 vs 50 minutes), rather than the type of training per se, accounted for the differences observed in the tests. However, in the app-based education, training on recovery position was excluded. Thus, there was time enough for the students in the app-group to carry out the same amount of cycles of compressions and ventilations as in the DVD-group.

Secondly, the questionnaire used to evaluate willingness to act contains only hypothetical questions. They do not fully answer how the students would act in a real situation.

Thirdly, it is a risk that the instructors experience and/or enthusiasm affects the learning. Therefore, the methods were standardized to ensure equivalent education, the teacher only had a role as a facilitator during the training, and the practical exercises were based on instructions from the app and the DVD, respectively.

Fourthly, we cannot exclude the possibility of contamination between classes of the same school. However, a potential contamination is not expected to have a significant impact on the test results, since the hands-on training is by far the most important factor to acquire practical CPR skills,[20]. Also, if contamination existed and had an effect on test results, it would rather lessen than enhance any differences between groups.

Lastly, we do not know if the number of students in each class affects the outcome, but the instructor only had the role of facilitator and previous studies have shown that larger DVD-based groups are performing equivalent to smaller traditional instructor-led groups,[16].

CONCLUSION

Overall, a 50-minute DVD-based training seemed to be superior to a 30-minute app-based education in terms of teaching practical CPR skills to seventh grade students. After CPR training, a majority of students, regardless of training method, were willing to make a life-saving effort. However, only a third of the students would do both compressions and ventilations if a stranger suffers a cardiac arrest. This needs to be considered when designing future educations.

Conflict of interest statement Nothing to declare.
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Contributors AN contributed to the study design, developed the modified cardiff test and the questionnaire, conducted all measurements, analysed results and wrote the initial draft of the manuscript. LS contributed to the study design, developed the modified Cardiff test and revised the manuscript. HH and SKS contributed to the study design and revised the manuscript. LN contributed to the study design,

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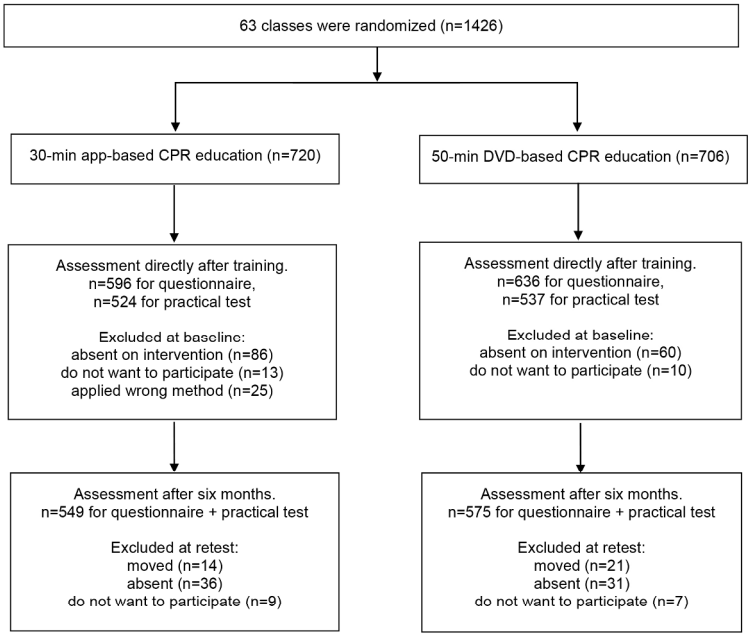
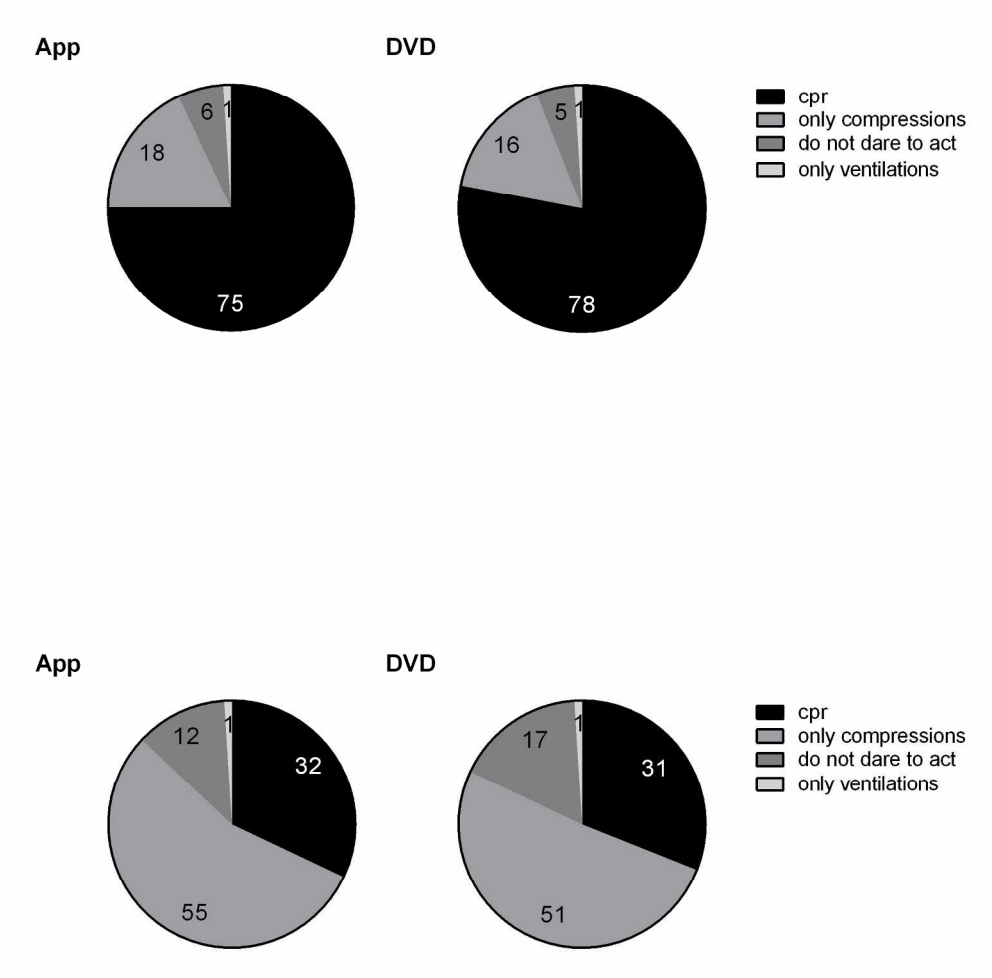
Figure 1 Flow chart on randomization and inclusion.

Figure 2 Students´ willingness to act if a friend suffers a cardiac arrests (upper panel) or if a stranger suffers a cardiac arrest (lower panel), as assessed six months after training. Values are given as percent. Numbers are n=549 (app) and n=575 (DVD).



Flow chart on randomization and inclusion.
178x273mm (300 x 300 DPI)



Students´ willingness to act if a friend suffers a cardiac arrests (upper panel) or if a stranger suffers a cardiac arrest (lower panel), as assessed six months after training. Values are given as percent. Numbers are n=549 (app) and n=575 (DVD).
208x203mm (300 x 300 DPI)

Supplementary file: the modified Cardiff test.

The modified version of the Cardiff test,[21], adapted to the ERC guidelines of 2010,[18]. The duration of the practical test was 3 minutes. The optimal conduct was 30 seconds for check responsiveness, check respiration and call for help, followed by 2.5 minutes of CPR. During the CPR, the participants were expected to perform at least 5 cycles of 30 compressions and 2 ventilations (30:2). The rules of assessment were pre-specified as follows:

Check responsiveness by talking
2. Yes, if some form of verbal communication as “are you ok” or “how are you”?
1. No, if no attempt at verbal communication was performed
Method: direct observation and real-time registration in the observation schedule by the test leader.

Check responsiveness by shaking
3. Yes, if the rescuer gently shake the victim shoulders.
2. No, if no attempt to shake the victim shoulders occurred.
1. Potentially dangerous, if the rescuer violently shakes the victim´s shoulders so the head lifted up and down against the ground, which can damage the head or the neck.
Method: direct observation and real-time registration in the observation schedule by the test leader.

Open the airway - chin lift, head tilt.
5. Perfect, if one hand on the forehead, two fingertips on the jawbone (not soft tissue) and gently lifted the chin and bent the head back ie by ERC guidelines.
4 Acceptable/partially correct if several indicators are performed, but not all.
3. Attempted other, if the rescuer tried in other ways than ERC recommendation.
2. Only one element is performed or if the rescuer tries but fails.
1. No, if no attempt to open the airway was performed.
Method: direct observation and real-time registration in the observation schedule by the test leader.

Checks respiration - see, listen, feel
2. Yes, if the rescuer did attempts of breath control, even if not all three actions see, listen and feel were performed and although if the total time of the control was less than 10 seconds.
1. No, if no attempt to check for breathing was performed.
Method: direct observation and real-time registration in the observation schedule by the test leader.

Calls for help or dials 112
2. Yes, calls for help and dials 112. Alarm should be done within the first minute.
1. No, if no attempt to get help was performed.
Method: direct observation and real-time registration in the observation schedule by the test leader.

Compression/ventilation ratio
4. 30:2 (28-32:2), if the rescuer practical applied compressions and ventilations with the relationship 28-32:2 during the whole test.
3. Other, if the rescuer applied different ratio of compressions and ventilations than 28-32:2.
2. Compressions only.
1. Ventilations only.
Method: Data from Laerdal PC Skill Reporter Systems was transferred to a scoring sheet after the test.

Hand-position during compression
Incorrect hand-position was recorded if one compression was in the wrong place, since one wrong compression can cause rib fracture or fracture the xiphoid process of sternum.
4. Correct, if the rescuer place the heel of one hand in the centre of the victim’s chest and with the other hand above.
3. Other wrong, if the rescuer performs chest compressions too high up on the sternum or to the side of the sternum.
2. Too low, if the rescuer performs chest compressions too low on the sternum or on the abdomen.
1. Not attempted, if no compressions were performed.
Method: Data from Laerdal PC Skill Reporter Systems was transferred to a scoring sheet after the test.

Average compression depth
The PC Skill Reporter system version 2.4 measures up to 60 mm compression depth. To avoid that those who compress >60 mm obtain the highest score, highest score was given for an average compression depth of 50-59 mm. Those who compressed ≥60 mm received 5 points. We chose to retain the 6-point scale, as in previous studies,[22] even though no one could receive 3 points, which would corresponded to a > 65 mm compression depth.
6. 50-59 mm.
5. ≥ 60 mm
4. 35-49 mm
3.
2. 1-34 mm
1. Not attempted, if no compressions were performed.
Method: Data from Laerdal PC Skill Reporter Systems was transferred to a scoring sheet after the test.

Total compression counted
6. 140-190
5. ≥ 191
4. 121-139
3. 81-120
2. 1-80
1. Not attempted, if no compressions were performed.
Method: Data from Laerdal PC Skill Reporter Systems was transferred to a scoring sheet after the test.

Average ventilation volume
5. 500-600 ml
4. 1-499 ml
3. ≥ 601 ml
2. 0 ml, if the rescuer tried to do rescue breaths but failed.
1. Not attempted, if no rescue breaths were performed.
Method: Direct observation and real-time registration if the rescuer tried to do rescue breath. Exact volume, from Laerdal PC Skill Reporter Systems, was transferred to the scoring sheet after the test.

Total ventilation counted
5.8-12
4. 1-7
3. ≥ 13
2. 0, if the rescuer tried to do rescue breaths but failed.
1. Not attempted, if no rescue breaths were performed.
Method: Direct observation and real-time registration if the rescuer tried to do rescue breath. Exact number, from Laerdal PC Skill Reporter Systems, was transferred to the scoring sheet after the test.

Total ”hands-off” time
4. 0-60 s
3. 61-90 s
2. 91-135 s
1. 136-180 s
Method: Data from Laerdal PC Skill Reporter Systems was transferred to a scoring sheet after the test.

