# Learning aspects of out-of-hospital cardiac arrest and learning activities in basic life support – a study among laypersons at workplaces in Sweden

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Gothenburg, Sweden, 2021

Cover illustration
“Wide open lark heart”

Cover illustration by Madeleine Fjärilsdotter

**Learning aspects of out-of-hospital cardiac arrest and learning activities in basic life support – a study among laypersons at workplaces in Sweden**


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To my family and friends with love!

"Education is life itself"
"We learn on reflecting by experience."
–John Dewey

"There is probably purpose and meaning in our journey
but it is the pathway there, which is worth our while.
Move on, move on! The new day is dawning.
Endless is our great adventure"
–Karin Boye

# Abstract


### Learning aspects of out-of-hospital cardiac arrest and learning activities in basic life support – a study among laypersons at workplaces in Sweden



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**Background:** Out-of-hospital cardiac arrest (OHCA) is one of the leading causes of death worldwide. Despite healthcare improvements, prevention for cardiovascular health, training in adult basic life support (BLS) with cardiopulmonary resuscitation (CPR) and automated external defibrillation (AED), together with increased public awareness of cardiovascular disease, survival from OHCA still remains poor.

**Aim:** To 1) explore the effectiveness and the intended learning outcome after training in BLS calculated as a total score of practical skills, theoretical knowledge, confidence and willingness to act by comparing different learning activities among laypersons at workplaces and 2) describe characteristics and 30-day survival of OHCAs occurring at workplaces in comparison to OHCAs at other places and factors associated with survival after OHCA at workplaces in Sweden.

**Methods:** Studies **I-III** were conducted as cluster randomised, controlled trials with parallel analyses. The outcome was the total score on the Cardiff Test for the intended learning outcome of theoretical knowledge and practical skills in BLS, primarily six months after training and secondarily directly after training. Study **IV** was performed as a register-based, observational study and the outcome was survival to 30 days for cases of OHCA reported by the emergency medical service and factors associated with the outcome after OHCA at workplaces.

**Results:** Study **I** was unable statistically to demonstrate a difference in learning outcome in BLS between self-learning and instructor-led learning. Studies **II** and **III** showed that a preparatory, web-based, interactive education on stroke, acute myocardial infarction, OHCA, CPR, AED and healthy lifestyle factors, in addition to instructor-led and film-based (Study **III**) practical training in BLS, improved the learning outcome for practical skills in CPR and AED. Study **IV** showed that the incidence of OHCAs at workplaces in Sweden was low and survival was relatively high when compared with other places outside hospital. Being found in a shockable cardiac rhythm was a strong independent predictor of survival after OHCAs at workplaces. OHCAs at workplaces were defibrillated more frequently and with a shorter delay to shock when compared with other places outside hospital.

**Conclusion:** Instructor-led and film-based training in BLS, with the addition of a preparatory, web-based, interactive education, benefits the learning outcome for practical skills in BLS for laypersons at workplaces. Although the incidence of OHCAs at workplaces is low, the survival rate is relatively high and the probability of survival was lower at all other places outside hospital, apart from crowded public places, than at workplaces. Through existing legislation, workplaces have the opportunity regularly to offer training in BLS to employees and the clinical implications could be that more trained laypersons are able to start effective resuscitation both inside and outside the workplace environment, thereby increasing OHCA survival even more.

**Keywords:** Adult; Automated external defibrillation; Basic life support; Cardiff Test; Cardiopulmonary resuscitation; Cardiovascular disease; Confidence; Experiential learning; Feedback; Instructor-led learning; Layperson; Learning; Mobile application; Out-of-hospital cardiac arrest; Reflection; Survival; Self-learning; Training; Web-based education; Willingness

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# Sammanfattning


**Lärandeaspekter av hjärtstopp utanför sjukhus och lärandeaktiviteter i hjärt-lungräddning med hjärtstartare – en studie bland lekmän på arbetsplatser i Sverige**

**Bakgrund**
Hjärtstopp utanför sjukhus är en av de ledande dödsorsakerna i världen. Trots förbättringar inom hälso- och sjukvården, förebyggande åtgärder för ökad hjärt- och kärlhälsa, ökad medvetenhet om hjärt- och kärlsjukdom samt utbildning i hjärt-lungräddning (HLR) med hjärtstartare till allmänheten är överlevnaden vid hjärtstopp utanför sjukhus fortfarande mycket låg.

**Syfte:** Det övergripande syftet med avhandlingen var: 1) att utforska effekten av avsedda lärandemål efter träning i HLR med hjärtstartare, beräknat som totalpoäng av praktiska färdigheter och teoretiska kunskaper, självförtroende och vilja att agera vid hjärtstopp genom att jämföra olika lärandeaktiviteter för träning i HLR med hjärtstartare bland lekmän på arbetsplatser, och 2) att beskriva karakteristika, förekomst och överlevnad till 30 dagar efter hjärtstopp utanför sjukhus hos vuxna med fokus på arbetsplatser i Sverige.

**Forskningsfrågor**
I studie **I-III** var den övergripande forskningsfrågan vilken lärandeaktivitet som bidrog till högst totalpoäng för avsedda lärandemål efter utbildning i HLR med hjärtstartare: självlärande eller instruktörlett lärande (**I**); med eller utan en förberedande webbaserad utbildning i tillägg till utbildning i HLR med hjärtstartare (**II**); standardutbildning i HLR med hjärtstartare eller med tillägg av olika lärandeaktiviteter såsom instruktioner från en mobilapplikation eller en film, självlärande eller instruktörslett lärande, en förberedande webbutbildning, användning av mekanisk feedback vid bröstkompressioner eller reflekterande frågor (**III**). I studie **IV** var forskningsfrågan vilka karakteristika, vilken förekomst och vilket utfall efter hjärtstopp utanför sjukhus på arbetsplatser som förelåg jämfört med andra platser utanför sjukhus.

**Metoder**

Studie **I-III** genomfördes som kluster randomiserade kontrollerade studier med parallella analyser. Utfall var totalpoäng av Cardiff Test för avsedda lärandemål av teoretiska kunskaper och praktiska färdigheter i HLR med hjärtstartare, primärt sex månader efter träning och sekundärt direkt efter träning. Studie **IV** genomfördes som en registerbaserad observationsstudie och utfall var överlevnad till 30 dagar där behandling startats efter hjärtstopp utanför sjukhus samt faktorer som påverkar överlevnad.

**Resultat**

Huvudfynd från studie **I** visade en oförmåga att bevisa en statistisk skillnad i totalpoäng sex månader efter träning i HLR med hjärtstartare mellan självlärande och instruktörslett lärande. Däremot direkt efter utbildning visade instruktörslett lärande högre totalpoäng än självlärande. Det övergripande resultatet i studie **II** och **III** visade att en förberedande webbaserad interaktiv utbildning om stroke, akut hjärtinfarkt, hjärtstopp utanför sjukhus, HLR med hjärtstartare och hälsosamma livsstilsfaktorer utöver instruktörsledd och filmbaserad praktisk träning i HLR med hjärtstartare (studie **III**) ökade lärandet av teoretiska kunskaper och praktiska färdigheter i HLR med hjärtstartare. Resultatet av studie **IV** visade att förekomsten av hjärtstopp utanför sjukhus på arbetsplatser i Sverige var låg och överlevnaden var relativt hög med en högre chans till överlevnad jämfört med andra platser utanför sjukhus. Hjärtstopp på arbetsplatser utanför sjukhus som konstaterades med en hjärtrytm möjlig att ge en strömstöt, var en starkt oberoende faktor för en ökad chans att överleva. Dessutom gavs en strömstöt till personerna med hjärtstopp på arbetsplatserna oftare och med en kortare fördröjning till strömstöt jämfört med andra platser utanför sjukhus.

**Slutsatser**

Instruktörsledd och filmbaserad träning med tillägg av en förberedande webbaserad interaktiv utbildning kan gynna lärandet av praktiska färdigheter och teoretiska kunskaper i HLR med hjärtstartare. Även om förekomsten av hjärtstopp på arbetsplatser utanför sjukhus är låg är överlevnaden till 30 dagar relativt hög och sannolikheten att överleva visades vara lägre på andra platser utanför sjukhus, förutom på publika platser, än på arbetsplatser. Genom befintlig lagstiftning har arbetsplatser möjlighet att regelbundet erbjuda träning i HLR med hjärtstartare till alla anställda. En praktisk konsekvens kan vara att fler lekmän kan starta effektiv behandling både inom och utanför arbetsplatsen och därmed öka överlevnad vid hjärtstopp utanför sjukhus.

# List of papers

This thesis is based on the following studies, referred to in the text by their Roman numerals.

**I**

Bylow, H., Karlsson, T., Claesson A., Lepp, M., Lindqvist, J., Herlitz, J.
*Self-learning training versus instructor-led training for basic life support: a cluster randomised trial*.
Resuscitation 2019 June; 139:122-132

**I a**

Bylow, H., Karlsson, T., Claesson A., Lepp, M., Lindqvist, J., Herlitz, J.
*Supplementary dataset to self-learning training compared with instructor-led training for basic life support: a cluster randomised trial.*
Data in Brief 2019 May 26; 25:104064

**II**

Bylow, H., Karlsson, T., Lepp, M., Claesson A., Lindqvist, J., Herlitz, J.
*Effectiveness of web-based education in addition to basic life support learning activities: a cluster randomised controlled trial*
PLoS One 2019 July 11;14(7), e0219341

**III**

Bylow, H., Karlsson, T., Lepp, M., Claesson A., Lindqvist, J., Svensson, L., Herlitz, J. *Learning outcome after different combinations of seven learning activities in basic life support on laypersons in workplaces: a cluster randomised controlled trial.* Medical Science Educator 2020 Nov 18 e-ISSN 2156-8650 DOI 10.1007/s40670-020-01160-3

**IV**

Bylow, H., Rawshani, A., Claesson A., Lepp, M., Herlitz, J.
*Characteristics and outcome after out-of-hospital cardiac arrest with the emphasis on workplaces: an observational study from the Swedish Registry of Cardiopulmonary Resuscitation.* Accepted for publication in Resuscitation Plus, 2021 Jan 25

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# Abbreviations

**AED** • Automated external defibrillation
**AHA** • American Heart Association
**ALS** • Advanced life support
**AMI** • Acute myocardial infarction
**APP** • Mobile application
**BLS** • Basic life support
**CA** • Cardiac arrest
**CI** • Confidence interval
**CPC** • Cerebral performance category
**CPR** • Cardiopulmonary resuscitation
**CVD** • Cardiovascular disease
**DVD** • Digital video disc
**ECG** • Electrocardiography; Electrocardiogram
**EMS** • Emergency medical service
**ERC** • European Resuscitation Council
**GEE** • Generalised estimating equations
**HBH** • "Help-Brain-Heart" web-course education
**HRQoL** • Health-related quality of life
**IHCA** • In-hospital cardiac arrest
**ILCOR** • International Liaison Committee on Resuscitation
**IQR** • Interquartile range
**MI** • Myocardial infarction
**OHCA** • Out-of-hospital cardiac arrest
**OR** • Odds ratio
**PAD** • Public access defibrillation
**PEA** • Pulseless electrical activity
**PROM** • Patient-reported outcome measurements
**RCT** • Randomised controlled trial
**ROSC** • Return of spontaneous circulation

**SAEDREG** • The Swedish AED register

**SCA** • Sudden cardiac arrest

**SD** • Standard deviation

**SRC** • Swedish Resuscitation Council

**SRCR** • The Swedish Register of Cardiopulmonary Resuscitation

**VF** • Ventricular fibrillation

**VT** • Ventricular tachycardia

**WHO** • World Health Organisation

**WWW** • World Wide Web

# Introduction

Cardiovascular disease (CVD) is a true health burden and the leading cause of death worldwide [1]. Ischaemic heart disease and stroke are therefore the leading causes of death presented by the World Health Organisation [2]. Cardiac arrest (CA) can be an expected end to a long adventurous life or a completely unexpected end of life. Cardiac arrest can be defined as "the cessation of cardiac mechanical activity as confirmed by the absence of signs of circulation" [3, 4]. The blood stops flowing to the brain and the other organs in the body. The person is unresponsive and without normal breathing. Without immediate treatment, cardiac arrest causes death within a few minutes.

Out-of-hospital cardiac arrest (OHCA) worldwide is reported as 55 OHCAs per 100,000 person-years and as 56 OHCAs per 100,000 person-years in Europe [5, 6]. The delay to the treatment of OHCA has been shown to be the critical factor in increasing survival. The early detection of the cardiac arrest, the early alert of the emergency medical system (EMS), the early start of cardiopulmonary resuscitation (CPR), early defibrillation using an automated external defibrillator (AED) and the continuation of CPR following the instructions from the AED are crucial [7, 8]. According to the Swedish Registry of Cardiopulmonary Resuscitation, about 6,000 persons are affected by OHCA annually and 77 per cent of cases receive CPR from a bystander. The 30-day survival rate from OHCA has increased from four to five per cent in 2000 to 11 per cent in 2019. Five million people in Sweden have participated in BLS [9]. There is no goal for how high survival in Sweden can be, but survival in Norway is reported at 16 per cent and in Denmark at 13 per cent [10]. If an OHCA patient is witnessed at an early stage, receives CPR, is detected with a shockable cardiac rhythm and defibrillated, the survival rate could increase dramatically [11-13].

The present thesis on the learning aspects of an unexpected OHCA is designed to benefit the cardiac arrest patient through the rescuer. As a nurse, I believe that we can learn how to perform high-quality basic life support and act in a timely manner in the event of an OHCA. According to Kolb, learning is created through a transformation of experience [14] and learning may be one key for reducing the true health burden of CVD and OHCA.

# Background

## Out-of-hospital cardiac arrest

Despite increased public awareness of CVD, healthcare improvements, preventive actions to promote cardiovascular health, the improved management of cardiac arrest and training in basic life support (BLS), including CPR and AED, survival from OHCA still remains poor [1, 5, 6, 15-22].

The location of an OHCA event in a workplace environment has been reported to have a relatively low incidence, with relatively high survival when compared with other places outside hospital [6, 23-26]. However, there is a need for intensified knowledge of OHCA and the outcome, with the emphasis on workplaces, and there is a knowledge gap relating to different learning activities in adult BLS targeted at a workplace organisation. The purpose of the present thesis was therefore to extend our knowledge of adult OHCA and the learning aspects of different learning activities in adult BLS, with the emphasis on laypersons at workplaces outside hospital.

### Definitions

The definition of key concepts of learning about OHCA and BLS in the present thesis is an attempt to comply with the consensus of the International Liaison Committee on Resuscitation (ILCOR) [3, 27] and the European Resuscitation Council (ERC) guidelines [16, 17, 28, 29]. The purpose of the ILCOR consensus is to standardise overall definitions and the uniform reporting of sudden cardiac arrest (SCA) worldwide in a template. The ILCOR template was originally developed at a conference in 1991 held at Utstein Abbey in Norway and is referred to as “Utstein Style”. The template was updated in 2004 and 2015.

It is recommended that cardiac arrest patients, resuscitation and the outcome should be reported in national cardiac arrest registers and summarised in national and international reports. Some variables in the national registers vary [6] and comparisons of data between cardiac arrest registers are complicated due to variations in the structure of systems, geographical differences, variations in collecting and reporting the data and of several factors affecting the outcome [30, 31].

The word “sudden” in SCA is related to an unexpected cardiac arrest, but the word is discussed as the cardiac arrest can occur both suddenly and within hours of symptoms [32]. The structured framework in the consensus by the ILCOR comprises core groups of variables to report on the system, the emergency medical dispatch, the patient, the resuscitation process and the outcome of cardiac arrest. In the present thesis, the terms “cardiac arrest” and “OHCA” are mainly used.

Different terminology is used in the OHCA process [5, 6]. The collapse may be witnessed by a layperson who is defined as a bystander (bystander witnessed), or by the emergency medical service (EMS witnessed). The definition of a bystander is not clearly defined as community response systems have activated specially educated laypersons to respond as rescuers in the event of an OHCA. Personnel in the police and the rescue service, firefighters are defined as first responders in the event of an OHCA but may also be a part in the EMS system [33]. A resuscitation attempt is the action taken when attempting to maintain or restore life. The bystander can attend resuscitation, perform resuscitation attempts, initiate resuscitation, start CPR (bystander CPR) and use the AED (bystander AED use). The emergency number to call the dispatch centre varies between countries and in Sweden the universal number in Europe, 112, is established. The emergency medical dispatcher can give instructions on resuscitation and assist the bystander (DA-CPR). CPR can optimally be performed with chest compressions and rescue breaths or with only chest compressions. Resuscitation can also be initiated by a policeman or a firefighter from the fire brigade who is defined as a first responder, or by an off-duty medical healthcare staff member or by the EMS personnel. When the ambulance arrives (EMS arrival), the EMS personnel can continue high-quality resuscitation. Actions before the arrival of the EMS are an important measurement of the public implementation of resuscitation capacity. Publicly accessible defibrillators (PAD) are increasing in society and defibrillation (electric shock) may be delivered before the EMS arrives (AED before EMS arrival). The AED gives recommendations to defibrillate if a shockable cardiac rhythm is detected (shockable), or not to shock (non-shockable) if no shockable cardiac rhythm is detected. The location of the cardiac arrest, the characteristics of the patient and the cause of the cardiac arrest, together with the treatment, should be reported and registered in national cardiac arrest registers. It is recommended that the outcome should be reported in a short-term perspective (return of spontaneous circulation, ROSC) and a long-term survival perspective (30 days or at hospital discharge) [6]. The neurological outcome, sequelae and recovery can be assessed by using cerebral performance categories (CPC). CPC one is defined as a good cerebral performance with a good recovery, the ability to perform daily activities and work and with only a mild neurological reduction, CPC two is a moderate cerebral disability with the ability to perform daily work and reduced work, CPC three is a severe neurological disability with dependence for daily life activities, CPC four is neurological unresponsiveness or comatose and CPC five is neurological brain death [3, 4, 34].

In Sweden, the ambulance organisation in the EMS system is responsible for reporting the resuscitation of an OHCA patient (EMS reported) to a national register. If resuscitation is attempted with CPR and/or with AED, the OHCA is reported to the register [9]. Internationally, the reporting varies and the OHCA may only be reported to the national register if the EMS has started resuscitation [10].

The location of a cardiac arrest at a workplace is classified in the 2015 Utstein Style Template as industrial and workplace [27]. In the SRCR, the word used is "workplace" [9]. In previous studies, the words construction sites, factory industry, industrial building, industrial business, occupational, office, private office, public office, small office and work have been used [23, 25, 26].

The ILCOR is a worldwide association comprising the principal resuscitation organisations in the world [35]. Most of the definitions and global guidelines in BLS originate from the ILCOR consensus on science. The vision of the ILCOR is to collaborate to save more lives globally through a consensus summary of scientific data, focusing on resuscitation, cardiac arrest and first aid. The committee continuously reviews the science of resuscitation, summarises scientific data and publishes the consensus on treatment, education, implementation strategies and systems of care and addresses knowledge gaps for further scientific studies [20-22]. The principal resuscitation organisations recommend the guidelines to the connected national resuscitation organisations.

## Guidelines

National guidelines in Sweden are based on the ERC guidelines for resuscitation, and principles of education in resuscitation and education and the implementation of resuscitation [16, 17]. The "chain of survival" summarises the prevention of cardiac arrest and the cardiac arrest situation with all the vital links in resuscitation. The links are to recognise the victim at an early stage and call the dispatch centre for the EMS, the early start of CPR to provide circulation, early defibrillation to restart the heart and post-resuscitation health care to restore quality of life (Fig. 1).

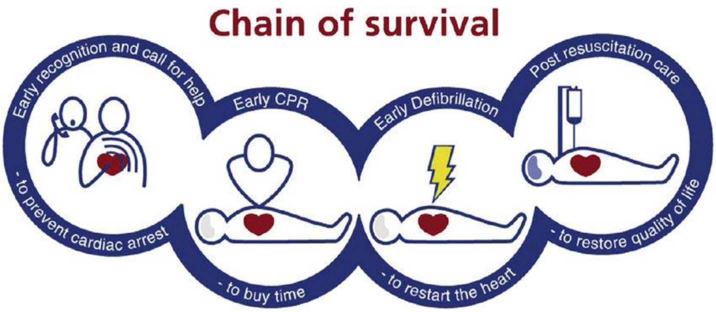



Figure 1. The chain of survival. Reprinted with permission from Elsevier. Adapted from Nolan, Soar and Eikeland (2006) [36].

The early recognition of symptoms such as chest pain from myocardial ischaemia may prevent a cardiac arrest if the EMS is called immediately, with the early arrival of the EMS to a deteriorating patient [32]. The emergency medical dispatcher can assist the bystander by giving instructions on how to examine the victim, perform CPR and use the AED and is an essential link in the chain of survival [37-41].

Early CPR is prompt resuscitation with vital support to the victim, such as circulation and breathing with chest compressions and ventilations. Early defibrillation is the use of an AED as soon as it arrives. The rescuer's, i.e. the bystander's, theoretical knowledge, practical skills and confidence in performing resuscitation, is dependent on the situation, self-efficacy and previous experience [16]. A bystander is recommended to assess the victim and, if the victim is unresponsive and not breathing normally, interpret the situation as an OHCA and call the EMS immediately. Abnormal breathing, i.e. agonal breathing, like abnormal slow, deep breaths with a snoring sound, has been shown to be an individual's sign of a brain reflex with gasping for air when suffering a cardiac arrest [42-46]. High-quality CPR is essential, i.e. chest compressions in the centre of the victim's chest, with a depth of 5-6 cm, at a rate of 100-120 compressions per minute, with recoil of the chest between compressions and with minimal interruptions and rescue breaths with a rise of the chest for no more than one second. If the rescuer is unable to give ventilations, continuous chest compressions should be performed. Bystanders are recommended to use the AED as soon as it arrives and follow the instructions for early shock delivery, ideally within three to five minutes of collapse, and then continue performing CPR and following the instructions from the AED [22].

Post-resuscitation care is the link with advanced life support such as high-quality CPR, airway management, medical drugs and other advanced treatments to restore quality of life [47, 48]. The interaction in a community between the dispatch centre and the emergency medical dispatcher, the rescuer providing CPR, the availability and use of an AED and the EMS can improve survival from OHCA (Fig.2) [16].


Figure. 2. Community response saves lives.
Reprinted with permission from Elsevier. Adapted from the European Resuscitation Council Guidelines for Resuscitation (2015) [16]

The early start of CPR may double and even quadruple survival from OHCA [7, 11, 49]. Early defibrillation may increase survival to 50-70 per cent for OHCA patients found in a shockable cardiac rhythm [11, 12, 50, 51]. The BLS and AED algorithm is a summary of key actions presented in a step-by-step sequence, easy to learn and easy to follow for a layperson (Fig. 3) [16].

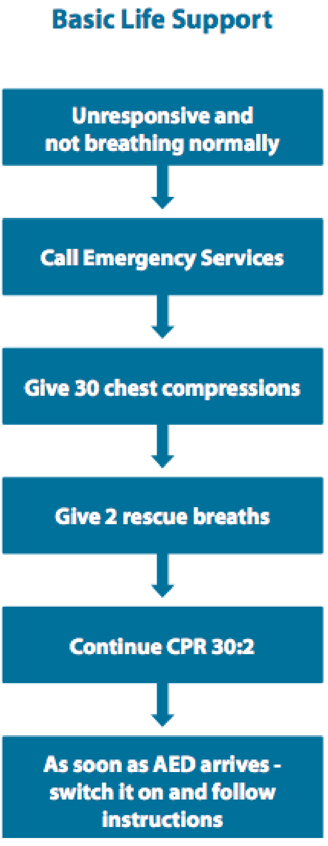



Figure. 3. The BLS/AED algorithm. Reprinted with permission from Elsevier. Adapted from the ERC Guidelines for Resuscitation (2015) [16]

The ERC guidelines have defined the basic principles of training and teaching [17, 21, 29]. High-quality resuscitation together with effective education can increase survival from SCA [17, 52]. The formula of survival [53] summarises the evidence from medical science and effective education, as it should be implemented in society to improve survival from cardiac arrest (Fig. 4).

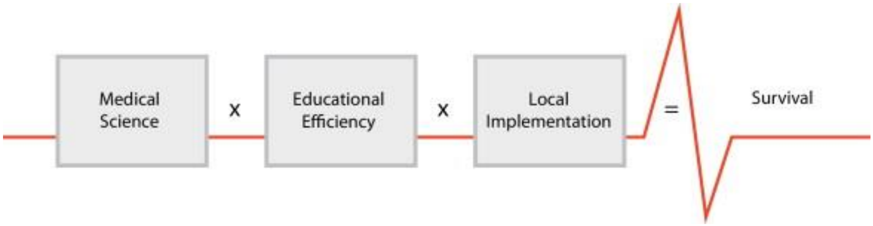



Figure 4. The formula of survival in resuscitation. Reprinted with permission from Elsevier. Adapted from Søreide (2013) [53]

Educational guidelines in BLS for laypersons include a safe approach, recognition of the OHCA patient, calling for help, CPR and the use of an AED, the recovery position and the technique for foreign body airway obstruction (FBAO) [16, 17, 21]. All citizens are recommended to train both chest compressions and ventilations. The definition of implementation comprises actions to implement the evidence from medical science, educational science and courses and the use of practical skills and theoretical knowledge in practice. The use of technology, feedback devices and social media, applications for mobile phones and tablets and multi-media learning for learning in BLS has been considered for implementation. Assessment and evaluation have been recommended throughout the course and at the end of the course by a summative test, in the 2010 ERC guidelines [29]. In the 2015 ERC guidelines, the instructor was supposed to provide constructive, goal-oriented, student-centred and action-planned feedback to the participants to achieve the learning objectives [17]. In the 2020 guidelines based on the ILCOR consensus, a formative assessment and a summative assessment were recommended [21]. Retraining should be performed more often than once a year, as practical skills in CPR decay within three to six months. Practical skill in using an AED has been shown to last longer [54-59] but should be retrained within seven weeks [60]. Retraining in a spaced learning format is shown to be effective for learning and retaining practical skills in BLS [21, 61]. The national Swedish educational guidelines based on ERC guidelines are updated regularly and the educational programmes are updated and published by the SRC every five years.

