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Bystander CPR

New aspects of CPR training among students and the
importance of bystander education level on survival

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Cover page photo: A Nord. The cover photo symbolizes the key to knowledge. The key to increased survival after out of hospital cardiac arrest is large-scale CPR training of the public. The little heart, youngsters, can also save the lives of adults.

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To my family with love!

*"Education is the most powerful weapon
which you can use to change the world."*

- Nelson Mandela

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PAPERS

LIST OF PAPERS

This thesis is based on following original publications, which are referred to by their Roman numerals.

- I. **Nord A**, Svensson L, Hult H, Kreitz-Sandberg S, Nilsson L. Effect of mobile application-based versus DVD-based CPR training on students' practical CPR skills and willingness to act: a cluster randomized study. *BMJ Open* 2016;6:e010717
- II. **Nord A**, Hult H, Kreitz-Sandberg S, Herlitz J, Svensson L, Nilsson L. Effect of two additional interventions, test and reflection, added to standard cardiopulmonary resuscitation training on seventh grade students' practical skills and willingness to act: a cluster randomized trial. *BMJ Open* 2017;7:e014230
- III. **Nord A**, Svensson L, Claesson A, Herlitz J, Hult H, Kreitz-Sandberg S, Nilsson L. The effect of a national web course *Help-Brain-Heart* as a supplemental learning tool prior to CPR training; a cluster randomized trial. *Scandinavian Journal of Trauma Resuscitation and Emergency Medicine* 2017;25:93
- IV. **Nord A**, Svensson L, Karlsson T, Claesson A, Herlitz J, Nilsson L. Increased survival from out-of-hospital cardiac arrest when off duty medically educated personnel perform CPR compared with laymen. *Resuscitation* 2017;120:88-94

ABSTRACT

Background: It has been proved that bystander cardiopulmonary resuscitation (CPR) saves lives; however, which training method in CPR is most instructive and whether survival is affected by the training level of the bystander have not yet been fully described.

Aim: The aim of this thesis was to identify the factors that may affect seventh-grade students' acquisition of CPR skills during CPR training and their willingness to act, and to describe 30-day survival from out-of-hospital cardiac arrest (OHCA) after bystander CPR and the actions performed by laymen versus off-duty medically educated personnel.

Methods: Studies I–III investigate a CPR training intervention given to students in seventh grade during 2013–2014. The school classes were randomized to the main intervention: the mobile phone application (app) or DVD-based training. Some of the classes were randomized to one or several additional interventions: a practical test with feedback, reflection, a web course, a visit from elite athletes and automated external defibrillator (AED) training. The students' practical skills, willingness to act, self-reported knowledge and knowledge of stroke symptoms, symptoms of acute myocardial infarction (AMI) and lifestyle factors were assessed directly after training and at 6 months using the Laerdal PC SkillReporting system 2.4 (and entered into a modified version of the Cardiff test scoring sheet) and a questionnaire. The modified Cardiff test resulted in a total score of 12–48 points, and the questionnaire resulted in a total score of 0–7 points for stroke symptoms, 0–9 points for symptoms of AMI and 0–6 points on lifestyle factors. Study IV is based on retrospective data from the national quality register, the Swedish registry of cardiopulmonary resuscitation, 2010–2014.

Results: A total of 1339 students were included in the CPR training intervention. The DVD-based group was superior to the app-based group in CPR skills, with a total score of 35 (standard deviation [SD] 4.0) vs 33 (SD 4.2) points directly after training ($p<0.001$) and 33 (SD 4.0) vs 31 (SD 4.2) points at six months ($p<0.001$). Of the additional interventions, the practical test with feedback had the greatest influence regarding practical skills: at six months the intervention group scored 32 (SD 3.9) points and the control group (CPR training only) scored 30 (SD 4.0) points ($p<0.001$).

Reflection, the web course, visits from elite athletes and AED training did not further increase the students' acquisition of practical CPR skills.

The students who completed the web course, *Help-Brain-Heart*, received a higher total score for theoretical knowledge in comparison with the control group directly after training: stroke 3.8 (SD 1.8) vs 2.7 (SD 2.0) points ($p<0.001$); AMI 4.0 (SD 2.0) vs 2.5 (SD 2.0) points ($p<0.001$); lifestyle factors 5.4 (SD 1.2) vs 4.5 (SD 2.0) points $p<0.001$.

Most of the students (77% at 6 months), regardless of the training intervention applied, expressed that they would perform both chest compressions and ventilations in a cardiac arrest situation involving a relative. If a stranger had cardiac arrest, a significantly lower proportion of participants (32%; $p<0.001$) would perform both compressions and ventilations. In this case, however, many would perform compressions only.

In most cases of bystander-witnessed OHCA, CPR was performed by laymen. Off-duty health care personnel bystanders initiated CPR within 1 minute vs 2 minutes for laymen ($p<0.0001$). Thirty-day survival was 14.7% among patients who received CPR from laymen and 17.2% ($p=0.02$) among patients who received bystander CPR from off-duty health care personnel.

Conclusions: The DVD-based training method was superior to the app-based method in terms of teaching practical CPR skills to seventh-grade students. Of the additional interventions, a practical test with feedback was the most efficient intervention to increase learning outcome. The additional interventions; reflection, web course, visit from elite athletes and AED, did not increase CPR skills further. However, the web course, *Help-Brain-Heart*, improved the students' acquisition of theoretical knowledge regarding stroke, AMI and lifestyle factors. For OHCA, off-duty health care personnel bystanders initiated CPR earlier and 30-day survival was higher compared with laymen bystanders.

Key words: CPR; CPR training; BLS; Laymen, Bystander CPR; Students; Out-of-hospital cardiac arrest; Cardiac arrest; Mobile application; DVD; Feedback; Reflection; Web course; Cardiff test; Myocardial infarction; Stroke; Lifestyle factors; Elite athletes; Willingness; Survival.

SVENSK SAMMANFATTNING

Bakgrund: Hjärt-lungräddning (HLR) ökar bevisligen chansen för överlevnad vid plötsligt oväntat hjärtstopp, men vilken utbildningsmetod i HLR som är mest lärorik samt om överlevnad påverkas av livräddarens utbildningsnivå är ofullständigt beskrivet.

Syfte: Syftet med denna avhandling var att identifiera faktorer som kan påverka sjunde klass elevers förvärv av kunskaper vid HLR-utbildning samt elevernas vilja att agera vid hjärtstopp. Syftet var även att på nationell nivå beskriva om livräddarens utbildningsnivå (icke vårdutbildade, så kallade lekmän, jämfört med vårdutbildade som inte är en del av larmkedjan) påverkar 30-dagars överlevnad vid hjärtstopp som sker utanför sjukhus.

Metod: Delarbete I–III utgörs av en utbildningsintervention i HLR till sjunde klass elever, år 2013–2014. Klasserna randomiserades till huvudinterventionerna mobil applikation- (app) eller DVD-baserad HLR utbildning. Därtill randomiserades klasserna till en eller flera tilläggsinterventioner; praktiskt test med återkoppling, reflektion, webb utbildning, studiebesök av elitidrottare samt träning med hjärtstartare. Elevernas praktiska HLR kunskaper, vilja till att agera, egenskattade kunskaper, teoretiska kunskaper om levnadsvanor samt symtom på stroke och hjärtinfarkt utvärderades direkt efter utbildningstillfället samt efter sex månader via mätinstrumentet Laerdal PC SkillReporting system version 2.4 och en modifierad version av observationsschemat Cardiff test samt en enkät. Möjlig totalpoäng på det praktiska HLR testet var 12–48 poäng, för teoretiska kunskaper om stroke; 0–7 poäng, hjärtinfarkt; 0–9 poäng och levnadsvanor; 0–6 poäng. Delarbete IV baseras på en retrospektiv analys av registerdata från kvalitetsregistret Svenska hjärt-lungräddning registret för hjärtstopp utanför sjukhus under åren 2010–2014.

Resultat: Totalt 1339 elever inkluderades i utbildnings interventionen i HLR. Den DVD-baserade gruppen var överlägsen den app baserade gruppen avseende praktiska HLR-kunskaper; totalt 35 (SD 4.0) vs 33 (SD 4.2) poäng direkt efter HLR utbildning ($p<0.001$) och 33 (SD 4.0) vs 31 (SD 4.2) poäng vid sex månaders uppföljning ($p<0.001$). Av tilläggsinterventionerna hade praktiskt test med återkoppling störst effekt avseende förvärv av praktiska kunskaper; interventions gruppen 32 (SD 3.9) poäng och kontroll gruppen 30 (SD 4.0) poäng ($p<0.001$) vid sex

månaders uppföljning. Tilläggsinterventionerna reflektion, hjärtstartare utbildning, webb utbildning samt studiebesök av elitidrottare ökade inte ytterligare elevernas förvärv av praktiska HLR kunskaper.

De elever som genomfört webbutbildningen *Hjälp Hjärna Hjärta* erhöll högre totalpoäng för teoretiska kunskaper, i jämförelse med kontrollgruppen; stroke 3.8 (SD 1.8) vs 2.7 (SD 2.0) poäng ($p<0.001$), hjärtinfarkt; 4.0 (SD 2.0) vs 2.5 (SD 2.0) poäng ($p<0.001$) samt levnadsvanor; 5.4 (SD 1.2) vs 4.5 (SD 2.0) poäng ($p<0.001$), direkt efter utbildningstillfället.

Majoriteten av eleverna (77% vid sex månaders test), oavsett utbildningsintervention, angav att de skulle utföra både bröstkompressioner och inblåsningar om en anhörig eller vän drabbas av hjärtstopp. Om en främling drabbas, skulle en signifikant lägre andel (32%; $p<0.001$) utföra både kompressioner och inblåsningar. Då skulle majoriteten istället endast ge bröstkompressioner.

Vid hjärtstopp utanför sjukhus erhöll majoriteten av de drabbade HLR av lekmän. Sjukvårdsutbildade livräddare startade HLR inom 1 minut vs lekmän 2 min ($p<0.0001$). Trettio dagars överlevnad var 14.7% i gruppen som erhöll HLR av lekmän respektive 17.2% ($p=0.02$) hos de som erhöll HLR av sjukvårdsutbildade.

Slutsats: Den DVD-baserade utbildningsmetoden var överlägsen den app-baserade metoden när det gäller sjunde klass elevers förvärv av praktiska HLR-kunskaper. Av tilläggsinterventionerna var praktiskt test med feedback den mest lärorika intervention för att öka förvärv av praktiska kunskaper. Tilläggsinterventionerna reflektion, webbutbildning, studiebesök av elitidrottare och utbildning med hjärtstartare ökade inte ytterligare elevernas praktiska kunskaper i HLR. Webb utbildningen *Hjälp Hjärna Hjärta* ökade emellertid elevernas teoretiska kunskaper om stroke, hjärtinfarkt och levnadsvanor. Vid hjärtstopp utanför sjukhus initierade medicinskt utbildade livräddare HLR tidigare, samt ökad 30 dagars överlevnad sågs i jämförelse med HLR utfört av lekmän.

Nyckelord

HLR; HLR-utbildning; Lekman; Högstadiel elever; Hjärtstopp; Web-utbildning; Dvd; Mobil applikation; Återkoppling; Reflektion; Cardiff test; Hjärtinfarkt; Stroke; Levnadsvanor; Elitidrottare; Motivation; Överlevnad

ABBREVIATIONS

ACS	Acute coronary syndrome
AED	Automated external defibrillator
AHA	American Heart Association
AMI	Acute myocardial infarction
AO	App only (app-based CPR training without additional interventions)
App	Mobile telephone application
ART	App-based CPR training with reflection and test
AT	App-based CPR training with test
AWERT	App-based CPR training with web course, visit from elite athletes, reflection and test
AWET	App-based CPR training with web course, visit from elite athletes and test
AWT	App-based CPR training with a web course and test
BLS	Basic life support
CA	Cardiac arrest
CC	Chest compressions
CPC	Cerebral performance category
CPP	Coronary perfusion pressure
CPR	Cardiopulmonary resuscitation
CVD	Cardiovascular disease
DO	DVD only (DVD-based CPR training without additional interventions)
DRT	DVD-based CPR training with reflection and test
DT	DVD-based CPR training with test
DWERT	DVD-based CPR training with web course, visit from elite athletes, reflection and test
DWET	DVD-based CPR training with web course, visit from elite athletes and test
DWT	DVD-based CPR training with web course and test
ECG	Electrocardiography
EMS	Emergency medical services
ERC	European Resuscitation Council

EuPSF	European Patient Safety Foundation
GCP	Good clinical practice
GEE	Generalized estimating equations
HBH	<i>Help-Brain-Heart</i> web course
ICD	Implantable cardiac defibrillator
ICH	International Council for Harmonisation
ILCOR	International Liaison Committee on Resuscitation
Lay-ByCPR	Lay bystander CPR
LF	Lifestyle factors
Med-ByCPR	Medically educated bystander CPR
NS	Not significant
OHCA	Out-of-hospital cardiac arrest
PEA	Pulseless electrical activity
PCI	Percutaneous coronary intervention
PROM	Patient-reported outcome measures
QR	Quality registers
ROSC	Return of spontaneous circulation
RT	CPR training (app- and DVD-based) with reflection and test
SCA	Sudden cardiac arrest
SD	Standard deviation
SRCR	Swedish Registry of Cardiopulmonary Resuscitation
VF	Ventricular fibrillation
VT	Ventricular tachycardia
WFSA	World Federation of Societies of Anesthesiologists
WHO	World Health Organization
WERT	CPR training (app- and DVD-based) with web course, visit from elite athletes, reflection and test
WET	CPR training (app- and DVD-based) with web course, visit from elite athletes and test
WT	CPR training (app- and DVD-based) with a web course and test

INTRODUCTION

Sudden cardiac arrest (SCA) is a major health challenge and one of the most common causes of death in industrialized countries.¹⁻³ It is a natural end of life for some. For others, it is an unexpected, traumatic event that takes place too early in life. When out-of-hospital cardiac arrest (OHCA) occurs, the victim is dependent on public engagement and immediate intervention from a fellow human being, a so-called bystander. Prompt resuscitation is crucial to save these people's lives.^{4,5} Immediate start of cardiopulmonary resuscitation (CPR) can increase the chance of survival two to four times.⁴⁻⁶ The use of an automated external defibrillator (AED) within the first 3-5 minutes of collapse has been shown to produce survival rates as high as 50–70%.⁴ Access to a public on-site AED enables early defibrillation.^{7,8} An increased level of training within the community increases the proportion of patients with OHCA receiving CPR before arrival of the emergency medical services (EMS).⁶ Therefore, it is important that as many individuals as possible in the community acquire CPR skills.

My interest in CPR education to the public (students and adults) grew when I was responsible for the organization of CPR training for health care personnel at the University Hospital in Linköping. We also regularly received education assignments for the public (companies and schools). In general, the participants showed great interest, enthusiasm and commitment for the training. The need to train laymen was huge.

Earlier data showed that survival at OHCA may be affected by the type of bystander: a laymen or off-duty health care personnel.⁹ A limited numbers of studies have analysed the category of bystanders.¹⁰ However, whether the bystander's level of training (laymen or medically educated) affects response times, actions and survival is incompletely described.

Improving skill acquisition through simplified procedures and better training methods has been debated for decades.¹¹ Research on resuscitation is mainly based on the education of adults. Teaching children and teenagers may require different approaches.¹² The optimal format of training is unclear and further research and guidelines on the most effective method of training in CPR are needed.^{12,13} This dissertation contributes by filling some of these knowledge gaps, in order to save additional lives after OHCA, although further research is still needed.

BACKGROUND

Historical overview

The basic CPR technique, as used today, includes chest compressions, ventilation (mouth-to-mouth) and the use of an AED.⁴ The desire to save someone from death was described several hundred years ago.¹⁴ One of the first findings of resuscitation efforts is described in the Old Testament of the Bible (in the book of Kings 4:34-35), where the prophet Elijah performed some kind of mouth-to-mouth ventilation and restored the life of a little boy.¹⁵

During the 1600–1800 centuries, mainly three techniques were used to create some form of artificial respiration: various methods of mouth-to-mouth/mouth-to-nose breathing, ventilation using various tools (e.g. fireside bellows) and different manual or postural methods.^{16,17} The aesthetic aspect of physical contact during ventilation and fear of infection may have been contributing factors for the use of fireside bellows as a tool for artificial respiration, mainly during the 1600–1700s.¹⁷ Moreover, they were in everyone's home. During the 1800s, body positions were manipulated by push and pull techniques and postural techniques to squeeze out air or suck air into the lungs.¹⁶⁻¹⁸ Some of the most famous postural techniques were introduced by Hall (1855), Silvester (1898), Schafer (1903) and Nielsen (1932).¹⁷ In the 1950s, Safar showed the importance of neck extension and jaw thrust to create an open airway during mouth-to-mouth ventilation, and he proved that laymen could perform effective mouth-to-mouth ventilation.^{16,19} These findings were based on a series of spectacular experiments on voluntarily anesthetized and curarized apnoeic adults, where both professional rescuers and untrained laymen served as operators and performed artificial breathing.²⁰

In the late 1800s, several forms of compression on animals and internal compressions were described. Moritz Schiff, in 1874, was one of the first to describe “cardiac massage”. He noted carotid pulsation after manual compressions in the open thorax of a canine heart.¹⁶ In 1960, in a landmark study, Kouwenhoven, Jude and Knickerbocker published findings on a technique for closed-chest compressions, combined with ventilation and defibrillation. They reported the results of 20 cases of in-hospital cardiac arrest where 14 patients survived, and they stated “anyone, anywhere, can now initiate cardiac resuscitative procedures. All that is needed are two hands”.²¹ Their technique of chest compressions is similar to today's techniques.

Defibrillators started to evolve in the early 20th century. In 1947, one of the first recorded successful cases of internal defibrillation on a human (a young boy) was performed by Claude Beck.^{22,23} The first closed chest defibrillation was performed in 1955 by Paul Zoll.²⁴ Safar, Kouwenhoven and Zoll are three important contributors in the development of modern CPR.^{16,25,26}

In 1966, the first CPR guidelines for medically educated staff were published. Training of laypersons was formally sanctioned in 1974 by the American Heart Association (AHA).¹⁶ In Sweden, the first national training programme for CPR, which included training of both medically educated and lay people, was launched by the Swedish Society of Cardiology in 1983.

The implementation of CPR training in Sweden was started by inviting some physicians to attend a CPR instructor-trainer course in Marstrand (1983). By the so-called "cascade principle", these educated instructor-trainers returned to their work and could train new instructors, who in turn would train rescuers in the "adult one-rescuer CPR" technique.¹⁰

In 1992, the International Liaison Committee on Resuscitation (ILCOR) was set up. The aim was to gather together continental resuscitation organizations. Thus, similar evidence-based techniques could be used around the world. The European Resuscitation Council (ERC) is a member of the ILCOR. Based on ILCORs consensus and recommendations on resuscitation science, ERC and AHA have developed guidelines for best-practice techniques. The guidelines and CPR training programmes are revised every 5 years. The latest ERC guidelines for CPR and treatment recommendations were launched in 2015.⁴

The original and traditional basic life support (BLS) training took 3–4 hours and the number of participants per CPR course was limited, because several participants shared one training manikin during the training. In 2006, a new training format, the MiniAnne box (manufactured by Laerdal AS, Norway, laerdal.com), was launched in Sweden, consisting of an inflatable training manikin (MiniAnne), a DVD with training instructions and a simple AED trainer. The purpose of the new training format was partly to make the education more accessible (with the instructions on DVD), and partly so that all participants received individual practical training in a short time, because all participants used their own training manikin during the training. The increased access to training manikins with MiniAnne also allowed a larger number of participants per course. The DVD-based education with MiniAnne takes only approximately 60 minutes.