Supplementary file: questionnaires used directly after training and at six months follow-up

Questionnaire directly after training

Have you previously practiced

chest compressions?	Yes ☐	No ☐
ventilations?	Yes ☐	No ☐

Do you think that your skills are sufficient to perform

chest compressions?	Yes ☐	No ☐	Do not know ☐
ventilations?	Yes ☐	No ☐	Do not know ☐

Are you more confident now than before the training to act and start CPR?	Yes ☐	No ☐	Do not know ☐

You are at home. How would you act if a friend or relative suffered a sudden cardiac arrest? Tick one answer:

I would not dare or want to intervene ☐
I would give chest compressions only ☐
I would give ventilations only ☐
I would give both compressions and ventilations ☐

Enter the reason that you do not dare or want to do chest compressions?

Lack of knowledge ☐
Afraid to hurt the person ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

Enter the reason that you do not dare or want to do ventilations?

Lack of knowledge ☐
Afraid to hurt the person ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

You are standing at a bus stop. How would you act if an unknown person suffered a sudden cardiac arrest? Tick one answer:

I would not dare or want to intervene ☐
I would give chest compressions only ☐
I would give ventilations only ☐

I would give both compressions and ventilations ☐

Enter the reason that you do not dare or want to do chest compressions?

Lack of knowledge ☐

Afraid to hurt the person ☐

I do not want to touch a stranger ☐

Afraid of transmitted disease ☐

Other reasons ☐

Do not know ☐

Enter the reason that you do not dare or want to do ventilations?

Lack of knowledge ☐

Afraid to hurt the person ☐

I do not want to touch a stranger ☐

Afraid of transmitted disease ☐

Other reasons ☐

Do not know ☐

Questionnaire at six months follow-up

Have you done a lifesaving intervention in real life after the CPR training? Yes ☐ No ☐

If yes, please describe your lifesaving intervention and the situation:_____

Do you think it is important to learn cardiopulmonary resuscitation in school? Yes ☐ No ☐ Do not know ☐

Do you think that your skills are sufficient to perform

chest compressions? Yes ☐ No ☐ Do not know ☐

ventilations? Yes ☐ No ☐ Do not know ☐

Are you more confident now than before the training to act and start CPR? Yes ☐ No ☐ Do not know ☐

You are at home. How would you act if a friend or relative suffered a sudden cardiac arrest? Tick one answer:

I would not dare or want to intervene ☐

I would give chest compressions only ☐

I would give ventilations only ☐

I would give both compressions and ventilations ☐

Enter the reason that you do not dare or want to do chest compressions?

Lack of knowledge ☐

Afraid to hurt the person ☐

Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

Enter the reason that you do not dare or want to do ventilations?
Lack of knowledge ☐
Afraid to hurt the person ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

You are standing at a bus stop. How would you act if an unknown person suffered a sudden cardiac arrest? Tick one answer:
I would not dare or want to intervene ☐
I would give chest compressions only ☐
I would only give ventilations ☐
I would give both compressions and ventilations ☐

Enter the reason that you do not dare or want to do chest compressions?
Lack of knowledge ☐
Afraid to hurt the person ☐
I do not want to touch a stranger ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

Enter the reason that you do not dare or want to do ventilations?
Lack of knowledge ☐
Afraid to hurt the person ☐
I do not want to touch a stranger ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

How many times have you used/read on the app "Save the heart" (including any lesson in school)?
1 ☐
2-3 ☐
4-5 ☐
> 5 ☐
Do not know ☐

Have you shown the app for someone else? Yes ☐ No ☐ Do not know ☐

CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	4
	2b	Specific objectives or hypotheses	4
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	4
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	N/A
Participants	4a	Eligibility criteria for participants	4
	4b	Settings and locations where the data were collected	4, 6
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	4-5
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	6
	6b	Any changes to trial outcomes after the trial commenced, with reasons	N/A
Sample size	7a	How sample size was determined	6
	7b	When applicable, explanation of any interim analyses and stopping guidelines	N/A
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	4
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	4
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	4
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	4, 6
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	6

		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	5
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	6
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	N/A
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	6-7 and Figure 1
	13b	For each group, losses and exclusions after randomisation, together with reasons	Figure 1
Recruitment	14a	Dates defining the periods of recruitment and follow-up	5
	14b	Why the trial ended or was stopped	N/A
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Table 1
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	6, Figure 1
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	6-9
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	N/A
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	N/A
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	N/A
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	3, 11
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	9-11
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	9-10
Other information			
Registration	23	Registration number and name of trial registry	N/A
Protocol	24	Where the full trial protocol can be accessed, if available	N/A
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	12

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

BMJ Open

Effect of mobile application- versus DVD-based CPR training on students' practical CPR skills and willingness to act: a cluster randomised study

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Effect of mobile application- versus DVD-based CPR training on students' practical CPR skills and willingness to act: a cluster randomised study

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ABSTRACT

Objectives: The aim was to compare students´ practical CPR skills and willingness to perform bystander CPR, after a 30-minute mobile application (app)-based versus a 50-minute DVD-based training.

Settings: Seventh grade students in two Swedish municipalities.

Design: A cluster randomized trial. The classes were randomised to receive app- or DVD-based training. Willingness to act and practical CPR skills were assessed, directly after training and at six months, by using a questionnaire and a PC Skill Reporting System. Data on CPR skills were registered in a modified version of the Cardiff test, where scores were given in 12 different categories, adding up to a total score of 12-48 points. Training and measurements were performed from December 2013 to October 2014.

Participants: Sixty-three classes or 1232 seventh grade students (13-year old) were included in the study.

Primary and secondary outcome measures: Primary endpoint was the total score of the modified Cardiff test. The individual variables of the test and self-reported willingness to make a lifesaving intervention were secondary endpoints.

Results: The DVD-based group was superior to the app-based group in CPR skills; a total score of 36 (33-38) versus 33 (30-36) directly after training ($p<0.001$) and 33 (30-36) and 31 (28-34) at six months ($p<0.001$), respectively. At six months, the DVD-group performed significantly better in 8 out of 12 CPR skill components. Both groups improved compression depth from baseline to follow-up. If a friend suffered cardiac arrest 78% (DVD) versus 75% (app) would do compressions and ventilations, whereas only 31% (DVD) versus 32% (app) would perform standard CPR if the victim was a stranger.

Conclusions: At six months follow-up, the 50-minute DVD-based group showed superior CPR skills compared to the 30-minute app-based group. The groups did not differ in regard to willingness to make a lifesaving effort.

Strengths and limitations of this study

Largest randomised study to compare CPR training methods (mobile application versus DVD) in students.

The intervention was carried out in two major municipalities with schools from all socioeconomic areas and included 86% of eligible students.

Outcome measures of both practical CPR skills and willingness to act were evaluated directly after training and at six month.

The two CPR training methods differed in duration (30 vs 50 minutes) and thus we cannot differentiate between effects caused by type of training as opposed to duration of training.

INTRODUCTION

The incidence of out-of-hospital cardiac arrest (OHCA) in Sweden is approximately 54 per 100,000 persons per year,[1]. A majority of all OHCA occur at home, where the prognosis is poorer compared to cardiac arrests occurring at other locations in the community [2]. Early cardiopulmonary resuscitation (CPR) increases the chance of survival two to three times,[3-5]. Therefore, it is important that as many individuals as possible in the community acquire sufficient CPR skills.

The Swedish school curriculum specifies since 2011 that CPR skills are a core content in grade 7-9 (age 13-15),[6]. Each school decides how the education is offered; theoretical or practical, as one occasion or repeatedly. A statement from EuPSF, ERC, ILCOR and WFSA, approved by the WHO, recommend all schoolchildren CPR training every year from the age of 12,[7]. If all students receive practical CPR training in school, a large proportion of the population will have basic skills within a few decades. Such a situation could potentially increase CPR intervention of bystanders in OHCA and have significant impact on public health,[7-12].

Brief DVD-based courses are successful in teaching CPR-skills [12-16]. How short and simplified the training can be without negatively affecting students' skills and their willingness to act is, however, largely unknown [12]. There are plenty of different mobile applications (app), intended to spread how to perform CPR. An app is easily accessible and the format might appeal to young people. The aim of this study was to evaluate alternative CPR training methods by comparing the practical CPR skills and the willingness to act in 13-year old students, directly after a 30-minute app-based or a 50-minute DVD-based training session, and at six months of follow-up.

METHODS

Study population and design

In accordance with the Swedish school curriculum [6], the intervention was applied in grade 7 (13-year old students). Invitations to participate in the study were sent to the headmasters of all council schools in two municipalities (140,000 inhabitants). Eighteen of 24 schools agreed to participate. Four schools did not respond and two had CPR education only for grade 9. Prior to the study, students and their guardians obtained a letter with study information. Study participation of the individual students was completely voluntary and all participants gave an oral informed consent.

Inclusion criteria: seventh grade student in one of the participating schools. *Exclusion criteria*: student does not want to participate, student with a physical handicap that significantly limited the physical performance, classes of students with development disabilities (these classes are age-integrated and have fewer students per class).

The study used a cluster randomized design,[17]. A randomization list was generated by an independent statistician and each of the sixty-three participating classes were randomly assigned to one of main interventions: app- or DVD-based education. In addition to the main intervention, some classes were randomized to various additional interventions, which were equally distributed in both groups. Ten classes were randomly assigned to perform practical test only at six months. Thus, more students participated at the six-month retest (**Figure 1**). In the framework of this

study, the additional interventions have not been analysed. Training and measurements were performed from December 2013 to October 2014.

CPR education

The CPR education was performed in accordance with the European Resuscitation Council (ERC) guidelines 2010,[18]. Training was given to the entire class together. Classes consisted of 14-29 students. All participants in both interventions groups used an individual training manikin, MiniAnne, during the training. Ten teachers were previous CPR-instructors and 19 teachers received a five-hour education to become CPR-instructors. All teachers obtained individual oral and written information to assure they were up to date with present CPR guidelines and training. The teachers acted as facilitator; they introduced the lesson, gave advice on the fly, answered questions and completed the course. For the app-based method, the students practised independently by using eight images with related text in a mobile application; introduction, checks responsiveness, open the airway, checks respiration, alarm, chest compressions, ventilations and CPR 30:2,[19]. For the DVD-based method, the whole class practised CPR and recovery position together, based on instructions from a 31-minute DVD. A total of 14 cycles of compressions and ventilations were carried out. The DVD and app are produced by the Swedish Resuscitation Council.

Assessment

Previous studies indicate that CPR skills can deteriorate already in 3-6 months,[12, 20]. In the present trial, CPR skills and willingness to act were evaluated directly after training and at six months, in order to assess both immediate and long-term effects of the education. The six month follow-up was carried out without prior notice.

Laerdal PC skill reporting system version 2.4, linked to resuscitation manikin ResusciAnne, was used to automatically measure quantitative data; compression-ventilation ratio, hand-position, compression depth, total number of compressions and ventilations, ventilation volume, hands-off time, compression rate and incomplete release. The participants' actions regarding check responsiveness, check respiration and call for help were assessed by direct observation of the investigator (AN). Collected data were recorded directly into a scoring sheet, which was a modified version of the validated Cardiff Test,[21]. A score was given in each category and added up to a total score of 12-48 points. All categories of the scoring sheet are described in detail in the supplementary file 1. The tests were not filmed, because several students of a pre-study experienced filming as stressful,[22].

The ERC guidelines recommend a compression depth of 50-60 mm,[18]. The PC Skill Reporter System measures up to 60 mm compression depth. To avoid that those who compress >60 mm obtain the highest score (6 points), highest score was given for an average compression depth of 50-59 mm. Those who compressed ≥60 mm received 5 points. We chose to retain the 6-point scale, as in previous studies,[23] even though no one could receive 3 points, which would corresponded to a >65 mm compression depth.

The duration of the practical test was 3 minutes. The optimal conduct was 30 seconds to check responsiveness, check respiration and call for help, followed by 2.5

minutes of CPR. During the CPR, participants were expected to perform at least 5 cycles of 30 compressions and 2 ventilations. The tests were conducted at the schools with one student at a time. The student was introduced to the test by the following story: “You see an adult, someone you know, who collapsed in front of you. There is no one more on site. Show how you would act in a real life situation”. Directly after the practical test, students received individual constructive feedback from the investigator for two minutes. The students then answered a fixed-response questionnaire, where questions were asked about background factors and willingness to act. A majority of students responded to the survey online and each question had to be answered in order to proceed to the next. Two of the questions allowed the student to add their own comments. Prior to our study, the comprehension of the questionnaire was tested and found satisfactory in a separate cohort of 175 students. The questionnaire is included in the supplementary file 2.