## Epidemiology

The average global incidence of OHCA has been reported as 55 OHCAs per 100,000 person-years [1, 15] while EMS-treated OHCAs range from 30 to 97 per 100,000 person-years [5]**.** When reporting EMS-treated OHCAs per 100,000 person-years, the incidence was reported as 47 in North America, 46 in Asia, 51 in

Australia and 56 in Europe, with a range between 27 and 91 [1, 5, 6, 15]. The reporting varies from incidence to considered for resuscitation and to resuscitation attempts. In Sweden, EMS-reported OHCAs with resuscitation attempts have been reported as 60 per 100,000 person-years and approximately 6,000 cases of OHCA annually [9]. An OHCA event at a workplace has been estimated from one to 24 cases per one million person-years [23].

The majority, more than half of all the OHCAs globally, have been reported to be males with a median age of 64 to 79 years [5]. For Europe alone, 70 per cent were male and the mean age was 68 years [6]. Patients with OHCAs at workplaces have been reported to be younger and more frequently males compared with patients with OHCAs at other places [23, 25, 26].

In global terms, the location of the cardiac arrest has been reported to be mostly at home (52%-85%) and witnessed by a bystander in 37% to 70% [5]. In Europe, the location was at home or in a residential setting in 70% and bystander witnessed in 58% [6]. In a systematic review and meta-analysis by Descatha, a location at a workplace was reported in 0.3 to five per cent of all cases [23]. In the EuReCa TWO study, two per cent (n=391) of OHCAs occurred at workplaces or offices. In a report from the ILCOR, the EMS-treated OHCAs at workplaces were three per cent in Norway and one per cent in Finland [5].

In comparison with other places outside hospital, the OHCA patients at workplaces are more likely to be witnessed and receive bystander CPR more frequently [23, 25, 26]. In global terms, performed bystander CPR ranged from 19% to 79% and chest compressions only were performed in 15% to 47% [5]. In Europe, CPR was started before the arrival of the EMS in 58% and chest compressions only were performed in 72% of them [6]. Globally, the delay from dispatch to EMS arrival was a median of five to 11 minutes [5], while in Europe it was 11 minutes [6]. An initial shockable cardiac rhythm was detected in 20% both globally [5] and in Europe [6]. Bystander use of an AED globally varied from two per cent to 37% and a shock was delivered in half a per cent to seven per cent, while the delay from calling for the EMS to a shock being delivered was a median of 12 minutes [5]. For Europe, the AED was used in six per cent before the arrival of the EMS and the delay from calling for the EMS to a shock being delivered was a median of 11 minutes [6]. The use of AEDs before the arrival of EMS is low, even if there is an PAD near the OHCA [62] and improvements of early defibrillation are publicly reported [63]. An optimizing of the implementation of AEDs may be required to improve bystander use [64]. The availability of an AED at workplaces is difficult to estimate as registration varies and is not mandatory [65, 66].

Global 30-day survival ranges from three per cent to 20% and from 12% to 47% for bystander-witnessed shockable OHCA cases [5]. In Europe, eight per cent survived to hospital discharge and, of them, 14% of the survivors received CPR with both compressions and ventilations, while eight per cent of the survivors received CPR with only compressions [6]. From a Scandinavian perspective of 30-day survival and survival for bystander-witnessed shockable OHCA, Denmark reported 13% and 48% and Norway 16% and 44% respectively [6], while Sweden reported 30-day survival as 11% and 33% respectively [9].

From a workplace perspective, the 30-day survival rate globally has been reported to range between six per cent and 28% [23-26]. In Europe, the 30-day survival was recently reported as 24% [6]. Survival is reported to be higher during the day and the most common working hours [67]. After surviving an OHCA in Europe, most of the patient's neurological outcome is reported to be good (CPC 1 or 2) and more than half of OHCA patients are able to return to work [6]. Previous studies have reported that 60-80 per cent of OHCA patients of working age returned to work [68-73]. Several health-related quality of life measurements are used in health care and for survival from cardiac arrest [70, 74]. From the patient's perspective, quality of life with patient-related outcome measurements (PROM) has been used and some patients experienced a reduced working capacity or had to change jobs or tasks at work. Patients have reported their cognitive function and quality of life as impaired social ability, fatigue, anxiety, a poorer physical health and function, depression, symptoms of stress, emotional problems and experiencing a lower degree of overall health and satisfaction with life, with sick leave as a result [68-73, 75-79]. In contrast, in a recent study, patients with OHCA reported fewer problems than patients with IHCA [80]. Factors associated with return to work for OHCA patients were being male, being EMS witnessed, being discharged home directly from hospital and favourable health-related quality of life one year after the OHCA using the EQ-5D [72]. Other locations of survival from OHCA in Europe are reported as home (9%), street (13%), public buildings (18%), sports arenas (32%) and other locations (16%) [6].

## Aetiology

A medical and a presumed cardiac aetiology are the most common causes of OHCA in adults [1, 6, 15]. A medical cause of OHCA has been reported globally to range from 52% to 95% [5], 92% in the US alone [1] and 91% in Europe [6]. In Sweden, 60% had a presumed cardiac aetiology [9], as reported by the SRCR in 2020. Even at workplaces, most patients have a reportedly presumed cardiac aetiology [23, 25, 26].

A cardiac arrest may occur within an hour of the first symptom of chest pain when suffering from coronary heart disease [32]. The initial rhythm at the time of cardiac arrest with a cardiac aetiology is usually ventricular tachycardia (VT) or ventricular fibrillation (VF), which is unorganised electrical activity in the heart muscle without the ability to generate blood circulation. This rhythm is shockable, but, after a few minutes without treatment, the rhythm deteriorates to asystole, a non-shockable rhythm [16]. Chest compressions maintain circulation and may prolong the VF until defibrillation which increase the chance of survival dramatically [7, 81, 82].

The leading cause of global death is CVD (www.who.int). The age-adjusted death rate in CVD was 219 per 100,000 population in the US, while globally it was 233 per 100,000 population [1]. General risk factors are the high use of tobacco, alcohol and a high salt intake, physical inactivity, obesity, raised blood pressure, high blood cholesterol and high blood glucose. Of all CVDs, the cause of death was a coronary heart disease in 43%, a stroke in 17%, high blood pressure in 11% and heart failure in nine per cent. Coronary heart disease is the leading cause of death, followed by cancer, unintentional injuries, chronic lower respiratory disease and stroke [1].

Other causes of OHCA are traumatic, drowning, drug overdose, electrocution, airway obstruction, hanging or strangulation [1]. In Europe, other causes of cardiac arrest (with survival to hospital discharge) have been reported as traumatic in 4% (3%), asphyxia 3% (6%), drug overdose 1% (14%), drowning 0.6% (5%) and electrocution in less than 0.1% (25%) respectively [6].

## Factors associated with survival

Early treatment with CPR and defibrillation [7] is associated with an increased chance of survival among persons suffering a cardiac arrest outside hospital. The initial cardiac rhythm, age, time to starting CPR, time to EMS response and location of the OHCA are the most important predictors of 30-day survival [83]. Age is an independent factor and 30-day survival increases with decreasing age. Female gender has been reported to be a predictor of survival in a Swedish register-based study [84], but, in a recent Swedish study, female gender was not shown to be associated with survival from OHCA [85]. The location of the cardiac arrest outside the home and a short delay to the arrival of the EMS are independent predictors of an increased chance of survival [5-7, 86]. A witnessed event and the immediate initiation of CPR have been proven to save lives [7, 82, 87-89]. Moreover, an initial shockable cardiac rhythm and early defibrillation within three to five minutes of collapse are two of the main predictors of increased survival [11, 50, 51, 87, 88, 90]. The use of an AED by laypersons providing CPR increases survival in public places [51, 91, 92]. The early start of bystander CPR and defibrillation has been shown to be associated with a higher chance of long-term survival to one year [8, 93].

### The Swedish registry of cardiopulmonary resuscitation

Patients with a suspected OHCA and an attempt at resuscitation of either CPR and/or defibrillation are reported by the EMS personnel to the Swedish registry of cardiopulmonary resuscitation (SRCR) [9]. This is called EMS-reported OHCA. This definition is analogous to the definition of EMS treated used in the Utstein-style template [4]. The report is an Utstein-based template in a web-based system. Resuscitation attempted outside hospital is registered as being attempted by a bystander, a first responder, or the EMS, i.e. ambulance personnel. If bystander CPR is being performed when the EMS arrives but the EMS personnel notice clear signs of death and do not start resuscitation, the patient is not reported to the register.

The reporting of OHCA is both prospective and retrospective. Prospective data are reported by the EMS personnel directly after or shortly after the event. Retrospective data are cases that were not reported by the EMS personnel but were subsequently discovered in medical records in hospital, by a co-ordinator function, mostly an experienced registered nurse in the healthcare system. The SRCR performs continuous validation to ensure that all cardiac arrest cases are entered in the register. In a previous validation paper, it was estimated that data were missed in 25 per cent of cases [94], but, when retrospective data were checked, the collection of data improved [9]. The coverage for reporting cardiac arrest to the SRCR is estimated to be almost 100 per cent for OHCA. All EMS systems in the country report data on OHCAs. The validation of the register is performed on a regular basis [9]. Definitions in different cardiac arrest registers globally vary in some variables [30] and the variables in the SRCR are described more thoroughly elsewhere [94, 95].

The SRCR was founded in 1990 and is a nationwide register which covers the entire Swedish population. In 2007, the register was developed into a web-based register. In 2009, data on defibrillation using a publicly accessible defibrillator (PAD) before the arrival of the EMS were included as a variable. The SRCR is a national quality register with the same overall aim as Swedish national quality registers to generate valuable knowledge for healthcare improvements. The specific aims of the SRCR are to investigate weak links in the "chain of survival", identify the unexpected cardiac arrest population and the circumstances surrounding the cardiac arrest, describe the delays and treatment, the effects of treatment in outcome measurements such as survival, provide an annual report, give feedback and stimulate registration, describe improvements and maintain the status of a national quality register in order to improve health care [9].

The register contains data on the individual level of each case of cardiac arrest regarding background factors, characteristics, diagnoses, treatment and the outcome. The outcome is reported as ROSC after a resuscitation attempt, survival to hospital discharge, CPC at hospital discharge and survival to 30 days. Follow-up data three to five months after the arrest and six to 11 months after the case describe patient-reported outcome measurements (PROMs) and other patient-reported health effects. Health-related quality of life (HRQoL) among cardiac arrest survivors is reported to be more valuable than ROSC and CPC as outcome measurements [48]. According to recommendations, survival should be assessed at least at hospital discharge or at 30 days [74]. The patient receives information about the SRCR and is given the opportunity to apply for a copy of the information in the register and to withdraw their data from the register [9]. In personal communication with the register holder, there is no patient who has withdrew their registration (1 October 2020).

The SRCR also presents the number of trained people in BLS in Sweden. Five million people in Sweden have participated in BLS training [9]. There are various organisations in Sweden that offer training in BLS and some of them reports the number of trained participants to the Swedish registry of education, but not all.

### The Swedish Resuscitation Councils registry of education

The educational guidelines in Sweden by the SRC are summarised in course materials for each educational programme. There are basic courses in paediatric CPR, adult CPR with AED, first aid and CPR in school. The next level is CPR and AED for first responders and for healthcare personnel. The advanced level is advanced paediatric CPR, advanced adult CPR and advanced life support in collaboration with ERC. The number of trained participants in each programme is registered in the Swedish educational registry by each instructor [96]. The registration of educated participants is not validated and data on educated participants may be missing. In a personal communication from the chair of the SRC (October 12, 2020), more than five million individual training registrations (1984-2018) and more than one million individual re-training registrations (2007-2018) have been registered. These estimated data is from all educational programmes and refers to a registration of an activity. These data cannot be referred to the total number of unique individuals who have been trained or the total numbers of courses and is probably underestimated as not all instructors register their courses. The number of educated instructors since 1984 to 2018 has been estimated at 131,500 and of educated head instructors at about 6,500 (personal communication on October 12, 2020 with Andreas Claesson, chair of the SRC).

Available data from the Swedish education registry have been extracted from January 1984 to November 2020 (by the data technician on November 09, 2020) on adult CPR and were later estimated as follows. The number of educated participants in adult CPR was 3,7 million, educated instructors was 87,000 and educated head instructors was 4,000. How many of those individuals that are active is unknown and since several organisations offers training in BLS the true numbers of educated participants in Sweden are unknown.

### *The Swedish registry of automated external defibrillators*

The Swedish AED registry (SAEDR) was initiated in 2009 and contains information on public AEDs outside hospital. The owner or the responsible party voluntarily register the AED in the register by registering the location, availability and contact information for validation in an internet-based format. The register uses geographic information systems to produce co-ordinates and map the AEDs for graphs and maps visualised in internet-based formats freely available to the public, the EMS dispatch centre and the healthcare system [66, 97]. The SRCR also contains brief data from the SAEDREG. Some 16,000 validated AEDs were registered in 2016, representing only about 40 per cent of all AEDs sold in the country. Among them, about 45 per cent were reported to be placed at workplaces and offices [66]. In June 2020, there were a total of 16,470 validated AEDs in the register (data from the register holder, personal communication, June 2020). Among them, 7,150 (43%) were placed at workplaces, 1,195 (7%) at shops and stores, 982 (6%) at public buildings and 860 (5%) at sport facilities.

# Initial actions and treatment for OHCA

The initial actions and treatment of OHCA are the early detection of the patient with an OHCA, an immediate call for the EMS, the prompt start of CPR and the use of an AED with the delivery of an electric shock as soon as possible while continuing BLS [7, 8, 12, 90]. The dispatch of laypersons and treatments may optimise actions taken in a timely manner [90, 98-101]

The recognition of symptoms of coronary heart disease, such as warning signs, by the patient or by a layperson prior to a cardiac arrest is possible and may prevent OHCA. Some OHCAs occur suddenly and some occur with warning signs or typical symptoms within hours before the arrest [32]. Typical known symptoms are chest pain in the middle of the chest, with heavy pressure on the chest. The pain can be experienced as located in or radiating towards the jaw, one or both arms, the neck, the back and the epigastrium and abdomen. Other symptoms are nausea, vomiting, dyspnoea and sweating [32, 102-104]. The initial action is to call the EMS immediately to enable early medical health care by the EMS before the cardiac arrest occurs [89, 105, 106]. The action for the bystander is to stay with the patient, maintain contact with the emergency medical dispatcher and be ready to start initial treatment.

The early detection of a patient with signs of an OHCA is performed through examination. If the victim is unconscious without normal breathing, the initial treatments are to call for the EMS and start CPR. Abnormal breathing, i.e. agonal breathing, is a reflex from the brain stem due to hypoxia and a sign of cardiac arrest. This gasping often occurs in the first minutes and within ten minutes of the arrest and is a sign that may increase the chance of a successful resuscitation [42, 43, 45, 107, 108]. This gasping is misleading for lay bystanders who do not start CPR [46]. Other misleading factors when the initial action is to start CPR are a form of seizure when the patient is in cardiac arrest [109] and an unconscious person without normal breathing with a suspected FBAO [110, 111]. In some circumstances and for some groups of individuals, the risk of an FBAO is higher, but the initial action for an unconscious person without normal breathing is to start CPR [110, 112, 113].

Cardiopulmonary resuscitation by laypersons should be initiated with chest compressions and ventilations alternately, 30:2 [22]. If the rescuer is unable to perform ventilations, chest compressions only can be performed [114, 115]. The optimal hand placement for chest compressions has been investigated over the years and the lower third of the sternum, demonstrated as the centre of the chest, has been shown to be effective in different studies and for different individuals [116-120]. The chest compression rate, depth and recoil have also been investigated, but no results were found to change guidelines [116]. Instructions for laypersons are still to perform chest compressions in the centre of the chest, with a rate of 100 to 120 per minute, a depth of a minimum of 5 cm and a maximum of 6 cm and with full recoil of the chest between each compression [22]. If possible, the victim should be lying on a firm surface to obtain effective compressions [121].

As soon as the AED is present, the treatment is immediately to connect the AED and defibrillate, ideally within three to five minutes of collapse and in optimal circumstances, the survival rate can be 50-70 per cent [11, 12, 122]. Even though PADs are implemented in society, there is a variation in the use and location of AEDs [50, 62, 100, 123, 124]. Different interventions are activated in society; they include positioning systems to alert laypersons to initiate CPR in a timely manner and the delivery of an AED for defibrillation as well as the delivery of an AED by a drone [90, 101, 125-127]. Laypersons can follow the instructions from the AED with or without prior education [122]. Studies of the placement of the defibrillation pads has been investigated such as anterior and posterior placement but the anterior lateral position is recommended for adult PAD [22]. The availability of AEDs at workplaces is difficult to estimate, since registration varies and is not mandatory [65]. Half the workplaces in Flanders, Belgium have been reported to have AED in place [128]. In Sweden, half the registered AEDs were based at offices and workplaces [66]. Initial actions in the event of an OHCA in a workplace environment are the same as for laypersons. Since training in BLS is organised at workplaces, initial actions may be taken even earlier and improve workplace safety [129, 130].

Advanced treatment by healthcare personnel and post-resuscitation care are important for resuscitation. The initial actions and treatments provided in a timely manner, in direct connection with the OHCA event, are the most crucial [7]. There is increased survival from OHCAs when healthcare personnel initiate CPR [7, 131]. Advanced treatment by the EMS, in addition to high-quality manual CPR, is mechanical chest compressions, which have advantages, but the improved survival compared with manual chest compressions is a matter of discussion [132-135]. Moreover, the administration of adrenaline, i.e. epinephrine, has been shown to improve survival to 30 days compared with placebo, but the improved neurological outcome at discharge from hospital and to three months is the subject of discussion [136-141].

# Learning

The learning aspects of OHCA and learning activities in BLS for adult laypersons involve both teaching and learning. Teaching is the transformation of information and learning is the process and the outcome. There is a complexity in both the teaching and the learning process, with a variety of different theories, perspectives, strategies and other factors that may affect the learning outcome [142, 143]. Learning theories can bridge the understanding of the learning process. Teaching can be like conveying a message in one direction (teacher-centred) to the learner who respond for an individual change of the behaviour (as in behaviourism) which can be measured. Another theory is that mental structures must be activated, and the learner must process the subject and understand to learn (as in cognitivism) or involve experiences and reflection to construct learning (as in constructivism). Those two can be a combination of a teacher- and student-centred learning in a social context with interaction with other learners and collaboration in a community. When learning is student-centred it is on the learner's individual level and involve the whole human being with both the intellect and the human needs (as in humanism) and is driven by motivation [142, 143]. The learner-centred approach can activate different learning strategies. When the knowledge is distributed by digital networks in connection and in communication, the learning reflects different social technological environments (as in connectivism). This theory of learning is a combination of different theories in a digital age [144].

Knowledge in BLS includes competence in theoretical knowledge and practical skills and confidence, self-esteem and willingness to perform BLS in a real-life OHCA situation. The learning objectives in BLS training are defined in educational guidelines and the learning outcome is described as specified learning outcomes which the participant should be able to demonstrate at the end of the course. According to the Higher Education Ordinance from the Swedish Council for Higher Education [145, 146], learning outcomes should be defined as knowledge and understanding, competence and skills and judgement and approach. The level of learning should be clearly defined in the learning objectives. According to Bloom's Taxonomy, the levels in learning are remembering, understanding, applying, analysing, evaluating and to creating [147]. Applying the learning outcome, means being able to demonstrate the given task.

Adult learners have a huge variety of life experiences as a factor that can affect the learning outcome. The learning theory, andragogy, according to Knowles, states that adults needs to be involved in the learning process (learner-centred), experience for themselves and feel that the subject is relevant to learn [148]. Learning may be understood as changes in behaviours and changes in mental processes. The learning process in BLS can be understood by the learning theory of experiential learning, according to Kolb [14]. The theory focuses on the way the learner processes and learns from practice. The theory comprises four stages: 1) concrete experience, 2) reflective observation, 3) abstract conceptualisation and 4) active experimentation. The learner learns through experiencing, reflecting, thinking and acting. The theory is described in a learning cycle and learning can start at any stage at any time (Fig. 5).

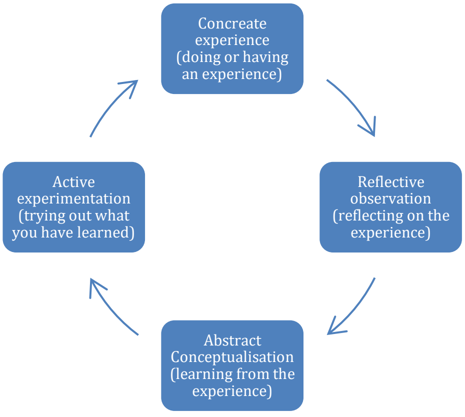



Figure 5. Illustration inspired by experiential learning, according to Kolb [14]

According to the theory of experiential learning, learning is a constant process including new learning and re-learning. Furthermore, experiential learning is originally influenced by the learning theory of pragmatism and the thoughts of Dewey. Education is life itself and we learn by reflecting on experience, according to Dewey [149-151]. Active experimentation with hands-on practice, interaction with other learners and reflecting on the experiences instead of traditional teaching with classroom lectures were described by Dewey. The learning process is also affected by the construction of new knowledge based on previous knowledge and experience influenced by Piaget. New information may be modified to suit what we have already experienced, and we add this information to our mental knowledge (assimilation), or the information may create new mental structures and new knowledge (accommodation). With the re-learning of new knowledge that the learner has experienced in some way at an earlier stage, "the new knowledge" may be missed if the information is simply added without creating new mental structures. The definition of learning according to Kolb is that learning is the process whereby knowledge is created through transformation of experience" (Kolb 1984, page 41). According to Dewey, reflection is defined as the transformation of experiences to knowledge [149] and, according to Kolb, as the ability to perform an abstract, internal cognitive process, experiencing different situations and standing back and thinking about the experience [14].

The learner who is reflecting in practice has been described by Schön as a reflective practitioner [152]. As a result, the learning does not happen without reflection and the learners should be given enough time for practice to reflect as a learning objective. Fortunately, most laypersons have not been exposed to a real-life cardiac arrest situation and need to practise reflecting in education. A register-based OHCA study of survival at hospital discharge showed an increase in survival related to the paramedic's previous OHCA experiences [153]. In this field of research, there are studies that show that EMS personnel's and healthcare personnel's experiences have impact on resuscitation, while some studies show no difference [154-158].

### *Learning at the workplace*

Learning at the workplace benefits the organisation, but it is the individual who learns and is central in the process [159]. The workplace is organised for learning in daily work and different educational theories and strategies may be used in combination to improve learning (Merriam 2007). The information may take the form of the transmission of knowledge and behaviour, such as in a teacher-centred strategy. It may also take the form of learners constructing their own knowledge based on previous knowledge and making judgements and their own approaches to learning. The teacher is the facilitator who supports learning and actively engages the learners in their own learning and in social interactions with the other learners [160]. The role of the teacher, instructor or peer at a workplace may gradually be phased out, when the learners become more competent (scaffolding) [161]. The workplace is a place with individuals within a professional community, with situated learning, and it has been defined as a community of practice [162]. Learning can take place in the workplace environment, in social networks and in online communities. The overall goals are the translation and meaningful exchange of knowledge in the community and using the knowledge in practice and decision-making at the workplace. The learning may additionally be self-directed and self-regulated [163], to give the learner a chance to reflect and understand and then discuss the problem in a team as collaborative learning, for example. Furthermore, problem-based learning (PBL) is a learner-centred approach in collaboration in a group at the workplace which focuses on discussions and learning related to solving a problem in a structured format [164]. A facilitator supports the learning in the group to ensure that the participants achieve the appropriate learning objectives. Work-based learning is valuable both to the individual employee and to the workplace organisation [165]. Regular feedback between the learner and the teacher may clarify the learning objectives, motivate the learner to reach the learning outcome, encourage reflection and improve self-efficacy [166]. The learning may occur naturally, in relation to a real-life experience in practice, and in a simulated training situation as active experimentation (Kolb 1984). Applying educational theory in practice is challenging and designing teaching material to promote participant learning is a complex process. Learner-centred learning with the active involvement of the learner to interact by asking questions and taking responsibility for their own learning is valuable for the workplace organisation. Hattie (2009) has summarised practical learning factors in educational settings, such as student-centred learning, problem-based learning, strategies for understanding learning, i.e. meta cognition, reflective questions, formative evaluation and feedback as a powerful tool for learning [167, 168].

However, learning can be constructed in different learning activities and may create different conditions for learning in the workplace. The activities can be instructor led, self-directed, based on peer learning, seminar based, problem based, web based, multimedia based, used with technological devices, virtual reality learning and blended with both classroom teacher-centred lectures and self-regulated outside the classroom (flipped classroom) in multimedia-based learning environments.