Definition of cardiac arrest

Over time, a number of different definitions of cardiac arrest (CA) or SCA have been used.²⁷⁻³¹ The duration of the CA and whether it was witnessed or not are some of the factors that have influenced the definitions.^{28,29,31} To enable comparison between different regions, several scientific communities at the Utstein consensus conference in 1990 drafted the first common definition for CA and published guidelines for resuscitation and the uniform reporting of OHCA: "Cardiac arrest is the cessation of cardiac mechanical activity, confirmed by the absence of a detectable pulse, unresponsiveness and apnoea (or agonal, gasping respirations)."³² Since then, the term Utstein templates is synonymous with consensus reporting guidelines for resuscitation.³³ The definition was updated and simplified in the Utstein templates for resuscitation in 2004, which states that CA is "the cessation of cardiac mechanical activity as confirmed by the absence of signs of a circulation".³⁴ Since 2010, ERC guidelines emphasize that checking for a pulse is an incorrect method of confirming the presence or absence of circulation. Unresponsive and not breathing are normally the signs of CA.³⁵ Cardiac arrest that takes place outside a hospital is referred to as out-of-hospital cardiac arrest (OHCA).

Definition of bystander CPR

According to the Utstein templates for resuscitation, bystander CPR is "an attempt to perform basic cardiopulmonary resuscitation by someone who is not a part of an organized emergency response system",³² i.e. the term also includes action by medically educated persons (e.g. doctors, nurses) who are not a part of the emergency response system.³²⁻³⁴ Lay responder CPR and citizen CPR are synonyms for bystander CPR. The Utstein templates prefer the term bystander CPR.³² In this dissertation, bystander CPR is also categorized with respect to the bystander's training level: laymen bystander (non-medically educated bystanders, Lay-ByCPR) and off-duty medically educated bystander (Med-ByCPR, performed by professional bystanders with some form of health care education who are not part of the emergency system). Bystander CPR may be compression only, compression with ventilation and/or AED use.³³

Non-medical rescuers who are certified to provide medical care in emergencies before more highly trained medical personnel arrive on the scene, for example, police, fire brigade, or security officers, are called first responders. In this thesis, they are included in the Lay-ByCPR group.

Out-of-hospital cardiac arrest

Incidence

Sudden cardiac arrest is a major health problem worldwide and one of the most common causes of death in industrialized countries.^{1,2} There is a large variation in the reported incidence rate of SCA, and its outcome varies between countries and within different regions in a nation. Epidemiological data estimate that the global average incidence of adult OHCA varies between 55 and 84 per 100,000 person-years (range 19–140/100,000) with resuscitation attempted by EMS.^{1–3} Based on recent data from the Swedish Cardiac Arrest Register (SRCR), the corresponding incidence in Sweden is 54 per 100,000 person-years and a total of 5550 cases of OHCA were reported in 2015.⁵ Approximately 500,000 people suffer SCA annually in Europe and 325,000 cases annually in the United States.^{2–4} The variability in the incidence rate may reflect differences in the definitions of OHCA as well as differences in the risk, research methodology and EMS systems.^{2,36} An important aspect to consider is whether only cases where CPR was attempted were included. Most cases of OHCA where CPR was attempted, approximately 70%, occur in the patient's home where the prognosis is poorer compared with other locations in the community.^{1,3,5,37}

Causes of cardiac arrest

The pathogenesis to OHCA should, according to the Utstein templates, be divided into medical (presumed cardiac or unknown and other medical causes, e.g. anaphylaxis, asthma or gastrointestinal bleeding), traumatic, drug overdose, drowning, electrocution or external asphyxia causes (foreign-body airway obstruction, hanging or strangulation).³³ The most likely primary cause of OHCA is usually based on the clinical judgement of the EMS crew.⁵ The cause of OHCA is medical in approximately 90% of cases,^{1,38} of which acute coronary syndrome (ACS) is the most common underlying causal disorders in adults (approximately 70%).^{5,39} A quarter to a third of patients have symptoms of angina pectoris (myocardial ischaemia) before CA occurs.⁴⁰ Trauma is reported to be the cause in 2–4% of cases.^{1,5}

Survival rates

Similar to the incidence, the survival rate after OHCA varies among countries and even within different regions of a nation.^{2,41,42} It has been suggested that survival from CA is a result of medical science, education and implementation (Figure 1).⁴³ If one of these fails, the chance of survival deteriorates, despite optimizing the remaining two factors. The proportion of survivors is also influenced by witnessed status, availability of bystander

CPR, time from collapse to treatment, initial rhythm, the quality of CPR and EMS structure (including dispatcher-assisted CPR),^{1,33,37}

Figure 1. The Utstein formula for survival.⁴³
(Reproduced with permission from Laerdal Medical AS.)

Data on return of spontaneous circulation (ROSC) and survival are measured at different time points: ROSC at any point during the resuscitation attempt, alive at arrival to hospital, survival at hospital discharge and 30-day survival.³³ In EMS-treated adult OHCA where CPR is attempted, the overall percentage survival to hospital discharge varies between 7–11% for all rhythms and 20–31% for ventricular fibrillation (VF).^{1-3,38,42,44} In Sweden, the 30-day survival rate is 11% for all rhythms and 34% for patients with a shockable rhythm. The overall survival after OHCA has gradually increased since the turn of the century, from 4% to 11%. Some factors contributing to the increase in survival after OHCA in Sweden likely include the following: bystander CPR is initiated more frequently, more cases of OHCA are witnessed by ambulance staff (may indicate that the call to the EMS is made at the signs of warning symptoms) and may include improved post-resuscitation care.⁵ If no bystander CPR is performed before EMS arrival, the survival rate is 4%.⁶

Initial cardiac rhythm

The first cardiac rhythm refers to the first rhythm recorded by a monitor or a defibrillator. The rhythm can be shockable; VF or pulseless ventricular tachycardia (VT) or non-shockable; pulseless electrical activity (PEA) or asystole.³³ A higher proportion of the victims of CA survive if bystanders act immediately while shockable rhythm is still present. Successful resuscitation is less likely once the rhythm is non-shockable.⁴ The percentage of cases found in a shockable initial rhythm has decreased over the last 10–20 years.^{1,2,5,45} Berdowski et al. estimate in a review that of all cases of OHCA, 27% had VF as the first recorded rhythm.² Gräsner et al. in analysis of OHCA in Europe, reported 22% with a shockable initial rhythm.¹ In Sweden, 21% of all cases of OHCA had VF as the initial rhythm.⁵

The incidence of shockable initial rhythm is affected by, for example, the time from CA until the first rhythm is recorded and when CPR is initiated. Therefore, it is likely that many more victims have a shockable

rhythm at the time of collapse, but that the rhythm has deteriorated to asystole when the rhythm is recorded.^{4,46} Additional factors that have contributed to the decreased proportion of shockable rhythm include increased medical treatment with beta-blockers, widespread use of implantable cardiac defibrillators (ICD),^{2,45} and patients with acute myocardial infarction (AMI) seek and thus receive treatment earlier. A further possible cause is an aging population with an increased incidence of multiorgan failure, which often causes PEA.⁴⁵

Bystander CPR

Bystander CPR is independently associated with an increased chance of survival after SCA. During SCA, the brain can only survive for a few minutes without oxygen. The average response time for the EMS to arrive is on scene 7–10 minutes.^{4,5,41,47} Survival after SCA is dependent on the time from collapse to treatment,^{4-6,48} therefore the victim is dependent on immediate intervention from a fellow human (bystander).

In approximately 70% of cases, the OHCA is witnessed.^{1,5,7} The rates of bystander CPR vary across countries from 20 to 80%.^{1,7,47,49,50} Even socioeconomic factors affect the rate of bystander CPR.^{51,52} Overall, in Europe approximately 47% of cases receive bystander CPR.¹ In Sweden, 71% of all cases of OHCA received bystander CPR before arrival of the EMS (compared with 33% in 1992).⁵

The current CPR guidelines emphasize the supporting role of the emergency medical dispatcher during the resuscitation. Interactions between the emergency medical dispatcher and the bystander who provides CPR and access to an AED are all key elements for improving survival after OHCA (Figure 2).⁴

Figure 2. Key ingredients for survival from OHCA.⁴
(Reproduced with permission from Laerdal Medical AS.)

Adult basic life support (BLS) guidelines from 2015 recommend that bystanders with CPR training should perform both chest compressions and ventilation at a ratio of 30:2. High-performance CPR includes delivery of compressions “in the centre of the chest”, to a depth of 5–6 cm, at a compress rate of 100–120 per minute, with as few interruptions as possible and with complete chest recoil, and ventilation for one second per breath. If the bystander is untrained or unwilling to give rescue breaths, the emergency medical dispatchers give instructions for compressions only. An AED should be brought on site and applied as soon as possible. The sequence of steps for bystander CPR are summarized in Figure 3. The maximum interruption in chest compression to give two rescue breaths or for defibrillation should not exceed 10 seconds.⁴

Figure 3. ERC adult BLS algorithm.⁴

The chain of survival

The chain of survival summarizes the four vital links and actions needed for successful resuscitation: (1) early recognition and call for help, (2) early CPR, (3) early defibrillation, (4) post-resuscitation care (Figure 4).⁴ Recognition of CA, call for help, CPR and defibrillation can be performed by a bystander. Earlier versions of the chain of survival (in 2000 and earlier) contained only "emergency measures". Since 2005, the chain also contains pre-arrest identification and post-resuscitation care.⁴³ The chance of successful resuscitation decreases if any link is delayed or performed incorrectly.⁴

Figure 4. The chain of survival, ERC guidelines 2015.⁴
(Reproduced with permission from Laerdal Medical AS.)

Early recognition and call for help: to prevent cardiac arrest

Many people with CA display warning symptoms, such as chest pain, dyspnea and syncope, before the arrest.⁵³ The ideal situation is to recognize these warning signals and call for help immediately, because survival is higher when EMS responders witness the arrest.^{4,44,54} About a quarter of patients have symptoms of myocardial ischaemia before CA occurs.⁴⁰

If the victim is unconscious and not breathing normally, call for help and activation of CPR is critical. The emergency medical dispatcher plays an important role in the diagnosis of CA and can give instructions on how the rescuer can help the victim while waiting for the EMS. Not breathing normally (gasping, agonal breaths such as slow and deep breaths or snoring sound) and convulsions can also be signs of CA.^{4,55}

Early CPR: to buy time

Lay people have a core role to play in maintaining the circulation by starting bystander CPR immediately and using an AED when it is available. Early start of CPR can double or quadruple the likelihood of survival from CA.⁴⁻⁶ Patients who receive bystander CPR also show improved neurologic outcome compared with those who do not receive bystander CPR.^{56,57}

Through the chest compressions, the blood is circulated towards the brain, coronary arteries and the rest of the body. The blood is oxygenated by artificial respiration (rescue breathing). A critical first step to successful resuscitation is to restore the blood flow with sufficient aortic pressure.⁵⁵ The quality of CPR during resuscitation has a significant influence on the patient's chance of survival, because CPR only provides 30–40% of the normal blood flow to the brain and 10–30% of the normal blood flow to the heart.^{55,58} At each chest compression, the heart is squeezed between the sternum and the spine, which increases the intrathoracic pressure.⁵⁵ By the compressions, a diastolic pressure is built up, which is necessary for the coronary perfusion. It is thought that a coronary perfusion pressure (CPP)

of at least 15 mmHg is required to achieve ROSC.⁵⁹ During the decompression phase, the heart is refilled with blood. Decompression creates a slight vacuum or negative intrathoracic pressure, which augments venous return and draws some blood back into the heart and some air into the lungs. Excessive ventilation increases intrathoracic pressure, which reduces the return of the blood to the right side of the heart.⁵⁵ Cardiopulmonary resuscitation also act as a bridge to defibrillation, because CPR increases the amount of time that an electric shock from a defibrillator can be effective. The amplitude of VF decreases significantly less for patients who receive CPR than for those who do not.⁴⁶

The risks of damage to a person who has no CA with CPR is considered small.^{4,60,61} Complications of bystander CPR consist mainly of rib fractures or pain in the area of chest compression; aspiration of gastric contents from artificial ventilation and internal injuries are also seen but to a lesser degree.^{4,62} Böttiger et al state, “Lay people cannot do anything wrong – the only wrong would be to do nothing.”⁶³ It is much better to do something than do nothing at all if the rescuer is afraid that their knowledge or skills are incomplete. The difference between doing something and doing nothing can be someone's life.

Mechanical chest compression devices are not recommended routinely, but can be advantageous to maintain high-quality chest compressions during patient transport or in prolonged resuscitation such as in cases with unintentional hypothermia or ongoing percutaneous coronary intervention (PCI) for treating obstructive coronary artery disease.⁶⁴

Early defibrillation: to restart the heart

A defibrillator, commonly referred to as an AED, provides audiovisual guidance through the resuscitation, analyses the cardiac rhythm and instructs the bystander to deliver a shock if a shockable rhythm is identified. An AED can be used by both medical professionals and lay persons. Each minute of delay to defibrillation reduces the probability of survival by 10%.⁴ Early defibrillation can be achieved using an on-site AED.^{7,8} The purpose of a shock from a defibrillator is to restart the heart's disorganized electrical activity to a pulse-giving rhythm/sinus rhythm. Defibrillation needs to be performed as quickly as possible because the VF amplitude decreases over time with the risk of deteriorating to asystole.^{4,46} Cardiopulmonary resuscitation slows down the rate of VF deterioration.⁴⁶ Therefore, CPR should be started immediately (before the rhythm is identified) and it should continue while the defibrillator is applied. Defibrillation within 3–5 minutes of collapse can achieve a 50–70% survival rate.⁴

Post-resuscitation care: to restore quality of life

The last link in the chain of survival includes early advanced life support and standardized post-resuscitation care such as airway management, drug therapy, monitoring, targeted temperature management and actions to treat the cause. Coronary angiography and extracorporeal life support techniques should be considered in selected cases.^{4,65}

Possible interventions to increase survival at OHCA

The Utstein formula for survival is based on science, education and implementation.⁴³ To improve the overall survival rate after OHCA, several areas need to be developed, each important in itself: CA registry (measure performance and quality improvement or implementation and improvement efforts can be benchmarked), telephone-assisted CPR, rapid dispatch (specific goals are needed), public access to AEDs (geographic distribution), first responders (e.g. police, fire fighters), smart technologies for CPR and AED, mandatory CPR training (including AED) and hospital care (memorandum/promemoria).

Increasing bystander CPR for OHCA is a critical health issue.^{1,63} Cultural and socioeconomic circumstances contribute to major differences in the rate of bystander CPR interventions. Several different CPR training interventions, national campaigns, placement of AEDs in public locations, implementation of telephone-assisted CPR, use of new techniques as smartphones and mobile phone text messages and revision of the guidelines have been used to increase public engagement in response to CA.^{4,49,66-70} A lifesaving intervention is preceded by three critical steps: recognize the CA, make the decision to call the EMS and a bystander who is willing to perform CPR. Interventions to increase bystander CPR are all associated with overcoming barriers. These barriers have been summarized by Graham et al into four categories:⁷¹

1) Inability to recognize an OHCA.

Unresponsiveness and not breathing normally are the two key observations for early recognition of OHCA.⁴ Up to 40% of victims may have abnormal breathing in the first minute after CA.⁷² Agonal breathing has been shown to hinder recognition of OHCA.⁷³ Therefore, it is important that during CPR training, the participants acquire knowledge of agonal breathing. Seizure-like episodes, caused by anoxic brain injury as a result of the CA, can also be an early sign of CA and may be confused with epilepsy, hampering the identification of CA.^{4,74,75} The ERC Guidelines 2015 highlight the

supporting role of the emergency medical dispatcher in order to identify OHCA and to support and help the rescuer.⁴

2) A lack of adequate CPR training.

Training in CPR strengthened self-efficacy and increased participants' willingness to intervene in a real OHCA situation.^{12,76-81} At least 15% of the population needs to be trained to achieve a statistically significant increase in resuscitation outcomes.⁶³ This may, for example, be done by educating all school students annually. Furthermore, by mandatory CPR training in schools, all groups in society are reached.^{13,63} Reinier et al showed that access to health-related information is lower in the lowest socioeconomic quartile and the incidence of CA is higher than in the highest socioeconomic quartile.⁸² To increase the overall rate of bystander CPR in society, the ERC promotes compressions only for bystanders who are not trained in CPR or are unable or unwilling to do rescue breaths.⁴

3) Emotional considerations, psychological factors, rescuer confusion and health concerns.

Self-reported confidence and lack of CPR skills affect willingness to intervene.^{76,83} Fear of doing harm, lack of BLS skills and fear of doing it incorrectly are common reasons for not wanting to perform CPR.^{76,83-86} Data indicate that elementary schoolchildren are less fearful about CPR training than teenagers.¹³ In CPR training, it is important to emphasize that laypeople cannot do anything wrong – the only wrong thing would be to do nothing.⁶³ The risk of disease transmission during CPR training or an intervention is very low and there are no reports of transmission of blood disease.^{87,88}

4) Concerns about possible liability.