The investigator (AN) is a registered CPR instructor, experienced in the modified Cardiff test. The investigator was blinded to the allocated training method of the students.

Study outcome measures

Primary endpoint was the total score of the modified Cardiff test. The total score was calculated by adding the individual scores of the 12 different categories (check responsiveness by talking, check responsiveness by shaking, open the airway, checks respiration, calls for help or dials 112, compression/ventilation ratio, hand-position during compression, average compression depth, total compression counted, average ventilation volume, total ventilation counted, total hands-off time) assessed by the practical test. The individual categories of the test and self-reported willingness to make a lifesaving intervention were secondary endpoints.

Statistical plan and analyses

Data are presented as proportion (percent) or median (interquartile range). Differences in proportions were analysed with Pearson chi-square test. Differences in continuous variables were assessed using Mann-Whitney U-test or Wilcoxon Signed Rank test for unpaired and paired comparisons, respectively. By calculating the (individual total score-12)/(maximum total score-12)*100, we received a measure of CPR quality in relation to optimal CPR. Multiple linear regression analyses for the total score of the modified Cardiff test were performed, including baseline covariates (gender, previous compression and ventilation training, previous experience of a cardiac arrest situation, school, and class) as fixed effects. A p-value <0.05 was considered statistically significant.

Sample size calculations were based on data from a pre-study,[22]. To test for superiority with a 90% power to detect a 2 point intergroup difference of the total score of the modified Cardiff test with a significance level of 0.05, an effective sample size of 194 students would be needed. Intraclass correlation coefficient (95% CI) was 0.20 (0.19, 0.21),[17, 24]. The design effect, caused by the cluster randomization, was 4.22. A number of 1061 and 1124 students performed the first and the second test, respectively. This corresponds to an effective sample size of 251 and 266, respectively, which is well above the 194 needed to reach a power of 90%.

Analyses were performed using IBM SPSS version 21 and STATA version 13.1.

RESULTS

Student sample

A total of 1426 students from 63 seventh grade classes in 18 schools were randomized to receive a 30-minute app-based or 50-minute DVD-based CPR training. At baseline 1232 students, corresponding to 86% of the eligible students, were included in the study. At six months 1124 of these students completed the retest **(Figure 1)**. The baseline characteristics of the students are summarized in **Table 1.**

Table 1 Students´ characteristics.

	App (n=596)	DVD (n=636)	p-value
Male	285 (48)	294 (46)	NS
Previous compression training	192 (32)	171 (27)	NS
Previous ventilation training	158 (26)	113 (18)	<0.001
Previously experienced a cardiac arrest situation	19 (3)	21 (3)	NS
Number of schools in which methods were applied	16	14	NS

Values are presented as n (%). Differences in proportions between groups were analysed by Pearson chi-square test. NS, not significant.

CPR skills

The DVD-group performed significantly better in terms of total score at both time points; at baseline 36 (33-38) versus 33 (30-36) points (p<0.001) and at six months 33 (30-36) versus 31 (28-34) points (p<0.001). For individual variables, the DVD-group performed significantly better in six out of twelve immediately after training and eight out of twelve at six months. Results of the modified Cardiff-test are summarized in **Table 2.**

Baseline characteristics were well matched between the intervention groups, except that students in the app group had significantly more previous ventilation training. Nevertheless, multiple linear regression analyses (including all baseline covariates) were performed to adjust for potential confounding, without any significant change in effect of the intervention being observed. The mean difference (95% CI) in total score between intervention groups was 2.52 (2.03, 3.02) points before and 2.55 (2.05, 3.05) points after adjustment, directly after the intervention, and 1.61 (1.14, 2.07) points before and 1.62 (1.15, 2.09) points after adjustment, at the six months test.

Data on variables reflecting the quality of chest compressions are presented in **Table 3**. Of note, compression depth and hands-off time improved significantly from baseline to six months testing in both the DVD- and the app-group. Also, the DVD-group performed significantly better in terms of chest compressions with complete release.

Table 2 Assessment of CPR skills directly after app-based or DVD-based training (baseline) and at six months (retest).

	App, baseline (N=524)	DVD, baseline (N=537)	p-value	App, retest (N=549)	DVD, retest (N=575)	p-value
Checks responsiveness by talking						
2: Yes	241 (46)	354 (66)	<0.001	127 (23)	213 (37)	<0.001
1: No	283 (54)	183 (34)		422 (77)	362 (63)	
Checks responsiveness by shaking						
3: Yes	353 (67)	376 (70)	NS	164 (30)	219 (38)	0.004
2: No	169 (32)	160 (30)		385 (70)	356 (62)	
3: Potentially dangerous	2 (<1)	1 (<1)		0	0	
Open airway – chin lift, head tilt						
5: Perfect	6 (1)	23 (4)	<0.001	3 (1)	9 (2)	<0.001
4: Acceptable	46 (9)	110 (20)		9 (2)	17 (3)	
3: Attempted other	3 (<1)	1 (<1)		0	1 (<1)	
2: Only one element	130 (25)	186 (35)		18 (3)	73 (13)	
1: No	339 (65)	217 (40)		519 (94)	475 (83)	
Checks respiration – see, listen, feel						
2: Yes	388 (74)	396 (74)	NS	225 (41)	327 (57)	NS
1: No	136 (26)	141 (26)		324 (59)	248 (43)	
Call for help or dials 112						
2: Yes	396 (76)	431 (80)	NS	411 (75)	458 (80)	NS
1: No	128 (24)	106 (20)		138 (25)	117 (20)	
Compression/ventilation ratio						
4: 30:2 (28-32:2)	182 (35)	292 (54)	<0.001	165 (30)	233 (40)	<0.001
3: Other	299 (57)	230 (43)		319 (58)	304 (53)	
2: Compressions only	43 (8)	15 (3)		65 (12)	38 (7)	
1: Ventilations only	0	0		0	0	
Hand-position during compression						
4: Correct	50 (10)	68 (13)	NS	29 (5)	25 (4)	NS
3: Other wrong	312 (60)	333 (62)		250 (46)	299 (52)	
2: Too low	162 (31)	136 (25)		270 (49)	251 (44)	
1: Not attempted	0	0		0	0	
Average compression depth						
6: 50-59 mm	100 (19)	114 (21)	NS	183 (33)	224 (39)	0.031
5: ≥ 60 mm	5 (1)	2 (<1)		8 (2)	15 (3)	
4: 35-49 mm	255 (49)	271 (50)		239 (44)	242 (42)	
3:	0	0		0	0	
2: 1-34 mm	164 (31)	150 (28)		119 (22)	93 (16)	
1: Not attempted	0	0		0	0	
Total compression counted						
6: 140-190	179 (34)	240 (45)	<0.001	186 (34)	211 (37)	0.013
5: ≥ 191	266 (51)	223 (42)		253 (46)	285 (50)	
4: 121-139	29 (6)	42 (8)		51 (9)	37 (6)	
3: 81-120	36 (7)	19 (4)		43 (8)	38 (7)	
2: 1-80	14 (3)	13 (2)		16 (3)	4 (1)	
1: Not attempted	0	0		0	0	
Average ventilation volume						
5: 500-600 ml	27 (5)	31 (6)	<0.001	19 (4)	22 (4)	<0.001
4: 1-499 ml	43 (8)	59 (11)		50 (9)	49 (8)	
3: ≥ 601 ml	207 (40)	357 (66)		188 (34)	262 (46)	
2: 0 ml	204 (39)	75 (14)		225 (41)	204 (36)	
1: Not attempted	43 (8)	15 (3)		67 (12)	38 (7)	
Total ventilation counted						
5: 8-12	117 (22)	249 (46)	<0.001	98 (18)	139 (24)	0.001
4: 1-7	112 (21)	130 (24)		81 (15)	94 (16)	
3: ≥ 13	48 (9)	68 (13)		78 (14)	100 (17)	
2: 0	204 (39)	75 (14)		225 (41)	204 (36)	
1: Not attempted	43 (8)	15 (3)		67 (12)	38 (7)	
Total "hands-off" time						
4: 0-60 s	122 (23)	56 (10)	<0.001	196 (36)	164 (28)	0.018
3: 61-90 s	302 (58)	355 (66)		278 (51)	339 (59)	
2: 91-135 s	97 (18)	117 (22)		71 (13)	71 (12)	
1: 136-180 s	3 (1)	9 (2)		4 (1)	1 (<1)	

Total score	33 (30-36)	36 (33-38)	<0.001	31 (28-34)	33.0 (30-36)	<0.001

Results are presented as n (%) or median (25^{th}-75^{th} percentile). Differences in proportions between groups were analysed by Pearson chi-square test. Differences in continuous variables between groups were analysed by Mann-Whitney U test. P-values <0.05 were considered statistically significant. NS, not significant. The table lists the variable's best option at the top. All numbers are rounded to the nearest evenly integer.

Table 3 Chest compression data of the app- and the DVD-group.

	App directly after training (N=524)	DVD directly after training (N=537)	p-value	App at retest (N=549)	DVD at retest (N=575)	p-value
CC depth (mm)	41 (32-48)	42 (33-48)	NS	45 (36-52)*	47 (39-54)*	0.002
CC rate (n/min)	113 (91-131)	112 (100-124)	NS	102 (80-119)*	105 (89-119)*	0.013
CC rate 100-120/min	149 (28)	232 (43)	<0.001	166 (30)	217 (38)	0.008
CC with complete release	387 (74)	446 (83)	<0.001	416 (76)	476 (83)	0.004
Total hands-off time (s)	74 (61-86)	80 (71-90)	<0.001	68 (55-81)*	70 (58-81)*	NS

Values are presented as median (25^{th}-75^{th} percentile) or n (%). Differences in proportions were analysed by Pearson chi-square test. Differences between groups were analysed by Mann-Whitney U test. Differences between baseline and retest were analysed by Wilcoxon signed ranks test, where * indicates p<0.001. CC, chest compression; NS, not significant.

Willingness to act

For all variables reflecting willingness to act and potential obstacles, we found no significant differences between the DVD- and the app-group. At six months follow-up 81% in the DVD- and 78% in the app-group were more confident to act compared to prior to training. Also, students considered themselves to have enough knowledge to do chest compressions (91% in DVD- and 92% in app-group) and to do rescue breaths (74% in DVD- and 70% in app-group). Six students described situations where they had made a lifesaving intervention within 6 months after training. As shown in **Figure 2**, there was a huge difference in willingness to intervene in an OHCA situation of a friend compared to a situation involving a stranger (p<0.001). Fear to do harm (8% in DVD- and 7% in app-group) and fear of touching a stranger (6% in DVD- and 5% in app-group) are the two most common reasons for not wanting to perform chest compressions. Fear of disease transmission (8% in DVD- and 11% in app-group) and to touch a stranger (10% in DVD- and 8% in app-group) are the two most common reasons given for not wanting to perform ventilations on a stranger.

According to the questionnaire at six months, 31% of the students in the app-group had looked at the app one or several times after the training session and 26% had shown it to another person.

DISCUSSION

The main findings of the present study are two-fold. Firstly, a 50-minute DVD-based training method was superior to a 30-minute app-based education in terms of

teaching practical CPR skills to seventh grade students. Secondly, there was no significant difference in willingness to act between the app- and DVD-group. The study was carried out in schools from all socioeconomic areas and included 86% of eligible students, strengthening the generalisability of our findings.

The total score of the modified Cardiff-test differed significantly by 2-3 points between the app- and DVD-group at both occasions. The importance of this difference is unclear, since the size of a clinically relevant difference has yet to be established. The largest differences in favour of the DVD-based method were found for the following components: check responsiveness by talking, open airway, compression/ventilation ratio and ventilation. Three of these variables can be related; if students fail to create an open airway, they will fail with the ventilations, which result in the students making repeated attempts and thus losing the correct compression/ventilation ratio. Indeed, several studies have shown that a large proportion of participants after CPR training have limited knowledge on how to correctly perform rescue breath,[23, 25-26].