Assessment and evaluation are key to educational improvement and can take place at an individual or collective level. They are most effective as a process during the learning situation [169]. The workplace-based assessment can take the form of a written examination or be skill based and assess knowledge, skills and professional behaviour. It can be regarded as a measurement of safety at the workplace. The assessment can be summative at the end of the education or formative during the education. Before the assessment, the learners should be given enough time for practice, feedback and to reflect on their practice. The learning outcome should not be tested until the learners have developed sufficient knowledge, skills and attitudes according to the learning objectives [166, 169].

# Learning and teaching in BLS

The overall goal of learning and teaching BLS among laypersons is to improve survival from cardiac arrest [17, 21]. Teaching and learning theoretical knowledge, practical skills and attitudes in effective educations are included in the "Utstein formula of survival", where medical science, educational efficiency and local implementation are summarised [53]. The widespread implementation of education in resuscitation may improve layperson's CPR skills and self-efficacy to act in a timely manner in the event of an OHCA [19, 170]. The aim of learning in BLS is to ensure that the learners retain practical skills and theoretical knowledge and the motivation and willingness to act effectively in a real-life cardiac arrest situation and improve survival for the cardiac arrest patient [17, 21]. Motivation and self-efficacy are crucial in order to act effectively in a real-life OHCA situation. Educated laypersons appear to be more likely to perform CPR [171], but the actual performance in a real-life OHCA situation varies and appears to be low at global level [172]. With practical training, both the motivation and the quality of the performance can improve. The participants should be given enough time to practise achieving sufficient competence and skills. Mastery learning with deliberate practice has been shown to be effective for training in BLS [173]. The teaching of skills should also focus on non-technical skills such as communication and team training [16, 17, 28, 29].

The task for the instructor in BLS is to facilitate an educational setting with training, formative assessment with corrective feedback which can generate participants with sufficient practical skills and theoretical knowledge and motivation to perform high-quality CPR [21]. Strategies for the education of instructors have been recommended to be implemented to improve educational efficiency and learning in BLS [174], including the retraining of instructors [175]. A formative assessment of the educated instructor and feedback with supervision on the instructor's first courses are recommended [21]. The instructors are in a community of practice [162] which requires reflection both individually and in the community to maintain and improve instructor competence. Collaboration, networking, peer-coaching, peer-learning, participating in instructor activities, both individual in web-based education and in groups, are essential for all instructors [176-178].

The ERC educational guidelines have been based on the experiential learning theory according to Kolb [14, 179]. The ERC instructor's manuals recommend that the learning should be oriented on goals, relevance and practice and the participants should be actively engaged in their own learning. Learning objectives should be described at the start and defined as learning outcomes by the end of the course. In BLS training, the participants are encouraged to learn from their experiences by reflecting [179]. Teaching in BLS can be divided into 1) time and environmental preparation of the teaching session, 2) setting the session and informing the participants of the learning objectives, 3) dialogue with the four-stage approach for teaching BLS, assessment and feedback to the participants and 4) closure with questions from the participants, summary and termination by the instructor [179]. There are a variety of learning theories and teaching strategies to consider and educational guidelines are regularly updated to provide effective education and high-quality resuscitation [21]. As in other educational settings learning in BLS is moving from a teacher-centred learning to a more student-centred learning with different blended learning alternatives. Especially the learning of theoretical knowledge in web-based platforms is preferable and more flexible for the participant. It has been shown that practical training in BLS should be done more often than every or every other year, be shorter and spread over several occasions instead of all training at once to maintain abilities and skills [61]. The recommended training manikin for laypersons is a low-fidelity manikin, even if a high-fidelity manikin with high technological options to measure the quality of practical skills is more realistic. In health care high-fidelity manikins and advanced training in resuscitation are organised. Different learning activities can be used for training and learning BLS for laypersons at workplaces.

### *Learning activities*

*Instructor-led learning* has been the traditional educational method with massed learning of the whole content [174]. A stepwise approach to teaching practical skills is one teaching method in BLS. The activity is teacher centred and can take place in a four-stage approach. The approach comprises 1) a real-time demonstration by the instructor, 2) a demonstration and explanation of the facts by the instructor, 3) a demonstration by the instructor guided by the participant and 4) practice by the participant [17, 29, 179-182]. The approach can be simplified with a two-stage approach by 1) a demonstration by the instructor and 2) practice by the participant used in both pure instructor-led training and in film-based training. In contrast to massed learning, instructor-led spaced learning with shorter courses more frequently has been shown to be more effective for the retention of practical skills [61]. The duration of the courses in practice differs and less than one hour [183], two hours and four hours have been shown to be adequate. [184]. On the other hand, high-quality CPR practical skills require a longer duration of hands-on practice [184]. In addition, the quality of the BLS instructors for teaching laypersons has been shown to be low and the delivered content incomplete, which means that the education of instructors and training needs to be improved [185-187]. Professional teaching skills are not realistic for all instructors, but they appear to be superior to healthcare instructors in educational settings [188].

A facilitator- or instructor-led training with film-based instructions may be even more effective and simplified by training synchronised while watching the filmed instructions. In several previous studies, the filmed instructions have been shown to be as effective or even more effective than pure instructor-led training [54, 55, 189-194]. This educational method has been regarded as an effective alternative to pure instructor-led training [17]. Practice while watching standardised instructions, in combination with the use of a quality technological measurement of CPR skills may improve the performance even more [195]. Practice while watching has been shown to be effective for training in adult and infant BLS and in first aid at an industrial workplace [196]. Film-based instructions may provide a means of standardisation for the delivered content at workplaces. The standardisation of the content and the educational methods are specified by the national resuscitation councils, including requirements for the certification of participants and instructors in BLS. The certification of practical skills in BLS and workplace safety requires an instructor for the participants to demonstrate their skills and, for this reason, instructor-led training still is the traditional education method.

*Self-learning* with film-based instructions and practice while watching has been regarded as an alternative for learning if an instructor-led education is not available [17]. The practical skill of performing chest compressions appears to require real-time feedback in training [197]. However, in 2018, Pedersen et al. reported higher retention of practical skills three months after training for film-based self-learning training compared with film-based instructor-led training [198]. In another previous study, attitudes to and confidence in performing CPR did not differ when comparing self- with instructor-led training in BLS [199]. Self-learning alternatives appears therefore to be a complement to instructor-led learning.

*Web-based learning, e-learning or digital learning* using various digital technologies are widely accepted for teacher-centred, learner-centred and collaborative learning for their flexibility in the learning process [200-205] and are also available for learning in BLS. For example, web-based learning on different websites and platforms, web-based text documents and images, virtual reality learning (VRL), BLS games, videos, questionnaires and other multimedia tools have been developed for learning in BLS. Each national resuscitation council has various web-based solutions and the internet offers a variety of options developed by other organisations and companies. Web-based education alone in BLS has been shown to be less effective for learning practical skills specific to the quality of chest compressions but, for overall BLS knowledge, there appears to be no difference when compared with traditional BLS training [206, 207]. When it comes to maintaining skills and competence, individual web-based e-learning may not produce any improvement, due to the absence of social collaboration when compared with traditional training [208]. However, learning in BLS requires practical training and a combination of web-based learning and practical training appears to be beneficial for learning [207, 209].

*Blended learning* alternatives have been explored and found to be effective. A combination of digital media, with both self-directed learning and practical instructor-led training have been shown to improve the learning outcome in BLS [54, 129, 189, 190, 207, 209]. Web-based e-learning, first and foremost prior instructor-led courses, has been developed and has been shown to be effective and sustainable [210-213]. Castillo et al. reported that blended virtual training with practice was cost effective compared with traditional BLS training [214] and Lehman et al. found that virtual learning improved practical skills in a paediatric BLS course [215]. In contrast, studies with a BLS course with two hours of virtual training and two hours of practical instructor-led training, compared with a traditional four-hour course, did not reveal any difference in practical CPR skills or knowledge nine months after training [209, 216].

*Peer-led training*, peer learning and peer teaching for students is an approach without a traditional instructor and has been used for BLS training with positive results in terms of the learning outcome [217-219]. Peer coaching can be used both by colleagues and by teachers. In work-based learning in the community of practice, professionals and teachers can coach each other and the more experienced teacher may have superior knowledge valuable for learning and reflection. The students should not be aware of the coaching situation and the peers reflect on the performance and evaluate the performance after the course [176, 178]. The professional learning for teachers or instructors in peer coaching benefit the learner and is a standardised learning cycle to better learning outcomes for the students [220].

*Feedback* can be given by the instructor to the participant. The instructor can visually assess the participant correctly and give verbal feedback. Most of the training manikins in BLS have some mechanical feedback for compressions and ventilations and can be self-regulated by the participants or used by the instructor to assess the participant. There are different types of mechanical feedback such as a clicker with an analogue audio activated when performing chest compressions or a digital audio-visual feedback device for CPR or separate metronomes to help with the rate of chest compressions. The mechanical feedback CPR prompt and feedback devices have been discussed in BLS training designed to improve the quality of skill acquisition [175, 221, 222]. Notably, there is a risk of delaying the initiation of CPR [223] and pressing too hard and the devices are therefore only recommended in training [222, 224-227]. In particular, the compression depth is difficult to estimate without feedback. Rescuers may be able to judge the depth, but the overall target depth is difficult to estimate [228]. Previous studies of survival from cardiac arrest using real-time audio-visual feedback have been discussed. Even if the quality of performed CPR is improved, there is not enough evidence relating to improved survival [229-233]. For this reason, real-time audio-visual feedback in real-time cardiopulmonary resuscitation is not recommended [20, 22]. However, in training, feedback can be used by both the participant and the instructor.

Feedback on practical skills by the instructor can also take the form of specific "deliberate practice" and mastery learning (Ericsson 1993, Ericsson 2006, McGaghie 2015) which means that the participant trains actively and systematic until mastery level is achieved. The instructor gives formative feedback during the practice in communication with the participant. When simulating a cardiac arrest situation, short practical training sessions with deliberate practice has been shown to be positive for practical skills when compared with traditional simulation with debriefing in a healthcare setting, but this was found to be more exhausting for the participants [234].

*Simulation-based learning* can integrate both technical and non-technical skills (human factors) and different levels of training in BLS [235]. Simulation is an approach with practice, feedback, debriefing and reflection in the concept. Cardiac arrest scenarios can be simulated and communication, collaboration, decision-making and teamwork can be practised [236-238]. The setting of the scene and the relevance of the simulation have been shown to be more important than using high-fidelity manikins [239, 240]. Debriefing with reflection after the simulation improves learning but needs to be facilitated and is mostly used in health care [174, 241].

*Problem-based learning (PBL)* in combination with simulation is a successful learning strategy in BLS in nursing education and when simulation for medical students was compared with traditional BLS training. The PBL learning group put in a better performance for practical skills directly after training, but there was no difference at the six-month follow-up [242]. Problem-based simulation can activate more student-centred learning [243].

*Reflection* in a learning conversation has been developed to open up reflections by discussing instead of the more closed feedback given by the instructor to the participant [179]. Reflection on the experience to improve learning in BLS has been shown to be an effective learning tool, together with debriefing [174, 244]. Reflection is central to the learning process and may strengthen the participant's ability achieve the learning outcome.

*Retraining* for laypersons needs to be regular and frequent, as practical CPR skills deteriorate after three to six months [54-56, 245]. Practical skills appear to deteriorate more rapidly than theoretical knowledge and the training should therefore focus on practising the task [246]. The retention of practical skills in using an AED appears to be retained for longer than CPR skills [59, 60]. The training interval for laypersons is recommended to be no more than 12 months [21]. A spaced format with short duration of CPR training monthly with feedback improved practical skills compared with every three, six or 12 months [175], as well as a 15-minute retraining intervention [102], a study comparing spaced versus massed instruction [247] and brief daily training [248]. The optimal training interval for laypersons needs to be further investigated, even if frequent brief training in a spaced format is beneficial for learning practical skills [21, 61, 174]. More trained laypersons may improve confidence [249], willingness [189] and the number of potential bystanders [172, 250, 251].

*Assessment* of the learning outcome in terms of practical skills in BLS and the fraction of compressions has previously been recommended to be at least 80 per cent and with delivery of a shock within 180 seconds [29, 174, 179]. To achieve competence and provide high-quality CPR, some form of assessment is recommended, but it is not stated for laypersons. The visual assessment of chest compressions is poor compared with mechanical feedback [252]. Assessment in the form of a summative test with a checklist at the end of the training increased learning both directly after training and six months after training in previous studies, when compared with using scenario training at the end of the course [253, 254]. The summative test has also been shown to benefit the learning outcome for both females and males and an increased level of cortisol was associated with the learning outcome for males [255]. The assessment can be performed by one assessor or by different assessors in separate stations such as an objective structured clinical observation (OSCE) including feedback and evaluation [256]. A continuous, formative assessment during the course with student-centred learning has been shown to be preferable in educational settings [166]. Assessments performed by healthcare instructors of healthcare personnel are recommended to include a checklist in a summative test at the end of the course to support effective learning, but this is not recommended for lay instructors assessing laypersons [21]. Previous studies have compared different tools and checklists for assessment [158, 257], but there is no defined form of assessment or evaluation for laypersons training in BLS more than the recommendation of a formative assessment with corrective feedback and spaced learning [21].

## The standard Swedish national training in BLS

The standard adult BLS training in Sweden is based on the ERC guidelines and the national educational guidelines from the SRC. The updated 2015 international and national guidelines for the BLS treatment algorithm were almost identical to those in 2010. The learning objectives according to the instructor's manual from the SRC [258] is presented below.

By the end of the course, the learning outcome for the participant is to be able to demonstrate how to

- *perform control of consciousness*
- *perform control of breathing*
- *call for help, 112*
- *perform chest compressions and rescue breathing*
- *operate an automated external defibrillator*
- *place an unconsciousness victim in the recovery position and*
- *handle a choking victim.*

The instructions for the training included how to assess a collapsed victim and initial treatments. In short, the elements were to

- *check responsiveness by talking to and shaking the victim*
- *check breathing by opening the airway with head tilt and chin lift and look, listen and feel for breathing*
- *call for help, 112, or ask a helper to call 112 and find the nearest AED*

- *perform chest compressions with the hand placed in the centre of the chest, a depth of at least 5 cm but no more than 6 cm, a rate of 100-120 a minute, 30 chest compressions consecutively followed by two rescue breaths and releasing the pressure between the chest compressions without losing contact with the skin and the position on the breastbone*
- *perform ventilations by opening the airway and performing two rescue breaths that produce a visible elevation of the chest for about one second*
- *perform CPR (30:2) with minimal interruptions on a hard surface and, if possible, change the bystander who performs CPR every two minutes*
- *operate the AED and use it as soon as it arrives, attach the electrodes to the victim's chest as instructed, follow the instructions from the AED and give a shock as soon as possible*
- *continue chest compressions and rescue breaths (30:2) and follow the instructions from the AED*
- *perform one OHCA scenario with one rescuer and two OHCA scenarios with two rescuers in collaboration*
- *perform the recovery position in pairs and*
- *know how to assess and treat a choking victim with an FBAO by back blows, abdominal thrusts and by starting CPR when the victim becomes unresponsive.*

In short, BLS training for laypersons focuses on practical hands-on training in BLS, CPR, AED and FBAO. One training manikin per participant has been recommended for public training. The SRC recommends using small training manikins for personal use and half- and full-body training manikins. The national courses are either facilitated by an instructor with film-based instructions and practice while watching the instruction film or pure instructor-led training when the instructor teaches. The formal summative assessment with a checklist for practical skills at the end of the course was removed from the SRC educational guidelines in 2011. A continuous feedback and assessment of the participants to achieve the learning outcome is recommended without a final grade.

## Learning in BLS at the workplace

The Swedish Work Environment Authority Act [130] comprises preventive action for occupational illness and accidents. It includes recommendations for training in

BLS, together with first aid and crisis support, separately in the 1999:7 Act [259]. The definitions of first aid are actions and treatments needed and applied immediately at the workplace "in the event of an accident or acute illness, in order to restore and maintain vital bodily functions or prevent further development of an injury". First aid must be planned and organised at the workplace. The employees must have a knowledge of the organisation and how to activate the plan. A defined number of workers must have sufficient theoretical knowledge of and practical skills in first aid and crisis support. Basic life support for treating an obstructed airway, anaphylaxis, severe bleeding, preventing circulation failure and providing CPR are general recommendations to be included in regular practical training. All workplaces must have sufficient, appropriate and easily accessible equipment and the employees must have the knowledge necessary to handle the equipment in a safe way. The training should be organised according to the type of work. The act contains instructions for the equipment and what to train.

Worldwide, there are guidelines and recommendations for first aid training [260] and BLS [21], which can be adapted for workplaces and for workplace occupational health [261]. Internationally, more than half the countries have laws and regulations for first aid in workplaces and having someone at work who is trained and able to perform BLS [262]. However, there is a need for the improvement of standards of emergency preparedness and for training in BLS at workplaces [263, 264].

The workplace can have BLS instructors that organise training and they can organise self-learning training. It has been shown that using a self-directed BLS programme at workplaces was comparable to pure instructor-led courses and was a more cost-effective alternative [129]. The workplace is a common place for training in BLS. In a nationwide survey in Norway, 90 per cent of the respondents answered that they had participated in first aid training, but their knowledge of the first action was poor. Only 43 per cent said that they would start CPR if they found an unconscious victim without normal breathing [265]. In an international survey from 64 countries, 60 per cent of the employees answered that they had participated in first aid training [262]. The workplace is an unusual location for OHCA and was estimated to account for 0.3 per cent to four per cent of all OHCAs, by Descatha et al. in 2015. Even if the CPR educational level of the rescuers was unknown the survival was higher at workplaces compared with elsewhere [23]. The workplace has the potential with its organisation and training to manage OHCAs better than elsewhere [23, 25, 129, 261, 266].

### *Barriers to training and performing BLS*

The challenges that need dealing with are the barriers and obstacles for laypersons to training and performing BLS in a real-life OHCA situation. There is an ethical aspect to both the real-life situation of an OHCA and training for laypersons to consider. Fear and anxiety about the transmission of infectious transmissible disease when performing ventilations have been shown generally to influence attitudes and willingness to perform CPR [172, 251, 267]. In a pandemic situation, the public barriers to performing CPR increase even more. The safety aspect of protecting yourself and others and calling the EMS for help immediately is always present. The emergency medical dispatcher may help to identify the risk in the situation and guide the layperson according to the guidelines for resuscitation [16, 268, 269]. Chest compression-only CPR has been regarded as an alternative if the rescuer is unable to perform rescue breaths [270, 271]. There are concerns about the way chest compressions and defibrillation generate the aerosol transmission of infection to the rescuer [271].

A feeling of confidence and trust in the context surrounding the OHCA situation and support from the emergency medical dispatcher have been reported to be positive factors for performing CPR in a real-life situation [272]. Laypersons who have performed bystander CPR in real life have said that they are willing to do it again [273, 274], but bystanders have also described experiencing challenges in social life and emotional feelings and concerns about the victim after the event [275].

Training in BLS has been shown to increase willingness and confidence to perform CPR, regardless of self- or instructor-led learning [193, 199, 251]. However, there are barriers which have an ethical perspective that needs to be considered. Common barriers are a feeling of lack of confidence, competence and a fear of panic, harming and exposing the victim and one's own risk of transmitting an infectious disease or of legal consequences [89, 172, 276-280]. Additionally, females have been shown to receive less CPR compared with men [281] and less defibrillation by lay bystanders [282]. In a public survey of perceptions of performing CPR to females, the barriers for to touching a fragile female, touching the chest of a female or causing injury or sexual and legal consequences were expressed [283].

Other barriers to overcome are that laypersons with a low educational level, social status or income appear to be less confident about performing CPR and training BLS [278, 284, 285]. Physical abilities, a low bodyweight and fatigue may reduce the quality of chest compressions [134, 286-289] and the technique and quality when performing chest compressions are even more important to consider. In contrast, trained healthcare professionals may not feel exhausted [290] and this can be an indication that training in BLS and physical fitness can improve CPR performance [291].

To overcome the barriers, learning aspects of OHCA and BLS can take the form of different interventions in society to reach the public. Widespread training, media campaigns and the use of the technology infrastructure may reduce barriers and improve survival, but they must be carefully planned and implemented to be successful [90, 101, 123, 124, 126, 251, 292-297]. International campaigns include “World Restart a Heart Day” [298, 299], that creates awareness that everyone can learn CPR and facilitate BLS courses, “Kids Save Lives”, an implementation and education of school children, and the “Hands-Only CPR” campaign [292], which promoted to push hard and rapidly in the centre of the chest and can be learned by anyone and may increase performance in a real-life situation [300, 301]. Every year, the AHA publishes updated statistics and easy-to-understand images to increase public awareness of heart disease, stroke and cardiovascular risks in the “My Life Check - Life’s Simple 7”, on core healthy life behaviours and lifestyles [1]. The AHA strongly urges population-based interventions targeting healthy lifestyles and training in BLS throughout the nation at workplaces, public locations, schools and healthcare settings. Nationally, the Swedish National Stroke Campaign run by the Swedish Association of Local Authorities and Regions was a large, successful campaign that increased laypersons’ awareness of stroke symptoms and the importance of calling 112 (www.1177.se/Vastra-Gotaland/stroke) [302, 303]. This intervention was spread in the media, public locations and health care and is still available. Increased public knowledge of the causes of CVD can improve cardiovascular health. In Sweden, the World Restart a Heart Day, Kids Save Lives and several other interventions are promoted by the SRC (www.hlr.nu). Different foundations also play significant role in distributing knowledge in different interventions to the public, in addition to raising funds for research. A broad-based strategy with different learning approaches, which is available free of charge to every member of society, may encourage the learner to seek to improve their own cardiovascular health and educational and training interventions in CVD, BLS and healthy lifestyles. This may also target local communities, workplaces, schools and organisations in society. The overall goal for interventions in society regarding OHCA is to improve bystander BLS and survival from cardiac arrest through the involvement of laypersons in combination with a health-related approach [296].

## History of education in BLS

Historically, training and performing BLS was only allowed for medical health care personnel and mainly for doctors. A form of course plan was developed in the US by the scientists Kouwenhoven, Jude and Knickerbocker and the anaesthesiologists Elam and Safar in 1961. This was after several years of scientific studies from open-chest cardiac massage and open-chest defibrillation to closed-chest cardiac massage, cardiopulmonary resuscitation and closed-chest defibrillation [304]. The first medical guidelines in resuscitation were produced and published by the AHA in 1966. As late as 1972, laypersons were allowed to perform CPR. At that time, mass education of the public started in the US and first and foremost in Seattle. A standardised training programme in BLS for laypersons was published in 1974 by the AHA and was spread around the world as a model for education. The education started with a film "The pulse of life", followed by "The breaths of life", to motivate the participants. Most of the international BLS courses for laypersons lasted a minimum of eight hours or longer, primarily with lecturing on theoretical knowledge and with some training in practical skills [244, 304-308].

Earlier in Scandinavia, there were several activities in training in resuscitation. In 1961 in Norway, the anaesthesiologist Björn Lind, together with the toy company, Laerdal AS, produced a training manikin for rescue breaths for EMS personnel, later used by laypersons [305, 309, 310]. Norway has had a long tradition of teaching rescue breaths in schools from 1939 as drowning among fishermen was common. The Resusci Anne training manikin was introduced to the AHA in 1961 and, with a complement for training chest compressions, the training manikin was ready for education and training in BLS worldwide [309]. This training manikin is continuously updated by the Laerdal AS company for healthcare and resuscitation training and is used worldwide. The original shape and feeling of a human person are still there. Local recommendations for CPR and a training programme for healthcare personnel were established at Uppsala Hospital in Sweden, also in 1961 [311]. The Swedish National Board of Health published recommendations for CPR in healthcare in 1962 [311].

Historical barriers to overcome are some changes in guidelines. For example, checking the carotid pulse on an OHCA victim by laypersons was removed from the ERC educational programmes in 2001 [312, 313]. In 2005 the CPR ratio of 15:2 was changed to 30:2 and using an AED was recommended for laypersons [314]. After all, medical findings from Kouwenhoven, Jude and Knickerbocker and Elam and Safar in the early 1960s on CPR with chest compressions and ventilations and defibrillation, conforms with modern treatment for OHCA [304].

## History of training in BLS in Sweden

The history of BLS education and training in Sweden started with the cardiologists Stig Holmberg, Lars Ekström and Bertil Wennerblom at Sahlgrenska University Hospital in Gothenburg and the cardiologist Lars Mogensen at the Karolinska Institute in Stockholm, in collaboration with registered nurse (RN) Marianne Jarlöv and colleagues, mostly nurses from Sahlgrenska University Hospital [315]. In a working group in the Swedish Society of Cardiology and later in the Swedish Resuscitation Council, a national educational programme was produced, based firstly on the AHA guidelines and then on the ERC guidelines. Dr Holmberg was the chair of the working group and the first chair of the SRC. The mission was that all people should learn CPR, both healthcare personnel and laypersons [316]. In the educational materials, Dr Holmberg stated that *"It should be as easy to learn CPR as to learn to swim. You learn to swim to save you own life. CPR is learned to save someone else's life"* (Personal interview with Holmberg 2013 by Helene Bylow). This was the start of the national social popular movement of BLS training in Sweden [315].

The printed materials were produced in collaboration with the company Laerdal AS in Stavanger, Norway. The company and its owner, Asmund Laerdal, collaborated with the AHA and other resuscitation organisations on educational materials and training manikins. Sweden collaborated intensely with the pedagogue Harald Eikeland from Stavanger, Norway. In an interview with Dr Holmberg in 2013, he talked about Eikeland and said, "*Harald is, so to speak, the great thinker when it comes to pedagogy in BLS. He has been the great innovator in BLS training in the world"* (Personal interview with Holmberg 2013 by Helene Bylow).