Fear of legal consequences may be a reason for not starting CPR.⁸⁵ Several countries have Good Samaritan laws in order to offer legal protection to those who give assistance to a person who is injured or ill. The protection is intended to reduce bystander hesitation to assist.⁷¹

CPR training

An increased level of training within the community increases the proportion of OHCA victims who receive CPR before arrival of EMS.⁶ Teaching methods for CPR have changed over the years, from the early days of didactic theoretical delivery of teaching to more interactive, hands-on methods and the use of new technology tools and social media.¹²

Training in CPR can be organized in various formats, practical or theoretical; for example, instructor-led, peer learning, self-instruction kits, film-based, e-learning.^{12,13,89,90} Brief DVD-based courses have been proven to be successful in teaching CPR skills,⁹¹⁻⁹⁷ but how short and simplified the training can be without adversely affecting the participants' skills and their motivation to act is incompletely described. Computer-driven feedback, watching an instructional video before practical CPR training, task cards, use of virtual avatars in multiplayer online games and refresher courses are other activities that have been evaluated to investigate their impact on learning.^{12,89,98} Even different CPR training manikins or strategies using low-cost didactic tools have been evaluated to determine if acquisition of CPR skills could be affected by using different manikins.⁹⁹⁻¹⁰¹ Despite significant overall improvements after training, studies generally show that participants' knowledge acquired during CPR training is limited.^{89,90,102,103} The two main reasons considered to cause poor outcomes after CPR education are lack of knowledge about appropriate methods for BLS training^{12,89,104,105} and instructors devoting too much time to oral information and too little time to hands-on practice (inadequate training of instructors).¹¹ Practical training is essential for the acquisition of practical CPR skills.^{13,89,90,106} The quality of chest compression (depth, rate and minimizing interruptions) is associated with patient survival.^{55,107}

The curriculum should be kept as simple as possible and the education level should be adapted to the target audience.¹² Whether the training should include both compressions and ventilation or compressions only has been debated since some observational studies on compressions only reported comparable outcomes with standard CPR for OHCA in adults.¹⁰⁸⁻¹¹¹ However, in accordance with ERC guidelines the first three links in the chain of survival are the three compulsory teaching elements during CPR training: early recognition and call EMS, early CPR (compressions and ventilation) of good quality, and early and effective use of an AED.^{12,71} Even willingness to act and feedback are core components during training.¹² There is a huge difference between CPR training on a manikin and intervening in an emergency situation.⁸⁶

CPR training in Sweden

CPR training in Sweden is given according to the cascade principle, which means that an instructor-trainer (head instructor) educates instructors who then educate laymen. Instructors are trained in teaching and assessment. The cascade principle has enabled decentralization and mass education.¹⁰ In Sweden, more than 3 million people (of a population of approximately 10 million) have attended a CPR course during the last three decades.⁶ However, who is expected to train in CPR? The Swedish Resuscitation Council recommends that all health care personnel should train in CPR

annually. In Sweden, there are approximately 400,000 employees in health care (e.g. auxiliary nurses, nurses, physiotherapists, physicians).¹¹² According to Swedish legislation, the aim of the Work Environment Act (1999:7) is to prevent ill health and accidents at work and to create a good work environment. It states, for example, that the employer must have routines and knowledge of first aid (including CPR) at work.¹¹³ First aid and CPR are also core content in the Swedish curriculum for elementary schools (age 13-15 year).¹¹⁴

In order to teach CPR, a person must be trained and registered as a CPR instructor. However, in the Swedish curriculum for elementary schools there is no such recommendation about teachers' skills for teaching in CPR. A CPR instructor course takes at least 4 hours and the education is standardized with regard to medical content, teaching material and teaching methodology by using detailed manuals. The instructor must not deviate from the course content or change the technique of practical training.

Previous traditional instructor-led BLS training in adult CPR took at least three hours. In 2006, a new training format with an individual training manikin, MiniAnne (manufactured by Laerdal Medical AS), a DVD with training instructions and a simple AED trainer was launched. BLS training with the MiniAnne kit only takes about one hour, but still provides a lot of practical training when the participants use an individual training manikin.

The CPR course is introduced by presenting the course objectives (measurable). According to the Swedish Resuscitation Council's course curriculum (inspired by Kolbs¹¹⁵ learning cycle), the CPR course should be based on something concrete (e.g. a real situation) and with a lot of time for practice (active experimentation). There should also be time to link the active experiment to the theory. During training, the instructor should inform, motivate and structure as well as create opportunity for reflection and feedback. However, the time for reflection and feedback is limited during a one-hour DVD/film-based training session. The instructor evaluates continuously during the course, the practical training and skills, and checks whether the objectives have been achieved. The BLS course does not contain any form of final test (summative assessment). Everyone who participates in the BLS course receives a certificate of participation, regardless of performance. The training programmes and the guidelines are revised every five years, based on international guidelines and research.^{4,35,116,117}

School curriculum

In some countries, BLS training is a mandatory element included in the school curriculum.^{49,106} Some of the countries where CPR training is integrated in the school curriculum have shown increased rates of bystander involvement,^{49,104} even though a causal relationship between mandatory CPR training in schools and bystander CPR remains uncertain because of other related initiatives.¹³

In a statement from 2015, the European Patient Safety Foundation (EuPSF), ERC, ILCOR and the World Federation of Societies of Anesthesiologists (WFSA), approved by the World Health Organization (WHO), recommend that all schoolchildren receive CPR training annually from the age of 12 years or earlier.⁶³ Regular CPR training at school offers a natural opportunity to build up knowledge and skills in an ascending manner, step by step.¹³ Schoolchildren can even serve as multipliers. If the students are allowed to bring the manikin home, they can teach their siblings, parents and grandparents.^{69,71,104} CPR training in school can also contribute to a sense of social responsibility and help establish other social skills (e.g. caring for others and being afraid of oneself).^{118,119}

Since 2011, the Swedish compulsory school curriculum specifies that CPR skills are core content in grades 7–9.¹¹⁴ Each school decides how and in what form the education is offered: theoretical or practical, on one occasion or repeatedly. However, practical training is preferable, because children who only receive theoretical tuition perform poorly on practical testing.^{13,89,90,106}

Age for CPR training

Children from five to seven years of age are able to learn to recognize CA and initiate an emergency call.^{13,89,120} There is a significant correlation between age, weight and height on chest compression depth.¹²⁰⁻¹²³ According to Uhm et al, a body weight of 50 kg (about 13-14 years) is usually required to provide a chest compression depth of at least 38 mm.¹²² However, even younger children can learn the theory of the technique of chest compressions, which can have a positive long-term effect on practical skills.^{120,121} School children (aged 12 years or younger) generally have a positive attitude towards learning resuscitation.¹²

Facilitator

Training CPR in schools can be provided by, for example, school teachers, health care professionals or peer learning by older students. The importance of who provides CPR training, with regard to effectiveness, is unclear.^{89,104} Lukas et al indicate that the school teacher as a facilitator is as good as an emergency physician to teach CPR.⁸⁰ Training in CPR provided

by teachers at school has several advantages; it is less costly, it facilitates scheduling and the teachers are experts in education.^{13,80,89}

Counter arguments to CPR training

Some argue against CPR training: it is costly to educate, lack of time (e.g. school schedule), you do not know where CA occurs and everyone will die someday.¹²⁴ Two hours of CPR training in school annually from the age of 12 year is an easy and cheap way of educating an entire generation and could potentially have a significant impact on public health.^{63,104,125} A countywide CPR programme can be a cost-effective way of saving lives compared with other health care-related interventions.⁵⁷ Lack of time should not be a barrier because the new short training programmes have been proven to be as effective as the earlier education programmes lasting for six hours.^{91,93,94} Interventions in CPR can save lives and most survivors of an OHCA have a good neurological status.^{5,6,57}

Learning and teaching

The objective in designing teaching and educational material is to promote student learning. Learning is a complex process (not a product) and is influenced by several factors, with the aim of providing knowledge.^{114,115,126} According to the Swedish compulsory school curriculum, the concept of knowledge can be “expressed in a variety of forms – as facts, understanding, skills, familiarity and accumulated experience – all of which presuppose and interact with each other.”^{114 p12} Learning may involve change in behaviour or change in a mental process.¹²⁷ Ramsden emphasizes two factors that influence learning: whether the learner is searching for meaning or not when working with a learning task and how the student organizes a task. Ramsden states that this approach to learning is essential for teachers to understand. By change approaches, the teacher can change students’ experiences, conceptions or perceptions of something.¹²⁸ In this thesis, learning is defined as “a process that brings together cognitive, emotional and environmental influences and experiences for acquiring, enhancing or making changes in one’s knowledge, skills values and worldviews”.^{126 p277}

The complexity of how to learn, what knowledge is and strategies to enhance learning can be described by a variety of different learning theories, for example, behaviourism, cognitivism, constructivism, experiential learning theory, pragmatism, social cultural theory and the concept of practice theory, etc.^{115,126,127,129,130} The different learning theories contribute with various perspectives on learning and can all provide useful suggestions for helping students to learn more effectively.¹²⁷ Some theories

of learning have some common elements. Merriam et al state that there is no single theory that explains the complex learning process. Different theories or approaches to learning can be used in combination to create productive learning environments for different students.¹²⁶

Knowledge includes both competence (practical skills and theoretical knowledge) and confidence (self-esteem and willingness to perform).¹³⁰ Practical skills are obtained through exercise, by repeated imitative activities and by use of physical tools (e.g. training manikins, simple AED trainer). Theoretical knowledge involves understanding what happens when the heart stops, its consequences and how to identify a CA. Training in CPR is also about motivating the students to want to act in an emergency situation (willingness, values, attitudes, motivations, feedback and confirmation).

In this thesis, the design of the various CPR interventions evaluated in the study is partly inspired by an experiential learning cycle. The experiential learning theory is characterized by its focus on transformation of experience. Knowledge is considered as being a result of the interaction between theory and experience. Experiential learning describes a four-stage cycle, the Kolbs learning cycle. The cycle can start at any stage, even though all stages are required to learn effectively (Figure 5):¹¹⁵

- Concrete experience - a task includes active involvement, not only observation.
- Reflective observation (on the experience) - refers to taking time out from "doing" to think critically about what has been done and experienced or what happened in a particular situation.
- Abstract conceptualization - the process of linking the experience to theories, concepts or hypotheses. Thus, it involves interpreting events and understanding the relationships between them.
- Active experimentation - the learner is testing what has been learned in practice (new situations). Most learners need to place the knowledge in a relevant context for them, otherwise there is a risk that they quickly forget.

Figure 5. Kolbs learning cycle.¹¹⁵

According to Kolb's theory, learning develops if it is based on something concrete, in combination with doing (experimentation), linked to the theory and with the opportunity to reflect. The model is structured to suit many different learning styles, thus addressing all target groups. Learning is a continuous process (based on experience), which implies that all learning is relearning.¹¹⁵ Since 2016, the Swedish Resuscitation Council's educational materials for CPR training are inspired by the worldview of experiential learning in the design of education and training.

Beyond learning theories or teaching methods, improving students' motivation is an additional key factor affecting learning.^{131,132} Motivation can be about an individual's desire to participate in the learning processes. "Motivation is the process whereby goal-directed activity is instigated and sustained."¹³² ^{p4} Motivation is affected by both internal and external factors.¹³¹⁻¹³³ Internal factors such as the individual's own intrinsic motivation and curiosity, include the will and actions to achieve a goal. Extrinsic factors can involve reward or encouragement and praise. Both intrinsic and extrinsic motivation is necessary for learning to take place, although research shows that intrinsic motivation can promote learning better than extrinsic motivation.^{131,132} Similar to theories of learning, there are several theories of motivation.¹³² Some key concepts in theories of motivation are the role of personal beliefs, socialization and the environment. Thomson and Wery state that it may involve, for example, expectations of students (both one's own and the teacher), feedback, choice of assessment method, feelings of success and failure, usefulness (connection between a school assignment and the outside of the school),

realistic goals (individual adapted, but challenging tasks and activities), and various problems that individuals face in and out of school.¹³¹

Feedback is also an essential ingredient for learning. Hattie stated in a synthesis of meta-analyses relating to achievement that feedback is one of the most powerful influences on performance. Feedback includes information from the teacher to the student but also information from the student to the teacher. Feedback from the students is about what the students know, what they understand or do not understand and mistakes, etc. The feedback is a consequence of achievements.¹³⁴ Feedback aims to reduce the gap between what is understood and a goal.¹³⁵

In the design of educational materials and teaching, there are some core issues that should be considered:¹²⁸

- What is the goal of the education?
- Which technological approach or strategies provide the greatest chance to stimulate learning?
- Assessment and effectiveness of the teaching? How do I know that the students learned in accordance with the objectives?
- Evaluation? How to use this information to improve the teaching?

Ethical aspects of OHCA research, care and bystander CPR

After OHCA, mortality is approximately 90%.¹⁻³ Thus, there are both humanitarian and scientific reasons to strive to improve survival at OHCA. Otherwise, there is a risk that this group of patients will be discriminated against the possibility of improved prognosis and care, in itself an unethical act.

Research must be conducted in accordance with the World Medical Association guidelines, the Helsinki declaration (ethical principles for medical research involving human subjects), and the International Council for Harmonisation (ICH) guidelines for good clinical practice (GCP).^{136,137} Approval of a research ethics committee is also required.¹³⁷ Research in the field of resuscitation is complicated by the need for informed consent, which is needed to include participants in a study. Since 2013, there is clarification in the Helsinki declaration regarding research involving persons who are physically or mentally incapable of giving consent, for example, unconscious patients.¹³⁷ Deferred consent can then be applied if consent is obtained as soon as possible.^{137,138}

Health care personnel decisions on care must be taken quickly, possibly based on a suboptimal level of information available at the time of the

resuscitation.¹³⁹ The ERC states the basic and important key principles of medical ethics:¹³⁸

- Autonomy, refers to the patients' right to refuse or accept treatment. Applying this principle during CA, where the victim is unconscious and their will is rarely known to EMS staff, is a challenge.
- Beneficence, refers to the need for health care personnel to assess the relevant risk and benefit, which can be difficult to assess at the accident site. The interventions must benefit the individual patient.
- Non-maleficence, refers to the balance between benefit and risks with CPR, it may be that health care personnel restrain from resuscitation where survival is apparently impossible.
- Justice and equal access, including avoiding inequalities.
- Dignity and honesty, refers to the importance of providing care with dignity, as well as the patient's right to honest information.

Sudden cardiac arrest involves, besides the victim, family and friends. In addition to the aspects of resuscitation and the possibility of restoring life to the patient, there is a need to provide a sense of closure and resolution of guilt for the relatives.¹³⁹

CPR education is included in the curriculum for elementary schools. It also specifies that the core content includes ethical fundamental values, such as responsibility, questions about what it may mean to do good and moral dilemmas or deontological ethics.¹¹⁴ When teaching resuscitation to students, the teachers need to be responsive and attentive to whether the subject has a strong effect on any student. There may be students who have previously experienced a lifesaving situation.⁷⁶ The student may need to talk, alternatively the teacher can mediate contact with a curator or school nurse. With regard to, for example, different cultures, par exercises can be experienced as uncomfortable situations. This can be solved by organizing training in pairs of the same gender. Despite mandating legislation, there are schools that do not offer students CPR training.¹⁴⁰ From an ethical point of view, it is important that the students receive education in resuscitation so they know how to act if they face a lifesaving situation and want to intervene. Since bystander CPR is one of the most effective interventions to improve survival from CA, bystander CPR can be considered as a "civic duty".¹⁴¹ However, it is important to emphasize that the bystander should not feel guilty in situations when the resuscitation is not successful or if they are afraid that they have acted improperly. "Laymen cannot do anything wrong, the only wrong would be to do nothing."⁶³

Rationale for this thesis

After sudden CA, the time from the arrest to treatment is crucial to save the person's life. For each minutes of delay to treatment, the chance of survival decreases by up to 10%.⁴ Practical training is essential for acquisition of CPR skills and in order to be able to act effectively in a lifesaving situation.^{13,89,90,106} However, the most effective CPR training method is unknown, and whether the outcome of OHCA is affected by the bystanders' education level (laymen versus off-duty health care personnel) has not been investigated fully.¹²

The goal of this thesis was to identify the factors that may affect 13-year-old students' learning during CPR training and their willingness to act in case of an emergency, and to describe 30-day survival from OHCA after bystander CPR and the actions performed by laymen versus health care personnel.

AIM

The overall aim of this thesis was to identify the factors that may affect students' acquisition of CPR skills during CPR training and their willingness to act, and to describe the role of bystander CPR in society in general by describing bystander CPR actions and survival on a national level.

The aim of each of the papers included in this thesis was as follows:

- I. To evaluate alternative CPR training methods by comparing the practical CPR skills and 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 follow-up.
- II. To investigate if two additional interventions, test or reflection, after standard CPR training facilitate learning by comparing 13-year-old students' practical CPR skills and willingness to act, directly after training and at six months.
- III. To investigate if a web course, *Help-Brain-Heart*, given to 13-year-old students before CPR training could influence practical CPR skills, willingness to act or theoretical knowledge about stroke, AMI and lifestyle factors, directly after training and at six months.
- IV. To describe 30-day survival from OHCA after bystander CPR and the actions performed by laymen versus off duty medically educated.

METHOD

In order to identify the factors that may affect students' acquisition of skills at CPR training and to describe bystander CPR actions and survival after OHCA on a national level, various methods have been used in this thesis as summarized in Table 1. Detailed descriptions of the study population are presented below, followed by the study design, data collection and data analysis.

Study population

Studies I–III

The study population for papers I–III consisted of a strategic sample of seventh-grade students, partly because 13 years is the minimum age to be able to achieve CPR quality equal to that performed by adults,¹⁰³ and partly because CPR education is mandatory in the Swedish school curriculum from seventh grade.¹¹⁴ An invitation to participate in the study was sent to the principals of all council schools with seventh-grade students in two Swedish municipalities (Linköping and Norrköping), each with approximately 140,000 inhabitants. Thus, the sample consisted of participants with different cultural and socioeconomic backgrounds. Eighteen of 24 schools agreed to participate. Four schools did not respond and two schools had a routine of offering CPR education only to grade nine (all six schools from the same municipality). The 18 schools that agreed to participate consisted of 68 classes with a total of 1547 seventh grade students (Figure 6). Data collection started in December 2013 and ended in October 2014. Inclusion and exclusion criteria are presented on page 44.

Study IV

Data in study IV are based on the Swedish Registry of Cardiopulmonary Resuscitation (SRCR). All OHCA cases witnessed and treated by a bystander and reported to SRCR during January 1, 2010, to December 31, 2014, are included in the study. A flowchart of the study is presented in Figure 7. Inclusion and exclusion criteria are presented on page 47.

Table 1. Summary of the aims of the studies, study design, study period, outcome measures and data analyses used in the dissertation.

Study	Aim of study	Study design	Study period	Participants	Outcome measures	Data analyses
I	To evaluate app- vs DVD-based training methods by comparing students' practical CPR skills and the willingness to act, directly after training and at six months	Controlled cluster-randomized trial	2013–2014	n=1232 (app: 596, DVD: 636, from a total of 63 classes in 18 schools)	Practical CPR skills; the total score of the modified Cardiff test and the individual categories of the test Willingness to act	Descriptive statistics, chi-square test, Mann-Whitney U test, unpaired t test, paired t test, multiple linear regression analyses
II	To investigate if two additional interventions, test or reflection, after standard CPR training facilitate learning by comparing practical CPR skills and willingness to act, directly after training and at six months	Controlled cluster-randomized trial	2013–2014	n=587 (CPR only: 171, CPR + test: 224, CPR + reflection + test: 192, from a total of 29 classes in 13 schools)	Practical CPR skills; the total score of the modified Cardiff test and the individual categories of the test Willingness to act	Descriptive statistics, chi-square test, unpaired t test, linear mixed-model
III	To investigate if a web course, <i>Help-Brain-Heart</i> , given to 13-year-old students before CPR training could influence practical CPR skills, willingness to act or theoretical knowledge about stroke, AMI and lifestyle factors, directly after training and at six months	Controlled cluster-randomized trial	2013–2014	n=1232 (control: 587 intervention: 645, from a total of 63 classes in 18 schools)	Practical CPR skills; the total score of the modified Cardiff test and the individual categories of the test Willingness to act Theoretical knowledge of stroke, AMI and lifestyle factors	Descriptive statistics, unpaired t test, linear mixed-model generalized estimating equations (GEE)
IV	To describe 30-day survival from OHCA after bystander CPR and the actions performed by laymen versus off-duty medically educated personnel	Observational registry study (SRCR)	2010–2014	n=8294 cases	30 day survival and CPC score at OHCA Response times and intervention performed during resuscitation	Descriptive statistics, Fisher's exact test, Mann-Whitney U test, multiple logistic regression, multiple imputations

Figure 6. Flowchart illustrating randomization and the students included in studies I–III.