The cause of the differences observed between the app- and DVD-group in this study is unknown. The present study was not designed to explain the cause of any potential differences. In both methods, the students trained individually on a MiniAnne manikin and the training did not include any planned interaction or cooperation with classmates. In the DVD-based method, all students practiced the same task at the same time. It gave quantity of training and the teachers received an overview of the training and could easily see if a student did not follow the instructions. In the app-based method, the students could choose individually how many times they repeated the practical exercises. That makes it more difficult for the teacher to get an overview of the training and it is unclear if the students took responsibility and repeated the exercises until they felt they mastered each part.The moving instructions of the DVD in combination with repeated training might be considered a strength of the DVD-based method. An advantage with the app-method is that it can provide support in acute situations, and the app is also available after training has been completed, with the opportunity to repeat and to share with others. The DVD method has been applied for several years and has been revised and developed repeatedly. The app method is new and may need further development, for example by specifying the number of repetitions to be performed during training. A weakness with both the app- and the DVD-method is that no systematic and individual feedback was given to the students during training. The training was given to the entire class at the same time, to easily fit into the school schedule, but at the expense of limited opportunity to give feedback. Feedback is known to be one of the most powerful influences on performance,[27-28]. The issue of feedback is essential and should be explored in future research.

In our study, practical CPR skills were significantly reduced from measurement directly after training to six months in both groups, which is similar to other studies,[12, 20]. In evaluating the CPR skills of the participants, we consider the results of the six months test to be of most importance, since these results reflect the long-term knowledge of the students. At six months, the DVD-group obtained 58% (33 points) and the app-group 53% (31 points) of the maximum score, which is comparable with results of previous studies where seventh grade students performed 50% and adults 57-61% of the total score at 3-4 months after training,[23, 25].

At the 6 months retest, both groups performed 4-5 mm deeper compressions compared to baseline. Previous studies show significant correlations between age, weight, height and compression depth,[20, 29-31]. However, in our study it is unlikely that the strength of the students improved so much during 6 months as to explain the improved compression depth. Interestingly, similar results were observed in a pre-study, despite the retest being carried out after only 3 months,[22]. The oral feedback received by the students after the first test might have helped them to perform deeper chest compressions at the retest. Also, we cannot exclude the fact that the students at the retest were more familiar with the test doll and thus performed better. The proportion of students, who applied incorrect hand-position was high in both groups (at retest; 96% versus 95%). Previous studies, using diverse definitions, indicate a large variation (13-90%) regarding correct hand-position,[23, 25, 29, 31-32]. Isby et al argues that the definition of "incorrect hand-position" is important when results are compared,[25]. The poor hand-positioning in our study could possibly be explained by the fact that the compression place on MiniAnne, used during training, is “marked” and thus the students might not reflect on correct hand-positioning. At the test situation, however, the ResuciAnne has a "whole chest-skin" without marking.

Students generally have a positive attitude towards CPR training,[12,31,33-35]. Practical training reduces concern to make mistakes, increases self-reported confidence and willingness to intervene,[33,36-37]. In our study, there was no significant difference in willingness to act between the app- and DVD-group. However, we found a huge difference in willingness to intervene in a cardiac arrest situation of a friend compared to a situation involving a stranger. This is in accordance with previous studies,[33,36,38] and needs to be considered when designing educations. Common reasons for not starting CPR include lack of CPR knowledge and fear of not being able to do CPR correctly,[33,36,38-39]. In our study, fear to do harm was one of the most common reasons for not wanting to perform chest compressions on a stranger. In CPR training, it is important to emphasize that "laypeople cannot do anything wrong – the only wrong thing would be to do nothing",[7]. A common barrier for ventilation was fear of disease transmission. Therefore, it is important to emphasize that the risk of disease transmission during CPR intervention is very low,[40-41].

Clinical implication

The present study indicates that a DVD-based CPR training method might be preferable when teaching seventh grade students, although the clinical relevance of a 2-3 point difference is unclear. Further studies are needed to identify optimal and alternative teaching methods.

Study limitations

Firstly, we cannot exclude that the duration of the training (30 vs 50 minutes), rather than the type of training per se, accounted for the differences observed in the tests. However, in the app-based education, training on recovery position was excluded. Thus, there was time enough for the students in the app-group to carry out the same amount of cycles of compressions and ventilations as in the DVD-group.

Secondly, the questionnaire used to evaluate willingness to act contains only

hypothetical questions. They do not fully answer how the students would act in a real situation.

Thirdly, it is a risk that the instructors experience and/or enthusiasm affects the learning. Therefore, the methods were standardized to ensure equivalent education, the teacher only had a role as a facilitator during the training, and the practical exercises were based on instructions from the app and the DVD, respectively.

Fourthly, we cannot exclude the possibility of contamination between classes of the same school. However, a potential contamination is not expected to have a significant impact on the test results, since the hands-on training is by far the most important factor to acquire practical CPR skills,[9,20]. Also, if contamination existed and had an effect on test results, it would rather lessen than enhance any differences between groups.

Lastly, we do not know if the number of students in each class affects the outcome, but the instructor only had the role of facilitator and previous studies have shown that larger DVD-based groups are performing equivalent to smaller traditional instructor-led groups,[16].

CONCLUSION

Overall, a 50-minute DVD-based training seemed to be superior to a 30-minute app-based education in terms of teaching practical CPR skills to seventh grade students. After CPR training, a majority of students, regardless of training method, were willing to make a life-saving effort. However, only a third of the students would do both compressions and ventilations if a stranger suffers a cardiac arrest. This needs to be considered when designing future educations.

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Contributors AN contributed to the study design, developed the modified cardiff test and the questionnaire, conducted all measurements, analysed results and wrote the initial draft of the manuscript. LS contributed to the study design, developed the modified Cardiff test and revised the manuscript. HH and SKS contributed to the study design and revised the manuscript. LN contributed to the study design, developed the modified Cardiff test and the questionnaire, analysed results and revision of the manuscript.
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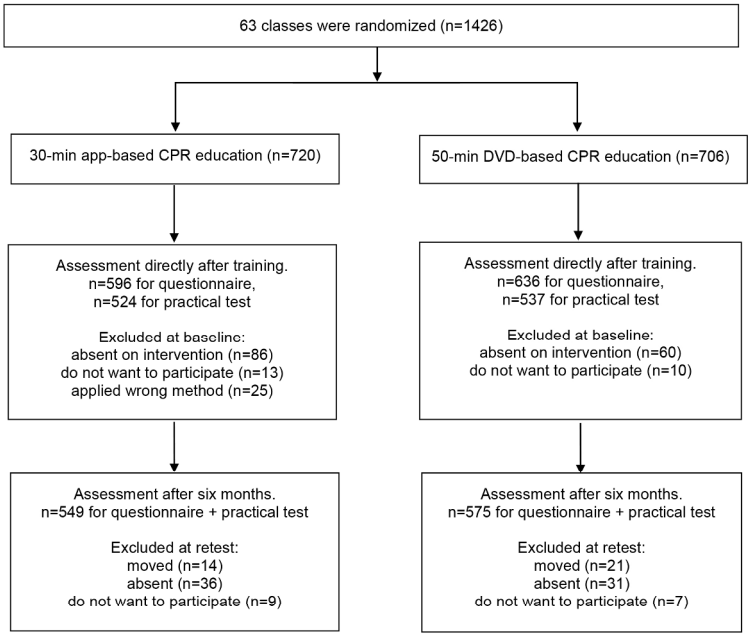
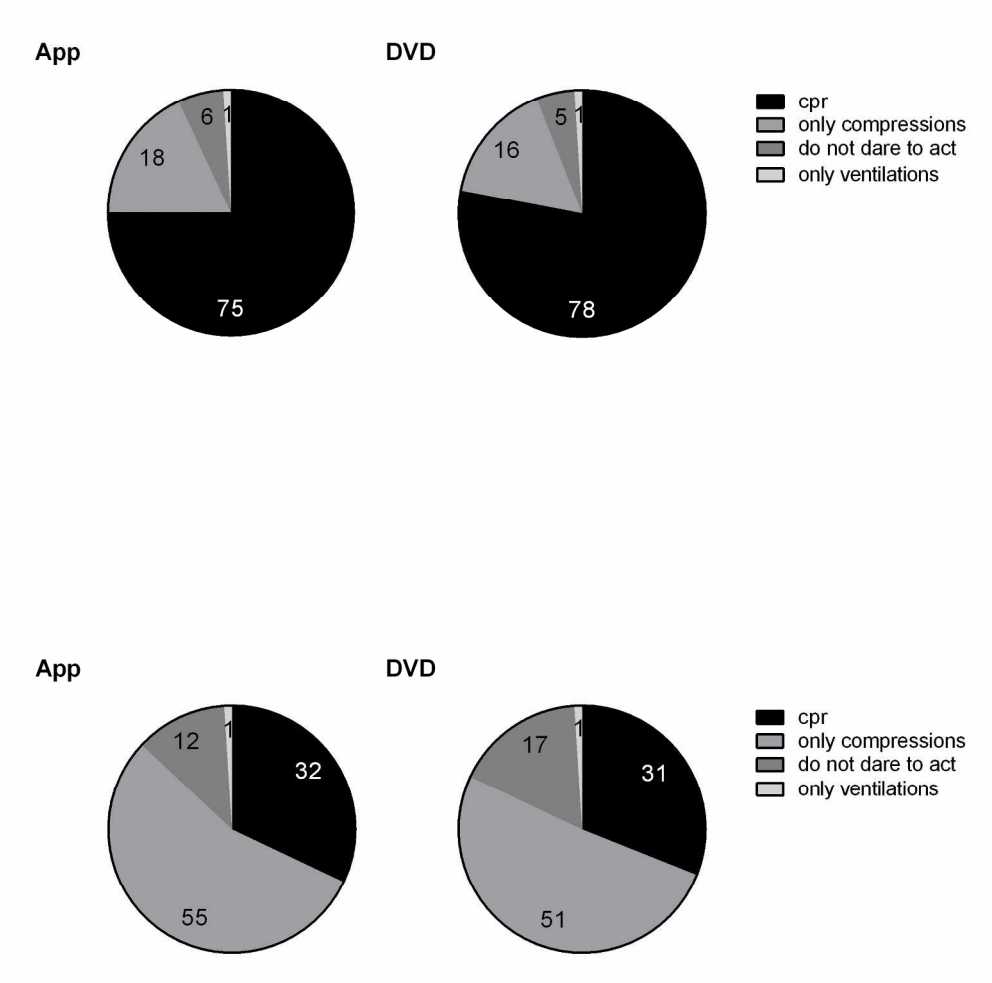
Figure 1 Flow chart on randomization and inclusion.

Figure 2 Students´ willingness to act if a friend suffers a cardiac arrests (upper panel) or if a stranger suffers a cardiac arrest (lower panel), as assessed six months after training. Values are given as percent. Numbers are n=549 (app) and n=575 (DVD).



Flow chart on randomization and inclusion.
178x273mm (300 x 300 DPI)



Students´ willingness to act if a friend suffers a cardiac arrests (upper panel) or if a stranger suffers a cardiac arrest (lower panel), as assessed six months after training. Values are given as percent. Numbers are n=549 (app) and n=575 (DVD).
208x203mm (300 x 300 DPI)

Supplementary file: the modified Cardiff test.

The modified version of the Cardiff test,[21], adapted to the ERC guidelines of 2010,[18]. The duration of the practical test was 3 minutes. The optimal conduct was 30 seconds for check responsiveness, check respiration and call for help, followed by 2.5 minutes of CPR. During the CPR, the participants were expected to perform at least 5 cycles of 30 compressions and 2 ventilations (30:2). The rules of assessment were pre-specified as follows:

Check responsiveness by talking
2. Yes, if some form of verbal communication as “are you ok” or “how are you”?
1. No, if no attempt at verbal communication was performed
Method: direct observation and real-time registration in the observation schedule by the test leader.

Check responsiveness by shaking
3. Yes, if the rescuer gently shake the victim shoulders.
2. No, if no attempt to shake the victim shoulders occurred.
1. Potentially dangerous, if the rescuer violently shakes the victim´s shoulders so the head lifted up and down against the ground, which can damage the head or the neck.
Method: direct observation and real-time registration in the observation schedule by the test leader.