The first national educational guidelines in Sweden were initiated in 1981 and introduced in 1983, with a handbook for BLS instructors [316]. The training was aimed at both healthcare personnel and laypersons. The first national head instructors in BLS were educated in 1983 on the island of Marstrand on the Swedish west coat and this started the "cascade principle" (Fig. 6). These 24 national head instructors were encouraged to educate both instructors and new head instructors who were supposed to educate new instructors and head instructors to achieve a constant, ongoing educational process in CPR, like a cascade. This was the national strategy for mass education and reaching everyone in society and, as far as we know, this was only used in Sweden.

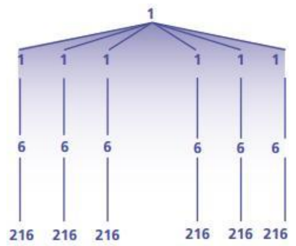



Figure 6. The "cascade principle" of educating head instructors in BLS in Sweden. Adapted from the head instructor's manual from the Foundation of the Swedish Council for Cardiopulmonary Resuscitation in 1987 with permission from the Swedish Resuscitation Council

This place on Marstrand became a centre for the education of instructors in CPR for many years. In an interview in 2013 with Dr Holmberg, he told the story of CPR education (Holmberg 2013, personal interview). He was inspired by the AHA when creating the national BLS programme and was the first chair of the ERC working group in BLS. Dr Holmberg was against the eight hours spent on international BLS courses. In collaboration with Norway, a three-hour course was developed. The motivation of the participants to learn and their willingness to perform CPR in a real-life OHCA situation were crucial to the development of the course. Influenced by the film "The pulse of life" from the AHA, a video film "You can save a life" was produced to be the introduction on all the Swedish courses. The film started with a short simulated real-life OHCA dramatization to put the participants in the context of an OHCA and to motivate them. The course was planned for six to eight participants and one full-body training manikin. The training was led by a trained BLS instructor. Learning objectives were introduced at the start of the course. The focus was on practical training. The instructor followed the standardised handbook for BLS instructors and used three stages in teaching practical skills, 1) teaching theoretical knowledge by the instructor, 2) a demonstration of practical skills on the training manikin by the instructor and 3) practical training on the training manikin by the participants. At the end of the course, the instructor assessed the participants one by on in a brief OHCA scenario using an assessment checklist with the steps of the BLS algorithm. After the assessment, the instructor gave feedback to the participants.

At a later stage, a smaller training manikin was produced as half-body training manikins to encourage more participants to train at the same time and to provide more time for practical hands-on training. In 1992, pairwise training was introduced, with the recommendation of one manikin for each pair of participants [317, 318]. The training in pairs was designed to simulate an OHCA situation and prepare the participants for real-life situations. An even smaller training manikin, with only a head and a chest for personal use, was produced in 2006. Every participant in the group was able to train on a personal manikin and, if video-based training and a widescreen were used, a large number of participants could train at the same time. This small training manikin also enabled self-learning training with video-based instructions. The handbook for instructors was changed in 2006 and included instructions for both a pure instructor-led course, at which the instructor taught all the skills, and an instructor-led course, with video-based instructions. The training model was to practise while watching the video. Instructor-led training with video-based instructions was regarded as the standardised national training method in BLS [96].

From an educational perspective, the Swedish courses ever since 1983, has been shorter and more simplified than the European courses. Since the start in 1983 until 2020, more than five million people have been trained in BLS in Sweden [9]. The national training programmes are updated every five years and based on the ILCOR and the ERC guidelines. In an interview with Dr Holmberg in 2013, he looked back at the 30 years of education and the cascade principle of training in BLS.

*What fascinates me most in this whole story is the whole cascade principle. It is fascinating and incomprehensible. All training in Sweden, as you know, started at Marstrand, with 24 doctors from Sweden, in November 1983. First, they were trained as students, then as instructors and then as head instructors. Then they were given a title that no longer exists, regional head instructor. The important thing is that, when we had done that, we told them that now you can go home to your hospitals and do the same with others as we have done with you.*

*All education in Sweden originates from these 24 doctors. And it is almost unbelievable that it has worked, because the whole development has been dependent on head instructors training new head instructors who in turn train new instructors. And this fact, that it has been happening for 30 years, is almost unbelievable. In addition, the transmission of information from generation to generation has not meant that the system has been destroyed and it is almost impossible to understand that this system can live on for 30 years with this kind of transmission. It has only rolled on automatically. For me, this is the most fascinating thing in this whole story and it is almost incomprehensible!*

*Actually, I thought quite early on that this system would die in a few years because the new head instructors would not be able to train so many new head instructors and then there would be fewer and fewer and eventually the system would die. But, if you look at the numbers year after year, they have been almost completely constant for decades. The number of trained head instructors has been constant year after year. The number of trained instructors has increased somewhat in recent years. That is, the annual production. That is the most remarkable thing about this self-driven system"* (Personal interview with Holmberg 2013 by Helene Bylow).

# Rationale

Early high-quality actions are crucial for survival when a person suffers an OHCA. Awareness, theoretical knowledge, practical skills and confidence and a willingness to act may reduce the delay to lifesaving actions. As a result, the rationale in the present thesis was to use a quantitative approach to explore different learning activities for laypersons in BLS at workplaces and to describe the OHCA patient at workplaces.

The cardiac arrest situation can be experienced in a real-life human situation and by real-life training on a manikin. Both experiences are a real-life world experience and involve learning. Learning from experience is a pragmatic view of knowledge. The theoretical framework to extend learning aspects can be understood through experiential learning, according to Kolb's experiential learning theory [14]. The research questions in Studies I-IV were therefore as follows.

**Study I:** Which learning activity is most effective and contributes most to the intended learning outcome for practical skills and theoretical knowledge after training in BLS, CPR and AED, 1) self-learning training or 2) instructor-led training?

**Study II:** Which learning activity is most effective and contributes most to the intended learning outcome for practical skills and theoretical knowledge after training in BLS, CPR and AED, 1) with or 2) without an additional preparatory web-based education in CVD, i.e. stroke, AMI, cardiac arrest, CPR, AED and healthy lifestyle factors?

**Study III:** Which modes of BLS learning activities are most effective and contribute most to the intended learning outcome for practical skills in BLS, CPR and AED, 1) instructions from a mobile application or 2) a film, 3) self- or 4) instructor-led learning, 5) a web-based education, 6) reflective questions, or 7) the use of mechanical feedback on chest compressions compared with standard training in BLS?

**Study IV:** What are the characteristics, incidence and outcome of OHCA at workplaces compared with other places and what factors are associated with survival?

# Aims

## Overall aim

The overall aim of this thesis was to 1) explore the effectiveness and the intended learning outcome after training in BLS, CPR and AED calculated as a total score for practical skills, theoretical knowledge, confidence and willingness to act by comparing different learning activities among laypersons at workplaces and 2) describe characteristics and 30-day survival of OHCA occurring at workplaces in comparison to OHCAs at other places and factors associated with survival after OHCA at workplaces in Sweden.

### Specific aims of the studies

In **Study I**, the aim was to compare the effectiveness of two BLS training interventions, i.e. self-learning training with instructor-led training six months after training and, secondarily, directly after training.

In **Study II**, the aim was to compare the learning outcome in terms of practical skills and theoretical knowledge of BLS, CVD and willingness to act after participating in learning activities related to BLS, with and without a web-based education in CVD, i.e. stroke, AMI, cardiac arrest, CPR, AED and healthy lifestyle factors.

In **Study III**, the aim was to evaluate whether there were other modes of BLS training that improved the learning outcome as compared with a control group, i.e. standard BLS training, six months after training and, secondarily, directly after training.

In **Study IV**, the aim was to describe 1) the characteristics and 30-day survival of OHCAs occurring at workplaces in comparison to OHCA at other places outside hospital and 2) factors associated with survival after OHCA at workplaces.

# Methods

## Overview of the research

In overall terms, to capture the complexity of the aims and answer the research questions regarding learning aspects of OHCA at workplaces, a quantitative experimental method was used in three studies and a descriptive method in one study.

This method section presents the design, population, data collection, outcome, data analyses and ethical considerations of each of Studies I-IV. An overview of the research is presented in Table 1.

*Table 1. Overview of the research, Studies I-IV*

| Study | I | II | III | IV |
|---|---|---|---|---|
| **Design** | Parallel experimental, cluster RCT | Parallel experimental, cluster RCT | Parallel experimental, cluster RCT | Observational register-based study |
| **Aim** | To compare self-learning training with instructor-led training in BLS | To compare BLS training with or without a web-based education | To compare several different BLS learning activities with BLS standard training | To describe characteristics, outcome and factors associated with outcome after OHCA |
| **Population** | Laypersons at workplaces 2014-2016 n=1,301 | Laypersons at workplaces 2014-2016 n=2,623 | Laypersons at workplaces 2014-2016 n=2,623 | Patients in the SRCR 2008-2018 n=49,803 |
| **Data collection** | Practical skills and theoretical knowledge | Practical skills and theoretical knowledge | Practical skills and theoretical knowledge | Characteristics, incidence and outcome of OHCA |
| **Outcome** | Total score Cardiff Test, individual variables, theoretical knowledge, confidence and willingness to act | Total score Cardiff Test, individual variables, theoretical knowledge, confidence and willingness to act | Total score Cardiff Test, individual variables, theoretical knowledge, confidence and willingness to act | Survival to 30 days and factors associated with outcome for OHCA at workplaces compared with other places |
| **Data analyses** | Mixed linear regression models, GEE analysis (logit link function) and Fisher's exact test, McNemar's test, Wilcoxon signed rank test | Mixed linear regression models, GEE with logit link function and Fisher's exact test | Mixed linear regression models, Dunnett's method for multiple comparisons | Logistic regression, computed regression model, logistic regression for OR |
| **Ethical approval** | D.no: 2014/134-14 | D.no: 2014/134-14 | D.no: 2014/134-14 | D.no: 2019-04066 |

# Design

The study design used in the three first studies (I-III) was a cluster randomised, controlled trial (RCT). Different learning activities were composed, explored and compared with the national standard BLS training. The design, power calculation, cluster randomisation, materials, learning activities, different interventions and the organisation of the BLS training for the RCT are described in this section. The standard BLS training is presented in the background section.

In Study IV, the design was observational, with retrospective descriptive register data from the SRCR. These two study designs complement one another and the results may expand our knowledge of the learning aspects of OHCA with the emphasis on workplaces.

## Studies I-III

A cluster RCT was used in Studies I-III. If strictly applied, an RCT can increase the quality of the study and minimise systematic bias in the study results. Randomisation may ensure that only random differences (if any) are present at the start of the trial [319]. In an RCT, when comparing different medical treatments, for example, the optimal randomisation is to assign each patient individually. In the present thesis, when comparing different learning activities, a cluster randomisation commonly used in educational and healthcare research [320, 321] was used, primarily for practical reasons, instead of the randomisation of individuals. Research on BLS training methods and approaches incorporated in work-based learning may be considered in a special context with a natural cluster structure, making it meaningful and feasible for the present trials. The disadvantages are that cluster randomisation requires a large sample size and complex statistical methods.

The trials were performed prospectively and the interventions that were tested were different learning activities in BLS training. The trials had a parallel design (two arms) and one intervention at a time was compared with a control group, i.e. a parallel exploratory design. The design and the interventions were intended to meet the requirements of guidelines, working environment and workplace learning. The design was tested in a pilot study in 2013 [322].

The trial was retrospectively registered on 7 August 2018, at ClinicalTrials.gov (clinicaltrials.gov/ct2/show/NCT03618888). Transparency in reporting a cluster RCT is crucial and the trials in Studies I-III were reported by a flowchart, i.e. the flow diagram. The CONSORT (CONsolidated Standards of Reporting Trials) 2010 statement for transparent reporting of RCT with standard parallel groups (http://www.consort-statement.org/) was used in Studies I-II [323]. The statement for extensions of the CONSORT (http://www.consort-statement.org/extensions) was used in Study III [324, 325]. The flow diagrams are presented alongside each study in the present thesis.

### *Power calculation*

For the primary endpoint, a calculation to detect a two-point difference in the mean of the total score for the modified Cardiff Test, with an assumed standard deviation of five points, a significance level of 0.05 (two-sided test) and a power of 95 per cent, an effective sample size of 163 participants in each of the two training groups was needed. To ensure enough participants well above the 163 needed to reach a power of 95 per cent, it was finally decided that, for the design of 16 groups, a total of 2,500 participants were sufficient.

### *Cluster randomisation*

Cluster randomised trials are commonly used in educational and public health research when testing differences in teaching methods and learning approaches, as in the present thesis [320, 321, 323, 325]. Training in BLS is generally targeted at a system for improved public health. Traditional BLS training is still commonly organised in a group and this is the natural learning situation. The risk of contamination between the groups may be reduced when using clusters. In this thesis, there was primarily a practical reason for randomising clusters instead of individuals. The cluster, i.e. the group of allocated laypersons at workplaces, was randomised to one of 16 training interventions in BLS.

For this design process, laypersons at workplaces signed up to participate in the research at their own workplace. An independent co-ordinator organised 25 employees per group, which was defined as a cluster. In collaboration with an independent statistician at another university, the randomisation list was calculated using the internet-based Research Randomizer. This is a resource for researchers and students offered by the Social Psychology Network [326]. The site randomly generates numbers to assign participants to experimental trials. The list of numbers was calculated with blocks of 25 individuals in 112 clusters and allocated laypersons at the workplaces were cluster randomised to one of 16 different BLS training interventions. The generated list was delivered by an independent co-ordinator at the central municipal office to the co-ordinator at the workplace, who delivered the generated intervention to the participants. The co-ordinator at the workplace was independent and did not participate in the training. The co-ordinator was briefly informed about the 16 different interventions in BLS training, administered the project locally and personally handed out the information and the randomised intervention to each participant at the workplace. The participants were only aware of their individual BLS training intervention and not that of the other participants. The clusters of participants in the instructor-led training and the instructors were aware of the training method but not the individual personal intervention for each participant. The investigator was blinded to the randomisation of the participants and the training intervention.

The design of this randomisation is according to the Prospective Randomised Open Blinded End-Point Evaluation design, abbreviated PROBE design [327]. The participants and the BLS instructor were naturally aware of the BLS training (the study treatment) but not the overall study design. The investigator was not aware of the randomisation for each cluster or the training intervention for each participant and was not involved in the training.

### *Material and equipment used in the BLS training*

The material used in the different learning activities was both standardised from the SRC and new and it was composed before the studies. A description of the material and equipment in the BLS training is presented below.

*The training manikin and the training AED*

The BLS training was based on a standardised training kit with additional material from the SRC. All the participants trained with an equal training manikin, which was a personal Mini Anne Plus manikin, and a paperboard training AED in a kit (Mini Anne kit, Laerdal Medical AS, Stavanger, Norway, Fig. 7). This small training manikin could be inflated using the bag and had only a head and a chest. There was a clicker for the correct position for chest compressions and depth and the chest rose when performing rescue breaths correctly. It was regarded as a low-fidelity manikin and a complete training solution for laypersons. The main reason for using the training kit was that it was useful both individually and in a group. There was standardised evaluated material from the SRC, commonly used in BLS courses, easy to organise training with at all the different types of workplace and an accessible and financial alternative for workplaces to use for implementation.


Figure 7. The Mini Anne Plus manikin and the training paperboard AED (reprinted with permission from Laerdal Medical AS and the Swedish Resuscitation Council)

*Film instructions*

The instruction film used in 12 of the interventions was standardised from the SRC national educational programme for adult CPR with an AED (Swedish Resuscitation Council, Fig 8). The film was led by a film instructor for a total of 60 minutes. The film started with a short simulated real-life OHCA dramatization to motivate the participants. It then comprised synchronised training instructions for BLS and CPR (30 minutes), how to use the AED and a demonstration of a short OHCA training scenario for the participants to simulate in pairs (15 minutes), the recovery position and how to handle a choking victim (15 minutes).


Figure 8. The DVD instruction, adult BLS, CPR with an AED, and an OHCA scenario in pairs (reprinted with permission from Laerdal Medical AS and the Swedish Resuscitation Council)

*The mobile application instructions*

For instructions in four of the interventions, the application of BLS instructions called "Save the Heart" (Swedish Resuscitation Council, Fig. 9), available for smartphones and tablets, was used. This application was designed in collaboration with the SRC and the Swedish Heart-Lung Foundation in 2013, before the study. The application started with a short film introduction to motivate the participants. It then comprised pictures, voice prompts and text messages for synchronised training instructions for CPR, how to use the AED and how to handle a choking victim. This part took about 30 minutes. The participants were encouraged to repeat the practical skills and were able to train as many times as they wanted. The application was designed to include all the necessary skills but in a simplified and short format. There was also a link function to call 112, search for the nearest AED and start a metronome for the correct chest compression rate inside the application.


Figure 9. The application for smartphones and tablets of BLS instructions, "Save the Heart" (reprinted with permission from the Swedish Resuscitation Council and the Swedish Heart-Lung Foundation)

*The preparatory web-based education*

For theoretical knowledge in half the interventions, a preparatory interactive web-based education called "Help-Brain-Heart" (Swedish Resuscitation Council, Fig. 10) was used prior to the BLS training. The education was developed in collaboration with the SRC and an interdisciplinary working group before the study. The group consisted of members from the SRC, the Swedish National Stroke Campaign, the EMS and specialists in cardiology, i.e. cardiac arrest and neurology, i.e. stroke, general medicine and healthy lifestyles.

The web-based education comprised theoretical knowledge of CVD in general and of stroke, acute myocardial infarction (AMI), OHCA, CPR, AED and healthy lifestyle factors in particular. The education was interactive with ten multiple-choice questions asked after each subject and with the requirement to tick the correct answer to continue. Information movies, animations, real-life drama videos and a storyteller conveyed the information. The web-based education lasted for about 30 minutes and a certificate could be saved or printed out after completing the course. The purpose of the interaction in the education was to engage the participants and force them to use decision-making skills when answering the questions.


Figure 10. The web-based education “Help-Brain-Heart”
(reprinted with permission from Swedish Resuscitation Council and Laerdal Medical AS)

*The CPR feedback device*

The equipment in one of the learning activities and in four of the interventions comprised the “CPRmeter” (Laerdal Medical AS, Stavanger, Norway, Fig. 11). This is a mechanical device for feedback on the depth of chest compressions. At the end of the instructor-led training, all the participants trained for about 15 minutes with a personal CPRmeter placed on the manikin’s chest to achieve the correct compression depth. The instructor facilitated and helped the participants and they were also encouraged to help each other.

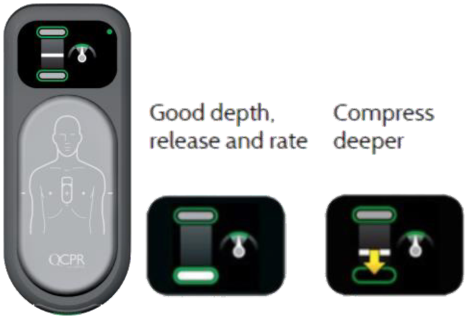



Figure 11. The CPRmeter (reprinted with permission from Laerdal Medical AS)

*Reflective questions*

Three reflective essential questions were included in half the interventions at the end of the training. The participants were encouraged to reflect on the importance of promptly calling 112, the hand placement for chest compressions and willingness to perform BLS in a real-life OHCA situation. In the instructor-led group, the participants discussed the questions in pairs for about 15 minutes. The participants in the self-learning interventions were encouraged to reflect on their own. The questions were as follows.

1. Your action may be the difference between life and death. Imagine yourself in a situation where you are present when a person suffers a sudden cardiac arrest. Reflect on what would affect you if you were to intervene in a real-life situation.
2. Imagine yourself in a situation where you are alone when a person has a cardiac arrest. In the event of cardiac arrest, you should first call 112, start CPR and ask someone to get the nearest AED, why this order?
3. Place your hands in the correct chest compression position on yourself. Reflect on the chest compression position. Why should the heel of the hand be placed in the centre of the victim’s chest, between the nipples?

### *The seven learning activities in BLS training*

The different learning activities were based on international and national guidelines for the treatment of OHCA and education in BLS [28, 29, 258]. The learning objectives were the same for all the learning activities and were included in the personal information to each participant. All the learning activities focused on hands-on practice. All the participants trained with an equal training manikin, which was a personal Mini Anne Plus manikin and a paperboard training AED in a kit (the Mini Anne kit, Laerdal Medical AS, Stavanger, Norway). The participants self-assessed their practical skills for chest compressions using a clicker and by a raised chest on the training manikin for rescue breaths. In the instructor-led training, the instructor helped, gave verbal feedback and visually assessed the participants to achieve the learning outcomes. In a short OHCA scenario in pairs, there was some brief peer assessment. The ERC guidelines [17, 29] promote continuous or formative assessments or formal or summative assessments of the participants by the instructor at the end of the course. In learning, the participant should be given the opportunity for some form of assessment such as self-assessment, assessment by the teacher or peer assessment or by feedback and mostly by learning experiences [14, 17, 166]. However, the learning approach and some of the equipment used differed in the seven learning activities.

### *1 Self-learning training*

Self-learning training was a learning activity for training according to personal instructions, without an instructor present. The participants were encouraged to train at work or at home with the personal BLS training kit as many times as they wanted for about two weeks for practical training and for theoretical knowledge with no limit. The learning model involved reading the information about the intervention and practising while watching and listening to the instructions. This learning activity was conducted since self-regulated learning is a flexible alternative to instructor-led face-to-face teaching. The participants can choose when and how often they want to train and can individually reflect on the experience. This might be both a strength and challenge for the participants. There are several advantages to self-learning as a result of its flexibility, but it is a disadvantage for the purpose of collaborative work-based learning. This activity was designed to explore a flexible, self-regulated training approach for work-based learning. Previous studies have revealed no difference between pure self-learning and instructor-led learning in different combinations [55, 194, 328], but no guidelines were available for pure self-regulated learning when planning the present study. Only if instructor-led training was not available could pure self-directed learning in BLS be considered for laypersons [17, 29].

### 2 Instructor-led training

Instructor-led training was a learning activity in groups of 12-25 participants per one or two instructors at the workplace. The learning model involved reading the information about the intervention, listening to the instructor and practising while watching and listening to the standardised instruction film from the SRC (DVD- or computer/video-based). The instructor introduced the learning activity and the learning objectives to the group. The instructor also helped and assessed the participants visually to achieve the learning objectives and answered the participants' questions for about 15 minutes, in addition to the film instruction. A short OHCA scenario with instructions from both the film instructor and the instructor was included. The scenario was simulated first alone and then in pairs. The instructor helped the pairs and summarised the learning objectives at the end. Teamwork in a simulated OHCA scenario has been recommended in BLS educational guidelines for laypersons to increase the realism of the training situation and to prepare the participants for an acute situation [17, 29]. The educational guidelines are based theoretically on Kolb's experiential learning [14] and that people learn best through their experiences [179]. Instructor-led face-to-face training has been the traditional teaching method. In the 2010 guidelines, self-instructions from video- or computer-based instructions in combination with hands-on practice were regarded as an alternative learning method [29]. Instructor-facilitated training with film-based instructions was regarded as a qualified training method. Since 2011, the national guidelines in Sweden have used the instructor-led training with film-based instructions as the standardised BLS education. Instructor-led training as a learning activity therefore constituted the control group.

### 3 Mobile application instructions

The mobile application instructions in BLS for smartphones or tablets as a learning activity were individually downloaded on a private or a workplace mobile phone or a mobile tablet. The application instruction lasted for about 30 minutes. It contained short audio-visual information on OHCA and the importance of calling 112, shouting for an AED, starting CPR and using the AED. For practical training, it contained pictures and short audio prompts and text messages with instructions on how to perform CPR, the use of the AED, the recovery position and how to handle a choking victim. The participants were encouraged to train as many times as they needed to realise the learning objectives. The practical training could be both synchronous and asynchronous with the instructions in the application. Applications for smart phones and tablets for the guidance of BLS were available from resuscitation councils in the US and the UK at the time of planning the study design. Based on international and national guidelines, the Swedish application was developed with core content from the algorithm in BLS and constituted the additional learning activity for instructions on training in BLS. All citizens should train BLS and education for the lay public should be kept as simple as possible [29]. Short instructions in a mobile application can help to reach more people, but the question of how short and simplified the instructions and the training can be without affecting the participants' practical skills in BLS is unknown. The learning activity with a mobile application was only used for self-learning training in four interventions to explore how simplified an intervention can be compared with the standard instructor-led training in BLS.

### *4 Film-based instructions*

The film-based instruction learning activity was the standardised national digital video disc (DVD) for BLS training and it lasted for 60 minutes. It contained a dramatized scenario from an OHCA situation, some theoretical knowledge on OHCA and practical instructions on how to perform CPR and use an AED, the recovery position and how to handle a choking victim with FBAO. The participants trained in a synchronised manner together with the video instructor. It also contained a short OHCA scenario with instructions and a demonstration for first simulating alone and then simulating in pairs. This learning activity was used both in self-learning training and in instructor-led training. Film-based instructions in BLS have been shown to be as effective or even more effective than if the instructor alone gives the instructions [189, 191, 317, 329]. The film-based learning activity was used in most of the interventions to maintain standardised content and sufficient time for hands-on practice and to avoid too much influence from the instructors [52].