Figure 7. Flowchart for study IV.

Study design

Studies I–III

Studies I–III used a cluster-randomized design,¹⁴² because randomization of individual students was impractical and not feasible.¹⁴³ Cluster randomization of classes also reduces the risk of contamination between the intervention groups (i.e. students communicate and share knowledge with students not receiving the intervention).¹⁴³ The school classes were randomly assigned to one of 13 interventions, based on a randomization list generated by an independent statistician (Figure 6).

The DVD-based method has been applied for several years while the others were created for the present study, based on core content in education and inspired by experiential learning theory.¹¹⁵ The main interventions were a mobile application (app) or DVD-based education. In addition to the main intervention, some classes were randomized to various additional interventions: a practical test, reflection, *Help-Brain-Heart* web course, visits from elite athletes and AED training. Training with AED was only performed with the DVD method because the app does not include any voice prompts for the AED. In order to evaluate if the addition of the various interventions affected student learning, groups were assessed as follows (Figure 6):

- CPR training only (group O; AO + DO)
- CPR training with a practical test including feedback (group T; AT + DT)
- CPR training with reflection and a practical test including feedback (group RT; ART + DRT)
- CPR training with a web course before training and a practical test including feedback (group WT; AWT + DWT)
- CPR training with a visit from elite athletes and a web course before training and a practical test including feedback (group WET; AWET + DWET)
- CPR training with all additional interventions: web course, elite athletes, reflection, practical test (group WERT; AWERT + DWERT)
- CPR training and AED training (group AED).

Cluster randomization implies that participants are not equally distributed between training methods due to different size at the classes. Therefore, a higher number needs to be included, to ensure a sufficient number of participants for each method.¹⁴⁴

Study I

How short and simplified the CPR training can be without negatively affecting students' skills and their willingness to act is largely unknown.¹⁰⁵ There are plenty of different mobile apps on CPR. Moreover, smartphones have become an integral part of many people's lives. So far, there are only limited examples of research in the field of mobile phone apps and CPR training. The AHA emphasizes that further research in this area is needed.¹⁴⁵ In study I, an alternative CPR training method was evaluated by comparing practical CPR skills and willingness to act among 13-year-old students, directly after a 30-minute app-based or a 50-minute DVD-based training session, and at six months follow-up.

In the framework of study I, the analyses are based on a total of 1232 (app 596, DVD 636) seventh-grade students from 63 classes in 18 schools.

Study II

Some key concepts in educational science are testing, feedback and reflection.^{115,134} In study II, we investigated if the addition of testing with feedback and reflection after standard CPR training facilitated learning and students' willingness to perform bystander CPR, by comparing seventh-grade students' practical CPR skills and willingness to act after participating in CPR training only, CPR training with a test or CPR training with a test and reflection.

In the framework of study II, the analyses are based on a total of 587 (CPR only 171, CPR + test 224, CPR + reflection + test 192) seventh-grade students from 29 classes in 13 schools.

Study III

Cardiovascular disease is the most common cause of CA.^{5,39} Public awareness of the symptoms of stroke and AMI are generally limited or low.^{3,146,147} Despite national efforts that include public education initiatives, many people who suffer AMI and stroke seek health care too late, which can adversely affect their prognosis.¹⁴⁸⁻¹⁵⁰ Timely recognition of symptoms and early call for help are crucial to the outcome; CA can be prevented and injuries reduced.^{145,148,151} Use of online learning platforms is a fast-growing technology trend.¹⁵² Sweden is in third place in the world for the use of the internet among individuals and companies; 93% of young people aged 12–15 years use the internet daily.^{153,154}

In study III, we evaluated an interactive web course, *Help-Brain-Heart* (HBH), teaching symptoms of stroke, symptoms of AMI and a healthy lifestyle. We also investigated whether this web course given before CPR training could influence not only theoretical knowledge about stroke, AMI

and lifestyle factors but also practical CPR skills and willingness to act in a CA situation.

In the framework of study III, the analyses are based on 1232 (control, 587; intervention, 645) seventh-grade students in 63 classes from 18 schools.

CPR training

All 13 CPR intervention methods included standardized practical CPR training and all the participants used an individual training manikin, MiniAnne (manufactured by Laerdal AS, Norway), during training. The schools were allowed to keep the training manikins after the end of the study. The CPR training was performed in accordance with the ERC guidelines of 2010.³⁵ Training was given to the entire class together. The classes consisted of 14–29 students.

Ten teachers had previous experience as CPR instructors and another 19 teachers received training for five hours to become CPR instructors. All teachers were given individual oral and written instructions with bullet points about how to implement the course for the intervention method randomized to each class to ensure that they were up to date with present guidelines and training. The teachers acted as facilitators; they introduced the lesson, gave advice on the fly, answered questions and completed the course.

The main interventions for the practical training were either app- or DVD-based; and various additional interventions were evaluated: reflection, HBH web course, visits from elite athletes, practical test and AED training. It was important that the design of the interventions facilitated implementation, the education was brief enough to fit into one lesson, that the lesson could be given to the whole class at the same time and that training could be provided by teachers at the school (less costly, facilitates scheduling).^{80,89,118,155} Instructor-led CPR training (the teacher demonstrates the practical exercises) was not evaluated, partly because previous studies have shown that DVD-based education is as effective as instructor-led education,^{91,92,95,156} and partly to ensure standardization of education and thereby reduce the risk that the instructor's characteristics affected the students' learning processes.

Description of training interventions

App-based method

For the app-based method, the student practised independently for 30 minutes, by using eight images with related text in a mobile application: introduction, check responsiveness, open the airway, check respiration,

alarm, chest compressions, ventilation, and CPR 30:2. The app also includes a beat generator for training in 30:2. The app was downloaded to the students' phone or tablet. The students could repeat the practical exercises as many times as they wanted. There was sufficient time to perform at least 14 cycles of compressions and ventilation, 30:2. The teacher introduced the lesson, gave advice on the fly, answered questions and completed the course. The app, *Save the Heart*, was produced by the Swedish Resuscitation Council and was available via the app store.

DVD-based method

For the DVD-based method, the whole class practised together using the Swedish resuscitation national programme: check to identify CA, alarm, CPR training (compressions and ventilation) and recovery position, based on instructions on the DVD (a 31-minute film). A total of 14 cycles of compressions and ventilation, 30:2, were carried out. The teacher introduced the lesson, started the film, paused if necessary, gave advice on the fly, answered questions and completed the course. The DVD was produced by the Swedish Resuscitation Council.

Additional intervention with a practical skill test including feedback

To compare the learning outcomes of different groups, the students in all groups (AT, DT, ART, DRT, AWT, DWT, AWET, DWET, AWERT, DWERT and AED) except CPR training only (AO and DO) performed a practical skill test including feedback for three minutes directly after the CPR training and at six months. The test was necessary to show the level of skill acquisition.¹⁵⁷ Because tests in various formats can increase learning outcomes,¹⁵⁸⁻¹⁶⁰ and the same applies to feedback,¹³⁴ we chose to investigate if the test contributed to the learning session. Thus, some classes were randomized to CPR training only, which meant that they only performed the test at 6 months (app-based CPR training only [AO] and DVD-based CPR training only [DO]). The test is described under the heading *Practical skill test including feedback* (page 45).

The test was not only a tool to assess skills but also an opportunity to give the students feedback.¹⁶¹ Feedback was defined as information provided by the investigator regarding aspects of one's performance or understanding. Feedback can be divided into four different levels of information: (1) the correctness of a task (outcome feedback) and (2) processing of the task (how something was done, process feedback). These two types of information are concrete and relate to a task in order to change strategy and improve; (3) information on self-regulation (why one should continue or change) is related to encouragement of effort and (4)

information about oneself (person feedback) is about an individual's traits or abilities.¹³⁵

Directly after the practical skill test, the students received individual constructive feedback from the investigator for two minutes. The feedback from the investigator to the students was partly based on Hattie and Timperley's model, where the following questions should be answered: "where am I going" (the goals, feed-up), "how am I going?" (feedback) and "where to next?" (advice for progress, feed forward).¹³⁵

Additional intervention with reflection

After the CPR training (app- or DVD-based), the students in the ART, DRT, AWERT and DWERT groups discussed three reflective questions for 15 minutes. In the present study, reflection is defined as afterthought, based on the students' experience, understanding and knowledge, in order to achieve deeper meaning and understanding. Afterthought, by critical and creative thinking, could be enriched with interpretations from a person with more experience.¹⁶²⁻¹⁶⁴ According to the Swedish school curriculum, students are expected to reflect on different situations and events and on their learning.¹¹⁴

The teacher asked one question at a time. The students discussed and reflected on each question pairwise. The pairs then shared what they had discussed with the whole class. The teacher summarized the answers and asked the next question. The three questions were:

1. Imagine yourself in a situation where you see a person having a CA. Reflect on the factors that influence you if you were to intervene in a real situation? Remember that your actions may be the difference between life and death.
2. You are alone when a person has a CA. According to the guidelines you should first call 112 and then start CPR. Why this order?
3. Place your hands on the correct compression position on yourself. Reflect on the compression position. Why should the heel of the hand be placed in the centre of the victims' chest?

The selection of questions was based on the following: we wanted the students to think about performing a lifesaving intervention so that during the training they would consider how they would act in a real-life situation; in a pre-study, most students failed to call 112; and previous studies have shown that a large proportion of participants apply an incorrect hand position during chest compression.^{95,96,98,121,156}

Additional intervention with a web course, Help-Brain-Heart

Before the CPR training, students in AWT, DWT, AWET, DWET, AWERT and DWERT groups performed the HBH web course (www.hjalphjarnahjarta.se). The course is about symptoms, causes and actions for stroke, AMI and CA and includes information about lifestyle factors (smoking, exercise and diet). The HBH web course is led by an animated storyteller (Figure 8). The narrative is interspersed with videos, animations and ten interactive questions. The purpose of the interactive questions is to engage the students and force them to use decision-making skills. This web course lasts for 20–30 minutes. If the students had access to a computer, the web course was conducted individually during a lesson, otherwise by the whole class together. After completing the course, the participants' received a course certificate if they had registered an email address. Students in the intervention group undertook the web course within seven days before the practical CPR training. The HBH web course was created for the study and produced by the Swedish Resuscitation Council.

Figure 8. Web course *Help-Brain-Heart*.
(Reproduced with permission from Laerdal Medical AS.)

Additional intervention with visit from elite athletes

Role models sometimes encourage students' commitment to the subject and can thus stimulate learning.¹³⁴ Professional athletes may act as role models and promote a healthy lifestyle among children and adolescents.^{165,166} Before the CPR training, students in the AWET, DWET, AWERT and DWERT groups had a 60 minute visit from two elite athletes, male hockey players or female soccer players. For the first 30 minutes, the athletes discussed the importance of acting in a CA situation, showed a video on CA during a sport event and promoted health lifestyle choices (exercise, diet and avoiding smoking) to prevent cardiovascular disease. For the next 30 minutes, the students performed the HBH web course, and the athletes answered the students' questions. The visit from elite athletes took place within seven days before the practical CPR training.

All additional interventions: web course, elite athletes, reflection and practical skills test

Students in the AWERT and DWERT groups were randomized to all additional interventions: visit from elite athletes, perform the HBH web course, discussion of reflective questions and practical skills test, as described under the respective headings above.

Additional intervention with AED training

After CPR training, students in the AED group were trained in the use of a simple AED trainer, by instruction from a 15-minute DVD. The AED training included three short scenarios: one scenario as a lonely rescuer and two scenarios with two rescuers who cooperate. The teacher introduced the lesson, started the film, paused if necessary, gave advice on the fly, answered questions and completed the course. The DVD was produced by the Swedish Resuscitation Council.

Study IV

Study IV is a retrospective registry-based observational study based on data from SRCR, which is a nationwide Swedish health care quality registry.⁵

In a study from 2005, Herlitz et al. indicated that survival can be affected by the person who performs bystander CPR (laymen or health care personnel).⁹ A health care personnel refers to a medically educated bystander who is not part of the EMS system.³³ Viereck et al showed that health care personnel bystanders are more inclined to initiate bystander CPR before the emergency call than laymen.¹⁶⁷ Only a limited number of studies have analysed the category of bystanders.¹⁰ Whether actions and survival are affected if the rescuer is a laymen or a health care professional has not been fully investigated. In study IV, we investigated if there were differences in the actions performed during OHCA when the rescuer was a laymen or an off-duty health care personnel and if this translated into differences in survival after an OHCA.

In the framework for study IV, the analyses are based on 8294 witnessed cases of OHCA, registered in SRCR 2010-2014 when bystander CPR was performed by laymen or health care personnel.

Swedish Registry of Cardiopulmonary Resuscitation

Since 1990, data on OHCA have been collected and recorded in a nationwide Swedish health care quality registry, called the Swedish registry of cardiopulmonary resuscitation (SRCR).¹⁶⁸ Only cases of OHCA treated by the EMS are registered in the SRCR. Cases where there are clear signs of death or when treatment is not started are not registered. For each case,

the reporting consists of two stages: the incidence and the follow-up. The incidence report includes information regarding patient identification, characteristics, location of CA, training level of the bystanders (laymen or medically educated), probable cause of the CA, first recorded rhythm on electrocardiography (ECG) and resuscitation procedures such as bystander interventions, response times and treatments. In the register, the bystander's training level is registered as lay bystander CPR (Lay-ByCPR, performed by non-medically educated bystanders), off-duty medically educated bystander CPR (Med-ByCPR, performed by bystanders with some form of health care education who are not responding as part of an EMS system) or unknown training level. The EMS staff ask for information on times (e.g. collapse to call, collapse to start of CPR), if bystander CPR has been performed, who the bystander is and if they have medical education. If there is more than one bystander on site, the highest level of the bystanders' education is recorded. The data for the incidence report in SRCR are recorded by the EMS crews immediately after the incident; since 2007, this is done online in the EMS system. The follow-up report includes information such as treatment in hospital, survival and patient-reported outcome measurement (PROM). The follow-up report is mostly provided by a health care provider in the hospital organization.⁵

The dispatchers use a standard protocol with a specific questionnaire for the identification of CA. Telephone-assisted CPR is offered to callers who answer that they do not know how to do CPR. The SRCR¹⁶⁹ and the EMS organization⁶ have been thoroughly described elsewhere.

Sweden has a population of approximately 10 million inhabitants in an area of 449,964 km². All Swedish EMS systems in 21 regions participate and report to SRCR. Continuous retrospective searches of EMS case records are performed to ensure that all treated cases of OHCA are reported to SRCR. Thus, today the register includes all treated cases of OHCA.^{5,168,169} Approximately 5500 cases of OHCA are reported to the register annually.⁵

Data collection

Papers I–III

In order to assess both the immediate and long-term effects of the education, students' CPR skills and attitude to taking action were measured directly after CPR training and at six months follow-up.

The inclusion criterion was:

- seventh-grade student in one of the participating schools

The exclusion criteria were:

- student did not want to participate
- student with a physical handicap that significantly limited their physical performance
- classes of students with development disabilities (these classes are age integrated and have fewer students per class).

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

Practical skill test including feedback

To compare learning outcomes, the students performed a practical skill test for three minutes. A skill test directly after training was necessary to demonstrate the initial level of skill acquisition.¹⁵⁷ Skills in CPR can deteriorate within 3–6 months,^{12,89} therefore the skill test was also performed after six months. All the tests were conducted in a room at the schools, one student at a time. The student was introduced to the test with following story: “You see an adult, someone you know, who collapsed in front of you. There is no one else on site. Show how you would act in a real situation.” During the test, the test leader answered questions about the victim's condition only if relevant actions had already been carried out. The optimal conduct was a maximum of 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 five cycles of 30 compressions and 2 ventilations. Directly after training, all students in the AT, DT, ART, DRT, AWT, DWT, AWET, DWET, AWERT, DWERT and AED groups performed the test. At the six months follow-up, all students in all 13 intervention groups performed the test.

Cardiff test and the SkillReporting system

The Cardiff test is a validated, international checklist designed to evaluate resuscitation performance.^{11,170} Different versions of the Cardiff test, ResusciAnne and the Laerdal SkillReporting system have been used in several studies.^{95,96,171-173} By direct observation, the investigator (AN) assessed the participants' actions regarding “checks responsiveness”, “checks respiration” and if they “called for help”. Collected data were recorded directly into a scoring sheet (supplementary file 1), which was a modified version of the Cardiff Test,^{11,170} updated according to the ERC guidelines of 2010.³⁵ The Laerdal PC SkillReporting system version 2.4, linked to resuscitation manikin ResusciAnne, was used to automatically measure the compression-ventilation ratio, hand position, compression depth, total number of compressions and ventilations, ventilation volume,

total hands-off time, compression rate and incomplete release. Data from the SkillReporting system was transferred to the scoring sheet after the test. A score was given in each category and added up to a total score of 12–48 points. All collected data were recorded in a dedicated database. Ten percent of all registrations in the scoring sheet were controlled for misspellings. All compression and ventilation rates were checked manually in the SkillReporting programme. All categories on the scoring sheet are described in detail in supplementary file 1. The test was not filmed because several students in a pre-study (master) experienced filming as stressful.¹⁵⁶

The ERC guidelines recommend a compression depth of 50–60 mm.³⁵ The PC SkillReporting system v.2.4 measures up to a depth of 60 mm. To avoid those applying compressions >60 mm getting the highest score (six points), the highest score was given for an average compression depth of 50–59 mm. Those who compressed >60 mm received five points. The few who compressed exactly 60 mm thus received lower scores even though they followed ERC guidelines. We chose to retain the six-point scale, as in previous studies,⁹⁵ even though no one could receive three points, which would corresponded to a compression depth >65 mm.

Calibration and reset of Laerdal PC SkillReporting system version 2.4 equipment occurs automatically each time the system is started. The compression depth and ventilation volume are measured using a rod with stripes (an encoder), which records the start/end of the compressions and ventilations. Each stripe encoder corresponds to 1 mm. Compression depth is 1:1. When performing ventilation, a table is used to translate each millimetre rise of the chest into volume. The system resets to a new zero value when the manikin is switched on, thus the system is self-calibrating.

Feedback

Directly after the practical test, the students received individual feedback from the investigator for 2 minutes as described under the heading *Additional intervention with a practical skill test including feedback* (page 40).

Retention test

At the six months follow-up, all participants (from all intervention groups) individually performed a practical CPR skill retention test. The retention test was carried out without prior notice and was conducted in the same way as the test directly after training.

Questionnaire (studies I–III)

Directly after training and at six months, all the students in all intervention groups answered a fixed-response questionnaire with questions about

background factors (sex, previous CPR training, native language, experience of resuscitation situations), self-reported confidence, willingness to act and knowledge about stroke, AMI and healthy lifestyle factors (supplementary file 2). Most of the students responded to the survey online and each question had to be answered in order to proceed to the next; others responded on paper format. The questionnaire took 6–15 minutes to complete. Two of the questions were open-ended and allowed the students to add their own comments because closed-ended questions sometimes tend to be too superficial.¹⁴⁴

For the questions about stroke, AMI and living habits, the following scoring system was used: 1 point for correct answers, 0 points for incorrectly answers and for “do not know”. The questionnaire resulted in a total score of 0–7 points for stroke symptoms, 0–9 points for AMI symptoms and 0–6 points for lifestyle factors.