Open the airway - chin lift, head tilt.
5. Perfect, if one hand on the forehead, two fingertips on the jawbone (not soft tissue) and gently lifted the chin and bent the head back ie by ERC guidelines.
4 Acceptable/partially correct if several indicators are performed, but not all.
3. Attempted other, if the rescuer tried in other ways than ERC recommendation.
2. Only one element is performed or if the rescuer tries but fails.
1. No, if no attempt to open the airway was performed.
Method: direct observation and real-time registration in the observation schedule by the test leader.

Checks respiration - see, listen, feel
2. Yes, if the rescuer did attempts of breath control, even if not all three actions see, listen and feel were performed and although if the total time of the control was less than 10 seconds.
1. No, if no attempt to check for breathing was performed.
Method: direct observation and real-time registration in the observation schedule by the test leader.

Calls for help or dials 112
2. Yes, calls for help and dials 112. Alarm should be done within the first minute.
1. No, if no attempt to get help was performed.
Method: direct observation and real-time registration in the observation schedule by the test leader.

Compression/ventilation ratio
4. 30:2 (28-32:2), if the rescuer practical applied compressions and ventilations with the relationship 28-32:2 during the whole test.
3. Other, if the rescuer applied different ratio of compressions and ventilations than 28-32:2.
2. Compressions only.
1. Ventilations only.
Method: Data from Laerdal PC Skill Reporter Systems was transferred to a scoring sheet after the test.

Hand-position during compression
Incorrect hand-position was recorded if one compression was in the wrong place, since one wrong compression can cause rib fracture or fracture the xiphoid process of sternum.
4. Correct, if the rescuer place the heel of one hand in the centre of the victim’s chest and with the other hand above.
3. Other wrong, if the rescuer performs chest compressions too high up on the sternum or to the side of the sternum.
2. Too low, if the rescuer performs chest compressions too low on the sternum or on the abdomen.
1. Not attempted, if no compressions were performed.
Method: Data from Laerdal PC Skill Reporter Systems was transferred to a scoring sheet after the test.

Average compression depth
The PC Skill Reporter system version 2.4 measures up to 60 mm compression depth. To avoid that those who compress >60 mm obtain the highest score, highest score was given for an average compression depth of 50-59 mm. Those who compressed ≥60 mm received 5 points. We chose to retain the 6-point scale, as in previous studies,[23] even though no one could receive 3 points, which would corresponded to a > 65 mm compression depth.
6. 50-59 mm.
5. ≥ 60 mm
4. 35-49 mm
3.
2. 1-34 mm
1. Not attempted, if no compressions were performed.
Method: Data from Laerdal PC Skill Reporter Systems was transferred to a scoring sheet after the test.

Total compression counted
6. 140-190
5. ≥ 191
4. 121-139
3. 81-120
2. 1-80
1. Not attempted, if no compressions were performed.
Method: Data from Laerdal PC Skill Reporter Systems was transferred to a scoring sheet after the test.

Average ventilation volume
5. 500-600 ml
4. 1-499 ml
3. ≥ 601 ml
2. 0 ml, if the rescuer tried to do rescue breaths but failed.
1. Not attempted, if no rescue breaths were performed.
Method: Direct observation and real-time registration if the rescuer tried to do rescue breath. Exact volume, from Laerdal PC Skill Reporter Systems, was transferred to the scoring sheet after the test.

Total ventilation counted
5.8-12
4. 1-7
3. ≥ 13
2. 0, if the rescuer tried to do rescue breaths but failed.
1. Not attempted, if no rescue breaths were performed.
Method: Direct observation and real-time registration if the rescuer tried to do rescue breath. Exact number, from Laerdal PC Skill Reporter Systems, was transferred to the scoring sheet after the test.

Total ”hands-off” time
4. 0-60 s
3. 61-90 s
2. 91-135 s
1. 136-180 s
Method: Data from Laerdal PC Skill Reporter Systems was transferred to a scoring sheet after the test.

Supplementary file: questionnaires used directly after training and at six months follow-up

Questionnaire directly after training

Have you previously practiced

chest compressions? Yes ☐ No ☐

ventilations? Yes ☐ No ☐

Do you think that your skills are sufficient to perform

chest compressions? Yes ☐ No ☐ Do not know ☐

ventilations? Yes ☐ No ☐ Do not know ☐

Are you more confident now than before the training to act and start CPR? Yes ☐ No ☐ Do not know ☐

You are at home. How would you act if a friend or relative suffered a sudden cardiac arrest? Tick one answer:

I would not dare or want to intervene ☐

I would give chest compressions only ☐

I would give ventilations only ☐

I would give both compressions and ventilations ☐

Enter the reason that you do not dare or want to do chest compressions?

Lack of knowledge ☐

Afraid to hurt the person ☐

Afraid of transmitted disease ☐

Other reasons ☐

Do not know ☐

Enter the reason that you do not dare or want to do ventilations?

Lack of knowledge ☐

Afraid to hurt the person ☐

Afraid of transmitted disease ☐

Other reasons ☐

Do not know ☐

You are standing at a bus stop. How would you act if an unknown person suffered a sudden cardiac arrest? Tick one answer:

I would not dare or want to intervene ☐

I would give chest compressions only ☐

I would give ventilations only ☐

I would give both compressions and ventilations ☐

Enter the reason that you do not dare or want to do chest compressions?

Lack of knowledge ☐
Afraid to hurt the person ☐
I do not want to touch a stranger ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

Enter the reason that you do not dare or want to do ventilations?

Lack of knowledge ☐
Afraid to hurt the person ☐
I do not want to touch a stranger ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

Questionnaire at six months follow-up

Have you done a lifesaving intervention in real life after the CPR training? Yes ☐ No ☐

If yes, please describe your lifesaving intervention and the situation:_____

Do you think it is important to learn cardiopulmonary resuscitation in school? Yes ☐ No ☐ Do not know ☐

Do you think that your skills are sufficient to perform

chest compressions? Yes ☐ No ☐ Do not know ☐

ventilations? Yes ☐ No ☐ Do not know ☐

Are you more confident now than before the training to act and start CPR? Yes ☐ No ☐ Do not know ☐

You are at home. How would you act if a friend or relative suffered a sudden cardiac arrest? Tick one answer:

I would not dare or want to intervene ☐
I would give chest compressions only ☐
I would give ventilations only ☐
I would give both compressions and ventilations ☐

Enter the reason that you do not dare or want to do chest compressions?

Lack of knowledge ☐
Afraid to hurt the person ☐

Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

Enter the reason that you do not dare or want to do ventilations?
Lack of knowledge ☐
Afraid to hurt the person ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

You are standing at a bus stop. How would you act if an unknown person suffered a sudden cardiac arrest? Tick one answer:
I would not dare or want to intervene ☐
I would give chest compressions only ☐
I would only give ventilations ☐
I would give both compressions and ventilations ☐

Enter the reason that you do not dare or want to do chest compressions?
Lack of knowledge ☐
Afraid to hurt the person ☐
I do not want to touch a stranger ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

Enter the reason that you do not dare or want to do ventilations?
Lack of knowledge ☐
Afraid to hurt the person ☐
I do not want to touch a stranger ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

How many times have you used/read on the app "Save the heart" (including any lesson in school)?
1 ☐
2-3 ☐
4-5 ☐
> 5 ☐
Do not know ☐

Have you shown the app for someone else? Yes ☐ No ☐ Do not know ☐

CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	4
	2b	Specific objectives or hypotheses	4
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	4
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	N/A
Participants	4a	Eligibility criteria for participants	4
	4b	Settings and locations where the data were collected	4, 6
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	4-5
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	6
	6b	Any changes to trial outcomes after the trial commenced, with reasons	N/A
Sample size	7a	How sample size was determined	6
	7b	When applicable, explanation of any interim analyses and stopping guidelines	N/A
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	4
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	4
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	4
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	4, 6
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	6

		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	5
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	6
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	N/A
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	6-7 and Figure 1
	13b	For each group, losses and exclusions after randomisation, together with reasons	Figure 1
Recruitment	14a	Dates defining the periods of recruitment and follow-up	5
	14b	Why the trial ended or was stopped	N/A
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Table 1
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	6, Figure 1
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	6-9
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	N/A
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	N/A
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	N/A
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	3, 11
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	9-11
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	9-10
Other information			
Registration	23	Registration number and name of trial registry	N/A
Protocol	24	Where the full trial protocol can be accessed, if available	N/A
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	12

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

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Effect of mobile application- versus DVD-based CPR training on students' practical CPR skills and willingness to act: a cluster randomised study

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Effect of mobile application- versus DVD-based CPR training on students' practical CPR skills and willingness to act: a cluster randomised study

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Keywords: CPR training, students, dvd, mobile application, willingness

Word count of abstract: 294
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ABSTRACT

Objectives: The aim was to compare students´ practical CPR skills and willingness to perform bystander CPR, after a 30-minute mobile application (app)-based versus a 50-minute DVD-based training.

Settings: Seventh grade students in two Swedish municipalities.

Design: A cluster randomized trial. The classes were randomised to receive app- or DVD-based training. Willingness to act and practical CPR skills were assessed, directly after training and at six months, by using a questionnaire and a PC Skill Reporting System. Data on CPR skills were registered in a modified version of the Cardiff test, where scores were given in 12 different categories, adding up to a total score of 12-48 points. Training and measurements were performed from December 2013 to October 2014.

Participants: Sixty-three classes or 1232 seventh grade students (13-year old) were included in the study.

Primary and secondary outcome measures: Primary endpoint was the total score of the modified Cardiff test. The individual variables of the test and self-reported willingness to make a lifesaving intervention were secondary endpoints.

Results: The DVD-based group was superior to the app-based group in CPR skills; a total score of 36 (33-38) versus 33 (30-36) directly after training ($p<0.001$) and 33 (30-36) and 31 (28-34) at six months ($p<0.001$), respectively. At six months, the DVD-group performed significantly better in 8 out of 12 CPR skill components. Both groups improved compression depth from baseline to follow-up. If a friend suffered cardiac arrest 78% (DVD) versus 75% (app) would do compressions and ventilations, whereas only 31% (DVD) versus 32% (app) would perform standard CPR if the victim was a stranger.

Conclusions: At six months follow-up, the 50-minute DVD-based group showed superior CPR skills compared to the 30-minute app-based group. The groups did not differ in regard to willingness to make a lifesaving effort.

Strengths and limitations of this study

Largest randomised study to compare CPR training methods (mobile application versus DVD) in students.

The intervention was carried out in two major municipalities with schools from all socioeconomic areas and included 86% of eligible students.

Outcome measures of both practical CPR skills and willingness to act were evaluated directly after training and at six month.

The two CPR training methods differed in duration (30 vs 50 minutes) and thus we cannot differentiate between effects caused by type of training as opposed to duration of training.

INTRODUCTION

The incidence of out-of-hospital cardiac arrest (OHCA) in Sweden is approximately 54 per 100,000 persons per year,[1]. A majority of all OHCA occur at home, where the prognosis is poorer compared to cardiac arrests occurring at other locations in the community [2]. Early cardiopulmonary resuscitation (CPR) increases the chance of survival two to three times,[3-5]. Therefore, it is important that as many individuals as possible in the community acquire sufficient CPR skills.

The Swedish school curriculum specifies since 2011 that CPR skills are a core content in grade 7-9 (age 13-15),[6]. Each school decides how the education is offered; theoretical or practical, as one occasion or repeatedly. A statement from EuPSF, ERC, ILCOR and WFSA, approved by the WHO, recommend all schoolchildren CPR training every year from the age of 12,[7]. If all students receive practical CPR training in school, a large proportion of the population will have basic skills within a few decades. Such a situation could potentially increase CPR intervention of bystanders in OHCA and have significant impact on public health,[7-12].

Brief DVD-based courses are successful in teaching CPR-skills [12-16]. How short and simplified the training can be without negatively affecting students' skills and their willingness to act is, however, largely unknown [12]. There are plenty of different mobile applications (app), intended to spread how to perform CPR. An app is easily accessible and the format might appeal to young people. The aim of this study was to evaluate alternative CPR training methods by comparing the practical CPR skills and the willingness to act in 13-year old students, directly after a 30-minute app-based or a 50-minute DVD-based training session, and at six months of follow-up.