### *5 Preparatory web-based education*

The preparatory web-based education as a learning activity contained theory and dramatized videos of symptoms of the most feared complications and treatment for CVD, i.e. stroke, AMI and SCA and healthy lifestyle factors, plus ten multiple-choice questions. The web-based education lasted for about 30 minutes. The platform was interactive and to proceed both correct answers to questions and clicks to continue were required. Feedback in the form of text and voice messages and a certificate was generated by the platform. This learning activity was used both in self-learning training and in instructor-led training in half the interventions. The purpose was to prepare the participants before training with theoretical knowledge, awareness of CVD and how to treat OHCA to increase learning in BLS. It was crucial actively to involve the learner in different activities in the website design to increase learning. Ten interactive multiple-choice questions were developed with different interactions, such as tick the right answer, fill in the blank, drag and drop and image choice, and with both reading and listening. To be able to continue, the participants had to give the correct answer and this forced them to use decision-making skills.

### *6 CPR feedback device*

The "CPRmeter" technical device (Laerdal Medical AS Stavanger, Norway) for feedback on compression depth was used as a learning activity in four of the interventions. It was only used in the instructor-led groups for about 15 minutes at the end of the course. The portable device was placed on the manikin's chest and an accelerometer measured the depth, visible to the participant in order to self-evaluate the performance and achieve the correct compression depth. The instructor facilitated the learning activity, helped the participants with the technique to achieve the learning outcome for compressions and encouraged them to help each other. The use of CPR feedback devices has been shown to improve the quality of CPR and increase the retention of psychomotor skills for chest compressions, but there are some risks to consider [222, 225, 330, 331]. Overestimation of the depth, incorrect hand position and distraction of the participant to perform CPR have been reported [224, 225]. This learning activity was therefore only used in the instructor-led training.

### *7 Reflective questions*

The reflective questions were three essential questions printed in a text document about the importance of promptly calling 112, hand placement for compressions and performing BLS in a real-life OHCA situation. The instructor in the instructor-led group introduced the questions and the participants discussed the questions in pairs for about 15 minutes. The self-learning participants were encouraged to reflect on their own. There is a natural gap between the real-life learning situation and a real-life OHCA situation. The practical skills learned in training must be transferred to reality and self-efficacy may be an obstacle. By reflecting on thinking about the experience in training and a potential experience of an OHCA situation, the obstacle may be reduced and the self-efficacy increased [14]. The questions were influenced by the motivation, willingness and preparedness to start a life-saving action. The reflection may mirror the learning activity, the participants' attitude to their own psychomotor skills and their mental ability to perform BLS in a timely manner in a real-life situation. The position of chest compressions may be an issue in BLS training. The manikins in general BLS training are different and the manikin in the present trial was small, without arms and legs, totally different from a human being. The participants come from varied backgrounds and experience. They have different perceptions of the human body, together with a varied ability to perform practical skills on a manikin and to transfer the skills to a real human being. The reflection may increase the awareness of the correct chest compression position either in pairs or individually.

### *The interventions, 1-16*

A summary (Table 2) and a public overview (Fig. 12) of the BLS training interventions, numbers 1-16, with seven additional learning activities in different combinations, are presented below.

*Table 2. Summary of the BLS, CPR and AED training interventions, 1-16*

| **1-16** | **Interventions with additional learning activities** | **Approximate time in minutes for each unit of learning material** |
|---|---|---|
| **1** | Self-learning training with instructions from a mobile application | 030 – 060 (min 30) |
| **2** | Self-learning training with instructions from a mobile application and a preparatory web-based education | 060 – 090 (min 30+30) |
| **3** | Self-learning training with instructions from a mobile application and reflective questions | 045 – 075 (min 30+15) |
| **4** | Self-learning training with instructions from a mobile application, a web-based education and reflective questions | 075 – 105 (min 30+30+15) |
| **5** | Self-learning training with instructions from a video film | 060 – 090 (min 60) |
| **6** | Self-learning training with instructions from a video film and a web-based education | 090 – 120 (min 60+30) |
| **7** | Self-learning training with instructions from a video film and reflective questions | 075 – 105 (min 60+15) |
| **8** | Self-learning training with instructions from a video film, a web-based education and reflective questions | 105 – 135 (min 60+30+15) |
| **9** | Instructor-led training with instructions from a video film (control-group) | 075 – 105 (min 60+15) |
| **10** | Instructor-led training with instructions from a video film and a web-based education | 105 – 135 (min 60+15+30) |
| **11** | Instructor-led training with instructions from a video film and reflective questions | 090 – 120 (min 60+15+15) |
| **12** | Instructor-led training with instructions from a video film, a web-based education and reflective questions | 120 – 150 (min 60+15+30+15) |
| **13** | Instructor-led training with instructions from a video film and feedback from a compression depth device | 090 – 120 (min 60+15+15) |
| **14** | Instructor-led training with instructions from a video film, a web-based education and feedback from a compression depth device | 130 – 160 (min 60+15+30+15) |
| **15** | Instructor-led training with instructions from a video film, reflective questions and feedback from a compression depth device | 105 – 135 (min 60+15+15+15) |
| **16** | Instructor-led training with instructions from a video film, a web-based education, reflective questions and feedback from a compression depth device | 135 – 165 (min 60+15+30+15+15) |

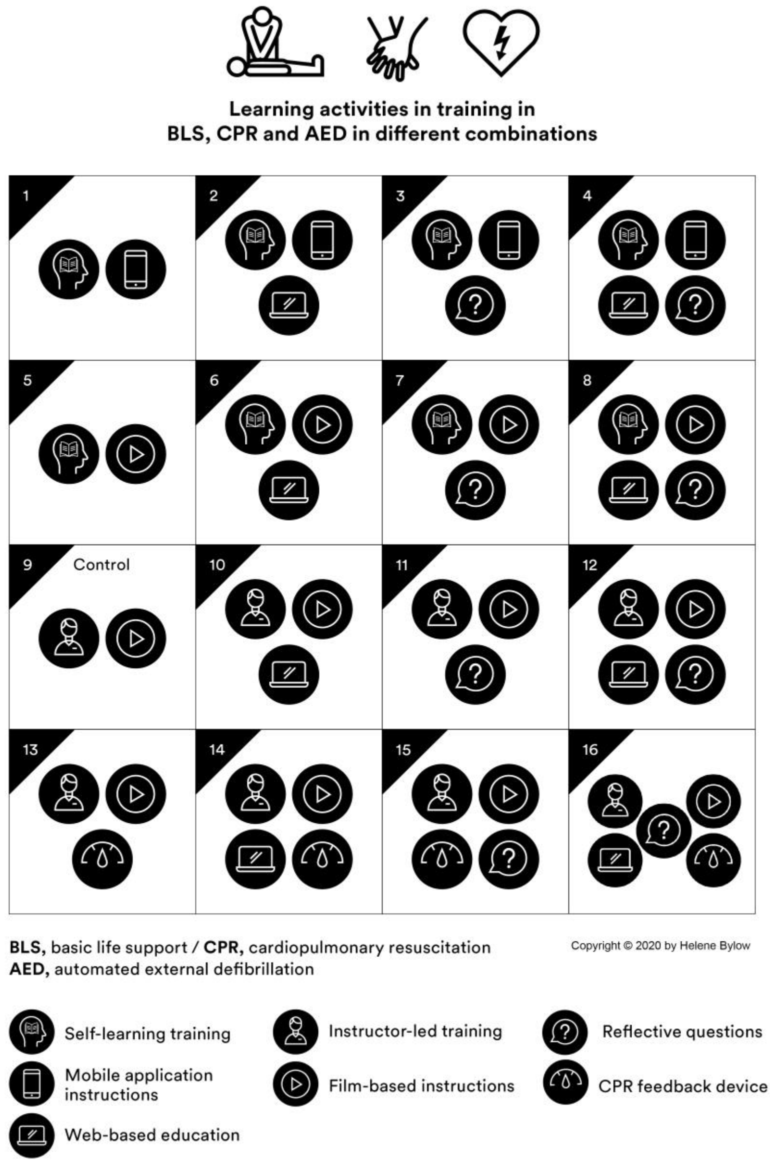



Figure 12. Learning activities in basic life support (BLS), cardiopulmonary resuscitation (CPR) and automated external defibrillator in different combinations, 1-16 (produced by the author)

### *The organisation of the BLS training*

All the learning activities were organised by a co-ordinator at each workplace. The co-ordinator administered the project and delivered the interventions to the participants according to the randomisation list. The co-ordinator handed out the self-learning material and organised the instructor-led courses. The BLS instructor then facilitated and taught as an instructor in the education according to the intervention. The co-ordinator at the workplace organised the time schedule for the follow-up for all participants directly after the training and six months after the training.

The instructor-led training was facilitated overall by sixteen experienced, independent, nationally certified BLS instructors. One or mostly two instructors facilitated the courses. The instructors' experience comprised around or more than ten years of consistent teaching in BLS at workplaces. Their professional background was assistant nurses educated at high school, working outside hospital in administrative services and municipal activities, registered nurses educated at college or university, working at occupational health care, lifeguards working as swimming pool attendants and other municipal services with basic education at high school. Half the instructors were women and half were men and they were between 35 and 55 years of age. The instructors were updated and re-trained on the medical and educational BLS guidelines. The instructor both facilitated and taught by introducing the course, some theoretical knowledge and practical skills and by answering questions and helping the participants with the technique to achieve the learning objectives. The participants practised while watching the film and the film instructor. The instructor helped and visually assessed, gave feedback and corrected the participants' technique on the spot. The instructor was able to pause the film if necessary. There was no formal assessment at the end of the course.

## Study IV

Study IV was a retrospective, observational, population-based register study. The design was intended to explore 30-day survival from OHCA at different locations in relation to OHCA with the location at workplaces outside hospital in Sweden. Factors to be considered in a register-based study are confounders, such as the age of the patient, which may influence the measured outcome, differences in the patients' baseline characteristics and missing values. In Study IV, only cases with complete data were used and the analyses were adjusted for possible confounders.

Globally, the 30-day survival from OHCA at workplaces outside hospital has been described as higher than survival at other places outside hospital [23-26]. In Sweden, the characteristics and outcome of OHCA at workplaces are poorly described and need to be further explored. An observational and descriptive register-based design is therefore appropriate. The reporting of Study IV, the register-based study, was mainly according to the Utstein style [3, 27].

# Population

The study population in Studies I-III comprised laypersons at workplaces. The study population in Study IV comprised OHCA patients reported to the SRCR.

## Studies I-III

The study population in Studies I-III consisted of a strategic sample of laypersons working at the included workplaces. To reach the study population, brief information in an announcement aimed at workplaces outside hospital was published in a local newspaper. Local BLS instructors and a network for BLS instructors were also informed and asked to spread the invitation to workplaces. There was no answer to the announcement. The co-ordinators at the workplaces said afterwards that some of them had seen the announcement, but the decision to participate was taken after contact and information from the BLS instructor. The decision to participate was also taken after encouragement at the workplaces from some employees who had heard about the BLS research project. The workplaces informed all their employees and encouraged them to participate.

A total of 84 workplaces in the south of Sweden in the community outside hospital agreed and were registered to participate. Among them, 2,623 employees, laypersons, signed up and were included. This means that both the workplaces and the participants were a strategic sample. We did not stratify the study population for variables such as gender, age, type of work, size of workplace, cultural or socio-economic background, for reasons of convenience. The workplaces consisted of industrial workplaces, factories, construction sites, industrial businesses, public businesses, educational institutions, companies, public offices, municipal workplaces such as administrative staff, individual, family and social care, occupational therapy, teachers, kitchens and restaurants, cleaning, forest workers, caretakers, services and sanitation**.** The groups of working individuals were practical workers (blue collar) and administrative workers (white collar). The educational level was elementary school, high school, college and university.

Information about the inclusion and exclusion criteria was given both to the workplaces and to the participants. The inclusion criteria were laypersons, working at the registered workplace outside hospital, without previous BLS training at all or more than five years ago and being eighteen years of age or older. The exclusion criteria were healthcare professionals and missing at the six-month follow-up retention test. The workplaces and the participants were given both oral and written information. Written informed consent was obtained from all the participants. The consent form was stored in a safety deposit and was separated from the identification code. The informed consent is presented alongside Study I.

### Study IV

The population in Study IV comprised patients in the SRCR. The data were obtained through an application for the disclosure of data on cardiac arrest occurring outside hospital from 2008 to 2018. The ethical application was approved by the Swedish Ethical Review Authority on 28 October 2019 (2019-04066). Informed consent was not waived since the study population is unknown in a register-based study design. Patients who survive to three months are given information about the registration in the SRCR. The patients are given the opportunity to withdraw their data from the register at that time. This was not relevant in this study.

The variables asked about were baseline characteristics, aetiology, location of the arrest, delays to EMS alert and arrival, if and by whom the arrest was witnessed, treatments and survival to 30 days. The inclusion criteria were EMS-reported patients with OHCA in whom resuscitation was attempted who were 18 years of age or older. The exclusion criteria included cases with missing data.

## Data collection

To compare the learning outcome after training in BLS in Studies I-III, the data were collected from the participants' performance in a test of practical skills in BLS and from the answers to a questionnaire on theoretical and self-assessed knowledge of BLS and confidence and willingness to act in a real-life OHCA. To describe and compare the 30-day survival from OHCA in Study IV, the data were collected from patients registered in the SRCR.

## Studies I-III

The data collection in Studies I-III was performed by the investigator (HB) from 2014 to 2016. The investigator was blinded to the 16 different interventions allocated to the participants according to the PROBE design [327]. The co-ordinator at the workplaces organised the activities and a follow-up schedule for the participants. The co-ordinator was independent of the test and the investigator was independent of the participants' allocated interventions. The participants were aware of a follow-up but not the test situation with the collection of data. For logistical reasons, a converted motorhome was used to collect data from the practical test. The motorhome was parked in different specific central places which were easily accessible for the participants. The motorhome was converted into a simulation studio in a private setting. The sofa had been removed to create a floor on which to place the training manikin. A table and a chair for the participant and a chair for the investigator were left. A video camera was mounted on the wall and the data equipment was placed on a table. As a reserve, equipment and equal training manikins and training AEDs were prepared.

### *Questionnaires*

The questionnaires were based on the overall aim of the study, a pilot study [322] and previous studies [251, 302, 332-337]. The questionnaires were designed to be answered by all the participants directly after the training and six months after the training. The paper-based questionnaires included 38 closed, semi-optional, multiple-choice and open-ended questions. The questions were about background factors such as a personal code number, training and follow-up dates, age, gender, weight, height, language, education, occupation and previous own CVD or a relative who had suffered a CVD, stroke, suspected AMI or cardiac arrest. They also comprised self-assessed theoretical and practical knowledge to perform chest compressions, ventilations and instructions from an AED, self-assessed confidence and willingness to act and start CPR on a relative and on an unknown person and use an AED, theoretical knowledge of the symptoms of stroke and AMI, first action in the event of stroke, AMI or cardiac arrest and healthy lifestyle factors.

The scoring system for the questions on the theoretical knowledge of symptoms of stroke and AMI, first action in the event of stroke, AMI or cardiac arrest and healthy lifestyle factors was one point for a correct answer and zero points for either an incorrect answer or for the answer, do not know. The minimum and maximum score for first action was 0-1 point, for stroke 0-7 points, for AMI 0-9 points and for healthy lifestyle factors 0-6 points. Symptoms of CVD may differ for different people and situations and we therefore used classical symptoms. At the time at which the Help-Brain-Heart web-based education was being developed, the interdisciplinary working group discussed these symptoms and healthy lifestyle factors and considered them classical.

### *Practical test*

The practical skills test (Cardiff Test) was conducted for the primary endpoint of six months after training, as practical skills have been shown to deteriorate within three to six months after training [16, 17, 28, 29]. Six months was previously recommended [52] and it was regarded as relevant for the present study at workplaces. For the secondary endpoint, the test was conducted directly after training to demonstrate the initial level of skills acquisition [52]. A baseline test was not conducted, as the test itself was regarded as a learning situation and could distract the participants.

The test was conducted as the intended ERC assessment in BLS with a structured simple OHCA scenario [29]. The environment was as close as possible to a real-life situation and close to identical for all participants. The test was individual and only the assessor, i.e. the investigator, was present. Essential skills from the training in BLS were assessed. The sheet for checking the practical skills has previously been validated, evaluated and modified to match the current guidelines and has been used in previous research [191, 251, 338]. This was an outcome-based test for assessing the learning outcomes in BLS training. At the time in Sweden and for the present study, there was no formal assessment at the end of the course in BLS. The participants were therefore not informed of any assessment at all.

The equipment used in the test was a Resusci Anne full-body manikin and a Heart-Start 1 AED trainer (Laerdal Medical AS, Stavanger, Norway). The training manikin was wearing a private sweater and a pair of pants and was lying on a mat on the floor. The training AED was not visible at the start. BLS practical skills were measured automatically by the PC Skill Reporting system software V.2.4 (Laerdal Medical, Stavanger, Norway) commonly used in previous studies [191, 251, 337, 338].

The variables that are automatically measured on the training manikin were check responsiveness by shaking, check breathing, chest compression position, depth, rate and total number, ventilation volume, rate and total number, compression-ventilation ratio, time to start of CPR and time to shock, total hands-off time and chest compression incomplete release. Some variables were also checked by direct observation by the assessor, such as check responsiveness and breathing, call for help, 112, and ask for an AED and time to first shock. The time was measured by the system and with a manual stopwatch. All the measured variables were automatically presented and saved in a data document and all the variables were transferred to the test scoring sheet. The scenario was filmed by a mounted Sony HD video camera to check the observations after the test [52].

The equipment was calibrated automatically and checked manually every day. The PC Skill Reporting system was calibrated and was reset automatically at every start, mostly twice a day. This means that the system was self-calibrated and reset to a zero value. The depth of the compressions and the volume of the ventilations were measured by an encoder which recorded the start and the end of the chest compressions and the ventilations. Each stripe on the encoder corresponded to 1 mm. The depth of the compressions was counted as 1:1. For the ventilations, each millimetre for the rise of the chest was translated to the ventilation volume by a fixed table. There was some concern about the chest compressions on the training manikin connected to the PC Skill Reporting system. The current guidelines recommended a chest compression depth of 50-60 mm and the PC Skill Reporting system v.2.4 only measured up to 60 mm. Not being able to measure above 60 mm was a limitation. However, at the time, we decided to use this validated equipment.

In a traditional assessment of training in BLS, the equipment should be close to the training situation or the participants should be given the time to make themselves familiar with the equipment and ask questions [17, 29]. For the purpose of the present research, this was not applied and a short, standardised introduction was given to all the participants. The reason was that an interaction between the assessor and the participants could occur and result in a learning situation and distract the participant. The training manikin and the training AED were different from the training situation and this was meant to create an equal situation for the participants and showed the difference from a learning situation to a real-life OHCA situation and could be discussed as a limitation.

The participant was first briefly introduced to the follow-up meeting and the test situation sitting in the chair opposite the assessor. After permission from the participant for the test and the video recording, the briefing for the scenario was started by the assessor with the following story.

> *You are at work. A colleague looks pale, puts her/his hand in the middle of her/his chest and says, 'I have chest pain' and then suddenly collapses in front of you. Act as if it is a real-life situation!*

Directly after the story, the assessor showed with a gesture in total silence as recommended for assessment [52] towards the training manikin, started the PC Skill Reporting System and the stopwatch. The test lasted for about five minutes. Three minutes were required for the participant to be able to recognise the OHCA victim, shout for help, call for 112, ask for an AED and perform CPR. At three minutes from the start of the scenario, the assessor placed the AED next to the manikin. About two minutes were required to use the AED. The test was terminated after one shock had been delivered and the resumption of CPR. In total, the time for the follow-up was 15 minutes – five minutes to step into the motorhome with a short briefing, five minutes for the test and five minutes to terminate the scenario with a few comments and drying the sweat by the participant and liquor for the manikin and to step out of the motorhome. There was no learning feedback or learning situation after the assessment by the assessor. Interaction with the assessor could affect the result of the trial when comparing different learning activities and was therefore avoided [52].

### *Cardiff Test of basic life support and automated external defibrillation*

The practical skills test was based on the validated Cardiff Test of basic life support and automated external defibrillation [52, 339]. The Cardiff Test was described as a prototype for assessment in detail in the ILCOR advisory statement from an Utstein symposium in Stavanger, Norway, in 2001 [52]. The test was originally developed in an educational setting in Cardiff, Wales, in the UK. The ILCOR symposium in Utstein stated that there was a need for a change in randomised clinical trials to explore the courses in BLS for laypersons to improve the training and increase the quality of performed CPR. A scoring system like the Cardiff Test was regarded as objective. The checklist could also be modified to match the current guidelines. Strategies for the education of adults should be established with learning objectives to bring about a change in the participants' behaviour and in a potential resuscitation attempt. An outcome-based template for research like the Cardiff Test to assess the participants was recommended directly after the training and six months later. A mechanical training manikin connected to a practical skills reporting system for the automatic recording of compressions and ventilations was required. The statement also stated that one person as an assessor was enough and, together with previous studies [52, 191, 251, 337, 338], this strengthened the decision to use the Cardiff Test in the studies. The assessment was videotaped as recommended [52] and the tape was checked after the test. The test was modified to match the 2010 ERC guidelines and the 2011 SRC guidelines. In the 2000 ERC guidelines, the check for pulse was removed for laypersons [312] and the checklist was therefore modified.

To compare learning outcomes, the variables in the modified Cardiff Test were in accordance with the learning outcomes and the BLS algorithm. The total score of 19-70 points was based on the variables in the Cardiff Test modified to match the BLS algorithm and the current guidelines. The minimum score of 19 points was calculated as one point for each variable in the test. Even if the variable was not performed, this was the minimum score. The maximum score of 70 points was calculated for maximum adherence to each variable in the test. To obtain a measurement of the quality of performed skills in relation to optimal performance in per cent, we used a calculation (individual total score - 19 points)/maximum total score -19) x 100.

### Study IV

The data collection, i.e. the registration in the SRCR, was organised in three steps. Firstly, the data were collected by the EMS personnel who prospectively registered the OHCA incidence as a case in an Utstein-based template in a database. In most cases, this first registration was performed directly after the patient had arrived in hospital or resuscitation was terminated at the scene. Secondly, a report was registered by a co-ordinator, a member of the healthcare staff in the EMS or hospital organisation [94, 316]. In this part of the procedure, some retrospective data were collected from in-hospital records. Thirdly, the data were extracted from the register by the register holder of the SRCR and the data were thus collected for Study IV. The data were extracted from 2008 to 2018, apart from the variable that showed whether the patient had received a shock from an AED before the arrival of the EMS, which was only available from 2009. The collected data, i.e. the variables, were baseline characteristics of the OHCA patients (by the EMS personnel), delays to calling for the EMS (by the bystander), delays to treatments (by the bystander, the EMS dispatcher and the EMS personnel) and survival to 30 days.

# Outcome

Outcome is described as primary outcome and secondary outcome to cover the aim of each study. Together, the outcome variables were set to answer the research questions and to expand knowledge of learning activities for BLS at workplaces, the characteristics of the patients in cardiac arrest, the treatment and the 30-day survival from OHCA at workplaces.

## Studies I-III

The primary outcome was the total score for the modified Cardiff Test six months after training in BLS. The primary outcome reflected the participants' practical skills, adherence to the learning outcomes and the BLS algorithm in a simulated OHCA scenario. The effectiveness of an educational intervention is the acquisition of practical skills, psychomotor skills and the retention of these skills. The secondary outcome was the total score for the modified Cardiff Test directly after training in BLS and the quality of individual and separate variables, theoretical knowledge, self-assessed confidence and willingness to act in a real-life situation of OHCA, both directly and six months after training. The secondary outcome reflected the practical skills directly after the training in BLS and the participants' direct utilisation of the training. All these outcome variables may indicate the effect of the interventions and the different learning activities and whether a participant subsequently as a potential bystander has the self-efficacy and willingness to really start a life-saving action in the event of an OHCA.

## Study IV

In the register-based study of characteristics and outcome after OHCA with the emphasis on workplaces, the outcome variable was 30-day survival for EMS-reported cases of OHCA and factors associated with outcome. For definitions of the location of the arrest, the updated Utstein-style template in 2015 recommended the variable of EMS treated [3, 27]. This term is therefore used for the outcome variable, even if the term EMS reported is also used, as in this thesis according to the SRCR [9, 340, 341].

# Data analyses

In the studies, various statistical analyses were applied and performed, depending on the study design, the aims and the properties of the data for each study. The data analyses for each of Studies I-IV are summarised in Table 1.

## Studies I-III

In Studies I-III, all the available data were included, regardless of whether data were available on both occasions or not.  In Study I a (Data in Brief), the analysis of change from post-test directly after training to the retention test six months after training, only participants with data available on both occasions were included.

In Studies I-II, patient characteristics and results are presented as crude numbers and proportions (per cent), crude means with standard deviation (SD) or crude medians with corresponding 25th and 75th percentiles. In Study III, patient characteristics are presented as percentages or medians and the results are presented as least square means (lsmeans) with corresponding standard errors for each intervention group, together with 95% confidence intervals and p-values, for the difference from the standard intervention group, adjusted for multiple comparisons using Dunnett's method.

In Studies I and II, to detect a two-point difference in the means of the total score for the modified Cardiff Test at the retention test after six months (primary outcome), with an assumed standard deviation of five points, significance level of 5% (two-sided test) and a power of 95%, an effective sample size of 163 participants in each of the two training groups would be needed. The intraclass correlation coefficient was 0.080 in Study I and 0.062 in Study II. Based on an average cluster size of 23.2 and 23.4 respectively, the design effect caused by the cluster randomisation was calculated to be 2.78 and 2.40, respectively. In Study I, 670 and 567 individuals in respective training group performed the retention-test, which corresponds to an effective sample size of 241 and 202, respectively, and in Study II, 1,268 and 1,212 performed the test, corresponding to an effective sample size of 529 and 506, respectively, i.e., in both Studies I and II both groups were well above the number needed to reach a power of 95%.