Questions about AMI were partly based on a previous survey.¹⁴⁹ Before the study, comprehension of the questions about self-efficacy and scenarios about willingness to act were tested and found satisfactory in a separate cohort of 175 students. The questionnaire did not include any Likert scales because several school teachers considered that the students may have difficulty to evaluating or scoring on a Likert scale.

Outcome measures

In studies I–III, the primary endpoint was the total score of the modified Cardiff test at six months. The total score was calculated by adding the individual scores for the 12 different categories (checks responsiveness by talking, checks responsiveness by shaking, opens the airway, checks respiration, call for help, compression/ventilation ratio, hand position during compression, average compression depth, total compressions counted, average ventilation volume, total ventilation counted, total hands-off time) assessed by the practical test.

The total score directly after training, the individual variables for the practical test, self-reported confidence and willingness to intervene were secondary endpoints. In study III, theoretical knowledge about stroke, AMI and lifestyle factors were secondary endpoints.

Study IV

In study IV, all data were based on documentation in SRCR. The first incidence report in SRCR is registered by the EMS crew. The follow-up report is registered by a health care provider in the hospital organization.⁵

The inclusion criteria were:

- bystander-witnessed OHCA

- treated OHCA, receiving bystander CPR by a laymen or off-duty health care personnel
- cases recorded in the SRCR from January 1, 2010, to December 31, 2014.

The exclusion criteria were:

- non-witnessed cases
- crew-witnessed cases
- unknown if witnessed
- witnesses but unknown whether by EMS or bystander
- cases where no bystander CPR was initiated before EMS arrival
- unknown if CPR started before or after arrival of EMS
- unknown whether CPR performed by laymen or health care personnel
- cases with unknown 30-day survival.

Outcome measures, study IV

In study IV, the primary endpoint was 30-day survival at OHCA, depending on whether bystander CPR was performed by a laymen or medically educated bystander who was not part of the EMS system.

The secondary endpoint was to describe whether bystanders' education (laymen or off-duty health care personnel) influenced actions performed during OHCA and cerebral performance category (CPC) score among survivors at discharge from hospital.

Statistical analysis

Data analyses for each study in this thesis are summarized in Table 1 (page 34).

Studies I–III

In brief, data are presented as the mean (standard deviation [SD]), median (interquartile range) or proportion (percent), as appropriate. Differences in proportions were analysed with Pearson's χ^2 test. Differences in median total score between intervention groups were assessed using the Mann-Whitney U test. Differences in mean values between the intervention groups were analysed using unpaired t tests and differences within groups by paired t tests. To account for a potential cluster effect of the school classes, logistic regression within generalized estimation equations was

applied for a comparison of categorical variables (study III).¹⁷⁴ We used regression within a mixed-models linear test to be able to control for a potential cluster effect for the school classes, for comparisons of the total score (studies II and III).¹⁷⁴ By calculating $(\text{individual total score} - 12) / (\text{maximum total score} - 12) \times 100$, we obtained 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 CA situation, school and class) as fixed effects.

Sample size calculations were based on data from a pre-study,¹⁵⁶ and was performed as described by Chow et al.,¹⁷⁵ in order to detect a two-point difference in the total score for the modified Cardiff test, at a significance level of 0.05 and a power of 90% (study I) and 80% (studies II–III). To adjust for cluster effects, the intraclass correlation coefficient was calculated.^{174,176} In studies I–III, there were pre-specified and separate research questions where the groups were compared pairwise:

- To evaluate the effect of the test including feedback, groups AO and DO (CPR training only) were compared with groups AT and DT (CPR training with a test).
- To evaluate the effect of reflection, groups AT and DT (CPR training with a test) were compared with groups ART and DRT (CPR training with reflection and a test).
- To evaluate the effect of a web course before CPR training, groups AT and DT (CPR training with a test) were compared with groups AWT and DWT (CPR training with web course and a test).
- To evaluate the effect of visit from elite athletes before CPR training, groups AWT and DWT (CPR training with web course and a test) were compared with groups AEWT and DEWT (CPR training with visit from elite athletes, web course and a test).

Because the research questions were specified before the study, we have not adjusted for multiple testing. A p value < 0.05 was considered statistically significant. Analyses were performed using IBM SPSS V.21 and STATA V.13.1.

Study IV

Descriptive statistics are presented as percentages or medians with 10th and 90th percentiles. Comparisons between two groups were performed using Fisher's exact test for proportions and the Mann-Whitney U test for continuous variables/ordinal variables. Multiple logistic regression was used to adjust for potential baseline confounders. This was performed using complete analysis (i.e. including only those patients with no missing

data on the confounder variables) as well as multiple imputations of missing data (i.e. all patients included). The latter was regarded as the primary analysis in the study. Missing data were assumed to be missing at random (MAR) and 50 imputed datasets were generated with the Markov chain Monte Carlo method and using the expectation-maximization algorithm. Rubin's rules were used to pool the results from the imputed datasets. All tests were two-sided and p values <0.05 were considered statistically significant. All analysis was performed using SAS for Windows v9.3.

Ethics approval and considerations

All studies in the thesis were conducted in accordance with the principles of human research in the Declaration of Helsinki.¹³⁷ All studies (I–IV) were approved by the Regional Ethics Review Board in Linköping, Sweden:

- Dnr: 2013/358-31 (studies I–III)
- Dnr: 2016/468-31 (study IV)

Studies I–III are educational studies and according to Swedish legislation, written informed consent was not required. Before entering the studies (I–III), all students and their guardians were given written information about the studies. Study participation was completely voluntary and all students gave oral informed consent. No clinical trial registration was performed before study entry, because the study did not include any medical treatment or health-related interventions to evaluate the effects on the participants' health outcomes. However, registration was requested by a scientific journal and retrospective registration at ClinicalTrials.gov was performed (NCT03233490, date of registration; July 26, 2017).

In study IV, data are based on information registered in the National Registry SRCR. All patients who survive CA are informed that they are registered in the SRCR and advised of personal data recorded. They are also informed that all data can be erased if they so wish. When the authors acquired data from the SRCR, all data was anonymised; the social security number had been replaced with a study number.

All data (studies I–IV) are stored in a research database, on a password-protected server, to which only the researcher has access. No analyses have been done on an individual level and none of the students or OHCA cases can be recognized.

RESULTS

Studies I–III

A total of 1547 students from 68 seventh-grade classes in 18 schools were randomized to one of 13 training interventions. Directly after training, 1339 students, corresponding to 86% of the eligible students, were included in the study. At six months, 1219 of these students (91%) completed the follow-up test (Figure 6, page 35). The characteristics of the students are summarized in Table 2.

CPR skills performance

The mean total score (SD) for all students was 34 (4.3) points (directly after training and 32 (4.2) points at six months follow-up (Table 3).

The DVD-based group ($n=537$) showed superior CPR skills compared with the app-based group ($n=524$) at both measurement points: 35 (4.0) versus 33 (4.2) points ($p<0.001$) directly after training and 33 (4.0) versus 31 (4.2) points ($p<0.001$) at six months (Table 3).

At six months, the CPR with a test group ($n=224$) performed better than the CPR only group ($n=171$) in terms of total score: 32 (3.9) versus 30 (4.0) points ($p<0.001$, Table 3).

The additional interventions reflection, web course, visited by elite athletes or AED did not further influence the acquisition of practical CPR skills (Table 3).

Data on individual variables reflecting the quality of chest compressions, ventilations and hands-off time at six months are presented in Table 4. As seen in the table, a large proportion of students (regardless of intervention) had difficulty in performing rescue breathing. Furthermore, the DVD group performed significantly better than the app group in several of the variables that reflect quality of compressions and ventilations.

Table 2. Characteristics of the students.

Intervention	Male	Previous CC training	Previous ventilation training	Experienced CA situation	App-based	DVD-based	No. of schools
All included, <i>n</i> =1339	632 (47)	389 (29)	290 (22)	42 (3)	596 (45)	743 (55)	18
App, <i>n</i> =596	285 (48)	192 (32)	158 (26)	19 (3)	596	0	16
DVD, <i>n</i> =636 (AED group excluded)	294 (46)	171 (27)	113 (18)	21 (3)	0	636	14
App versus DVD, <i>p</i> value	NS	NS	0.016	NS			
CPR only (AO+DO=O), <i>n</i> =171	88 (52)	49 (29)	34 (20)	8 (5)	72 (42)	99 (58)	8
CPR + Test (AT+DT=T), <i>n</i> =224	116 (52)	54 (24)	41 (18)	5 (2)	113 (50)	111 (50)	7
O versus T, <i>p</i> value	NS	NS	NS	NS	NS	NS	
CPR + reflection + test (ART+DRT=RT), <i>n</i> =192	79 (41)	49 (26)	39 (20)	8 (4)	97 (50)	95 (50)	9
T versus RT, <i>p</i> value	NS	NS	NS	NS	NS	NS	
Web + CPR + test (AWT+DWT=WT), <i>n</i> =208	97 (47)	70 (34)	55 (26)	3 (1)	92 (44)	116 (56)	8
T versus WT, <i>p</i> value	NS	NS	NS	NS	NS	NS	
Web + elite + CPR + test (AWET+DWET=WET) <i>n</i> =243	119 (49)	72 (30)	61 (25)	10 (4)	134 (55)	109 (45)	9
WT versus WET, <i>p</i> value	NS	NS	NS	NS	NS	NS	
Web + elite + CPR + reflection + test (AWERT+DWERT=WERT), <i>n</i> =194	80 (41)	69 (36)	41 (21)	6 (3)	90 (46)	104 (54)	8
O versus WERT, <i>p</i> value	NS	NS	NS	NS	NS	NS	
T versus WERT, <i>p</i> value	0.015	0.049	NS	NS	NS	NS	
DVD + test (DT), <i>n</i> =111	56 (50)	31 (28)	20 (18)	3 (3)	0	111	4
DVD + AED + test, <i>n</i> =107	53 (50)	26 (24)	29 (18)	2 (2)	0	107	5
DT versus AED, <i>p</i> value	NS	NS	NS	NS		NS	

Values are presented as n (%). Differences in proportions between groups were analysed with logistic regression within generalized estimation equations. CC, chest compression; NS, not significant. *p* values <0.05 were considered statistically significant.

Table 3. Total score for practical skill tests directly after training and at six months.

Intervention	Total score directly after training	Total score at 6 months
All included, $n=1339$	34 (4.3)	32 (4.2)
App, $n=524$	33 (4.2)	31 (4.2)*
DVD (AED group excluded), $n=537$	35 (4.0)	33 (4.0)*
App versus DVD, p value	<0.001**	<0.001**
CPR only (AO+DO=O), $n=171$	X	30 (4.0)
CPR + test (AT+DT=T), $n=224$	34 (4.4)	32 (3.9)*
O versus T, p value	X	<0.001**
CPR + reflection + test (ART+DRT=RT), $n=192$	34 (4.3)	32 (4.2)*
T versus RT, p value	NS*	NS*
Web + CPR + test (AWT+DWT=WT), $n=208$	34 (4.0)	33 (4.2)*
T versus WT, p value	NS*	NS
Web + elite + CPR + test (AWET+DWET=WET) $n=243$	34 (4.2)	33 (3.8)*
WT versus WET, p value	NS*	NS*
Web + elite + CPR + reflection + test (AWERT+DWERT=WERT), $n=194$	34 (4.5)	32 (4.3)*
O versus WERT, p value	X	<0.001
T versus WERT, p value	NS	NS
DVD + test (DT), $n=111$	35 (3.9)	34 (3.4)*
DVD + AED + test, $n=107$	35 (4.0)	34 (4.0)*
DT versus AED, p value	NS*	NS*

Results are presented as the mean (SD). Differences in total score between intervention groups were analysed by unpaired t test^o and mixed-models linear test*. Differences in the total score, between measurement points, within an intervention were analysed by paired t test where x indicates $p < 0.01$. NS, not significant; x, no practical test performed. The number of students included at the six months follow-up for each intervention was as follows: app, $n=549$; DVD, $n=575$; group O, $n=152$; group T, $n=213$; group RT, $n=184$; group WT, $n=186$; group WET, $n=221$; group WERT, $n=168$; group DT, $n=106$; group AED, $n=95$. p values <0.05 were considered statistically significant.

Table 4. Subgroup analysis of quality of CPR skills at six months.

Intervention	CC depth (mm) ^{o*}	CC 50-59 mm [*]	CC rate (n/min) ^{o*}	CC rate 100-120 /min [*]	CC with complete release [*]	Vent 500-600 ml [*]	None vent approved [*]	Total hands-off (s) ^{o*}
All included, n=1219	45 (10)	452 (37)	102 (24)	410 (34)	973 (80)	46 (4)	568 (46)	68 (22)
App, n=549	44 (10)	183 (33)	100 (27)	166 (30)	416 (76)	19 (4)	292 (53)	68 (24)
DVD (AED group excluded) n=575	46 (10)	224 (39)	104 (22)	217 (38)	476 (83)	22 (4)	242 (42)	69 (22)
App versus DVD, p value	0.002	NS	0.012	0.016	0.012	NS	0.022	NS
CPR only (AO+DO=O), n=152	43 (11)	55 (36)	98 (24)	53 (35)	104 (69)	5 (3)	109 (72)	70 (29)
CPR + test (AT+DT=T), n=213	46 (10)	79 (37)	102 (26)	57 (27)	168 (79)	7 (3)	94 (44)	69 (21)
O versus T, p value	0.007	NS	NS	NS	NS	NS	<0.001	NS
CPR + reflection + test (ART+DRT=RT), n=184	43 (11)	59 (32)	97 (25)	58 (31)	152 (83)	5 (3)	94 (51)	65 (23)
T versus RT, p value	0.01	NS	NS	NS	NS	NS	NS	NS
Web + CPR + test (AWT+DWT=WT), n=186	43 (11)	53 (28)	104 (24)	65 (35)	148 (80)	11 (6)	83 (45)	67 (21)
T versus WT, p value	0.013	NS	NS	NS	NS	NS	NS	NS
Web + elite + CPR + test (AWET+DWET=WET) n=221	47 (9)	99 (45)	105 (21)	96 (43)	188 (85)	9 (4)	77 (35)	70 (20)
WT versus WET, p value	<0.001	0.08	NS	NS	NS	NS	NS	NS
Web + elite + CPR + reflection + test (AWERT+DWERT=WERT), n=168	45 (11)	62 (37)	106 (25)	96 (57)	132 (79)	4 (2)	77 (46)	69 (23)
O versus WERT, p value	0.045	NS	0.003	NS	NS	NS	<0.001	NS
T versus WERT, p value	NS	NS	NS	NS	NS	NS	NS	NS
DVD + test (DT), n=106	48 (8)	52 (49)	103 (21)	31 (29)	86 (81)	4 (4)	36 (34)	69 (21)
DVD + AED + test, n=95	48 (10)	45 (47)	103 (23)	27 (28)	81 (85)	5 (5)	34 (36)	69 (18)
DT versus AED, p value	NS	NS	NS	NS	NS	NS	NS	NS

Values are presented as mean (SD) or n (%). Differences in proportions between groups were analysed with generalized estimation equations^{*}. Differences in mean values between intervention groups were analysed by unpaired t test^o and mixed-models linear test^{*}. p values <0.05 were considered statistically significant. CC, chest compression; vent, ventilation; NS=not significant.

Willingness to act

Most of the students in all intervention groups were willing to make a lifesaving effort (Table 5). As shown in Figure 9, there was a significant difference in willingness to intervene in an OHCA situation involving a friend compared with a situation involving a stranger ($p<0.001$). Only approximately a third of the students would do both compressions and ventilations if a stranger suffered a CA (Table 5).

Figure 9. Overall, students' willingness to act if a friend suffered a cardiac arrest (left) or if a stranger suffered a cardiac arrest (right), as assessed six months after training. Values are given as percentages. $n=1219$.

Experienced a cardiac arrest situation

At study entry, 3% of the students stated that they had previously experienced a CA situation (Table 2). At six months follow-up, six students described how they had performed a lifesaving intervention within six months after training in school:

"There was a girl in the bathhouse and one of my buddies ran to get help so I did CPR and she survived."

"I did CPR and called an ambulance. If the school hadn't taught me, I don't know what I would have done and then maybe she would have died."

"My mom has cancer, she had convulsions and something came out of her mouth. I checked her breathing and called 112."

"...she was drowning, and they pulled her up. She was unconscious, but no one knew what to do, so I had to start CPR."

"She started cramping when we were on a bridge, I screamed for help, held her so she would not fall in the water and put her in the recovery position. We got a little more time together before she died due to cancer."

"A buddy and I swam out to an island. When we swam back, he was tired and I had to help him and rescue him to the beach."

Table 5. Students self-reported willingness to act in an OHCA situation at six months follow-up.

Intervention	How to act if a friend suffered CA				How to act if a stranger suffered CA			
	CC and vent	CC only	Vent only	Not dare to act	CC and vent	CC only	Vent only	Not dare to act
All included, $n=1219$	940 (77)	196 (16)	14 (1)	64 (5)	395 (32)	634 (52)	8 (1)	177 (14)
App, $n=549$	414 (75)	98 (18)	4 (1)	31 (6)	174 (32)	304 (55)	4 (1)	65 (12)
DVD (AED group excluded), $n=575$	448 (78)	90 (16)	8 (1)	27 (5)	181 (32)	292 (51)	2 (1)	98 (17)
App versus DVD, p value	ref	NS	NS	NS	ref	NS	NS	NS
CPR only (AO+DO=O), $n=152$	114 (75)	26 (17)	3 (2)	7 (5)	46 (30)	74 (49)	0	30 (20)
CPR + test (AT+DT=T), $n=213$	155 (73)	41 (19)	1 (1)	14 (7)	66 (31)	111 (52)	0	34 (16)
O versus T, p value	ref	NS	NS	NS	ref	NS	NS	NS
CPR + reflection + test (ART+DRT=RT), $n=184$	143 (78)	37 (20)	0	4 (2)	53 (29)	106 (58)	1 (1)	24 (13)
T versus RT, p value	ref	NS	NS	NS	ref	NS	NS	NS
Web + CPR + test (AWT+DWT=WT), $n=186$	148 (80)	22 (12)	7 (4)	9 (5)	63 (34)	98 (53)	0	25 (13)
T vs WT	ref	NS	0.05	NS	ref	NS	NS	NS
Web + elite + CPR + test (AWET+DWET=WET), $n=221$	172 (78)	36 (16)	1 (1)	12 (5)	81 (37)	111 (50)	3 (1)	26 (12)
WT versus WET, p value	ref	NS	0.05	NS	ref	NS	NS	NS
Web + elite + CPR + reflection + test (AWERT+DWERT=WERT), $n=168$	130 (77)	26 (16)	0	12 (7)	46 (27)	96 (57)	2 (1)	24 (14)
O versus WERT, p value	ref	NS	NS	NS	ref	NS	NS	NS
T versus WERT, p value	ref	NS	NS	NS	ref	NS	NS	NS
DVD + test (DT), $n=106$	76 (72)	22 (21)	0	7 (7)	29 (27)	57 (54)	0	19 (18)
DVD + AED + test, $n=95$	78 (82)	8 (8)	2 (2)	6 (6)	40 (42)	38 (40)	2 (2)	14 (15)
DT versus AED, p value	ref	0.026	NS	NS	ref	NS	NS	NS

Values are presented as n (%). Differences in proportions were analysed with logistic regression within general estimating equations. p values <0.05 were considered statistically significant. CC, chest compressions; Vent, ventilation; NS, not significant.