METHODS

Study population and design

In accordance with the Swedish school curriculum [6], the intervention was applied in grade 7 (13-year old students). Invitations to participate in the study were sent to the headmasters of all council schools in two municipalities (140,000 inhabitants). Eighteen of 24 schools agreed to participate. Four schools did not respond and two had CPR education only for grade 9. Prior to the study, students and their guardians obtained a letter with study information. Study participation of the individual students was completely voluntary and all participants gave an oral informed consent.

Inclusion criteria: seventh grade student in one of the participating schools. *Exclusion criteria*: student does not want to participate, student with a physical handicap that significantly limited the physical performance, classes of students with development disabilities (these classes are age-integrated and have fewer students per class).

The study used a cluster randomized design,[17]. A randomization list was generated by an independent statistician and each of the sixty-three participating classes were randomly assigned to one of main interventions: app- or DVD-based education. In addition to the main intervention, some classes were randomized to various additional interventions, which were equally distributed in both groups. Ten classes were randomly assigned to perform practical test only at six months. Thus, more students participated at the six-month retest (**Figure 1**). In the framework of this

study, the additional interventions have not been analysed. Training and measurements were performed from December 2013 to October 2014.

CPR education

The CPR education was performed in accordance with the European Resuscitation Council (ERC) guidelines 2010,[18]. Training was given to the entire class together. Classes consisted of 14-29 students. All participants in both interventions groups used an individual training manikin, MiniAnne, during the training. Ten teachers were previous CPR-instructors and 19 teachers received a five-hour education to become CPR-instructors. All teachers obtained individual oral and written information to assure they were up to date with present CPR guidelines and training. The teachers acted as facilitator; they introduced the lesson, gave advice on the fly, answered questions and completed the course. For the app-based method, the students practised independently by using eight images with related text in a mobile application; introduction, checks responsiveness, open the airway, checks respiration, alarm, chest compressions, ventilations and CPR 30:2,[19]. For the DVD-based method, the whole class practised CPR and recovery position together, based on instructions from a 31-minute DVD. A total of 14 cycles of compressions and ventilations were carried out. The DVD and app are produced by the Swedish Resuscitation Council.

Assessment

Previous studies indicate that CPR skills can deteriorate already in 3-6 months,[12, 20]. In the present trial, CPR skills and willingness to act were evaluated directly after training and at six months, in order to assess both immediate and long-term effects of the education. The six month follow-up was carried out without prior notice.

Laerdal PC skill reporting system version 2.4, linked to resuscitation manikin ResusciAnne, was used to automatically measure quantitative data; compression-ventilation ratio, hand-position, compression depth, total number of compressions and ventilations, ventilation volume, hands-off time, compression rate and incomplete release. The participants' actions regarding check responsiveness, check respiration and call for help were assessed by direct observation of the investigator (AN). Collected data were recorded directly into a scoring sheet, which was a modified version of the validated Cardiff Test [21]. A score was given in each category and added up to a total score of 12-48 points. All categories of the scoring sheet are described in detail in the supplementary file 1. The tests were not filmed, because several students of a pre-study experienced filming as stressful,[22].

The ERC guidelines recommend a compression depth of 50-60 mm,[18]. The PC Skill Reporter System measures up to 60 mm compression depth. To avoid that those who compress >60 mm obtain the highest score (6 points), highest score was given for an average compression depth of 50-59 mm. Those who compressed ≥60 mm received 5 points. We chose to retain the 6-point scale, as in previous studies,[23] even though no one could receive 3 points, which would corresponded to a >65 mm compression depth.

The duration of the practical test was 3 minutes. The optimal conduct was 30 seconds to check responsiveness, check respiration and call for help, followed by 2.5

minutes of CPR. During the CPR, participants were expected to perform at least 5 cycles of 30 compressions and 2 ventilations. The tests were conducted at the schools with one student at a time. The student was introduced to the test by the following story: “You see an adult, someone you know, who collapsed in front of you. There is no one more on site. Show how you would act in a real life situation”. During the test, the test leader answered questions about the victim's condition only if relevant actions had already been carried out. Directly after the practical test, students received individual constructive feedback from the investigator for two minutes. The students then answered a fixed-response questionnaire, where questions were asked about background factors and willingness to act. A majority of students responded to the survey online and each question had to be answered in order to proceed to the next. Two of the questions allowed the student to add their own comments. Prior to our study, the comprehension of the questionnaire was tested and found satisfactory in a separate cohort of 175 students. The questionnaire is included in the supplementary file 2.

The investigator (AN) is a registered CPR instructor, experienced in the modified Cardiff test. The investigator was blinded to the allocated training method of the students.

Study outcome measures

Primary endpoint was the total score of the modified Cardiff test. The total score was calculated by adding the individual scores of the 12 different categories (check responsiveness by talking, check responsiveness by shaking, open the airway, checks respiration, calls for help or dials 112, compression/ventilation ratio, hand-position during compression, average compression depth, total compression counted, average ventilation volume, total ventilation counted, total hands-off time) assessed by the practical test. The individual categories of the test and self-reported willingness to make a lifesaving intervention were secondary endpoints.

Statistical plan and analyses

Data are presented as proportion (percent), median (interquartile range) or mean (SD), as appropriate. Differences in proportions were analysed with Pearson chi-square test. Differences in median total score between intervention groups were assessed using Mann-Whitney U-test. Differences in mean chest compression data between intervention groups were analysed using unpaired t-test and differences within groups by paired t-test. By calculating the (individual total score-12)/(maximum total score-12)*100, we received a measure of CPR quality in relation to optimal CPR. Multiple linear regression analyses for the total score of the modified Cardiff test were performed, including baseline covariates (gender, previous compression and ventilation training, previous experience of a cardiac arrest situation, school, and class) as fixed effects. A p-value <0.05 was considered statistically significant.

Sample size calculations were based on data from a pre-study,[22]. To test for superiority with a 90% power to detect a 2 point intergroup difference of the total score of the modified Cardiff test with a significance level of 0.05, an effective sample size of 194 students would be needed. Intraclass correlation coefficient (95% CI) was 0.20 (0.19, 0.21),[17, 24]. The design effect, caused by the cluster randomization, was 4.22. A number of 1061 and 1124 students performed the first and the second test,

respectively. This corresponds to an effective sample size of 251 and 266, respectively, which is well above the 194 needed to reach a power of 90%.

Analyses were performed using IBM SPSS version 21 and STATA version 13.1.

RESULTS

Student sample

A total of 1426 students from 63 seventh grade classes in 18 schools were randomized to receive a 30-minute app-based or 50-minute DVD-based CPR training. At baseline 1232 students, corresponding to 86% of the eligible students, were included in the study. At six months 1124 of these students completed the retest **(Figure 1)**. The baseline characteristics of the students are summarized in **Table 1.**

Table 1 Students´ characteristics.

	App (n=596)	DVD (n=636)	p-value
Male	285 (48)	294 (46)	NS
Previous compression training	192 (32)	171 (27)	NS
Previous ventilation training	158 (26)	113 (18)	<0.001
Previously experienced a cardiac arrest situation	19 (3)	21 (3)	NS
Number of schools in which methods were applied	16	14	NS

Values are presented as n (%). Differences in proportions between groups were analysed by Pearson chi-square test. NS, not significant.

CPR skills

The DVD-group performed significantly better in terms of total score at both time points; at baseline 36 (33-38) versus 33 (30-36) points (p<0.001) and at six months 33 (30-36) versus 31 (28-34) points (p<0.001). For individual variables, the DVD-group performed significantly better in six out of twelve immediately after training and eight out of twelve at six months. Results of the modified Cardiff-test are summarized in **Table 2.**

Baseline characteristics were well matched between the intervention groups, except that students in the app group had significantly more previous ventilation training. Nevertheless, multiple linear regression analyses (including all baseline covariates) were performed to adjust for potential confounding, without any significant change in effect of the intervention being observed. The mean difference (95% CI) in total score between intervention groups was 2.52 (2.03, 3.02) points before and 2.55 (2.05, 3.05) points after adjustment at the first test, and 1.61 (1.14, 2.07) points before and 1.62 (1.15, 2.09) points after adjustment at the six months test.

Data on variables reflecting the quality of chest compressions are presented in **Table 3**. Of note, compression depth and hands-off time improved significantly from baseline to six months testing in both the DVD- and the app-group. Also, the DVD-group performed significantly better in terms of chest compressions with complete release.

Table 2 Assessment of CPR skills directly after app-based or DVD-based training (baseline) and at six months (retest).

	App, baseline (N=524)	DVD, baseline (N=537)	p-value	App, retest (N=549)	DVD, retest (N=575)	p-value
Checks responsiveness by talking						
2: Yes	241 (46)	354 (66)	<0.001	127 (23)	213 (37)	<0.001
1: No	283 (54)	183 (34)		422 (77)	362 (63)	
Checks responsiveness by shaking						
3: Yes	353 (67)	376 (70)	NS	164 (30)	219 (38)	0.004
2: No	169 (32)	160 (30)		385 (70)	356 (62)	
1: Potentially dangerous	2 (<1)	1 (<1)		0	0	
Open airway – chin lift, head tilt						
5: Perfect	6 (1)	23 (4)	<0.001	3 (1)	9 (2)	<0.001
4: Acceptable	46 (9)	110 (20)		9 (2)	17 (3)	
3: Attempted other	3 (<1)	1 (<1)		0	1 (<1)	
2: Only one element	130 (25)	186 (35)		18 (3)	73 (13)	
1: No	339 (65)	217 (40)		519 (94)	475 (83)	
Checks respiration – see, listen, feel						
2: Yes	388 (74)	396 (74)	NS	225 (41)	327 (57)	NS
1: No	136 (26)	141 (26)		324 (59)	248 (43)	
Dials 112						
2: Yes	396 (76)	431 (80)	NS	411 (75)	458 (80)	NS
1: No	128 (24)	106 (20)		138 (25)	117 (20)	
Compression/ventilation ratio						
4: 30:2 (28-32:2)	182 (35)	292 (54)	<0.001	165 (30)	233 (40)	<0.001
3: Other ratio	299 (57)	230 (43)		319 (58)	304 (53)	
2: Compressions only	43 (8)	15 (3)		65 (12)	38 (7)	
1: Ventilations only	0	0		0	0	
Hand-position during compression						
4: Correct	50 (10)	68 (13)	NS	29 (5)	25 (4)	NS
3: Other wrong	312 (60)	333 (62)		250 (46)	299 (52)	
2: Too low	162 (31)	136 (25)		270 (49)	251 (44)	
1: Not attempted	0	0		0	0	
Average compression depth						
6: 50-59 mm	100 (19)	114 (21)	NS	183 (33)	224 (39)	0.031
5: ≥ 60 mm	5 (1)	2 (<1)		8 (2)	15 (3)	
4: 35-49 mm	255 (49)	271 (50)		239 (44)	242 (42)	
2: 1-34 mm	164 (31)	150 (28)		119 (22)	93 (16)	
1: Not attempted	0	0		0	0	
Total compression counted						
6: 140-190	179 (34)	240 (45)	<0.001	186 (34)	211 (37)	0.013
5: ≥ 191	266 (51)	223 (42)		253 (46)	285 (50)	
4: 121-139	29 (6)	42 (8)		51 (9)	37 (6)	
3: 81-120	36 (7)	19 (4)		43 (8)	38 (7)	
2: 1-80	14 (3)	13 (2)		16 (3)	4 (1)	
1: Not attempted	0	0		0	0	
Average ventilation volume						
5: 500-600 ml	27 (5)	31 (6)	<0.001	19 (4)	22 (4)	<0.001
4: 1-499 ml	43 (8)	59 (11)		50 (9)	49 (8)	
3: ≥ 601 ml	207 (40)	357 (66)		188 (34)	262 (46)	
2: 0 ml	204 (39)	75 (14)		225 (41)	204 (36)	
1: Not attempted	43 (8)	15 (3)		67 (12)	38 (7)	
Total ventilation counted						
5: 8-12	117 (22)	249 (46)	<0.001	98 (18)	139 (24)	0.001
4: 1-7	112 (21)	130 (24)		81 (15)	94 (16)	
3: ≥ 13	48 (9)	68 (13)		78 (14)	100 (17)	
2: 0	204 (39)	75 (14)		225 (41)	204 (36)	

1: Not attempted	43 (8)	15 (3)		67 (12)	38 (7)	
Total "hands-off" time						
4: 0-60 s	122 (23)	56 (10)	<0.001	196 (36)	164 (28)	0.018
3: 61-90 s	302 (58)	355 (66)		278 (51)	339 (59)	
2: 91-135 s	97 (18)	117 (22)		71 (13)	71 (12)	
1: 136-180 s	3 (1)	9 (2)		4 (1)	1 (<1)	
Total score	33 (30-36)	36 (33-38)	<0.001	31 (28-34)	33.0 (30-36)	<0.001

Results are presented as n (%) or median (25^{th}-75^{th} percentile). Differences in proportions between groups were analysed by Pearson chi-square test. Differences in total score between intervention groups were analysed by Mann-Whitney U test. P-values <0.05 were considered statistically significant. NS, not significant. The table lists the variable's best option at the top. All numbers are rounded to the nearest evenly integer.