Mixed linear regression models were applied to account for potential cluster effects in Studies I, II and III regarding comparisons of continuous measurements. For comparisons of proportions (Studies I and II only), generalized estimation equations (GEE) analysis with logit link function was applied, unless proportions were very small (<1.0%) where Fisher's exact test was used (i.e. without accounting for clustering).

In Study I a (Data in Brief), analyses of change from post-test to retention-test were performed using Wilcoxon's signed rank test for paired comparisons of clustered data [342] and Obuchowski's modified McNemar's test for clustered paired data [343] for continuous and dichotomous variables respectively. In the event of very small percentages (<1.0%) regarding the latter, the standard McNemar's exact test, without accounting for clustering, was used.

Due to the imbalance between the two training groups compared in Studies I and II, regarding some of the participant characteristics, comparisons between the groups were adjusted for the possible confounding influence of age (II), gender (I), educational level (I+II), occupation at training (II) and previous CPR training (I). We also accounted for the possible effect of additional interventions in these studies (i.e. web education and reflective questions in Study I and instructor-led training, film instructions, reflective questions and the feedback device on chest compression depth in Study II). In Study III, comparing each separate intervention group with a standard, adjustments were made for the possible confounding influence of age, gender, body mass index (BMI), mother tongue, educational level, occupation at training, previous CPR training and previous training on AED use. To describe the practical relevance of the results regarding the total Cardiff Test score for practical skills in Study III, we estimated the effect size by using Cohen's d, for comparisons with the standard training group.

All tests in Studies I-III were two-sided and p-values below 0.05 were considered statistically significant. SAS for Windows version 9.4 was used for all the performed analyses.

### Study IV

In Study IV, descriptive statistics, such as baseline characteristics, were presented with means, medians and proportions, with the appropriate measurement of dispersion. We did not perform hypothesis testing for baseline characteristics. P-values near 0.05 for statistical significance have been discussed regarding statistical inference (Wasserstein RL, Lazar NA. The ASA Statement on p-Values: Context, Process, and Purpose. The American Statistician. 2016; 70:129-33). Following discussions, we decided not to perform the hypothesis testing. Comparisons of delay to CPR and delay to defibrillation between all locations of OHCA were used with medians.

The 30-day survival was analysed using multivariate analyses, i.e. multiple logistic regression. The location of the cardiac arrest was the predictor of main interest. The models were adjusted for age, gender, location and calendar year as potential baseline confounders. One regression model was computed for the entire study population. Separate regression models were computed for OHCA cases with a shockable and a non-shockable rhythm.

Factors associated with outcome, 30-day survival after OHCA with all locations of arrest included, in a model with additional covariates, i.e. witnessed arrest, bystander CPR, defibrillation, initial rhythm, the use of adrenaline and cause of arrest, were calculated using logistic regression analyses. The data were expressed as the odds ratio (OR) with 95% confidence intervals (CI). An OR of >1 was regarded as higher odds of 30-day survival after OHCA. The OR of 30-day survival was also presented for OHCA at workplaces and was calculated separately with logistic regression.

Missing data in Study IV were assumed to be missing at random (MAR). For most of the variables, information was missing. For logistical reasons in reporting, a minority of OHCA cases in Sweden may not have been reported to the SRCR. Excluded cases with missed variables in Study IV were summarised in a supplementary data file (Appendix A1, Study IV) with missed variables, all cases and a complete case report. The baseline characteristics for missed data did not differ from those of the cohort which were consistent with the findings in the study. We also compared age and gender for interaction in the regression analysis but there was no significant difference (p=0.1).

For all the analyses, we used the R statistical software, version 4.0.1, for statistical computing and graphics (Computing TRFfS, Mathematics coIfSa. The R Project for Statistical Computing [344].

## Ethical considerations

The studies included in this thesis were conducted in accordance with the principles of the Declaration of Helsinki, developed by The World Medical Association and the principles of autonomy, with respect for human rights [345]. Ethical vetting is currently always present in recommendations, rules and regulations for scientific research and was considered throughout the present thesis.

### Studies I-III

The ethical considerations of the trial were carefully discussed and formulated in an ethical application. Ethical approval by the Regional Ethical Review Board in Gothenburg was granted on 23 March 2014, with registration number 2014/134-14. Study participation was voluntary. All the participants had given their informed consent to participate in the research. They were informed about their right to withdraw from participation at any time. From an ethical perspective, training in BLS may raise different questions about life and death. The mortality for OHCA is 90 per cent and most of the patients are not alive 30 days after suffering an OHCA. There are humane reasons for learning and trying to save someone else's life, but some of the participants may have previous experiences and psychological reactions may occur in connection with the BLS training. The Work Environment Act (SFS 1977:1160) [130] includes recommendations for occupational safety to prevent illness and accidents and recommendations for first aid and crisis support (AFS 1999:7) [259]. The workplaces have preparedness and routines for crisis support in the event of psychological reactions among the employees. No time was planned for an ethical follow-up regarding the participants' questions and ethical aspects of training in BLS or OHCA. The information contained written contact details for the investigator and the supervisor, and the participants were encouraged to talk to the co-ordinator at the workplace in the event of questions and problems. In the instructor-led training, there were opportunities to talk to the instructor and the other participants, but, in the self-learning interventions, they were alone. However, we considered that there was a little or no risk of burdens for the individuals.

### Study IV

The ethical considerations of the register-based study were discussed and formulated in an ethical application. The Swedish Ethical Review Authority approved the ethical application on 28 October 2019, with registration number 2019-04066. The design with a retrospective analysis meant that it was not possible to obtain informed consent from the unconscious patients or from relatives in the acute cardiac arrest situation. A standardised follow-up meeting by the SRCR is organised three to five months and 11 months after the arrest. At this time, the patient is able to ask questions and discuss ethical issues. The patients receive both written and spoken information about the registration in the register. They are also informed about the opportunity to apply for a copy of the registration and to withdraw their data from the register.

# Results

This section presents the results of the analyses and comprises the following:

- Studies I-III, including characteristics of the study population, practical skills in each study and theoretical knowledge, confidence, willingness and theoretical knowledge of stroke, AMI and healthy lifestyle factors
- Study IV, including characteristics of the study population, 30-day survival from OHCA and factors associated with the outcome after OHCA at workplaces.

# Studies I-III

In educational research on training in BLS, seven different learning activities were explored in 16 combinations, of which one was the control group and the national standard training in BLS. The participants (n=2,623) from 84 workplaces were cluster randomised to one of 16 interventions. Three separate cluster RCTs with separate analyses were performed (Studies I-III).

## Characteristics of the study population

The characteristics of the study population in Studies I-III and the numbers of participants in each learning activity are summarised in Tables 3-5.

*Table 3. Characteristics of the study population in Studies I-III (Data in Study III)*

| **Characteristics, n=** | **2,529** |
|---|---|
| Age (median) | 45 |
| Female gender (%) | 57 |
| BMI (median) | 24.8 |
| Swedish mother tongue (%) | 86 |
| Educational level: | |
| - Elementary school (%) | 9 |
| - High school (%) | 49 |
| - College/university (%) | 42 |
| Occupation at training: | |
| - Blue collar, practical work (%) | 40 |
| - White collar, administrative work (%) | 39 |
| - Both (%) | 20 |
| No previous CPR training at all (%) | 36 |
| No previous AED training at all (%) | 80 |
| No previous CPR training within five years (%) | 64 |
| No previous AED training within five years (%) | 20 |
| Experienced OHCA (%) | 8 |

*Table 4. Characteristics by interventions, 1-16*

| **Intervention** | **n=** | **Age** | **Gen-der, female** | **BMI** | **Swe-dish mot her tong ue** | **Educa-tional level, elemen-tary/ high/ college** | **Occupa-tion, blue/ white/ both** | **No previ-ous train-ing in CPR/ AED** | **Ex-peri-ence d SCA** |
|---|---|---|---|---|---|---|---|---|---|
| **Number** | Numbers | Median | % | Median | % | % | % | % | % |
| **1** | 162 | 43 | 60 | 24.8 | 85 | 5/43/52 | 44/48/8 | 40/76 | 9 |
| **2** | 175 | 38 | 51 | 23.7 | 83 | 18/61/21 | 24/40/36 | 40/78 | 5 |
| **3** | 180 | 46 | 65 | 24.0 | 90 | 7/46/47 | 26/39/36 | 31/73 | 6 |
| **4** | 159 | 44 | 32 | 25.4 | 88 | 7/39/54 | 19/39/42 | 31/70 | 10 |
| **5** | 151 | 48 | 62 | 24.5 | 87 | 8/54/38 | 50/38/12 | 32/87 | 7 |
| **6** | 167 | 43 | 70 | 24.3 | 87 | 3/30/67 | 25/40/36 | 37/82 | 7 |
| **7** | 206 | 44 | 73 | 25.0 | 84 | 4/50/46 | 45/51/4 | 31/76 | 5 |
| **8** | 154 | 47 | 64 | 25.7 | 85 | 10/33/58 | 46/21/32 | 37/85 | 11 |
| **9** | 141 | 48 | 40 | 25.2 | 86 | 21/54/26 | 59/37/4 | 54/74 | 9 |
| **10** | 122 | 48 | 43 | 25.1 | 84 | 7/55/38 | 42/39/19 | 34/85 | 13 |
| **11** | 154 | 48 | 37 | 25.1 | 92 | 14/52/34 | 42/36/22 | 43/82 | 8 |
| **12** | 163 | 47 | 59 | 24.5 | 93 | 6/48/46 | 23/45/31 | 39/85 | 7 |
| **13** | 141 | 48 | 63 | 24.8 | 75 | 20/46/34 | 57/40/3 | 32/76 | 8 |
| **14** | 157 | 43 | 63 | 25.2 | 85 | 6/48/45 | 32/43/24 | 38/85 | 5 |
| **15** | 158 | 46 | 65 | 25.6 | 90 | 6/65/29 | 70/27/3 | 25/79 | 12 |
| **16** | 139 | 44 | 50 | 25.1 | 86 | 4/58/38 | 50/43/6 | 30/83 | 6 |

Age and body mass index (BMI) are presented as the median. Gender, Swedish mother tongue, highest educational level from elementary school, high school or college, occupation at training (blue collar, white collar, both collars) and previous training in cardiopulmonary resuscitation (CPR) and automated external defibrillation (AED) and previous experienced a sudden cardiac arrest (SCA) situation are presented as per cent (%)

*Table 5. Learning activities with numbers of participants in Studies I-III*

| **Learning activity** | **n=** |
|---|---|
| Self-learning training | 1354 |
| Instructor-led training | 1175 |
| Mobile phone/tablet application instructions | 676 |
| Film-based instructions | 1853 |
| Web-based education prior to training in BLS | 1236 |
| Feedback device on chest compressions | 595 |
| Reflective questions at the end of the training | 1313 |
| The values are presented as crude numbers. In Study I, the learning activities with BLS instructions by a mobile phone or tablet and a feedback device on chest compressions was not included | |

## Practical skills

The primary outcome in Studies I-III was the total score for practical skills in BLS calculated using the Cardiff Test of BLS and AED (19-70 points). The mean total score from all the Cardiff Tests including all the participants in all 16 interventions was 59.1 (84%) directly after training and 58.4 (83%) six months after training.

### *Practical skills Study I*

In Study I, data from comparable groups in the study design were included. The main interventions comparable in both study arms were the learning activities of self-learning, instructor-led learning, film-based instructions, web-based education and reflective questions. In Study I, 1,301 participants were allocated and cluster randomised to self-learning or instructor-led training in BLS. Of these, 1,231 participants were included in the analysis. The reason for missing data was that 15 participants from the self-learning group and 28 participants from the instructor-led group did not perform any of the practical tests due to shortage of time, physical or mental reasons. From the self-learning group, eight participants and, from the instructor-led group, 19 participants were missing at the retention test, six months after training. The reasons were that they experienced stress, a shortage of time, physical or other reasons. There were logistical reasons or technical reasons for incomplete data at post-test, directly after training, for 17 participants in the self-learning group and 40 participants in the instructor-led group and only the retention test at six months was therefore included in the analysis.

The total score for practical skills in Study I (Table 6) at post-test, directly after training, was a median of 59 points for the self-learning group (IQR 56-62) and 61 points for the instructor-led group (IQR 58-63). This indicates a significant difference ($p < 0.0001$) between the groups in favour of the instructor-led training for the secondary outcome. The total score for practical skills at the retention test, six months after training, was a median of 59 points (IQR 55-62) in the self-learning group and 59 points (IQR 55-63) in the instructor-led group. As presented, there was no statically significant difference ($p=0.44$) between the two BLS training groups for the primary outcome. Changes in the total score on the Cardiff Test of practical skills from directly after training to six months after training in BLS were higher in the instructor-led learning group ($p=0.0001$) compared with the self-learning group (Study I a, Data in Brief).

The quality of individual variables in the Cardiff Test was higher in the instructor-led group directly after training for opening the airway by head tilt and chin lift, checking breathing, asking for an AED, total correct compressions counted, total correct ventilations counted, attaching electrodes correctly, checking safety and resuming CPR immediately after shocking. The quality of individual separate variables showed that the delay to starting CPR ($p=0.008$) and the delay to the first shock ($p=<0.0001$), directly after training, were lower and in favour of the instructor-led group. However, six months after training, there was no difference between the groups.

*Table 6. Total score Cardiff Test of practical skills in basic life support (BLS), cardiopulmonary resuscitation (CPR) and automated external defibrillation (AED), self-learning training (SLT) compared with instructor-led training (ILT)*

| Total score | **Directly after intervention, post-test** | | | **Six months after intervention, retention test** | | |
|---|---|---|---|---|---|---|
| Min 19 Max 70 | SLT | ILT | | SLT | ILT | |
| Varia-bles | n=661 | n=540 | p-value | n=670 | n=561 | p-value |
| Median | 59 | 61 | <0.0001 | 59 | 59 | 0.44 |
| 25th, 75th percen-tile | 56,62 | 58,63 | | 55,62 | 55,63 | |
| Min, max | 37,69 | 44,68 | | 37,68 | 40,69 | |
| To account for potential cluster effects regarding comparisons of continuous measurement, mixed linear regression was used. Comparisons between the training groups were adjusted for the possible confounding influence of gender, educational level, previous CPR training and additional interventions as web-based education and reflective questions. All tests were two-sided and p-values below 0.05 were considered statistically significant | | | | | | |

### *Practical skills Study II*

In Study II, 2,623 laypersons were cluster randomised to BLS training with or without a preparatory web-based education. For the primary outcome of practical skills six months after training, 2,480 participants were included in the analysis. The reason for missing data was that 94 participants experienced a shortage of time or stress or mental or physical reasons for not participating and were excluded directly after training. For the same reasons as above, 49 participants were missing at the retention test, six months after training. The data at the test directly after training for 104 participants were incomplete or missing for logistical reasons, but they were complete at the retention test six months after training.

The total score on the Cardiff Test of practical skills (Table 7) was significantly higher (p=0.004) directly after BLS training in the web-based education group (mean 59.6, SD 4.8) than in the group without the web-based education (mean

58.7, SD 4.9). Moreover, the total score on the Cardiff Test of practical skills was significantly higher (p=0.03) six months after training with the web-based education (mean 58.8, SD 5.0) than without the web-based education (mean 58.0, SD 5.0).

Individual variables in the Cardiff Test directly after training showed a difference in favour of the web-based education group compared with the group without for the variables of asking for an AED (87.6% versus 78.3%, p=0.0001), attaching electrode pads completely in areas (93.4% versus 87.7%, p=0.0008) and resuming CPR immediately after shocking (93.6% versus 91.6%, p=0.04) respectively. Six months after training, there were several differences in favour of the web-based education group, such as checking for responsiveness by shaking (95.8% versus 92.5%, p=0.005), open airway perfectly as instructed (40.6% versus 34.5%, p=0.05), calling 112 (96.5% versus 93.8%, p=0.02), asking for an AED (86.8% versus 79.5%, p=0.0006) and attaching electrode pads completely in areas (94.3% versus 85.6%, p=0.0001). On the other hand, the correct hand position for chest compressions was better in the BLS training group without the web-based education (25.4%, p=0.02) compared with BLS training with the web-based education (20.0%) six months after training. This indicates a low rate of correct hand placement for chest compressions in both groups scored using the Cardiff Test.

Individual separate variables for practical skills directly after training showed that the web-based education group were more likely to perform overall chest compressions with the correct hand position, depth, rate and recoil (median 55, 25th, 75th percentiles 48, 59, p=0.04) compared with the group without the web-based education (median 54, 25th, 75th percentiles 46, 58), but there was no difference at six months. In addition, the participants with the web-based education were quicker to give the first shock in seconds compared with those without the web-based education (median 65 versus 68, p=0.004).

*Table 7. Total score Cardiff Test of practical skills in basic life support (BLS), cardiopulmonary resuscitation (CPR) and automated external defibrillation (AED), BLS with or without a web-based education*

| Total score | **Directly after intervention, post-test** | | | **Six months after intervention, retention test** | | |
|---|---|---|---|---|---|---|
| Min 19 Max 70 | BLS | BLS+ WEB | | BLS | BLS+ WEB | |
| Varia-bles | (n=1213) | (n=1212) | p-value | (n=1268) | (n=1212) | p-value |
| Mean | 58.7 | 59.6 | 0.004 | 58.0 | 58.8 | 0.03 |
| SD | ±4.9 | ±4.8 | | ±5.0 | ±5.0 | |
| Median | 60 | 60 | | 59 | 59 | |
| 25th, 75th percen-tiles | 56,62 | 57,63 | | 55,62 | 56,62 | |
| Min, max | 35,68 | 37,69 | | 41,69 | 37,69 | |

To account for potential cluster effects regarding comparisons of continuous measurement, mixed linear regression was used. Comparisons between the training groups were adjusted for the possible confounding influence of age, educational level, occupation at training and additional interventions as instructor-led training, film instructions, reflective questions and feedback device of chest compressions. All tests were two-sided and p-values below 0.05 were considered statistically significant

### *Practical skills Study III*

Study III was a multi-arm, parallel cluster RCT. A total of 2,623 laypersons at workplaces were cluster randomised to one of seven learning activities in 16 different combinations, of which number nine was the control group. For the primary outcome of practical skills six months after training, 2,480 participants were included in the analysis. The reason for missing data was that 94 participants directly after training and 49 participants six months after training experienced a shortage of time, stress, physical and mental reasons for not completing the retention test.

At the post-test, data from 104 participants were incomplete and 2,425 individuals were therefore analysed for primary outcome.

Including all 16 interventions, the mean total score on the Cardiff Test of BLS and AED (19-70 points) was 59.1 (84%) directly after training and 58.4 (83%) six months after training. When it came to the total score directly after training when comparing the BLS training interventions one by one with the control group, seven of the interventions scored marginally higher when adjusted for potential confounders. The control group, number nine, was the current standard BLS training and scored 58.0 ± 0.61 (lsmeans ± standard errors). Three of the interventions obtained significantly higher scores than the control group.

1) BLS training intervention number 12 included instructor-led learning, film-based instructions, a web-based education and reflective questions (lsmeans±st.err 60.5±0.54, 95% CI 0.3–4.8, p=0.02).

2) BLS training intervention number 14 included instructor-led learning, film-based instructions, a web-based education and a feedback device on chest compressions (lsmeans±st.err 60.5±0.57, 95% CI 0.2–4.8, p=0.02).

3) BLS training intervention number 16 included instructor-led learning, film-based instructions, a web-based education, a feedback device on chest compressions and reflective questions (lsmeans±st.err 60.8±0.57, 95% CI 0.5–5.1, p=0.008).

Six months after training, the primary outcome, the total score adjusted for potential confounders, showed that four interventions scored significantly higher than the control group (Table 8).

1) BLS training intervention number 10 included instructor-led learning, film-based instructions and a web-based education (lsmeans±st.err 58.1±0.58, 95% CI 0.1–4.4, p=0.03).

2) BLS training intervention number 11 included instructor-led learning, film-based instructions and reflective questions (lsmeans±st.err 58.5±0.55, 95% CI 0.5–4.7, p=0.006).

3) BLS training intervention number 14 included instructor-led learning, film-based instructions, a web-based education and a feedback device on chest compressions (lsmeans±st.err 58.1±0.52, 95% CI 0.2–4.3, p=0.02)

4) BLS training intervention number 16 included instructor-led learning, film-based instructions, a web-based education, a feedback device on chest compressions and reflective questions (lsmeans±st.err 58.8±0.54; 95% CI 0.9–5.0; p=0.001).

*Table 8. Total score Cardiff Test practical skills of BLS, CPR and AED, six months after training, at the retention test for interventions 1-8 and 10-16, compared with the control group, number 9 (Study III)*

| **1-16** | **UNADJUSTED** | | | **ADJUSTED#** | | |
|---|---|---|---|---|---|---|
| **N= 2,480** | lsmeans ±stderr* | 95% CI** | p** | lsmeans ±stderr* | 95% CI** | p** |
| **1** | 57.0±0.53 | -1.4–3.0 | 0.95 | 55.7±0.51 | -2.1–1.9 | 1.00 |
| **2** | 58.0±0.54 | -0.5–4.0 | 0.20 | 56.9±0.51 | -1.1–3.0 | 0.77 |
| **3** | 58.3±0.54 | -0.1–4.3 | 0.08 | 57.1±0.51 | -0.8–3.3 | 0.50 |
| **4** | 58.9±0.55 | 0.5–5.0 | 0.008 | 57.6±0.52 | -0.3–3.8 | 0.15 |
| **5** | 57.5±0.53 | -0.9–3.5 | 0.52 | 56.8±0.52 | -1.1–2.9 | 0.85 |
| **6** | 57.8±0.53 | -0.6–3.8 | 0.29 | 56.4±0.51 | -1.5–2.6 | 1.00 |
| **7** | 58.2±0.49 | -0.1–4.2 | 0.07 | 57.1±0.47 | -0.7–3.2 | 0.40 |
| **8** | 58.8±0.56 | 0.4–4.9 | 0.01 | 57.9±0.54 | -0.1–4.1 | 0.07 |
| **9** | 56.2±0.57 | Control group | | 55.9±0.54 | Control group | |
| **10** | 59.0±0.62 | 0.4–5.2 | 0.01 | 58.1±0.58 | 0.1–4.4 | 0.03 |
| **11** | 59.0±0.57 | 0.5–5.1 | 0.008 | 58.5±0.55 | 0.5–4.7 | 0.006 |
| **12** | 58.4±0.53 | -0.0–4.4 | 0.05 | 57.4±0.51 | -0.5–3.5 | 0.24 |
| **13** | 58.1±0.54 | -0.3–4.2 | 0.14 | 57.6±0.52 | -0.3–3.7 | 0.16 |
| **14** | 59.2±0.54 | 0.7–5.2 | 0.003 | 58.1±0.52 | 0.2–4.3 | 0.02 |
| **15** | 58.5±0.49 | 0.2–4.5 | 0.03 | 57.5±0.50 | -0.3–3.6 | 0.17 |
| **16** | 60.0±0.55 | 1.5–6.0 | <0.0001 | 58.8±0.54 | 0.9–5.0 | 0.001 |

# Adjusted for age, mother tongue, educational level, previous CPR training, gender, body mass index (BMI), occupation and previous AED use training using Dunnett's method for the difference of total score from the control group; * Least square means with corresponding standard errors (lsmeans±st.err); CI, confidence interval; p, p-values below 0.05 were considered statistically significant; ** For comparison with the control group

### Theoretical knowledge

Theoretical knowledge of the first action if a person suffers an OHCA, i.e. calling 112, did not differ significantly directly after training or six months after training between the self-learning group (83.9%, 73.5%) and the instructor-led group (84.9%, 68.2%) respectively. On the other hand, the correct answers in both groups were remarkably low (Study I). When comparing the answers from the participants in the BLS training with and without the web-based education (Study II), the web-based education group scored significantly higher both directly after (88.7% versus 77.1%, p=0.0001) and six months after (74.7% versus 66.5%, p=0.001) the training. As mentioned before, awareness of calling 112 directly was low in both groups. This question on first action can also be interpreted as an intention to call 112 and we do not know if the participants were intending to call after some other actions.

The participants in the instructor-led group self-assessed their theoretical knowledge and practical skills of being able to perform chest compressions, ventilations and use the AED as higher than in the self-learning group, both directly and six months after training (Study I). When comparing the BLS training group with or without the web-based education (Study II), there was no difference (Table 9). Overall, theoretical knowledge is described in Study III, when compared with the control group (number 9), the standard training in BLS with the four interventions that obtained a higher Cardiff Test score on practical skills of BLS after comparing all interventions (Study III, Supplementary file 5, Table 6a and 6b).