Self-reported confidence

Most of the students in all intervention groups stated that it is important to learn CPR in school and that they felt more confident to act after the CPR training compared with before the training (Table 6a). Overall, at the six months follow-up, the students stated that they were more confident about performing chest compressions than rescue breaths (Table 6b).

The CPR only group reported significantly lower confidence for several variables (confident to act, knowledge to do chest compressions and rescue breaths) compared with the control groups (O vs T and O vs WERT, Tables 6a and 6b).

Table 6a. Students self-reported confidence directly after training and at six months follow-up.

Intervention	Important to learn CPR in school			More confident about acting compared with before training		
	Directly after training		At 6 months test	Directly after training		At 6 months test
	Yes	No		Yes	No	
All included, $n=1339$	1298 (98)	23 (2)	1155 (95)	1117 (85)	203 (15)	972 (80)
App, $n=596$	580 (98)	13 (2)	523 (95)	498 (84)	95 (16)	430 (78)
DVD (AED group excluded) $n=636$	612 (99)	9 (1)	543 (94)	522 (84)	98 (16)	465 (81)
App vs DVD, p value	NS		NS	NS		NS
CPR only (AO+DO=O), $n=171$	150 (96)	7 (4)	145 (95)	115 (73)	42 (27)	109 (72)
CPR + test (AT+DT=T), $n=224$	219 (98)	5 (2)	199 (93)	196 (88)	28 (12)	174 (82)
O vs T, p value	NS		NS	0.001		0.022
CPR + reflection + test (ART+DRT=RT), $n=192$	191 (100)	(0)	179 (97)	167 (87)	24 (13)	147 (80)
T vs RT, p value	NS		NS	NS		NS
Web + CPR + test (AWT+DWT=WT), $n=208$	202 (98)	4 (2)	177 (95)	169 (82)	37 (18)	157 (84)
T vs WT, p value	NS		NS	NS		NS
Web + elite + CPR + test (AWET+DWET=WET) $n=243$	239 (98)	4 (2)	211 (96)	206 (85)	37 (15)	175 (79)
WT vs WET, p value	NS		NS	NS		NS
Web + elite + CPR + reflection + test (AWERT+DWERT=WERT), $n=194$	191 (99)	2 (1)	155 (92)	167 (87)	25 (13)	133 (79)
O vs WERT, p value	0.044		NS	0.001		NS
T vs WERT, p value	NS		NS	NS		NS
DVD + test (DT), $n=111$	109 (98)	2 (2)	97 (92)	99 (89)	12 (11)	90 (85)
DVD + AED + test, $n=107$	106 (99)	1 (1)	89 (94)	97 (91)	10 (9)	77 (81)
DT vs AED, p value	NS		NS	NS		NS

Values are presented as n (%). Differences in proportions between groups were analysed with logistic regression within generalized estimation equations. p values < 0.05 were considered statistically significant. The number of students included at six months measurement for each intervention was as follows: app, $n=549$; DVD, $n=575$; group O, $n=152$; group T, $n=213$; group RT, $n=184$; group WT, $n=186$; group WET, $n=221$; group WERT, $n=168$; group DT, $n=106$; group AED, $n=95$. NS, not significant.

Table 6b. Students self-reported knowledge of compressions and rescue breath, directly after training and-at six months follow-up.

Intervention	Enough knowledge to do chest compressions		Enough knowledge to do rescue breaths	
	Directly after training	At six months test	Directly after training	At six months test
	Yes	No	Yes	No
All included, $n=1339$	1063 (80)	259 (20)	1011 (76)	311 (24)
App, $n=596$	470 (79)	123 (21)	410 (69)	183 (31)
DVD (AED group excluded), $n=636$	507 (82)	115 (18)	515 (83)	107 (17)
App vs DVD, p value	NS	NS	<0.001	NS
CPR only (AO+DO=O), $n=171$	96 (60)	63 (40)	90 (57)	68 (43)
CPR + test (AT+DT=T), $n=224$	181 (81)	43 (19)	168 (75)	56 (25)
O vs T, p value	0.002	NS	0.027	0.032
CPR + reflection + test (ART+DRT=RT), $n=192$	161 (84)	30 (16)	154 (81)	37 (19)
T vs RT, p value	NS	NS	NS	NS
Web+ CPR + test (AWT+DWT=WT), $n=208$	170 (82)	36 (18)	160 (78)	46 (22)
T vs WT, p value	NS	NS	NS	NS
Web + elite + CPR + test (AWET+DWET=WET) $n=243$	203 (84)	39 (16)	197 (81)	46 (19)
WT vs WET, p value	NS	NS	NS	NS
Web + elite + CPR + reflection + test (AWERT+DWERT=WERT), $n=194$	166 (86)	27 (14)	156 (81)	37 (19)
O vs WERT, p value	<0.001	0.009	0.001	NS
T vs WERT, p value	NS	NS	NS	NS
DVD + test (DT), $n=111$	93 (84)	18 (16)	97 (87)	14 (13)
DVD + AED + test, $n=107$	86 (80)	21 (20)	86 (80)	21 (20)
DT vs AED, p value	NS	NS	NS (0.053)	NS

Values are presented as n (%). Differences in proportions between groups were analysed with logistic regression within generalized estimation equations. p values <0.05 were considered statistically significant. The number of students included at six months measurement for each intervention was as follows: app, $n=549$; DVD, $n=575$; group O, $n=152$; group T, $n=213$; group RT, $n=184$; group WT, $n=186$; group WET, $n=221$; group WERT, $n=168$; group DT, $n=106$; group AED, $n=95$. NS, not significant.

Additional intervention with reflection

At the six month follow-up, there were no significant differences between group RT (n=192) and group T (n=224) with regard to the total score for the modified Cardiff test, calling 112, hand position during compressions or willingness to act in a resuscitation situation (Table 7). Table 7 includes the variables that are directly linked to the intervention of reflection. All other variables of the test showed no significant differences between the two groups (T vs RT) and have not been included in the table.

Table 7. Variables directly linked to the intervention of reflection.

Directly after training				At 6 months		
	CPR + test (T), (n=224)	CPR + reflection + test (RT) (n=192)	p value	CPR + test (T) (n=213)	CPR + reflection + test (RT) (n=184)	p value
<i>Call 112</i>						
Yes	161 (72)	152 (79)	NS	171 (80)	147 (80)	NS
No	63 (28)	40 (21)		42 (20)	37 (20)	
<i>Hand position during CC</i>						
Correct	21 (9)	15 (8)	ref	7 (3)	7 (4)	ref
Other wrong	130 (58)	115 (60)	NS	107 (50)	95 (52)	NS
Too low	73 (33)	62 (32)	NS	99 (46)	82 (45)	NS
Not attempted	0	0		0	0	
Total score	34 (4.4)	34 (4.3)	NS*°	32 (3.9)	32 (4.2)	NS*°
<i>How to act if a friend suffers CA?</i>						
CC and vent	178 (80)	155 (81)	ref	155 (73)	143 (78)	ref
CC only	35 (16)	33 (17)	NS	41 (19)	37 (20)	NS
Vent only	2 (1)	1 (1)	NS	1 (<1)	0	
Not dare to act	9 (4)	2 (1)	0.052	14 (7)	4 (2)	NS
Missing	0	1 (1)		2 (1)	0	
<i>How to act if a stranger suffers CA?</i>						
CC and ventil	71 (32)	67 (35)	ref	66 (31)	53 (29)	ref
CC only	116 (52)	113 (59)	NS	111 (52)	106 (58)	NS
Vent only	3 (1)	0		0	1 (1)	
Not dare to act	34 (15)	11 (6)	0.048	34 (16)	24 (13)	NS
Missing	0	1 (1)		2 (1)	0	

Results are presented as n (%) or mean (SD). Differences in proportions between groups were analysed with logistic regression within generalized estimation equations. Differences in total score between intervention groups were analysed by mixed-models linear test* and unpaired t test*. p values <0.05 were considered statistically significant. NS, not significant. All values are rounded to the nearest whole number.

Additional intervention with web course

The additional intervention with the HBH web course before CPR training did not further influence the students' practical CPR skills (Tables 3 and 4), willingness to act (Table 5) or self-reported confidence (Table 6a and 6b).

Theoretical knowledge of stroke, AMI and lifestyle factors

The HBH web course before CPR training improved the students' theoretical knowledge of AMI, stroke and lifestyle factors in terms of the total score for the survey questions on these factors, both directly after training and at the 6-month follow-up (Table 8). Figure 10 shows the students' knowledge per symptom.

Table 8. Total score for the questionnaire concerning symptoms of stroke, acute myocardial infarction (AMI) and lifestyle factors, directly after training and after six months.

Intervention	Total score directly after training			Total score at 6 months		
	Stroke symptoms	AMI symptoms	Lifestyle factors	Stroke symptoms	AMI symptoms	Lifestyle factors
Control, <i>n</i> =587	2.7 (2.0)	2.5 (2.0)	4.5 (2.0)	2.8 (1.6)	2.6 (2.0)	3.2 (1.2) [‡]
Web, <i>n</i> =645	3.8 (1.8)	4.0 (2.0)	5.4 (1.2)	3.2 (1.4) [‡]	2.9 (1.9) [‡]	3.4 (1.0) [‡]
<i>p</i> value	<0.001 ^{°*}	<0.001 ^{°*}	<0.001 ^{°*}	<0.001 ^{°*}	0.008 ^{°*}	<0.001 ^{°*}

The results are presented as the means (SD). Differences in total score between intervention groups were analysed by unpaired *t* test[°] and mixed-models linear test^{*}. Differences between measurement points within an intervention were analysed by paired *t* test where [‡] indicates *p*<0.001. Theoretical knowledge resulted in a total score of 0–7 points for stroke symptoms, 0–9 points for AMI symptoms and 0–6 points for lifestyle factors. The number of students included at six months measurement for each intervention was as follows: control, *n*=549; web, *n*=575. *p* values <0.05 were considered statistically significant.

Figure 10. Students’ theoretical knowledge about symptoms of stroke, acute myocardial infarction (AMI) and lifestyle factors (LF). Upper panel: assessment directly after training (control, $n=587$; web course, $n=645$). Lower panel: assessed at six months (control, $n=549$; web course, $n=575$). Values are given as the percentage of correct answers.

Instructors

Of the 29 CPR instructors who taught the students in the study, 27 responded (11 men, 16 women) to a questionnaire after the intervention. Twenty-four of the instructors were teachers, one was a school nurse and two had other professions. Ten teachers were CPR instructors for more than one year and 19 teachers received CPR instructor education before study entry.

Thirty percent ($n=8$) of the instructors reported that they had limited knowledge to answer the students' questions about CPR (2 out of 5 on a Likert scale), and 70% ($n=19$) stated medium skills (3 out of 5 on a Likert scale).

The instructors considered the following grades appropriate to start CPR training in schools: <grade 7, 30% ($n=8$); grade 7, 30% ($n=8$); >grade 7, 40% ($n=11$).

Study IV

From January 1, 2010, to December 31, 2014, 24,643 patients with OHCA were reported to the SRCR. Among these, 8294 were known to have been witnessed and to have received CPR by laymen (Lay-ByCPR, $n=6850$) or by off-duty medically educated personnel (Med-ByCPR, $n=1444$) before arrival of EMS and where survival status at 30-day follow-up was known, and were included in the study (Figure 4).

Patients' characteristics

A cardiac factor was the assumed underlying cause of CA in 70% in both groups. Patients who received Lay-ByCPR differed significantly from those receiving Med-ByCPR by being younger, median 69 vs 77 years ($p<0.0001$), including more males, 72% vs 61% ($p<0.0001$), more frequently suffering OHCA at home, 67% vs 50% ($p<0.0001$) and were more frequently found to have a shockable rhythm as the first recorded ECG rhythm, 36% vs 29% ($p<0.001$), respectively (Table 9).

Table 9. Baseline characteristics of the patients.

Variable	Lay- ByCPR ($n=6850$)	Med- ByCPR ($n=1444$)	<i>p</i> value
Median age (10th, 90th percentile), years (150/12) ^a	69 (47,86)	77 (53,90)	<0.0001
Female sex, % (0/0)	27.9	39.3	<0.0001
Cardiac cause of cardiac arrest, % (394/68)	70.4	69.8	0.70
Collapse at home, % (0/0)	67.4	50.2	<0.0001
VF or VT as initial ECG rhythm, % (298/68)	36.3	28.9	<0.0001

^aValues in parentheses denote the number of patients with missing information in the two groups, respectively.

Survival

The 30-day survival rate was 14.7% among patients who received Lay-ByCPR and 17.2% among patients who received Med-ByCPR ($p=0.02$). When adjusting for differences in age, sex, cause of CA, location of CA, time from dispatch to arrival of EMS, initial ECG rhythm, year and using

multiple imputations to handle missing data, the odds ratio regarding 30-day survival for patients who received Med-ByCPR in relation to Lay-ByCPR was 1.34 (95% CI; 1.11–1.62, $p=0.002$). When also adjusting for time for collapse to start of CPR, the corresponding odds ratio was 1.24 (95% CI; 1.03–1.50, $p=0.03$).

Of the subgroups analysed, 30-day survival was significantly higher among patients receiving Med-ByCPR, those aged <70 years (29.6% vs 20.3%, $p<0.0001$), males (21.8% vs 17%, $p=0.0007$), those with a cardiac cause of CA (18.6% vs 15.4%, $p=0.01$) and among those found with a shockable rhythm (40.3% vs 30.3%, $p<0.0001$). On the other hand, when CA occurred at home, those receiving Lay-ByCPR had higher 30-day survival than those receiving Med-ByCPR (9.5% vs 5.5%, $p=0.0006$).

CPR actions

The median delay time from collapse to call for EMS was 2 minutes in both the Lay-ByCPR and the Med-ByCPR groups, and 2 minutes versus 1 minute ($p<0.0001$) from collapse to start of CPR. The median delay from dispatch of EMS to arrival of EMS was also longer in the Lay-ByCPR group (11 vs 9 minutes; $p<0.0001$), as was the median delay from collapse to defibrillation (14 vs 11 minutes; $p<0.0001$) of those found in a shockable rhythm. There was no significant difference in the proportion of patients who received chest compressions only or standard CPR (Table 10).

Table 10. Response times and interventions for OHCA.

Variable	Lay-ByCPR (<i>n</i> =6850)	Med-ByCPR (<i>n</i> =1444)	<i>p</i> value
Median intervals (10th, 90th percentile), min			
Collapse to call for EMS (1733/344) ^a	2 (0,9)	2 (0,9)	0.97
Call to EMS to dispatch of EMS (504/101)	1 (0,3)	0 (0,2)	<0.0001
Dispatch of EMS to arrival of EMS (1537/82)	11 (5,23)	9 (4,20)	<0.0001
Collapse to start of CPR (729/126)	2 (0,13)	1 (0,8)	<0.0001
Collapse to defibrillation ^b (341/42)	14 (7,25)	11 (4,23)	<0.0001
Bystander actions performed, %			
Chest compressions only (741/82)	33.8	32.6	0.43
Ventilation only (741/82)	0.8	0.4	0.22
Chest compressions and ventilation (741/82)	64.3	65.7	0.33

^aValues in parentheses denote the number of patients with missing information in the two groups, respectively. ^bFor patients found with ventricular fibrillation or ventricular tachycardia (*n*=2376/397).

Comprehensive description of students' CPR skills and bystander actions and survival on a national level

Overall, most of the students expressed that it is important to learn CPR in school.

At the six months measurement, the DVD-based training method was superior to the app-based method in terms of teaching practical CPR skills to seventh-grade students. In the evaluation of the additional interventions (test with feedback, reflective questions, visited from elite athletes, HBH web course before practical CPR training, AED training), only adding test with feedback had a significant impact on the students acquisition of practical CPR skills.

The HBH web course improved the students' theoretical knowledge of stroke, AMI and lifestyle factors compared with the control group who had not performed the web course.

Most students, regardless of the intervention applied, indicated that they would intervene in an OHCA situation. However, willingness to act differed significantly between CA situations involving a friend compared with a stranger.

At a national level, most cases of bystander-witnessed OHCA involved CPR by laymen. Off-duty health care personnel bystanders initiated CPR earlier and 30-day survival was higher than with laymen bystanders.

DISCUSSION

Method discussion

Statistical considerations

The statistical plan developed for studies I–III (to ensure that the plan was hypothesis-led rather than data-driven) has been supplemented by analysis to take a potential cluster effect into account. Studies I–III used cluster randomization. A limitation with cluster randomization is that there is a risk that students in one cluster are more similar than students in a different cluster.¹⁴³ Inappropriate analysis of a cluster effect may lead to inaccurate results and misleading conclusions.¹⁷⁷ Therefore, in the statistical analysis, it is important to adjust for a possible clustering effect,¹⁴³ which also requires inclusion of a higher number of participants. Failure to include a clustering effect (lack of independence within classrooms) in the analysis increases the risk for type I errors (incorrect rejection of a true null hypothesis).¹⁷⁸

To take potential clustering into consideration, we performed a linear mixed-model on the total score of the practical test (the primary endpoint) and the total score for the survey questions regarding stroke, AMI and lifestyle factors.¹⁷⁴ Using this approach, we receive close to identical *p* values for the unpaired *t* test and mixed-models linear test for all comparisons of the continuous variables. For study II, this finding demonstrated that, in this study, the clustering effect was insignificant for school class. Thus, we applied Pearson's chi-squared test for categorical variables (secondary endpoints). Pearson's chi-squared test does not take a potential clustering effect into account.¹⁷⁹ Because we found no significant cluster effect for the total score, it was reasonable to assume there was no significant cluster effect on the individual items.

In the analysis of the categorical data in study III, a possible clustering effect has been taken into account by logistic regression within generalized estimation equations.¹⁷⁴ For a few variables (characteristics of the students, self-rated confidence, willingness to act) in some of the interventions, there was a loss of statistical power in comparison with analyses where a clustering effect had not been taken into account.

From a learning perspective, the two observation time points are not of equal importance. The long-term knowledge of the students is of superior importance and better reflected by the six months test. Therefore, we chose

to analyse the two observation time points separately (and did not use, e.g. the linear mixed model for longitudinal data).

As described in the Method section, all council schools in two municipalities were invited to participate in the study. By this approach, we were guaranteed to have enough classes and students to perform the study. It is difficult to estimate missing data at six months, therefore we chose to include all available students, more than required. The teachers acted only as facilitators during the CPR training sessions. Each teacher was facilitator for one or only a few school classes. Because the role of the teacher was only to facilitate the training, we believe that a clustering effect on CPR skills is unlikely and thus it is not accounted for in the analyses.