Table 3 Chest compression data of the app- and the DVD-group.

	App directly after training (N=524)	DVD directly after training (N=537)	p-value	App at retest (N=549)	DVD at retest (N=575)	p-value
CC depth (mm)	40 (11)	40 (11)	NS	44 (10)*	46 (10)*	0.002
CC rate (n/min)	111 (27)	112 (20)	NS	100 (27)*	104 (22)*	0,012
CC rate 100-120/min	149 (28)	232 (43)	<0.001	166 (30)	217 (38)	0.008
CC with complete release	387 (74)	446 (83)	<0.001	416 (76)	476 (83)	0.004
Total hands-off time (s)	73 (21)	81 (19)	<0.001	68 (24)*	69 (22)*	NS

Values are presented as mean (SD) or n (%). Differences in proportions were analysed by Pearson chi-square test. Differences between intervention groups were analysed by unpaired t-test. Differences between baseline and retest were analysed by paired t-test, where * indicates p<0.001. CC, chest compression; NS, not significant.

Willingness to act

For all variables reflecting willingness to act and potential obstacles, we found no significant differences between the DVD- and the app-group. At six months follow-up 81% in the DVD- and 78% in the app-group were more confident to act compared to prior to training. Also, students considered themselves to have enough knowledge to do chest compressions (91% in DVD- and 92% in app-group) and to do rescue breaths (74% in DVD- and 70% in app-group). Six students described situations where they had made a lifesaving intervention within 6 months after training. As shown in **Figure 2**, there was a huge difference in willingness to intervene in an OHCA situation of a friend compared to a situation involving a stranger (p<0.001). Fear to do harm (8% in DVD- and 7% in app-group) and fear of touching a stranger (6% in DVD- and 5% in app-group) are the two most common reasons for not wanting to perform chest compressions. Fear of disease transmission (8% in DVD- and 11% in app-group) and to touch a stranger (10% in DVD- and 8% in app-group) are the two most common reasons given for not wanting to perform ventilations on a stranger.

According to the questionnaire at six months, 31% of the students in the app-group had looked at the app one or several times after the training session and 26% had shown it to another person.

DISCUSSION

The main findings of the present study are two-fold. Firstly, a 50-minute DVD-based training method was superior to a 30-minute app-based education in terms of teaching practical CPR skills to seventh grade students. Secondly, there was no significant difference in willingness to act between the app- and DVD-group. The study was carried out in schools from all socioeconomic areas and included 86% of eligible students, strengthening the generalisability of our findings.

The total score of the modified Cardiff-test differed significantly by 2-3 points between the app- and DVD-group at both occasions. The importance of this difference is unclear, since the size of a clinically relevant difference has yet to be established. The largest differences in favour of the DVD-based method were found for the following components: check responsiveness by talking, open airway, compression/ventilation ratio and ventilation. Three of these variables can be related; if students fail to create an open airway, they will fail with the ventilations, which result in the students making repeated attempts and thus losing the correct compression/ventilation ratio. Indeed, several studies have shown that a large proportion of participants after CPR training have limited knowledge on how to correctly perform rescue breath,[23, 25-26].

The cause of the differences observed between the app- and DVD-group in this study is unknown. The present study was not designed to explain the cause of any potential differences. In both methods, the students trained individually on a MiniAnne manikin and the training did not include any planned interaction or cooperation with classmates. In the DVD-based method, all students practiced the same task at the same time. It gave quantity of training and the teachers received an overview of the training and could easily see if a student did not follow the instructions. In the app-based method, the students could choose individually how many times they repeated the practical exercises. That makes it more difficult for the teacher to get an overview of the training and it is unclear if the students took responsibility and repeated the exercises until they felt they mastered each part.The moving instructions of the DVD in combination with repeated training might be considered a strength of the DVD-based method. An advantage with the app-method is that it can provide support in acute situations, and the app is also available after training has been completed, with the opportunity to repeat and to share with others. The DVD method has been applied for several years and has been revised and developed repeatedly. The app method is new and may need further development, for example by specifying the number of repetitions to be performed during training. A weakness with both the app- and the DVD-method is that no systematic and individual feedback was given to the students during training. The training was given to the entire class at the same time, to easily fit into the school schedule, but at the expense of limited opportunity to give feedback. Feedback is known to be one of the most powerful influences on performance,[27-28]. The issue of feedback is essential and should be explored in future research.

In our study, practical CPR skills were significantly reduced from measurement directly after training to six months in both groups, which is similar to other studies,[12, 20]. In evaluating the CPR skills of the participants, we consider the results of the six months test to be of most importance, since these results reflect the

long-term knowledge of the students. At six months, the DVD-group obtained 58% (33 points) and the app-group 53% (31 points) of the maximum score, which is comparable with results of previous studies where seventh grade students performed 50% and adults 57-61% of the total score at 3-4 months after training,[23, 25].

At the 6 months retest, both groups performed 4-5 mm deeper compressions compared to baseline. Previous studies show significant correlations between age, weight, height and compression depth,[20, 29-31]. However, in our study it is unlikely that the strength of the students improved so much during 6 months as to explain the improved compression depth. Interestingly, similar results were observed in a pre-study, despite the retest being carried out after only 3 months,[22]. The oral feedback received by the students after the first test might have helped them to perform deeper chest compressions at the retest. Also, we cannot exclude the fact that the students at the retest were more familiar with the test doll and thus performed better. The proportion of students, who applied incorrect hand-position was high in both groups (at retest; 96% versus 95%). Previous studies, using diverse definitions, indicate a large variation (13-90%) regarding correct hand-position,[23, 25, 29, 31-32]. Isby et al argues that the definition of "incorrect hand-position" is important when results are compared,[25]. The poor hand-positioning in our study could possibly be explained by the fact that the compression place on MiniAnne, used during training, is “marked” and thus the students might not reflect on correct hand-positioning. At the test situation, however, the ResuciAnne has a "whole chest-skin" without marking.

Students generally have a positive attitude towards CPR training,[12,31,33-35]. Practical training reduces concern to make mistakes, increases self-reported confidence and willingness to intervene,[33,36-37]. In our study, there was no significant difference in willingness to act between the app- and DVD-group. However, we found a huge difference in willingness to intervene in a cardiac arrest situation of a friend compared to a situation involving a stranger. This is in accordance with previous studies,[33,36,38] and needs to be considered when designing educations. Common reasons for not starting CPR include lack of CPR knowledge and fear of not being able to do CPR correctly,[33,36,38-39]. In our study, fear to do harm was one of the most common reasons for not wanting to perform chest compressions on a stranger. In CPR training, it is important to emphasize that "laypeople cannot do anything wrong – the only wrong thing would be to do nothing",[7]. A common barrier for ventilation was fear of disease transmission. Therefore, it is important to emphasize that the risk of disease transmission during CPR intervention is very low,[40-41].

Clinical implication

The present study indicates that a DVD-based CPR training method might be preferable when teaching seventh grade students, although the clinical relevance of a 2-3 point difference is unclear. Further studies are needed to identify optimal and alternative teaching methods.

Study limitations

Firstly, we cannot exclude that the duration of the training (30 vs 50 minutes), rather than the type of training per se, accounted for the differences observed in the tests. However, in the app-based education, training on recovery position was excluded.

Thus, there was time enough for the students in the app-group to carry out the same amount of cycles of compressions and ventilations as in the DVD-group.

Secondly, the questionnaire used to evaluate willingness to act contains only hypothetical questions. They do not fully answer how the students would act in a real situation.

Thirdly, it is a risk that the instructors experience and/or enthusiasm affects the learning. Therefore, the methods were standardized to ensure equivalent education, the teacher only had a role as a facilitator during the training, and the practical exercises were based on instructions from the app and the DVD, respectively.

Fourthly, we cannot exclude the possibility of contamination between classes of the same school. However, a potential contamination is not expected to have a significant impact on the test results, since the hands-on training is by far the most important factor to acquire practical CPR skills,[9,20]. Also, if contamination existed and had an effect on test results, it would rather lessen than enhance any differences between groups.

Lastly, we do not know if the number of students in each class affects the outcome, but the instructor only had the role of facilitator and previous studies have shown that larger DVD-based groups are performing equivalent to smaller traditional instructor-led groups,[16].

CONCLUSION

Overall, a 50-minute DVD-based training seemed to be superior to a 30-minute app-based education in terms of teaching practical CPR skills to seventh grade students. After CPR training, a majority of students, regardless of training method, were willing to make a life-saving effort. However, only a third of the students would do both compressions and ventilations if a stranger suffers a cardiac arrest. This needs to be considered when designing future educations.

Conflict of interest statement Nothing to declare.
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Contributors AN contributed to the study design, developed the modified cardiff test and the questionnaire, conducted all measurements, analysed results and wrote the initial draft of the manuscript. LS contributed to the study design, developed the modified Cardiff test and revised the manuscript. HH and SKS contributed to the study design and revised the manuscript. LN contributed to the study design, developed the modified Cardiff test and the questionnaire, analysed results and revision of the manuscript.
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Ethics approval The study was approved by the Regional Ethical Review Board of Linköping, Sweden (2013/358-31).

Data sharing statement No additional unpublished data is available.

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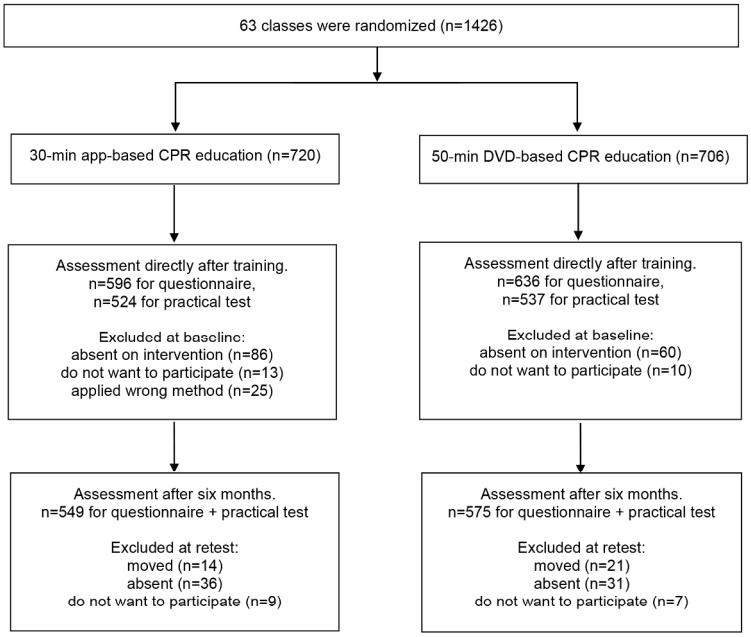
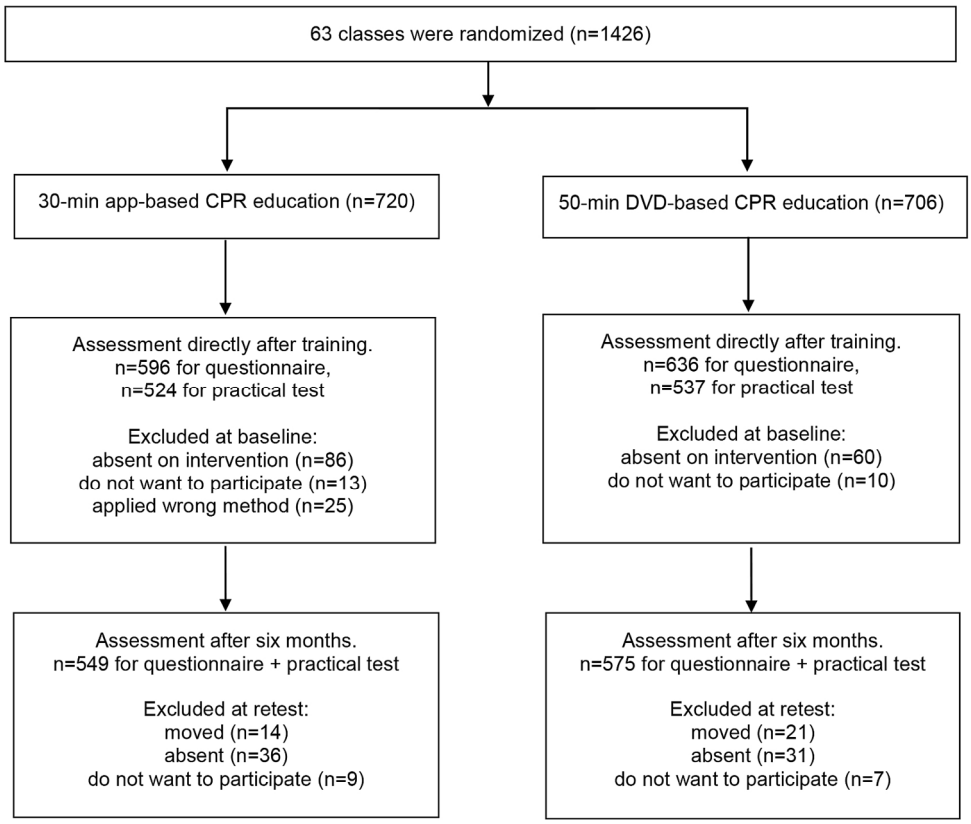
Figure 1 Flow chart on randomization and inclusion.