*Table 9. Self-assessed theoretical knowledge and practical skills to be able to perform chest compressions (CC), ventilations and use the automated external defibrillator (AED), when compared self-learning training (SLT) with instructor-led training (ILT) and BLS with or without a web-based education (WEB)*

| Study, % | **Post-test, directly after training** | | | **Retention test, six months after training** | | |
|---|---|---|---|---|---|---|
| **I** | **SLT** | **ILT** | | **SLT** | **ILT** | |
| | n=661 | n=540 | p | n=670 | n=561 | p |
| CC | 95.4 | 98.2 | 0.009 | 97.3 | 98.3 | 0.19 |
| Vent | 94.9 | 98.6 | 0.0005 | 96.9 | 98.7 | 0.03 |
| AED | 85.9 | 97.1 | <0.0001 | 93.7 | 97.0 | 0.03 |
| **II** | **BLS** | **BLS+WEB** | | **BLS** | **BLS+WEB** | |
| | n=1213 | n=1212 | p | n=1268 | n=1212 | p |
| CC | 96.7 | 96.1 | 0.12 | 97.1 | 98.1 | 0.33 |
| Vent | 96.6 | 96.5 | 0.34 | 97.1 | 97.8 | 0.66 |
| AED | 91.4 | 91.4 | 0.55 | 95.1 | 95.4 | 0.91 |

## Confidence

Confidence directly after training in BLS was higher in the instructor-led group (99.6%) than in the self-learning group (97%), but there was no difference six months after training (Study I). The participants in the BLS training with and without the web-based education (Study II) scored themselves as being more than 97 per cent confident both directly after training and six months after training in both groups (Table 10). Self-assessed confidence to intervene and act in a real-life OHCA situation after the BLS training can also be interpreted as self-efficacy.

*Table 10. Self-assessed confidence to act in a real-life OHCA situation after the basic life support (BLS) training, when compared self-learning training (SLT) with instructor-led training (ILT) and BLS with or without a web-based education (WEB)*

| **Study, %** | **Post-test, directly after training** | | | **Retention test, six months after training** | | |
|---|---|---|---|---|---|---|
| **I** | **SLT** | **ILT** | | **SLT** | **ILT** | |
| | n=661 | n=540 | p | n=670 | n=561 | p |
| | 97.4 | 99.6 | 0.02 | 97.8 | 98.5 | 0.49 |
| **II** | **BLS** | **BLS+WEB** | | **BLS** | **BLS+WEB** | |
| | n=1213 | n=1212 | p | n=1268 | n=1212 | p |
| | 97.7 | 97.9 | 0.34 | 98.1 | 98.7 | 0.43 |

### Willingness

Regarding the participants' willingness to intervene in a real-life OHCA situation, this differed between the self-learning group and the instructor-led group (Study I). The participants in the instructor-led group were more likely to perform both chest compressions and ventilations if a relative suffered an OHCA compared with the self-learning group (98% versus 95%) directly after training, but there was no difference six months after training (Table 11). If an unknown person suffered an OHCA, more participants in the self-learning group said that they would not dare or want to intervene at all, compared with the instructor-led group (4.4% versus 1.7%). The participants in the self-learning group were less likely to give ventilations than those in the instructor-led group. The answers from both groups were that they were afraid of transmissible contagious disease. In the open-ended questions on ventilations, other reasons from both groups were unpleasant, blood, vomiting, mucus, dirty, smells bad, snuff, disgusting, uncomfortable, little too intimate, fear, drunk or drug affected, AIDS, infection, shock, panic and I have asthma, physical causes or depends on the situation, the person and if it is an old person or a child (Study I a, Data in Brief). In Study II, there was no difference between the participants' willingness to intervene in a real-life OHCA situation (Table 12).

*Table 11. Self-assessed willingness to intervene in a real-life OHCA situation when compared self-learning training (SLT) with instructor-led training (ILT)*

| **Study I** | **Post-test, directly after training** | | | **Retention test, six months after training** | | |
|---|---|---|---|---|---|---|
| **Variables, %** | SLT/ILT | ILT | | SLT | ILT | |
| | n= | n= | p-value | n= | n= | p |
| **Self-assessed willingness to act if a relative suffers an OHCA (%)** | | | | | | |
| **Would not dare or want to intervene** | 1.7 | 0.4 | 0.05## | 1.2 | 0.5 | 0.36## |
| **Would only give ventilations** | 0.6 | 0.0 | 0.13## | 0.7 | 0.2 | 0.23## |
| **Would only give chest compressions** | 2.7 | 1.7 | 0.13 | 1.6 | 2.5 | 0.29 |
| **Would give both chest compressions and ventilations** | 95.0 | 98.0 | 0.002 | 96.4 | 96.8 | 0.81 |
| **Self-assessed willingness to act if an unknown person suffers an OHCA (%)** | | | | | | |
| **Would not dare or want to intervene** | 4.4 | 1.7 | 0.02 | 3.9 | 2.3 | 0.11 |
| **Would only give ventilations** | 0.5 | 0.6 | 1.00## | 0.3 | 0.4 | 1.00## |
| **Would only give chest impressions** | 30.5 | 26.9 | 0.72 | 33.5 | 31.3 | 0.80 |
| **Would give both chest compressions and ventilations** | 64.6 | 70.9 | 0.23 | 62.3 | 66.0 | 0.85 |

Data collected from questionnaires. Comparisons were performed using generalised estimation equations (GEE) analysis with logit link function or when proportions were very small or very high (<1.0% or >99.0%, '##' in the table), Fisher's exact test, without adjustment for clustering and co-variates, was used. All tests were two-sided and p-values below 0.05 were considered statistically significant

*Table 12. Self-assessed willingness to intervene in a real-life OHCA situation when compared BLS with or without a web-based education (WEB)*

| **Study II** | **Post-test, directly after training** | | | **Retention test, six months after training** | | |
|---|---|---|---|---|---|---|
| **Variables, %** | BLS | BLS+WEB | | BLS | BLS+WEB | |
| | n=1213 | n=1212 | p | n=1268 | n=1212 | p |
| **Self-assessed willingness to act if a relative suffers an OHCA (%)** | | | | | | |
| **Would not dare or want to intervene** | 1.6 | 0.9 | 0.20## | 1.1 | 0.3 | 0.03## |
| **Would only give ventilations** | 0.1 | 0.2 | 0.62## | 0.6 | 0.2 | 0.34## |
| **Would only give chest compressions** | 2.9 | 2.1 | 0.32 | 2.4 | 2.3 | 0.88 |
| **Would give both chest compressions and ventilations** | 95.5 | 96.8 | 0.21 | 96.0 | 97.1 | 0.22 |
| **Self-assessed willingness to act if an unknown person suffers an OHCA (%)** | | | | | | |
| **Would not dare or want to intervene** | 3.9 | 2.7 | 0.15 | 3.5 | 2.2 | 0.18 |
| **Would only give ventilations** | 0.3 | 0.2 | 0.73## | 0.3 | 0.2 | 1.00## |
| **Would only give chest compressions** | 27.3 | 29.1 | 0.18 | 32.7 | 31.9 | 0.96 |
| **Would give both chest compressions and ventilations** | 68.5 | 67.9 | 0.38 | 63.5 | 65.6 | 0.66 |
| Data collected from questionnaires. Comparisons were performed using generalised estimation equations (GEE) analysis with logit link function or when proportions were very small or very high (<1.0% or >99.0%, '##' in the table), Fisher's exact test, without adjustment for clustering and covariates, was used. All tests were two-sided and p-values below 0.05 were considered statistically significant | | | | | | |

### Theoretical knowledge of stroke, AMI, OHCA and lifestyle factors

Theoretical knowledge of the most common symptoms of stroke, AMI and healthy lifestyle factors was higher in the web-based education group compared with the group without the web-based education (Study II), both directly after training and six months after training (Table 13).

*Table 13. Theoretical knowledge of first action if stroke, acute myocardial infarction (AMI) or OHCA, i.e. calling 112 and symptoms of stroke, AMI and lifestyle factors, when compared BLS with or without a web-based education (WEB)*

| **Study II** | **Post-test, directly after training** | | | **Retention test, six months after training** | | |
|---|---|---|---|---|---|---|
| **Variables with total score for each correct answer** | BLS | BLS+ WEB | | BLS | BLS+ WEB | |
| | n=1213 | n=1212 | p-value | n=1268 | n=1212 | p-value |
| **First action if stroke or AMI, (%)** | 98.7 | 99.1 | 0.44 | 98.6 | 99.3 | 0.11 |
| **First action if OHCA, (%)** | 77.1 | 88.7 | <0.0001 | 66.5 | 74.7 | 0.001 |
| **Symptoms of stroke (mean, SD)** | 4.2±2.1 | 5.5±1.6 | <0.0001 | 4.6±2.0 | 5.7±1.5 | <0.0001 |
| **Symptoms of AMI (mean, SD)** | 4.5±2.4 | 6.4±2.1 | <0.0001 | 4.8±2.3 | 6.7±2.2 | <0.0001 |
| **Healthy life-style factors (mean, SD)** | 5.2±1.3 | 5.8±0.6 | <0.0001 | 5.3±1.3 | 5.7±0.7 | <0.0001 |
| The minimum and maximum total score for first action was 0-1 point, for stroke 0-7 points, for AMI 0-9 points and for lifestyle factors 0-6 points | | | | | | |

# Study IV

In this nationwide, observational study from the Swedish Registry of Cardiopulmonary Resuscitation (SRCR), 47,685 OHCA cases from 2008 to 2018 were included.

## Characteristics of the study population

Patients with OHCA at workplaces were more likely to be younger, with a mean age of 56 years, and male, compared with other places outside hospital. These victims received bystander CPR and were detected with an initial shockable rhythm more often than at other places outside hospital (Table 14).

*Table 14. Baseline characteristics OHCA 2008-2018*

| **Variable** | **Workplace, private office** | **Ambulance, witnessed by EMS** | **Crowded public place** | **Health care facility** | **Home/residential setting** | **Hotel room** | **Unspecified non-public place** | **Unspecified public place** |
|---|---|---|---|---|---|---|---|---|
| **Total, n %** | 529 1.1% | 2312 4.8% | 5844 12.2% | 1574 3.3% | 33724 70.7% | 75 0.2% | 2074 4.3% | 1553 3.3% |
| **Age, years, mean (SD)** | 55.9 (12.53) | 72.0 (13.70) | 64.4 (16.46) | 75.2 (16.13) | 70.4 (15.68) | 62.2 (17.85) | 61.1 (17.69) | 65.8 (15.85) |
| **Gender, female** | 15 | 39 | 19 | 46 | 37 | 21 | 21 | 20 |
| **Witnessed arrest** | 69 | 100 | 72 | 76 | 62 | 61 | 62 | 69 |
| **Witnessed by a bystander** | 90 | 0.4 | 91 | 82 | 83 | 69 | 89 | 88 |
| **No bystander CPR** | 20 | 98 | 27 | 28 | 40 | 29 | 27 | 30 |
| **Initial rhythm, shockable** | 47 | 32 | 41 | 12 | 18 | 23 | 29 | 32 |

The presumed cause of cardiac arrest was cardiac disease in more than half of all the OHCA cases, at all locations and with the highest figure at workplaces (69%) (Table 15).

*Table 15. Baseline characteristics OHCA 2008-2018 – cause of arrest*

| Varia-ble | Work-place, private office | Ambu-lance, wit-nessed by EMS | Crowd ed public place | Health care facility | Home/ resi-dential setting | Hotel room | Un-speci-fied non-public place | Un-speci-fied public place |
|---|---|---|---|---|---|---|---|---|
| **Total, n, %** | 529 | 2312 | 5844 | 1574 | 33724 | 75 | 2074 | 1553 |
| **Car-diac disease** | 69 | 67 | 66 | 58 | 64 | 68 | 56 | 65 |
| **Acci-dent** | 9 | 1 | 8 | 0.6 | 0.8 | 2 | 5 | 7 |
| **Drown ing** | 0 | 0 | 5 | 0.1 | 0.1 | 0 | 2 | 1 |
| **Other** | 19 | 21 | 15 | 23 | 21 | 12 | 22 | 17 |
| **Over-dose** | 0.4 | 0.7 | 2 | 2 | 3 | 12 | 7 | 3 |
| **Pulmo-nary disease** | 1 | 9 | 1 | 7 | 6 | 3 | 2 | 2 |
| **Suffo-cation** | 0.8 | 0.9 | 0.9 | 7 | 3 | 3 | 2 | 3 |
| **Suicide** | 1 | 0.3 | 2 | 2 | 2 | 2 | 4 | 3 |

CPR was initiated more frequently by a bystander at workplaces (80%) compared with all other places. Both chest compressions and ventilations were performed in 49 per cent of cases at workplaces, which was lower than at healthcare facilities but higher than at other places. CPR with only chest compressions was performed at workplaces in 50 per cent of cases and in more than 50 per cent in other places, except in ambulances and healthcare facilities. The OHCA patients at workplaces were more likely to be defibrillated before the arrival of the EMS (23%) and were defibrillated (61%) more frequently in overall terms than at all the other places (Table 16). Adrenaline was used in 80 per cent of the OHCA cases at workplaces.

*Table 16. Baseline characteristics for out-of-hospital cardiac arrest 2008-2018 – initial treatment*

| Variable | Work-place, private office | Ambu-lance, wit-nessed by EMS | Crowd ed public place | Health - care facility | Home/ resi-dential setting | Hotel room | Un-speci-fied non-public place | Un-speci-fied public place |
|---|---|---|---|---|---|---|---|---|
| **Total, n %** | 529 | 2312 | 5844 | 1574 | 33724 | 75 | 2074 | 1553 |
| **By-stander CPR** | 80 | 12 | 74 | 73 | 61 | 75 | 73 | 71 |
| **Com-pression and ventila-tion** | 49 | 19 | 48 | 57 | 37 | 42 | 47 | 47 |
| **Chest com-pression only** | 50 | 25 | 51 | 42 | 61 | 58 | 53 | 52 |
| **Ventila-tion only** | 0.6 | 0 | 0.6 | 0.4 | 0.7 | 0 | 0.2 | 0.8 |
| **Defibril-lated before EMS arrival** | 23 | 13 | 17 | 9 | 6 | 13 | 15 | 14 |
| **Defibril-lation** | 61 | 43 | 51 | 21 | 31 | 41 | 40 | 44 |
| **Adrena-line** | 80 | 52 | 74 | 77 | 83 | 72 | 79 | 78 |

The shortest time from collapse to the start of CPR and to defibrillation was found for OHCAs at workplaces (Table 17). Patients with a shockable rhythm at workplaces were defibrillated before the arrival of the EMS in 23 per cent, which was higher than at other places. The median delay from dispatch to the arrival of the EMS at workplaces was eight minutes and the median delay from collapse to shock delivery was 11 minutes.

*Table 17. Baseline characteristics OHCA 2008-2018 – time from collapse to treatment*

| **Variable** | **Workplace, private office** | **Crowded public place** | **Health care facility** | **Home/ residential setting** | **Hotel room** | **Unspecified non-public place** | **Unspecified public place** |
|---|---|---|---|---|---|---|---|
| **n** | 321 | 3639 | 953 | 16779 | 31 | 1104 | 898 |
| Only bystander-witnessed cases. Time in minutes, median and interquartile range [IQR] | | | | | | | |
| **Time from collapse to alarm** | 2 [1.00, 3.00] | 2 [1.00, 3.00] | 2 [1.00, 5.00] | 2 [1.00, 5.00] | 2 [2.00, 4.75] | 2 [1.00, 5.00] | 2 [1.00, 4.00] |
| **Time from collapse to CPR** | 1 [0.00, 5.00] | 2 [0.00, 5.00] | 1 [0.00, 5.00] | 5 [1.00, 10.00] | 5 [2.00, 10.00] | 2 [0.00, 7.00] | 2 [0.00, 6.00] |
| **Time from collapse to defibrillation** | 11 [8.00, 17.00] | 12 [8.00, 18.00] | 14 [8.00, 22.00] | 17 [12.00, 25.00] | 17.5 [10.00, 20.50] | 15 [9.00, 23.00] | 13 [9.00, 20.00] |
| **Time from arrival of call to EMS dispatch** | 1 [0.00, 1.00] | 1 [0.00, 1.00] | 1 [0.00, 1.00] | 1 [0.00, 2.00] | 0 [0.00, 1.00] | 1 [0.00, 1.00] | 1 [0.00, 2.00] |
| **Time from dispatch to EMS arrival** | 8 [5.00, 12.00] | 8 [5.00, 13.00] | 9 [6.00, 13.00] | 10 [7.00, 16.00] | 8.5 [5.00, 18.00] | 10 [6.00, 16.00] | 8 [5.00, 15.00] |

## 30-day survival from OHCA

The main finding on survival from OHCA outside hospital in Study IV was that the location at workplaces was associated with a higher probability of survival to 30 days, apart from crowded public places, than at all other places outside hospital. This was demonstrated in a logistic regression model to obtain odds ratio, included ten predictors as follows, location, age, gender, witnessed arrest, bystander CPR, initial cardiac rhythm, defibrillation, calendar year, adrenaline and cause of arrest (Study IV, Fig. 3).

Survival to 30 days from OHCAs at workplaces was 30 per cent with crude data and this was higher than at all other places. When adjusted for age, gender, location of cardiac arrest and calendar year, survival was higher (22%) than at all other places except for the location in the ambulance (28%). In Figure 13, the unadjusted and the adjusted survival rate to 30 days in relation to all the locations of OHCA is presented.

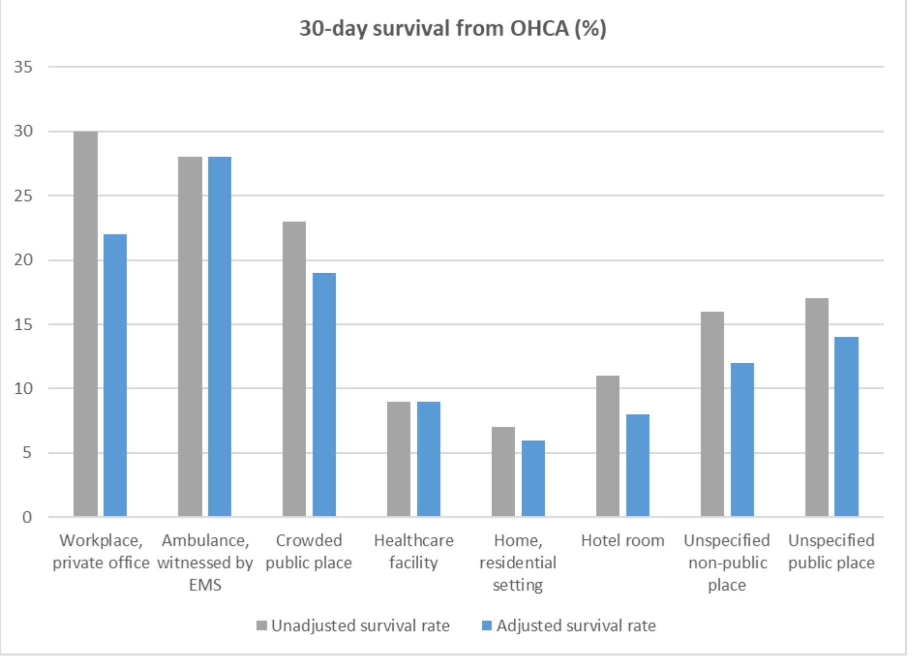



Figure 13. 30-day survival from out-of-hospital cardiac arrest (OHCA), 2008-2018. The data are presented as percentages and as both unadjusted and adjusted for potential confounders such as age, gender, location of the arrest and calendar year of the arrest

### Factors associated with outcome after OHCA at workplaces

The strongest predictor of 30-day survival from OHCA at workplaces was an initial detected shockable cardiac rhythm, with an OR of 5.80 (95% CI 2.92-12.31, $p<0.001$), and thereafter female gender, with an OR of 2.08 (95% CI 1.07-4.03, $p=0.03$), compared with men (Study IV, Fig. 4a). Moreover, no bystander CPR was associated with a decreased chance of survival at workplaces when private offices was excluded from the location at a workplace, with an OR of 0.41 (95% 0.16-0.95, $p=0.05$), compared with the OHCAs which received bystander CPR (Study IV, Fig. 4b).

# Discussion

## Method discussion

In this section the method is discussed in relation to the design, population, data collection, outcome, data analyses and ethical considerations for Studies I-IV.

### Design

The design in Studies I-III was based on previous studies [191, 251, 337, 338] and tested in a pilot study in 2013 [322]. The randomisation increased the objectivity in the studies and the investigator was blinded to each participant's intervention [327]. A cluster RCT with seven different learning strategies to explore may be regarded as a multifactorial design and a limitation for the studies. However, the design was a parallel design and one intervention at a time was explored and compared with a control group [323, 325]. Although two primary research questions were defined a priori (Study I and Study II), we made a number of comparisons between the different groups which may be criticised and therefore need to be interpreted with caution (Study III).

In Study IV, an observational and descriptive design was the obvious choice to describe OHCA at workplaces. The two designs used in the studies were regarded as appropriate for the overall aim. There are other designs that could have been used in the studies. A quantitative approach with an investigation of experiences of training in BLS was planned with collected data but was not performed due to lack of time and size of the thesis. Furthermore, the register-based study with retrospective data on OHCAs at workplaces could have included representative controls from another register, such as the Swedish Population Register, Statistics Sweden or the Cause of Death Registry, which could have expanded the learning aspects of OHCA even more.

## Population

The study population in Studies I-III with laypersons at workplaces outside hospital was a choice early in the planning process to emphasise different opportunities for training at workplaces. The educated participant, that is a layperson who is a potential bystander, may benefit the OHCA victim both inside and outside the workplace. The included workplaces and the large sample size of the study population were regarded as a varied background. The groups of working individuals included practical workers and administrative workers from workplaces of all types and sizes such as offices and industrial workplaces. The fact that we did not stratify the study population to have comparable groups of the participants' gender, age, type of work, size of workplace, educational level, cultural or socioeconomic background, might be regarded as a limitation. On the other hand, we adjusted for imbalances in characteristics in the statistical analyses. Moreover, we included participants who had never trained CPR or had previously trained CPR more than five years ago and this may be regarded as a limitation. However, practical skills appear to deteriorate three to six months after training and we regarded five years as a relevant period of no education. If we had included only participants without any previous CPR training, we might have had another result.

In Study IV, the study population was recruited from the SRCR which included a large number of OHCA cases which are representative of Sweden. In spite of this, there were many cases that we excluded due to incomplete data. If we had performed analyses with imputation of missed values, we would have had an even larger study population.

## Data collection

The measurements must be relevant and the collected data must answer the research questions (validity). The internal validity refers to the inference and relationship between variables. The question to answer is whether the dependent variable, the result (BLS skills in Studies I-III and 30-day survival in Study IV), is an effect of the intervention, the independent variable (different learning activities in BLS for Studies I-III and location of arrest in Study IV). There are many factors that may affect the results. The Cardiff Test in BLS and AED is a validated and updated test, but the variables in the checklist should be validated more regularly to meet current guidelines which are currently updated every year. For example, the practical skills of rescue breaths have changed over time in training for laypersons. The scoring system in the Cardiff Test is sensitive and may be discussed as a limitation for the internal validity or the sensitivity of the measurement instrument in the present thesis. Separate variables, such as the quality of chest compressions, are therefore presented in Studies I-III and the reporting was in accordance with clinical trials [323]. The composition of the questionnaire was based on previous studies [191, 251, 322, 332-336, 338], while the classical symptoms of CVD were based on previous studies and discussion with the interdisciplinary working group but has not been validated. Moreover, there were a great many questions for the participants to answer and this may be regarded as a limitation in terms of internal validity.

In Study IV, the collection of data was dependent on what was available in the SRCR, which is a Swedish national quality register, based on international statements [3, 27] and regarded as reliable. However, the number of variables collected in a quality register has to be limited for practical reasons (feasibility). The data in the SRCR have been validated in a subset of patients and the internal validity has been reported to be high with an agreement with source data in > 95%. Nevertheless, all the source data cannot be verified, e.g. times communicated by the bystander and the EMS personnel, cause of arrest and the compliance with reporting the data by the EMS [94]. Some data missed being collected for logistical reasons. The reporting of retrospective data may be a limitation regarding selection bias. Some OHCA patients may die alone and in some cases the EMS is not called for unknown reasons. In 25 per cent of reported cases in the SRCR, the OHCA was subsequently discovered by a local regional co-ordinator in the healthcare system and, according to the validation paper in 2013, those patients were older, received less bystander CPR and had a higher survival rate compared with the other cases in the SRCR [94]. After the validation paper, the data in the SRCR were continuously re-assessed by the co-ordinator and almost all cases are currently finally reported to the register.

A representative sample to obtain transferability and generalisability (external validity) to a wider context was considered when the decision was made to collect the data at workplaces with the sample size of 2,500 participants in Studies I-III. We did not stratify the inclusion of the population for gender or socioeconomic backgrounds, for example, to obtain greater generalisability, as we felt that the sample size was large enough to obtain a varied background. However, the statistical analyses were adjusted for potential confounders. The SRCR in Study IV already contained a large study population from which to collect data and was regarded as valid.

The correctness of the measurements regardless of time (applicability), the use of the measurements (reliability) and being able to repeat the study with the measurements (repeatability) were considered when using the Cardiff Test and the PC Skill Reporting system. Some of the variables were collected both automatically in the PC Skill Reporting system and with direct observation, e.g. opening the airway correctly, and this was a limitation, even though the variables were checked on the film after the test situation. Moreover, we considered whether the investigator should collect the data or whether a specially educated team should be hired. The investigator, who is an experienced registered national head instructor in all SRC national programmes and an educated instructor in advanced life support (ALS) by the ERC, with knowledge and skills for the test used in the study, was finally decided to collect the data. The decision was also based on economic and logistical reasons, as it was time consuming. However, the data collection took a long time and was extended over two guideline periods. Fortunately, the guidelines were stable and the BLS algorithm, for example was the same during the study period.

## Outcome

The outcome of the total score for practical skills and theoretical knowledge in BLS and 30-day survival from OHCA with the emphasis on workplaces has increased the learning aspects relating to OHCA and learning activities in BLS.