In the analysis of non-randomized registry data (study IV), it is important to pay attention to potential confounders, which otherwise can lead to bias in the results.¹⁴⁴ One method to adjust for confounders is multiple logistic regression analysis, where adjustment is performed using important confounders as covariates in the model. This is the method used in our study. However, only measured variables can be adjusted for. Contrary to a randomized trial, unmeasured confounders might still cause bias in the results.^{144,179}

Proper handling of missing data is important, because this might also represent a source of bias in multivariable analysis. There are several ways to deal with missing data. One is to use only cases with complete data on all variables used in the analysis. The drawbacks with this method are partly that the subgroup of complete cases might not be representative of the whole cohort and partly that the reduced sample size causes loss of precision in the parameters. Another method to deal with missing data is the use of multiple imputations. In short, this means that data are imputed in the missing entries multiple times, thus resulting in a number of completed datasets. Thereafter, each of the completed datasets are analysed separately, and, finally, the results from all these are pooled.^{179,180} In study IV, we used both complete case analysis as well as multiple imputations (with 50 imputed datasets). The latter was considered as the primary analysis.

Validity, reliability and generalization

Important criteria when assessing the quality of the research are validity (internal and external), reliability and objectivity. Validity means that I measure what is relevant in the context, i.e. the collected data can answer my research questions. In quantitative studies, internal validity refers to inferences and relationship between variables; e.g. is the result (the dependent variable/CPR skills) an effect of the intervention (the independent variable/CPR intervention).¹⁴⁴ There are no uniform

guidelines for which variables best reflect practical CPR skills for training situations. Therefore, the variables used to measure practical CPR skills (studies I–III) are based on a modified version of the validated Cardiff test checklist, updated to the guidelines of 2010.¹⁷⁰ A weakness of the composition of the variables included in Cardiff test is that the checklist was drawn up more than 10 years ago.¹⁷⁰ Since then, the guidelines have changed and now further highlight the critical importance of chest compressions and the interaction between the emergency medical dispatcher and the bystander who provides CPR.⁴ Therefore, additional variables are presented (table 4) in accordance with the uniform reporting of measured quality of CPR in clinical trials.¹⁸¹ Internal validity is also about the content and the framework of the questionnaire.¹⁴⁴ Some of the issues in the questionnaire (studies I–III) have been used in other studies, but the use of a non-validated survey is a limiting factor. Even the choice of statistical methods can affect the internal validity.¹⁸² The selection of statistical methods used in this study is discussed under the heading statistical considerations.

External validity is about transferability and generalizability to other contexts.^{144,182} To obtain a representative sample (studies I–III), we invited all council schools in two municipalities and we received classes from various geographic and socioeconomic areas, thereby improving the generalizability of the results. We did not collect any data to characterize the classes and students (such as ratings, socioeconomics, education level of parents, etc.) in the two municipalities. Although interesting, we believe that comparing the two municipalities in terms of CPR skill acquisition would risk shifting the focus of the study, and thus such comparisons have not been included. External validity is also about the applicability of findings to other periods of time, which in our studies involve the timing of measurements.¹⁸² The measurements were performed directly after the CPR training (on the same day) and after 6–7 months. The time difference of a month should not affect the results because retention of resuscitation skills is short.¹⁸³

Reliability is about the correctness of a measurement regardless of investigator, i.e. that the instrument measures the same result each time and about the consistency of a measurement.¹⁴⁴ Quantitative data collection requires reliability with good repeatability. The Cardiff test checklist used to measure the students' practical CPR skills had been validated for inter- and intra-observer reliability and considered satisfactory for most of the variables. However, the reliability was less satisfactory with respect to control of responsiveness and check for open airway (assessed by direct observation).¹⁷⁰ All measurements were carried out by one investigator. Thus, it is a strength that all measurements were assessed in the same way. But this is also a limitation; since in the event of improper assessment, the

error will be repeated. Furthermore, none of the measurements were filmed. However, most of the variables were obtained from the PC SkillReporting system and thus not influenced by the investigator. The PC SkillReporting system v.2.4 is self-calibrating, which can be both a strength (occurs regularly) and a limitation (cannot be manually calibrated). Internal consistency reliability, i.e. consistency in the results between different parts of the questionnaire (on the same topic)¹⁴⁴ has not been evaluated.

To increase the objectivity of studies I–III, cluster randomization was applied, inclusion and exclusion criteria were pre-specified, a statistical plan was developed at study design and, during the measurement, the investigator was blinded to the interventions applicable to each participant.¹⁴⁴

Validity regarding a quality register (QR, study IV) is about the extent to which the register reflects the real world or the general population of patients in a specific area or context.¹⁶⁸ The SRCR registry is based on parameters recommended in the Utstein style guidelines.³³ Reliability is the credibility in measured variables, regardless of who reports. Validity, reliability, completeness (proportion of eligible persons with, for example, a diagnosis or event in the target population who are registered in the QR), coverage (number of participating units), degree of timeliness (if data records are collected promptly) and level of comparability (requires uniform definitions and content) are all variables that contribute to the quality of a register.¹⁶⁸

Even though Emilson et al.¹⁶⁸ estimated that the internal validity of the SRCR is high (>95%), there are limitations in the SRCR because all the source data cannot be verified. The internal validity can differ between variables because several of the recorded variables are based on assessments or estimates of different categories of personnel, which were not verified within this study. For example, some of the variables are based on data communicated by EMS staff on site (collapse to call, collapse to start of CPR and other bystanders actions). Also, the EMS staff independently estimate and register the cause of the CA based on, for example, symptoms before the arrest or descriptions by relatives, without access to proper instruments or a physician's opinion. The internal validity is also affected by the EMS staff compliance with reporting. To ensure completeness in the SRCR, cases of OHCA are checked against an ambulance database and missing data are added. Despite this, there is a risk that early survivors as well as non-survivors are missed. Early intervention can be lifesaving, and thus EMS personnel "only" encounter unconscious individuals. Strömsöe et al.¹⁶⁹ reported that missed data also consisted of cases in which CPR was terminated on scene by EMS personnel. How this bias can affect data analysis is unclear. However,

Strömsöe et al.¹⁶⁹ compared the missing cases with the correctly reported cases and found that there was a higher survival rate for the missing group (11.9 vs 9.2, $p=0.035$), even though they were older (69 vs 67 years, $p=0.003$) and received bystander CPR less frequently (60% vs 65%, $p=0.023$). Moreover, the proportion of missing data differs among the variables. With regard to coverage, all EMS units report to the registry.¹⁶⁸ With regard to degree of timeliness, some data are recorded soon after the OHCA event, others through follow-up.

Result discussion

This thesis identifies factors that may affect seventh-grade students' acquisition of CPR skills and their willingness to act and describes bystander CPR actions and survival on a national level. By merging the results from all four papers, we have gained knowledge about how CPR training can be improved and thereby hopefully increase the chance of survival after OHCA.

CPR training

In general, previous research shows that participants' CPR skills are limited after CPR training.^{89,90,102,103} Overall, the students in our educational intervention achieved 58–64% of the possible total score at the practical test directly after training and 50–61% at six months follow-up. The outcomes are comparable with results from previous studies, even though different evaluation tools were used. Isbye et al.⁹⁶ reported that seventh-grade students ($n=72$) at three months follow-up achieved 50% of the median total score. Reder et al.⁹⁰ measured the practical skills of high school students ($n=376$) and reported that the mean successful outcome at two months follow-up was 51–61%. When comparing our results (50–61% of total score at six months) with results for adults (58–61% of total score at three months),^{95,96} skill acquisition seems to be nearly comparable. However, how does the outcome correspond to the learning goals? Even though there is a checklist to support the instructors' assessment, there are no guidelines specifying the proportion of correctly performed CPR after training to the public that should be achieved. The guidelines emphasize CPR of good quality.^{4,12} The depth and rate of chest compressions are associated with survival.¹⁰⁷ Thus, it may be desirable that participants perform even better than we achieved here.

Main interventions mobile app versus DVD

Arousing students' curiosity can stimulate learning. One way is to use training methods that appeal to students.¹² Before study entry, we

speculated if an app-based method might be an alternative way to make the topic more attractive in order to keep the students' attention, compared with the DVD-based method. A mobile app is a more modern format, which the students use daily in different contexts. In addition, the participants have access to the information in the app even after the training. Despite this, the students in the DVD group showed significantly better practical skills than those in the app group on the practical skill tests (directly after training, 35 (4.0) vs 33 (4.2, $p<0.001$); at six months, 33 (4.0) vs 31 (4.2, $p<0.001$). Perhaps the students in the app-based group did not take responsibility for activating and repeating the practical exercises. If so, the results show the importance of repeated psychomotor practice to improve practical CPR skills.⁸⁹ Another contributing factor to the result may be that the DVD has been revised (2006, 2011), whereas the app (*Save the Heart*) is the original version. Many of the available apps do not comply with current CPR guidelines and do not offer acceptable usability.¹⁸⁴⁻¹⁸⁶

Additional interventions: practical test with feedback

With regard to the additional CPR interventions in the present study, the practical test with feedback had the greatest influence on the students' performance and skill acquisition (32 (3.9) vs 30 (4.0, $p<0.001$ points at six months), even though the feedback was short and concentrated. It is unclear whether this outcome is a result of further hands-on training on the manikin under supervision of the investigator for three minutes or a result of the individual feedback the students received after the test for two minutes.¹⁵⁷

The effects of feedback depend on the level, context, timing and on the receiver.¹³⁵ Feedback on assessed work or answering the question "where to next", i.e. goal-directed feedback, is assumed to be very important for learning,^{115,128,134,135,187} but some studies show that information about oneself or praise is less effective.¹³⁵ However, Bandura¹⁸⁸ and social cognitive theory emphasize that feedback and verbal persuasion can also strengthen participants' self-esteem or self-efficacy. An individual's self-efficacy may affect their performance.¹⁸⁹ In a pre-study, some students described that confirmation and feedback helped to strengthen their self-esteem so that they would dare to act in a real-life situation.¹⁵⁶

A limitation in the present study is that the feedback to the participants was given when the training was completed. Systematic and individual feedback to participants at traditional CPR training to the public is limited. When teaching large groups, it can be difficult to find time to give individual feedback.

Another form of feedback that has been proven to increase practical skill acquisition can be obtained through use of feedback/prompt devices.^{12,190} These forms of feedback include, e.g. voice prompts, waveforms, metronomes, numerical displays or visual alarms.⁴

Further research is needed to develop and evaluate the best format for testing and providing feedback; should it be given during or after training and how can it be included as a mandatory element of the training in order to strengthen practical skills, self-reported confidence and participants' willingness to act.

Additional interventions: reflection

Reflection is derived from the Latin term *reflectere*, which means bending back or turn back. Within optics, the concept of reflection describes the physical phenomena of light reverberating against a surface or a mirror. When the term is used in education, it refers to a mental process where the human consciousness turns on itself and you discover your own thoughts and values.¹⁶³ The process is based on critical and creative thinking in order to create connections between experience and learning.¹⁶²

Reflective questions during CPR training did not improve the total score for the practical test or for the variables for calling 112, hand position during compressions or willingness to act, despite all three being included in the reflective questions. The students perhaps perceive the reflective questions as discussion questions. The difference between discussion and reflection is that discussion is characterized by the exchange of opinions without analysing the elements, while reflection involves afterthought and analysis of knowledge and experience in order to achieve a deeper meaning and understanding.^{162,163} Another possible reason for the outcome is that some questions were a cognitive complement to the practical training. Thus, the students might have discussed and answered these questions as knowledge questions, rather than questions to reflect upon. The study outcome might be explained by the content and the framing of the reflective questions. Perhaps the outcome would have been different if these reflective questions had been asked when the action was practised, so-called reflection in action, or in combination with reflection after training.¹⁶⁴ Further research is needed to examine other formats of reflection and the role of reflection in combination with CPR training.

Additional intervention: web course

Our hypothesis was that basic knowledge of cardiovascular disease, through the HBH web course, places CPR knowledge in context and thus further increases acquisition of CPR skills. In addition, if the participants come prepared, perhaps the time can be used more effectively for practical

training.¹² We also speculated that the online learning format could make the topic attractive.¹³ In this study, the content of the HBH web course and its format did not contribute to improved practical CPR skills or willingness to act at six months compared with the control group. Hattie¹³⁴ stated that, based on meta-analyses of the effect of web-based learning, the variability across studies was huge and that the average effect was small. Results from various e-learning researches are difficult to compare because of differences in the design and content of the courses. Possible reasons may be that important educational foundations such as interaction and timely adapted feedback are often ignored in web-based learning.^{134,191} Practical training still seems to be superior for acquisition of practical CPR skills.^{13,89,90,106}

Although the practical skills were not affected by the HBH web course, the students in the web group performed significantly better than the control group on the theoretical issues regarding stroke and AMI, both directly after training and at six months. In practice, the clinical effect of one point difference is unclear and possibly limited. However, knowledge of one additional symptom may help the rescuer to decide to seek health care earlier. The time interval between symptom onset and reperfusion is associated with the outcome and mortality in patients with stroke and AMI.¹⁴⁵ Public awareness of the typical symptoms associated with stroke and AMI and early recognition are essential to the outcome.^{192,193}

The students in the web group also performed significantly better than those in the control group on the issues about lifestyle factors. The AHA emphasizes that it is important to teach young people about lifestyle factors. Therefore, the AHA has developed a "Health Campaign for Life's Simple 7" to teach young people about staying heart healthy. The seven approaches to staying heart healthy include: "be active, keep a healthy weight, learn about cholesterol, don't smoke or use smokeless tobacco, eat a heart-healthy diet, keep blood pressure healthy, and learn about blood sugar and diabetes".³

Thus, the web course needs further development so that the participants acquire even better theoretical knowledge from the course. Further research is needed to investigate the optimal format and use of web-based learning as a supplemental learning tool.¹⁹⁴

Additional intervention: elite athletes

The complex learning process is affected by students' motivation, interest in the subject and how they perceive the meaning of the subject or a task.^{128,131} Thus, sports clubs and elite athletes are sometimes used as role models to generate students' commitment to the subject and to promote healthy lifestyles of youngsters.^{135,165,166} Therefore, we examined the impact

of elite athletes as role models to increase students' motivation, willingness to act and to promote learning. The athletes introduced the lesson by showing a video on a CA during a sports event (by emotional involvement, hopefully, they increased the participants' interest in the topic) and then gave an oral presentation integrated within discussion.^{127,195} Even though the teachers reported that the athletes' visits in general were appreciated by the students, the intervention had no further effect on students' acquisition of practical CPR skills or willingness to act compared with the control group. Contributing factors to this outcome may be that the athletes have no experience in teaching or only a limited number of the students perceived the athletes as idols or role models. A limitation is that we did not assess how the students experienced the visit from elite athletes.

Motivation

Motivation associated with CPR education can be about (a) motivation to learn during training (which is affected by internal and external factors)^{131,133} and (b) motivation to want to use the knowledge and skills in an emergency situation. An individual's motivation is a well-known predictor of learning outcomes.^{131,132} This is also reported in CPR training of, for example, police officers.¹⁹⁶ Even though both intrinsic and extrinsic motivation is necessary for learning to take place, Wery and Thomson emphasize active work to strengthen students' intrinsic motivation.¹³¹ In this dissertation, repeated practical training (DVD-based method) and feedback seems to have had a great influence on students' learning. We assume that these methods affect both intrinsic and extrinsic motivation.

A limitation in the questionnaire used in this thesis is that the participants were not asked about motivation to learn, only whether they considered it important to learn CPR in school. In accordance with previous studies reporting that elementary students generally have a positive attitude and interest in learning CPR skills,^{12,123,197,198} most of the students stated that, regardless of the training intervention, they considered it important to learn CPR in school.

Motivation or willingness to act can be affected by an individual's self-assessed knowledge or skills. Several studies report that CPR training increases participant's self-reported confidence and motivation to act in a real situation.^{12,78,199} Most of the seventh-grade students' stated that they felt more confident to act after participating in CPR training, even though the proportion was lower in the CPR-only group, and that they were willing to make a lifesaving intervention. However, there was a significant difference in how the students would act (compressions and ventilations vs compressions only) in a CA situation involving a friend compared with a

situation involving a stranger, which has also been reported in previous studies.^{76,78,83}

Lifesaving efforts

Approximately two thirds of CAs occur at home.^{1,3,5} Based on a survey with students aged 16–19 years, Kanstad et al.⁷⁶ reported that 8% of the respondents had witnessed a CA. In the present study, 3% of the students stated that they had experienced a CA situation before study entry. At six months follow-up, 6 students had made a lifesaving intervention within six months of the training. Both previous studies and the quotes in this thesis show that adolescents may face situations where lifesaving effort is required. This may involve a drowning situation, someone suffering a CA, relatives with cancer or someone who is unconscious, for example, due to alcohol or drugs. Creating an open airway, putting the victim in the recovery position and calling the EMS are also lifesaving interventions that can prevent a CA. Thus, it is important to teach young people CPR. A large proportion of the population can be reached by mandatory CPR training in the school curriculum.⁶³

Experiential learning

Kolb¹¹⁵ emphasizes that all four stages (concrete experience, reflective observation, abstract conceptualization and active experimentation) in the learning cycle are required to learn effectively, even though the time for each step may vary. A limitation in the evaluation of the different CPR training methods (interventions) in this study is that some of the methods did not include all four stages of the learning cycle. All interventions were based on active experimentation (app- or DVD-based) and practicing results in a concrete experience. Time is needed to link the experience to theory i.e. abstract conceptualization. Both the app and the DVD include limited information (theory), which is necessary to be able to identify a CA and to understand what happens when the heart stops. Some of the additional interventions (e.g. web course, elite athletes) offered more time for abstract conceptualization. The elite athletes introduced the lesson by showing a film on CA during a sports event. Even the DVD-based method is introduced by a CA story. These films show that everyone can face a CA situation (i.e. a connection between a school assignment and the world outside the school, and affecting students emotionally).¹³¹ However, the story in the DVD film is about an older man who suffered a CA, as opposed to the film from a sports event. The survey contained scenarios that described different CA situations. Maybe the outcome of how the students would act in different situations would have been different if the survey had included different situations such as a teenager with CA during a sports event instead of an older lady at a bus stop. In traditional BLS training, the

time for reflection is limited, even though it may occur individually while watching the DVD or app. Some classes were randomized to discuss three reflective questions, which surprisingly did not affect the outcome. Maybe the outcome would have been different if the reflection session had been led by an instructor with medical knowledge to enable other reflective discussions, if the time for reflection had been longer or if the reflection had been carried out in direct connection with the situations. In the present study, the intervention that included a practical test with feedback had the largest effect on the outcome. Feedback can stimulate several of the stages in the learning cycle (concrete experience, reflection and abstract conceptualization). Test and feedback are activities that are not usually included in traditional BLS training, but obviously should be included in future BLS training. However, the best format of feedback during a CPR course is still unclear.

School personnel as instructors

The importance of the person who provides CPR training in terms of effectiveness is unclear,^{89,104} and several studies show various attitudes regarding teachers' responsibility for CPR training in school.²⁰⁰⁻²⁰² In the current study, the school personnel acted as facilitators during training. All 29 teachers responsible for the CPR training in studies I–III were educated and registered as CPR instructors and had obtained information to ensure that they were up to date with the present CPR guidelines and training. According to the questionnaire, 30% of the instructors considered that they had limited skills to respond to the students questions regarding CPR and 70% rated their skills as medium good (3 of 5 on a Likert scale). The results are similar to other studies reporting that teachers in general feel they have limited expertise in educating students in CPR.^{201,202} In a Danish qualitative study based on interviews, Zinckernagel et al.²⁰² indicated that teachers considered CPR training to differ substantially from teaching other subjects because they believed that special skills were required to conduct CPR training, a matter of life and death. Thus, it is important to further ensure that the teachers' skills are sufficient for CPR training. The effect of how teachers estimate their own competence on students' acquisition of CPR skills is insufficiently investigated.