Figure 2 Students´ willingness to act if a friend suffers a cardiac arrests (upper panel) or if a stranger suffers a cardiac arrest (lower panel), as assessed six months after training. Values are given as percent. Numbers are n=549 (app) and n=575 (DVD).



Flow chart on randomization and inclusion.
178x273mm (300 x 300 DPI)



Students´ willingness to act if a friend suffers a cardiac arrests (upper panel) or if a stranger suffers a cardiac arrest (lower panel), as assessed six months after training. Values are given as percent. Numbers are n=549 (app) and n=575 (DVD).
149x150mm (300 x 300 DPI)

Supplementary file: the modified Cardiff test.

The modified version of the Cardiff test,[21], adapted to the ERC guidelines of 2010,[18]. The duration of the practical test was 3 minutes. The optimal conduct was 30 seconds for check responsiveness, check respiration and call for help, followed by 2.5 minutes of CPR. During the CPR, the participants were expected to perform at least 5 cycles of 30 compressions and 2 ventilations (30:2). The rules of assessment were pre-specified as follows:

Check responsiveness by talking
2. Yes, if some form of verbal communication as “are you ok” or “how are you”?
1. No, if no attempt at verbal communication was performed
Method: direct observation and real-time registration in the observation schedule by the test leader.

Check responsiveness by shaking
3. Yes, if the rescuer gently shake the victim shoulders.
2. No, if no attempt to shake the victim shoulders occurred.
1. Potentially dangerous, if the rescuer violently shakes the victim´s shoulders so the head lifted up and down against the ground, which can damage the head or the neck.
Method: direct observation and real-time registration in the observation schedule by the test leader.

Open the airway - chin lift, head tilt.
5. Perfect, if one hand on the forehead, two fingertips on the jawbone (not soft tissue) and gently lifted the chin and bent the head back ie by ERC guidelines.
4 Acceptable/partially correct if several indicators are performed, but not all.
3. Attempted other, if the rescuer tried in other ways than ERC recommendation.
2. Only one element is performed or if the rescuer tries but fails.
1. No, if no attempt to open the airway was performed.
Method: direct observation and real-time registration in the observation schedule by the test leader.

Checks respiration - see, listen, feel
2. Yes, if the rescuer did attempts of breath control, even if not all three actions see, listen and feel were performed and although if the total time of the control was less than 10 seconds.
1. No, if no attempt to check for breathing was performed.
Method: direct observation and real-time registration in the observation schedule by the test leader.

Dials 112
2. Yes, dials 112 within the first minute. A call for help without dialling 112 was not enough, since students were instructed they were alone at the site.
1. No, if no attempt to get help was performed.
Method: direct observation and real-time registration in the observation schedule by the test leader.

Compression/ventilation ratio
4. 30:2 (28-32:2), if the rescuer practical applied compressions and ventilations with the relationship 28-32:2 during the whole test. Participants unable to ventilate the manikin but who attempted a ratio of 28-32:2 were registered as such, as they apparently had learned the skill ratio.
3. Other ratio, if the rescuer applied different ratio of compressions and ventilations than 28-32:2.
2. Compressions only.
1. Ventilations only.
Method: Direct observation and real-time registration in combination with data from Laerdal PC Skill Reporter Systems transferred to the scoring sheet after the test.

Hand-position during compression
Incorrect hand-position was recorded if one compression was in the wrong place, since one wrong compression can cause rib fracture or fracture the xiphoid process of sternum.
4. Correct, if the rescuer place the heel of one hand in the centre of the victim’s chest and with the other hand above.
3. Other wrong, if the rescuer performs chest compressions too high up on the sternum or to the side of the sternum.
2. Too low, if the rescuer performs chest compressions too low on the sternum.
1. Not attempted, if no compressions were performed.

Method: Data from Laerdal PC Skill Reporter Systems was transferred to a scoring sheet after the test.

Average compression depth
The PC Skill Reporter system version 2.4 measures up to 60 mm compression depth. To avoid that those who compress >60 mm obtain the highest score, highest score was given for an average compression depth of 50-59 mm. Those who compressed ≥60 mm received 5 points. We chose to retain the 6-point scale, as in previous studies,[23] even though no one could receive 3 points, which would corresponded to a > 65 mm compression depth.
6. 50-59 mm.
5. ≥ 60 mm
4. 35-49 mm
2. 1-34 mm
1. Not attempted, if no compressions were performed.
Method: Data from Laerdal PC Skill Reporter Systems was transferred to a scoring sheet after the test.

Total compression counted
6. 140-190
5. ≥ 191
4. 121-139
3. 81-120
2. 1-80
1. Not attempted, if no compressions were performed.
Method: Data from Laerdal PC Skill Reporter Systems was transferred to a scoring sheet after the test.

Average ventilation volume
5. 500-600 ml
4. 1-499 ml
3. ≥ 601 ml
2. 0 ml, if the rescuer tried to do rescue breaths but failed.
1. Not attempted, if no rescue breaths were performed.
Method: Direct observation and real-time registration if the rescuer tried to do rescue breath. Exact volume, from Laerdal PC Skill Reporter Systems, was transferred to the scoring sheet after the test.

Total ventilation counted
5.8-12
4. 1-7
3. ≥ 13
2. 0, if the rescuer tried to do rescue breaths but failed.
1. Not attempted, if no rescue breaths were performed.
Method: Direct observation and real-time registration if the rescuer tried to do rescue breath. Exact number, from Laerdal PC Skill Reporter Systems, was transferred to the scoring sheet after the test.

Total ”hands-off” time
Total hands-off time was the total time when compressions were not being performed (i.e. also includes time for check responsiveness, check respiration and dial 112).
4. 0-60 s
3. 61-90 s
2. 91-135 s
1. 136-180 s
Method: Data from Laerdal PC Skill Reporter Systems was transferred to a scoring sheet after the test.

Supplementary file: questionnaires used directly after training and at six months follow-up

Questionnaire directly after training

Have you previously practiced

chest compressions? Yes ☐ No ☐

ventilations? Yes ☐ No ☐

Do you think that your skills are sufficient to perform

chest compressions? Yes ☐ No ☐ Do not know ☐

ventilations? Yes ☐ No ☐ Do not know ☐

Are you more confident now than before the training to act and start CPR? Yes ☐ No ☐ Do not know ☐

You are at home. How would you act if a friend or relative suffered a sudden cardiac arrest? Tick one answer:

I would not dare or want to intervene ☐

I would give chest compressions only ☐

I would give ventilations only ☐

I would give both compressions and ventilations ☐

Enter the reason that you do not dare or want to do chest compressions?

Lack of knowledge ☐

Afraid to hurt the person ☐

Afraid of transmitted disease ☐

Other reasons ☐

Do not know ☐

Enter the reason that you do not dare or want to do ventilations?

Lack of knowledge ☐

Afraid to hurt the person ☐

Afraid of transmitted disease ☐

Other reasons ☐

Do not know ☐

You are standing at a bus stop. How would you act if an unknown person suffered a sudden cardiac arrest? Tick one answer:

I would not dare or want to intervene ☐

I would give chest compressions only ☐

I would give ventilations only ☐

I would give both compressions and ventilations ☐

Enter the reason that you do not dare or want to do chest compressions?

Lack of knowledge ☐
Afraid to hurt the person ☐
I do not want to touch a stranger ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

Enter the reason that you do not dare or want to do ventilations?

Lack of knowledge ☐
Afraid to hurt the person ☐
I do not want to touch a stranger ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

Questionnaire at six months follow-up

Have you done a lifesaving intervention in real life after the CPR training? Yes ☐ No ☐

If yes, please describe your lifesaving intervention and the situation:_____

Do you think it is important to learn cardiopulmonary resuscitation in school? Yes ☐ No ☐ Do not know ☐

Do you think that your skills are sufficient to perform

chest compressions? Yes ☐ No ☐ Do not know ☐

ventilations? Yes ☐ No ☐ Do not know ☐

Are you more confident now than before the training to act and start CPR? Yes ☐ No ☐ Do not know ☐

You are at home. How would you act if a friend or relative suffered a sudden cardiac arrest? Tick one answer:

I would not dare or want to intervene ☐
I would give chest compressions only ☐
I would give ventilations only ☐
I would give both compressions and ventilations ☐

Enter the reason that you do not dare or want to do chest compressions?

Lack of knowledge ☐
Afraid to hurt the person ☐

Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

Enter the reason that you do not dare or want to do ventilations?
Lack of knowledge ☐
Afraid to hurt the person ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

You are standing at a bus stop. How would you act if an unknown person suffered a sudden cardiac arrest? Tick one answer:
I would not dare or want to intervene ☐
I would give chest compressions only ☐
I would only give ventilations ☐
I would give both compressions and ventilations ☐

Enter the reason that you do not dare or want to do chest compressions?
Lack of knowledge ☐
Afraid to hurt the person ☐
I do not want to touch a stranger ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

Enter the reason that you do not dare or want to do ventilations?
Lack of knowledge ☐
Afraid to hurt the person ☐
I do not want to touch a stranger ☐
Afraid of transmitted disease ☐
Other reasons ☐
Do not know ☐

How many times have you used/read on the app "Save the heart" (including any lesson in school)?
1 ☐
2-3 ☐
4-5 ☐
> 5 ☐
Do not know ☐

Have you shown the app for someone else? Yes ☐ No ☐ Do not know ☐

CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	4
	2b	Specific objectives or hypotheses	4
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	4
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	N/A
Participants	4a	Eligibility criteria for participants	4
	4b	Settings and locations where the data were collected	4, 6
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	4-5
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	6
	6b	Any changes to trial outcomes after the trial commenced, with reasons	N/A
Sample size	7a	How sample size was determined	6
	7b	When applicable, explanation of any interim analyses and stopping guidelines	N/A
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	4
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	4
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	4
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	4, 6
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	6

		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	5
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	6
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	N/A
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	6-7 and Figure 1
	13b	For each group, losses and exclusions after randomisation, together with reasons	Figure 1
Recruitment	14a	Dates defining the periods of recruitment and follow-up	5
	14b	Why the trial ended or was stopped	N/A
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Table 1
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	6, Figure 1
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	6-9
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	N/A
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	N/A
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	N/A
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	3, 11
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	9-11
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	9-10
Other information			
Registration	23	Registration number and name of trial registry	N/A
Protocol	24	Where the full trial protocol can be accessed, if available	N/A
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	12

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.