Bystander interventions and outcome of OHCA

The main finding in study IV was that the 30-day survival rate was higher for OHCA patients who received bystander CPR performed by off-duty health care personnel compared with laymen (17.2% vs 14.7%). The results are similar to those reported previously from SRCR in 2005, but with markedly higher 30-day survival in both groups for the present study period.⁹ The reason for the observed difference is unclear and we can only

speculate on potential factors. A multivariate analysis, adjusting for the time from collapse to start of CPR (medically educated bystander 1 minute vs 2 minutes by laymen), suggests that the time interval is important, even though it does not fully explain the difference in survival between the groups. An additional contributing explanation may be the shorter time interval from dispatch of EMS to arrival of EMS, seen in the Med-ByCPR group (9 minutes vs 11 minutes).^{37,203} The longer response time by the EMS may be explained by longer geographic distances, because Lay-ByCPR more often occurred at home. Pre-hospital predictors of increased survival rates include a shorter EMS response time, a shorter time to CPR and a shorter time to defibrillation.^{4,7,203}

A significant association has been shown between the time from collapse to start of CPR and 30-day survival.⁶ According to the Swedish Resuscitation Council, the treatment goals for OHCA in the community are that call to EMS and start of CPR should be initiated within 1 minute. In study IV, the median time from collapse to the call for EMS was 2 minutes in both groups, which needs to decrease for both the Med-ByCPR and the Lay-ByCPR groups. Thus, this must be further emphasized at CPR training. Hasselqvist et al.⁶ reported that the emergency call was initiated faster when bystander CPR was initiated before the arrival of EMS. Therefore, they speculate that bystanders with CPR training (compared with those without training) recognize CA more rapidly and then initiate action.⁶

The overall improved survival after OHCA during the last decades is probably a result of several different contributing factors such as large-scale teaching of CPR to laymen, improved quality of CPR, the implementation of telephone-assisted CPR and possibly generally better reporting from the EMS.^{6,41} In order to maintain and even increase the CPR skills of the public, regular CPR training and continued large-scale education initiatives are needed. However, the optimal method and frequency of training is unclear and further research is needed.^{12,58}

Development areas in CPR training

In this thesis, several areas for further development in CPR training have been identified, in order to increase participants' learning. In the design of future training interventions (a whole course or an individual learning activity), it is important to change the focus away from content to activities and the optimal and final learner experience.²⁰⁴

Based on the results in study IV, in real situations the time interval from collapse to call for EMS needs to be reduced (both by laymen and health care personnel) as well as the time interval from collapse to start of CPR (laymen). At the practical skill test on manikins at six months (studies I–III), most of the students dialled 112 (75–80%, except the CPR only

group in which 53% called for help) and started CPR within the first minute, but identifying that a training manikin is unconscious and not breathing normally probably takes less time than in a real emergency situation. To be effective in an emergency, participants need theoretical knowledge, practical skills and they need to be mentally prepared that the situation will not be like the manikin.

The subgroup analysis of CPR skills (studies I–III) at six months (Table 4) shows that the proportion of students who performed compressions to the correct depth (50–60 mm) and rate (100–120/min) was less than 50%. Most of the students also applied the wrong hand position during chest compressions. To compare hand position with other studies is complicated because different definitions are applied and thus, the results vary from 13% to 90%.^{90,95,96,121,123} Several studies show that participants acquire limited skills during CPR training.^{90,102,103} Because CPR is inherently inefficient (provides limited blood flow), it is important to train the participants/bystanders to deliver the highest possible quality of CPR.⁵⁸ Devices that provide feedback about actual CPR performance in real time can be a way to improve the quality of CPR. Feedback devices have been used both in training and in clinical settings.^{12,71,190}

In general, a large proportion of the participants had difficulty ventilating the manikin. Limited knowledge on performing rescue breaths has also been reported by several previous studies.^{95,96,100,120} In most of the interventions, a large proportion of students also failed to apply the correct compression and ventilation ratio (18–45% at six months). A contributing factor may be that students who find it difficult to perform rescue breaths make repeated attempts and thus lose the correct compression/ventilation ratio. The use of standard CPR (compressions and ventilations) versus compressions only is widely debated.⁸⁴ Some studies have reported that compressions-only CPR has comparable results or leads to improved survival after OHCA in adults compared with standard CPR,^{108–111} whereas others studies show increased survival and a more favourable neurologic outcomes with standard CPR after OHCA (mainly patients with CA of non-cardiac cause, when there was a delay in the start of CPR or in younger people).²⁰⁵ A contributing reason for the different study results may be differences in age and cause of CA.²⁰⁵ Ventilation is recommended according to the guidelines.⁴ In order to perform adequate ventilations, proper technique is required but also barriers such as fear of disease transmission and fear of being incapable must be overcome.^{76,83,85} The limited skills in rescue breathing show the importance of repeated training during the education. A contributing reason for the difference in outcome between the app versus the DVD method may be that the students did not take responsibility for repeated training with the app-based intervention.

CPR knowledge includes both competence (skills to perform CPR) and confidence (self-esteem and willingness to perform). Regardless of the training intervention, most of the students reported that they would intervene in a real situation. However, in accordance with other studies, there was a huge difference in willingness to act dependent on whether the victim was a relative/friend or a stranger.^{76,78,83} Thus, this is a cognitive and emotional process that needs to be dealt with during the training and needs to be considered when developing new educational material.

Feedback is known to be very important for learning,^{115,128,134,135,187} as seen in this study. In traditional BLS training, feedback to the participants is limited, but it should be a mandatory activity included in future BLS training.

Implementation of CPR training in school

The Utstein formula for survival emphasizes three key components essential for improved survival after OHCA: medical science (guidelines), educational efficiency (e.g. CPR quality and increased bystander rate) and local implementation (change needs to start at local level). Publishing guidelines for resuscitation and training without an implementation plan is insufficient. It has been found that it is more difficult to apply evidence-based educational recommendations compared with evidence-based treatment recommendations.⁴³ Therefore, a concrete action plan for implementation of best practice (guidelines, training) is required to improve survival after OHCA.⁷¹ The plan should include equipment and decision-making strategies (including political).²⁰⁶ Implementation takes time.²⁰⁷ Implementation and improvements may need to take place gradually. Start with one area/variable, achieve some success and confidence, and then move on to the next. The implementation process can be described as four phases: exploration stage, installation stage, initial implementation stage and full implementation stage. These implementation stages are interactive, not linear.²⁰⁷ Successful implementation requires interaction between evidence, context and facilitation.²⁰⁸

If all students receive practical CPR training in school, a large proportion of the population will have basic skills within a few decades and such a situation could potentially increase CPR intervention by bystanders in OHCA and have a significant impact on public health.^{12,106,118,119} Even though CPR training is mandatory in the Swedish school curriculum and in several other countries, it is a risk that the systematic implementation of practical CPR training varies across schools.¹⁴⁰ Thus, additional efforts are necessary to support and ensure successful implementation of CPR training in schools.^{106,140} Hansen et al.¹⁴⁰ argue that in order to increase implementation, it is necessary to monitor implementation and

systematically inform teachers and school leaders about the requirements. In addition, the curriculum needs to state that practical training is required. Factors associated with successful implementation of CPR training in Danish schools were the belief that other schools conducted training (OR, 9.68), knowledge of legislation (OR, 4.19), CPR education coordinators (OR, 3.01), the school personnel feel competent to be responsible for the training (OR, 2.78) and access to training equipment (OR, 2.08). According to an ERC statement, it is recommended that all students receive at least two hours of CPR training annually from the age of 12 years or earlier.⁶³

Conclusions

The main findings of the present study:

- The DVD-based group showed superior practical CPR skills compared with the app-based group.
- A practical test including feedback directly after training improved the students' acquisition of CPR skills.
- Reflective questions added to CPR training, involvement of elite athletes before practical CPR training, a web course before CPR training or AED training did not increase practical CPR skills further.
- At the six months test, the student's performance in all intervention groups decreased significantly as a result of the time interval.
- The *Help-Brain-Heart* web course improved the students' theoretical knowledge of AMI, stroke and lifestyle factors.
- Most of the students, regardless of the intervention applied, indicated they would intervene in an OHCA situation.
- Willingness to act differed significantly between cardiac arrest situations involving a friend compared with a stranger.
- Six students had made a lifesaving intervention within six months after training.
- Several of the school staff felt they had limited knowledge to answer the students' questions during CPR training.
- Most cases of bystander-witnessed OHCA received CPR from laymen.
- Medically educated bystanders initiated CPR earlier in cases of OHCA and such an intervention was associated with an increased 30-day survival compared with interventions performed by lay bystanders.

Clinical implications

This thesis has presented details on survival from OHCA after bystander CPR and the actions performed by laymen versus off-duty health care personnel. In most cases of OHCA witnessed by a bystander, CPR was administered by laymen, thus it is important to train the public in CPR. The quotes from the students show that even young people face situations where they need to be able to make lifesaving efforts. The present study supports the need for further large-scale teaching of laymen. Both adults and children should be trained.

The DVD-based method and test with feedback were the most successful methods for skill acquisition at CPR training of 13-year-old students. However, the difference between the groups was quite small, 2 points, and its clinical impact is unclear. Thus, the other intervention methods can also be applied in order to optimize the students' learning experience, although some of these methods were more time consuming. Further studies are needed to identify optimal teaching methods.

Use of online learning platforms and mobile applications are fast-growing technologies, so even though the web course and the app did not increase the participants' practical skills, the format may be useful to increase interest in the subject and in addition, these formats are available before and after the course. The web course improved the students' theoretical knowledge of AMI, stroke and lifestyle factors.

Regarding generalizability, the results for survival and actions performed by bystanders were based on data from the SRCR registry, which covers nearly all treated cases of OHCA.^{5,168,169} The CPR training intervention was carried out in two major municipalities with schools from all socioeconomic areas and included 86% of eligible students, strengthening the generalizability of our findings on CPR training.

Future research

This thesis describes bystander CPR actions and survival on a national level and evaluates different CPR training interventions to students in order to identify the factors that may affect students' acquisition of CPR skills and their willingness to act. Learning, however, is a complex process that is influenced by many factors. The challenge for the future is still to offer instructive training methods that can be implemented in, for example, the school curriculum. The optimal format is unclear and further research is needed.^{12,118}

- What is the best format of feedback at CPR training and how can it be included as a mandatory element of the training?

- Examine other formats of reflection in combination with CPR training.
- Investigate the optimal format and use of web-based learning as a complementary learning tool.¹⁹⁴
- What affects participants motivation and willingness to intervene in a real situation, regardless of whether the victim is a relative or a stranger?
- What level of competence and confidence in CPR does the teacher/instructor need to have?
- What is the most favourable time needed for training?
- Should different training methods be used in CPR training of adults versus adolescents?^{12,89}

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Observation schedule for three minute skill test in CPR according to ERC guidelines of 2010.

Studienummer		
Måttillfälle	Direkt efter utb	Efter 6 månader
Kön	Flicka	Pojke

Medvetande kontroll			
Tilltal	2. Ja	1. Nej	
Skakar lätt personens axlar	3. Ja	2. Nej	1. Farligt

Andningskontroll					
Öppnar luftvägen, lyfter hakan, böjer huvud bakåt	5. Perfekt	4. Acceptabelt	3. Försökt på annat sätt	2. Endast en åtgärd	1. Nej
Andningskontroll se, lyssna, känn	2. Ja	1. Nej			

Larmar 112	2. Ja	1. Nej
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Förhållande kompression/ventilation	4. 30:2 (28-32:2)	3. Annan relation	2. Enbart kompression	1. Enbart ventilation
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Handplacering kompression	4 Korrekt	3. Andra fel	2. För lågt	1. Ej utfört
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Genomsnittlig kompressions djup	6. 50-60 mm	5. 61-65 mm	4. 35-49 mm	3. > 65 mm	2. 1-34 mm	1. ej utfört
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Totalt antal utförda kompressioner	6. 140-190	5. >190	4. 121-139	3. 81-120	2. 1-80	1. ej utfört
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Genomsnittlig ventilationsvolym	5. 500-600 ml	4 <500 ml	3. > 600 ml	2. 0 ml	1. ej utfört
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Totalt antal inblåsningar	5. 8-12	4. 1-7	3. >12	2. 0	1. ej utfört
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Total hand off tid	4. 0-60 s	3. 61-90 s	2. 91-135 s	1. 136-180s
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Delay tid till första kompression [s]	
Kompressionsdjup [mm]	
Kompressions frekvens [n/min]	

Kommentarer

Description of the variables in the modified Cardiff test.

The modified version of the Cardiff test, adapted to the ERC guidelines of 2010.^{35,170} The duration of the practical test was 3 minutes. The optimal conduct was maximum 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 such 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 shakes the victim's shoulders.

2. No, if no attempt to shake the victim's shoulders occurred.

1. Potentially dangerous, if the rescuer violently shakes the victim's shoulders so the head lifts 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, i.e. by ERC guidelines.

4. Acceptable/partially correct if several indicators are performed, but not all.

3. Attempted other, if the rescuer tried in ways other than the 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 attempt to check for breathing, even if not all three actions see, listen and feel were performed and even if the total time of the check 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 that 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 applied compressions and ventilations with the relationship 28-32:2 for 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 a 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 SkillReporting system 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 the sternum.

4. Correct, if the rescuer placed the heel of one hand in the centre of the victim's chest with the other hand on top.

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 SkillReporting system was transferred to a scoring sheet after the test.

Average compression depth

The ERC guidelines recommend a compression depth of 50-60 mm.³⁵ The Laerdal PC SkillReporting system version 2.4 measures up to 60 mm compression depth. To avoid the situation where those who compress >60 mm obtain the highest score, the 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,⁹⁵ even though no one could receive 3 points, which would corresponded to a compression depth >65 mm.

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 SkillReporting system 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 system 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 SkillReporting 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 breaths.

Exact number, from Laerdal PC SkillReporting 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 SkillReporting systems was transferred to a scoring sheet after the test.

Questionnaire used directly after training and at six months follow-up.

Questionnaire directly after training

Study number:

1) Have you previously practised

1a) chest compressions?

Yes

No

1b) ventilations?

Yes

No

2) Have you ever been in a situation when someone suffered a

2a) suspected stroke?

Yes

No

Do not know

2b) suspected myocardial infarction?

Yes

No

Do not know

2c) suspected sudden cardiac arrest?

Yes

No

Do not know

3) Do you think it is important to learn

cardiopulmonary resuscitation in school? Yes

No

Do not know

4) Do you think that your skills are sufficient to perform

4a) chest compressions?

Yes

No

Do not know

4b) ventilations?

Yes

No

Do not know

5) Are you more confident now than before the

training to act and start CPR?

Yes

No

Do not know

6) 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

6b) State 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

6c) State 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

7a) 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

7b) State 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

7c) State 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

What is correct regarding symptoms of stroke?

8a) Pain in one side of the body	Yes	No	Do not know
8b) Pain in both the left and the right side of the body	Yes	No	Do not know
8c) Weakness in one side of the body	Yes	No	Do not know
8d) Weakness in both sides of the body	Yes	No	Do not know
8e) Onset of symptoms occur slowly	Yes	No	Do not know
8f) Onset of symptoms occur quickly	Yes	No	Do not know
8g) Speech difficulties or slurred speech	Yes	No	Do not know

What is correct regarding symptoms of acute myocardial infarction?

9a) Discomfort/pain in right arm	Yes	No	Do not know
9b) Discomfort/pain in left arm	Yes	No	Do not know
9c) Discomfort/pain in the chest	Yes	No	Do not know
9d) Discomfort/pain in right leg	Yes	No	Do not know
9e) Discomfort/pain in left leg	Yes	No	Do not know
9f) Discomfort/pain in the back	Yes	No	Do not know
9g) Discomfort/pain in the stomach	Yes	No	Do not know
9h) Headache	Yes	No	Do not know
9i) Nausea	Yes	No	Do not know

Good living habits provide protection against stroke and myocardial infarction. Which living habits are protective?

10a) Regular strenuous exercise	Yes	No	Do not know
10b) To smoke	Yes	No	Do not know
10c) To eat fruits and vegetables every day	Yes	No	Do not know
10d) Daily use of the computer	Yes	No	Do not know
10e) To eat fish 2-3 times a week	Yes	No	Do not know
10f) To walk or cycle, so-called everyday exercise	Yes	No	Do not know

11) native language?

12) other comments?

Questionnaire at six months follow-up

Study number:

1a) Have you done a lifesaving intervention in real life after the CPR training?

Yes No

1b) If yes, please describe your lifesaving intervention and the situation:

2) Do you think it is important to learn

cardiopulmonary resuscitation in school? Yes No Do not know

3) Do you think that your skills are sufficient to perform chest compressions?

Yes No

Do not know

ventilations?

Yes No

Do not know

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

5a) 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

5b) State 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

5c) State 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

6a) 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

6b) State 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

6c) State 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

What is correct regarding symptoms of stroke?

7a) Pain in one side of the body

7b) Pain in both the left and the right side of the body

7c) Weakness in one side of the body

7d) Weakness in both sides of the body

7e) The onset of symptoms occur slowly

7f) The onset of symptoms occur quickly

7g) Speech difficulties or slurred speech

What is correct regarding symptoms of acute myocardial infarction?

8a) Discomfort/pain in right arm Yes No Do not know

8b) Discomfort/pain in left arm Yes No Do not know

8c) Discomfort/pain in the chest Yes No Do not know

8d) Discomfort/pain in right leg	Yes	No	Do not know
8e) Discomfort/pain in left leg	Yes	No	Do not know
8f) Discomfort/pain in the back	Yes	No	Do not know
8g) Discomfort/pain in the stomach	Yes	No	Do not know
8h) Headache	Yes	No	Do not know
8i) Nausea	Yes	No	Do not know

Good living habits provides protection against stroke and myocardial infarction. Which living habits are protective?

9a) Regular strenuous exercise	Yes	No	Do not know
9b) To smoke	Yes	No	Do not know
9c) To eat fruits and vegetables every day	Yes	No	Do not know
9d) Daily use of the computer	Yes	No	Do not know
9e) To eat fish 2-3 times a week	Yes	No	Do not know
9f) To walk or cycle, so-called everyday exercise	Yes	No	Do not know

10a) How many times have you used/read the app "Save the heart" (including any lesson in school)?

10b) Have you shown the app to someone else? Yes No Do not know

10d) How many people have you shown the app to?

11a) How many times have you performed the web course *Help-Brain-Heart* (including any lesson in school)?

11b) Have you shown web course *Help-Brain-Heart* to someone else?
Yes No Do not know

11c) How many people have you shown the web course *Help-Brain-Heart* to?

12) other comments?

Papers

The papers associated with this thesis have been removed for copyright reasons. For more details about these see:

<http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-142460>