The mean total score of all the Cardiff Tests including all the participants and all 16 interventions was 59.1 (84% of a maximum of 70 points) directly after training and 58.4 (83%) six months after training. This is in line with previous studies with 58-61% as a total score three and six months after training in BLS for laypersons [191, 346-349]. The score in the questionnaire was not validated, but the questions had previously been used. The outcome in Studies I-III could have been more related to willingness and the experience of the education by the participants. The questionnaires included questions not yet analysed on experiences, which may be regarded as a limitation for the study outcome.

Factors that may affect the outcome are potential confounders, such as age, gender and educational and work background. In the randomisation, a stratification of age, for example, could have been performed to obtain comparable groups. We did not stratify for confounders using feasible reasons of clusters as training groups, like classes in educational research [320]. For this reason, the statistical analyses accounted for a potential cluster effect and were adjusted for several potential confounders. In the register-based study, 30-day survival and factors associated with the outcome after OHCA could have been complemented with patient-reported outcome measurements of quality of life, six-months and one-year survival and return to work [25, 68, 69, 72, 74].

## Data analyses

All the statistical data analyses were carefully discussed and planned by the doctoral student in collaboration with the statisticians and the supervisory group. In Studies I-III, the statistician performed the formal analyses and, in Study IV, one of the co-authors with a high level of statistical competence performed the formal analyses. In the review process, there were many discussions regarding the analyses. There was a need for robust analyses, as Studies I-III were cluster RCTs and the effect caused by the clusters had to be calculated and the analyses had to be adjusted for several potential confounders. Moreover, the significance level of a p-value of $< 0.05$ and the risk of a mass significance may be regarded as a limitation in Studies I-III. With a large study population even small differences can be statistically significant. The clinical relevance of our findings may therefore sometimes be a matter of debate.

The analyses in Study IV were also adjusted for potential confounders, which is essential for observational data. First, we decided that age, gender, location and calendar year were clinically relevant as confounders in the regression model. After discussions, we also adjusted for witnessed arrest, bystander CPR, defibrillation, initial cardiac rhythm, use of adrenaline and cause of arrest in the logistic regression to obtain the odds ratio for 30-day survival.

Missing values in Studies I-III were regarded as missing at random (MAR) and we described the missing data in the result section for each study. In Study IV, only cases in the SRCR with complete data were included. Cases with missing information were regarded as MAR. We described the missing variables and a complete case report in Study IV (Supplementary, Appendix, A1), which was consistent with previous findings. We also provided baseline characteristics for those complete cases and noted no material differences with regard to the entire cohort, suggesting that no specific mechanism underlies missingness. We assessed a potential interaction between age and gender and noted that it was not significant ($p=0.1$), ruling out an age-gender interaction. We do not know exactly why the information was missing, so we can only discuss different possible reasons. Some of the reported data, such as time of arrest, cause of arrest, time to start of CPR and time to defibrillation with a PAD, are collected in an acute situation from bystanders and relatives by the EMS dispatchers or the EMS personnel and the communication may be stressful. Multiple imputation could have been used in the analyses when data were missing, but we only used cases with complete data.

## Ethical considerations

Research ethics are complex and apply to the entire thesis, including Studies I-IV. The methods used must relate to the research questions (validity). In Studies I-III, the research questions were related to different learning activities and the study design did not include time for ethical reflection on the experience after the trial for the participants. One of the interventions, i.e. the control group, was identical to the national standard education in BLS, but the other interventions were differently composed learning activities and it may be an ethical issue for some participants to train BLS in a different way. Even if the research studied different learning approaches in BLS, some participants may learn and react differently due to different personal experiences of learning. For example, one of the learning activities was self-learning and this may be experienced negatively by some participants, while the opposite experience could be that some participants may experience a group situation in learning negatively. Moreover, some participants may react emotionally due to a previously experienced OHCA event or having close relatives, friends or working colleagues with CVD. This might be considered as a limitation for the study design and we should have included time for ethical follow-up.

The ethical considerations in Study IV regarding the study design were that we were unable to obtain informed consent in an OHCA situation. Patients who survive are informed at follow-up about the opportunity to withdraw their data from the register and to discuss ethical questions from the patient's perspective.

# Result discussion

In this section, the results are discussed in the form of an inquiry-based presentation related to the overall aim as follows:

- to explore the effectiveness and the intended learning outcome after training in BLS, CPR and AED calculated as a total score for practical skills, theoretical knowledge, confidence and willingness to act by comparing different learning activities among laypersons at workplaces and
- to describe characteristics and investigate the incidence and outcome as 30-day survival of OHCA with the emphasis on workplaces in Sweden.

### *1 What are the most important aspects of education in BLS?*

Firstly, the most important aspect of training in BLS is the participants' own motivation and willingness to learn and self-efficacy to start high-quality actions when a person suffers an OHCA [14, 142, 350]. Motivation is a key aspect of learning [166]. Learning through reflection while practising hands on may activate motivation [14]. Secondly, the motivation to train regularly and thirdly the motivation to spread the message, like a cascade, are further important aspects.

The most effective learning activities related to a total score for practical skills in BLS in Study III included instructor-led training, film-based instructions, an interactive web-based education, a CPR feed-back device and reflective questions. This can be interpreted as meaning that a variety of learning activities, blended learning and more time spent on practice were a motivating factor for learning. As a result, the most important aspect of education in BLS is to design the education including blended learning with preparatory interactive theoretical knowledge, practical skills training and time for reflection. On the other hand, spaced learning with a short duration, frequently, has been shown to be more effective than mass learning [61, 248] and the time for reflection on the learning may be missed.

### *2 What is the significance of the presence of an instructor?*

The presence of an instructor can be significant for the participants performing high-quality CPR with feedback from the instructor. In Study I, we found that the presence of an instructor resulted in a significantly higher total score for practical skills directly after training in BLS compared with self-learning training in BLS.

For the separate variables of compressions and ventilations, time to the start of CPR and time to deliver a shock, for example, they were all in favour of instructor-led training. Moreover, the participants self-assessed their own competence more highly in the instructor-led group directly after training compared with the self-learning group. The instructor-led training included some corrective feedback to the participants from the instructor, which is a learning tool for achieving the learning objectives. This may indicate that the interaction and communication with an instructor has a positive effect on learning [166, 194, 199, 209, 351]. On the other hand, we are unable to confirm this, as the above-mentioned findings were defined as priori as secondary endpoints. However, our results should be interpreted in combination with findings from other studies and thereby indirectly support the presence of an instructor during education in CPR in a blended learning format [207, 209, 352]. In terms of the primary endpoint, i.e. practical skills after six months, we did not find that instructor-led training was preferred. It would have been interesting to evaluate the impact of instructor-led training on practical skills three months after training. Our findings may also be a result of the fact that instructor-led training included structured practice with learning in communication by reflection in the training group and with peers. In Study II, blended learning with a preparatory web-based education obtained a higher total score for practical skills and theoretical knowledge compared with learning without a web-based education. This is in line with other studies confirming that blended learning is more effective or non-inferior to traditional training in BLS [207, 209, 352]. In Study III, all of the four interventions that obtained a higher total score than standard training included an instructor. The instructor can also be present in an online meeting, a video webinar or in a digital conference room as an alternative. The differences in the studies regarding the presence of an instructor were small and should be investigated further in workplace settings.

### *3 Does a previous web-based education add anything of value? If so, how should it be designed?*

In Studies II and III, the BLS training with an additional web-based education resulted in higher scores for practical skills and theoretical knowledge compared with BLS training without the web-based education. This indicates values for both practical skills and theoretical knowledge. The participants are able to regulate their own learning and understanding by reflection before the practical training, as described by Kolb [14]. Being able to vary using different learning tools and activities in education is both challenging and strengthening for learning [201-203].

A previous study of web-based learning in adult BLS has shown that it improves practical skills and self-efficacy in BLS [353]. However, a study among seventh grade students did not reveal any improvement in practical skills, but, on the other hand, theoretical knowledge improved [348]. E-learning in addition to a shortened one-day instructor-led, face-to-face course in ALS produced equal overall scores for practical skills with no significant difference when compared with a traditional two-day instructor-led, face-to-face course in ALS [210, 212, 213]. In one of the cardiac arrest scenarios, the e-learning group obtained higher scores for practical skills than the traditional training group. For theoretical knowledge, the e-learning group had a slightly higher score. However, this meant that the course could be organised with e-learning for one day and practical instructor-led learning for one day [210, 212, 213]. Even web-based education without practical training has been shown to improve learning in BLS [194]. Blended learning in three steps is the current practice for BLS training with an online e-learning course, skills practice and some form of feedback and assessment [96, 354, 355]

The advantages of web-based learning are the flexibility of location, the timing and time spent on education, the education being easy to update and the opportunity for the design to be interactive and presented differently with multimedia and virtual reality learning. Self-learning, learning in communication and in social collaboration and assessment can be included [202, 204, 356, 357]. The disadvantages are social isolation, technical problems and a poor design, mainly with a text document for reading. The design of the web-based education must create different conditions for learning. The element that needs to be included is the interactivity by the participant with student-driven learning and social interactivity in work-based learning and in a community of practice [162, 204, 356]. The platform and the materials for web-based education must be easily accessible for individuals and for groups and need to be relevant to the learning objectives and learning outcome. Practical training with a personal training manikin included in a web-based education should be conducted and further investigated. The learning could be self-directed or in collaboration in peers or in a group with or without an instructor at the workplace

### 4 Should feedback be included in education in BLS and, if so, why?

Feedback on participating in education in BLS was received in several ways in Studies I-III, either visual and verbal from the instructor or mechanical from the training manikin and the CPR feedback device. The feedback from the training manikin by a clicker for chest compressions and a raised chest for rescue breaths was used for all learning activities and is regarded as the minimum feedback on CPR performance for laypersons. It can be used both as self-assessment and in communication with the instructor or peer. The mechanical feedback device on chest compressions was included in three of the learning activities that obtained a higher Cardiff Test score six months after training when compared with the standard training in BLS in Study III. The use of CPR feedback devices has been shown to increase learning and the retention of psychomotor skills for chest compressions in training for laypersons, but the ability to improve performance varies [222, 225, 330, 331]. CPR feedback improves basic CPR skill acquisition and the quality of compressions, but there are some risks to consider. An incorrect hand position for chest compressions, pushing too hard and a risk of delay or the distraction of the rescuer to perform CPR have been reported [224, 225]. Using a mechanical CPR feedback device in combination with debriefing has been shown to increase learning in BLS [358]. The CPR feedback device gives short, constructive feedback, which is relevant and timely for self-assessment but lacks the verbal human feedback and reflection in communication and interaction with the instructor or peers [167]. The effect of CPR feedback devices used on cardiac arrest patients has been shown to both improve [221] and not improve ROSC, short-term survival (seven days) or favourable neurological outcome (CPC 1 or 2) [359]. The type of CPR feedback devices differed and may have affected the results in previous studies. Portable devices appeared to be more effective than devices integrated in the AED [359]. A portable CPR device, previously used in a CPR manikin study, produced an improvement in the quality of compressions at six months, which was defined as long-term retention [331]. For laypersons, the CPR feedback should only be used in education in BLS [21, 224, 225].

Some form of feedback to obtain high-quality CPR should be included in all education in BLS. Visual assessment with verbal feedback from the instructor may be ineffective [58] and may be experienced as threatening in terms of self-esteem, confidence and motivation [360-362]. Technical feedback devices can be self-regulated and the participants can actively seek their own feedback and be motivated to improve and then reflect on the experience in communication [363]. This approach is like giving back the role of feedback to the learner. Feedback on participating in education in BLS should include both feedback and reflection on the feedback [166-168, 358]. In conclusion, a formative assessment with corrective feedback and reflection is essential to obtain the learning outcome and high-quality CPR and AED while training in BLS at workplaces.

### *5 Should reflection be included in education in BLS and, if so, why?*

Reflection can be a learning tool and a form of self-assessment in instructor-led training, peer learning and self-regulated learning [14, 166, 203]. In Study III, reflective questions were included in two of the four interventions that obtained a significantly higher Cardiff Test score six months after training compared with the standard training in BLS. We are unable to say whether the reflection alone was beneficial without further analysis. Reflection is time consuming but should be included in BLS training. However, the reflection time of 15 minutes was short and could be regarded as a limitation. Moreover, self-regulated reflection may miss learning in a sociocultural context, which can increase the ability for sense-making [364]. The motivation and willingness to perform both chest compressions and ventilations in a real-life OHCA situation were higher in the instructor-led group compared with the self-learning group directly after training (Study I). When comparing the BLS training with and without the web-based education, there was no difference between the participants' willingness to intervene in a real-life OHCA situation (Study II). Additionally, there were several barriers to performing CPR that should be reflected on, they include an unwillingness to perform ventilations and panic due to the participant's perceptions (Study 1 a, Data in Brief). Reflective practice, merging practical experience with theory, is part of the learning process, according to Schön [152]. All the participants should therefore be actively involved in and encouraged to reflect on learning in BLS in collaboration at work, at home and with friends and relatives.

### *6 Should the education in BLS be individualised?*

Education in BLS can be conducted on both an individual and a collective level and preferably both. A previous study found that blended learning in BLS was non-inferior to traditional BLS education [365]. For learning, the learner must be in the centre and find what is necessary for learning and mastering the task. By creating different conditions for learning and different learning activities for training in BLS, a variation may create learning for different situations [366]. Regarding the learning outcome of high-quality CPR, the instructor-led courses may include verbal communication, technical feedback and assessment by the instructor [16, 17, 166, 167, 253, 363, 367] which may be beneficial for the workplace.

### *7 What is the optimal method for testing a participant's proficiency? When should this testing take place?*

High-quality CPR and the use of an AED are the most important aspects of treatment when a person suffers an OHCA. In Studies I-III, practical skills were tested in a simulated scenario as a summative test of learning outcomes after training. The mean total score from all the Cardiff Tests was 59.1 (84%) directly after training and 58.4 (83%) six months after training. Traditional training in BLS for laypersons has no summative test and a formative assessment with feedback during the course is recommended. The assessment in the national instructor-led training and in Studies I-III was similar but more like feedback than formative and cannot be defined as a continuous, formative assessment by the instructor, with self-regulated learning and feedback [166]. This could be regarded as a limitation for the learning activities. However, this is a reasonable form of assessment of laypersons without any duty to respond but not for the aspects of the workplace safety. If a high-fidelity manikin with technical feedback and self-regulated learning with reflection and debriefing in communication with the instructor or with peers is used, this may be the optimal method [207] at workplaces. On the other hand, the test situation may be experienced as threatening and stressful [368] and high-fidelity manikins are expensive. Self-assessment with a low-fidelity manikin including feedback is an alternative to reach high-quality CPR. A low dose of brief training with high frequency (after one, three and six months) has been shown to improve retained practical skills in CPR by healthcare personnel [369] and spaced learning has been shown to be effective [61]. A CPR skills station with a high-quality manikin and computer-based feedback can be used for self-assessment or in collaboration with peers or with an instructor every three months. The assessment can also be organised online. However, before testing, the participants must be given enough time for training and learning to perform the given task practically.

### *8 How often does a layperson need to participate in BLS?*

A spaced format with a low dose of practical training in BLS with a high frequency of every three months has been shown to improve the retention of practical skills in a healthcare setting [370]. Practical skills in CPR may deteriorate after three to six months and after seven to 12 months for using the AED [54-56, 60]. Training every three months for laypersons without a duty to respond may be regarded as too often, while six months and yearly may be more reasonable. With alternative self-learning methods, it is possible to train more often. A combination of both instructor-led and self-learning alternatives can create retraining opportunities every six months and may be feasible for laypersons in work-based learning.

### *9 Should the education in BLS at workplaces differ from standardised education in BLS?*

The workplace must follow the Work Environment Act and the BLS training should follow the guidelines and therefore basically not differ from standardised education. However, the workplace is a community of practice and situated learning [162]. A workplace with team training and simulation in the natural environment may be of value for learning and preparedness for an event of OHCA. The workplace can have its own BLS instructor who facilitates the education or self-learning training. It has been shown that a self-directed BLS programme at workplaces was comparable to instructor-led courses and was a more cost-effective alternative [129]. Occupational safety and health are a priority and training in BLS can be incorporated in the first-aid education and be simulated in training at the workplace. The standardised training in BLS for laypersons can be complemented with deliberate practice and mastery learning [173]. Additionally, assessment with corrective feedback to achieve practical skills for high-quality CPR and cardiac arrest simulation with team training to prepare the participants to act in an OHCA situation at the workplace can be organised differently from standard training.

### *10 Should CPR register data be incorporated in the education in BLS?*

By describing the incidence and outcome of OHCA in the BLS education, the participants may feel more involved and motivated to learn high-quality CPR and act in a real-life OHCA situation. Moreover, the number of trained and re-trained people and the level of BLS education among the laypersons who perform BLS in a real-life OHCA situation should be registered, validated and incorporated in the education. Participation may increase when reflecting on whether BLS-educated laypersons perform BLS in reality [172]. Survival to 30 days from OHCA in global terms varied from three per cent to 20 per cent and the performance of bystander CPR has been reported to range from 19 per cent to 79 per cent [5]. In Sweden, survival to 30 days from OHCA is 11 per cent and bystander CPR is reported to occur in 77 per cent [9]. The data on that about five million people have participated in resuscitation training in Sweden is not validated and the register of educated people in Sweden is under reconstruction (personal communication by the chair of SRC, 12 October 2020). As soon as possible, register data should be incorporated into the BLS training and preferably in a preparatory web-based education on CVD and cardiac arrest.

### *11 How often does cardiac arrest occur at a workplace?*

The incidence of OHCA at a workplace is low. In a systematic review and meta-analysis, Descatha et al. estimated that the incidence ranged from one to 24 cases per one million person-years and 0.3 to five per cent of all cases of OHCA [23]. In Europe, two per cent of OHCAs occurred at a workplace or in an office [6]. The corresponding figures have been reported to be three per cent in Norway, one per cent in Finland [5] and one per cent in Sweden (Study IV). We did not investigate why the incidence is low at workplaces. The working population might be healthier and if having a CVD, with less co-morbidities than the adult population who is not working, but this, was not discussed in present thesis. The low incidence of OHCA at workplaces may be regarded as meaning that there are other locations more worthy of attention, but workplaces have opportunities to educate all workers in BLS. This may improve the quality of performed BLS and increase survival from OHCA. Additionally, a web-based education on CVD and training in BLS may serve as prevention and produce improved cardiovascular health, as well as reducing OHCA at workplaces even more.

### *12 Are there specific workplaces at which cardiac arrest occurs more often?*

The reporting of locations of OHCA varies due to the reporting of the categories at a workplace in different OHCA registers [23]. The EMS personnel in Sweden register the variable of location for the cardiac arrest at a workplace, but we did not further investigate the specific types of workplaces in Study IV. Occupation, education, employment and socioeconomic factors may affect survival from OHCA [371-373]. Industries that produce services or goods and requires large labour is reported to have employees to be less likely to return to work after an

OHCA compared with other workplaces [72] but a specific workplace at which OHCA occur more often was not found in in this thesis.

## *13 What is the difference between cardiac arrest at a workplace and cardiac arrests at other locations outside hospital?*

The OHCA patient at workplaces has been reported to more frequently be male, be younger, more frequently have presumed cardiac aetiology and finally to be detected with a shockable cardiac rhythm more often than at other places, as described in Study IV. Survival to 30 days after OHCA at workplaces appears to vary between 25 and 30 per cent and our results did not differ markedly from what others have reported [23, 26, 374]. A cardiac arrest occurring during work at the patient's own workplace, a profession as a manager or a worker with responsibility has been shown to be associated with an increased chance to return to work, when compared with OHCAs at other locations [69].

In addition, in Study IV, when the association between 30-day survival and ten predictors were analysed in the regression model, workplaces showed a higher probability of survival, apart from crowded public places, than at all other locations of OHCA. Being found in a shockable cardiac rhythm and being a female were independent predictors of an increased chance of survival at workplaces. Female gender has previously been reported as a factor independently associated with 30-day survival from OHCA [84, 375, 376] which is in line with Study IV but other studies reports no association for an increased odds of survival for females [83, 377]. The fact that females receives less CPR and defibrillation overall compared with men [281, 282], may be one critical perspective of the lower chance of survival for females. Finally, if excluding private office, the OR for survival to 30 days without bystander CPR was lower than for those patients suffering from OHCA who received bystander CPR at workplaces. Bystander CPR at the workplace have the potential to reach the level of performing high-quality CPR and use of an AED and those above-mentioned differences should be communicated to the workplace for the motivation of training and performing BLS in the event of an OHCA.

### 14 What is the difference between a resuscitation attempt in cardiac arrest at a workplace compared with other places outside hospital?

The main difference is that workplaces should have an organisation and education for occupational health and safety for the employees and therefore preparedness for acute situations and ways of handling these events [130, 259, 261]. Workplaces often have many employees who can help each other and there is a greater chance that the bystander will know the victim compared with other places, except for home, which may be a beneficial place in terms of motivation to start resuscitation. Reported barriers to training in BLS and to perform CPR in a real-life OHCA as lacking knowledge, confidence and competence, and fear of infectious disease or harming or exposing the victim [272, 278-280, 378] may be reduced at workplaces with an preparedness for acute situations. Moreover, barriers to perform chest compressions on females and that females appears to receive less defibrillation compared with men [281, 282] may also be reduced at workplaces if the rescuer knows the victim.

### 15 What are the weak links in the early chain of survival after cardiac arrest at a workplace?

The weakest link in the early chain of survival is most likely the delay to defibrillation, followed by the delay to calling for the EMS and the delay to starting CPR. However, the latter has improved markedly in Sweden during the last few decades [7, 9]. The presence of AEDs at workplaces appears to be relatively high, but it is uncertain how often they are used in the case of an OHCA [50, 62, 100, 123, 124]. The delay to the arrival of the EMS is another weak link in the EMS organisation as the response time for EMS is increasing [379]. This is not only a weak link for OHCA at workplaces, but also a strong weak link regardless of the place of OHCA.

### 16 What are the factors of importance for the chance of survival after a cardiac arrest at a workplace?

The factors of importance for the chance of survival after OHCA at a workplace are most likely the same as the well-known predictors of 30-day survival after OHCA when the place is not taken into consideration. The factors of importance include the first recorded cardiac rhythm, age, delay to start of CPR, the EMS response time and the location of the OHCA [83]. The patient suffering from OHCA who is found in a shockable cardiac rhythm can be defibrillated early with a greater chance of survival. Without treatment, a few minutes after the cardiac arrest, the shockable rhythm deteriorates to an asystole, which is a non-shockable rhythm. The delay to shocking and starting CPR is an important factor as well as the delay to EMS response with advanced life support treatments. A bystander-witnessed cardiac arrest event at a workplace can often be managed in a timely manner in the chain of survival [5-7, 26] and this is a factor of importance to communicate at workplaces.

### *17 How can we improve the chance of surviving a cardiac arrest at work?*

In the short term, the most important action is to call for the EMS at an early stage, start CPR, implement and use the AEDs, combined with regular training for all employees in BLS at workplaces. Instructor-led training with blended learning and feedback can improve the performance of high-quality CPR with AED, as well as alternatively educational methods. The most common cause of cardiac arrest is CVD and, in a long-term perspective, the prevention of CVD and the promotion of cardiovascular health can improve survival.

### *18 Can we prevent cardiac arrest from occurring in a workplace?*

The prevention of cardiac arrest in a short-term perspective can be achieved if all employees learns about risk factors and symptoms of CVD and prodromal symptoms of acute myocardial infarction, as well as OHCA [103, 104, 380]. Prevention is also to communicate the importance of calling for the EMS at an early stage. Prevention from a long-term perspective means communication of an increased cardiovascular health. Stopping smoking, a lower alcohol and salt intake, physical activity, normalised blood pressure, blood cholesterol and blood glucose are generally known health factors [1]. The workplace is the perfect place for prevention and promotion activities to increase cardiovascular health.

# Main findings and conclusions

## Studies I-IV

The learning aspects of different learning activities in BLS for laypersons at workplaces have been explored in the present thesis. In addition, OHCA with the emphasis on workplaces has been described. The main findings with pedagogic and clinical implications that can be found as a result of the studies are presented below.

In **Study I,** as the primary outcome, there was an absence of statistical evidence of any difference between self-learning in BLS compared with instructor-led learning in BLS six months after training. However, directly after training, the total score for practical skills, self-assessed theoretical knowledge, confidence and willingness to act were higher when the training was led by an instructor. The clinical implication is to support the continuation of training in BLS at workplaces led by an instructor. This implication has the following support.

- The instructor-led training obtained a higher total score for practical skills, directly after training.
- The participants in the instructor-led group self-assessed their theoretical knowledge as higher than in the self-learning group, directly after training.
- The motivation and willingness to perform chest compressions and ventilations in a real-life OHCA situation were higher in the instructor-led group compared with the self-learning group, directly after training.
- The participants self-assessed their confidence as higher in the instructor-led group compared with the self-learning group, directly after training.

In **Study II,** there was a statistically significant higher total score in the BLS training group with a preparatory web-based interactive education on stroke, AMI, OHCA, CPR, AED and healthy lifestyle factors, in addition to practical training in BLS. The web-based education can improve the learning outcome for practical skills and theoretical knowledge in CPR and AED. The difference was small and the results in **Study II** may be interpreted as limited in terms of clinical educational relevance.

- The clinical implications are to promote and offer blended learning with web-based education and practical training in BLS regularly to all employees at workplaces.
- A preparatory interactive web-based education on stroke, AMI, OHCA, CPR, AED and healthy lifestyle factors can improve theoretical knowledge and practical skills in BLS.

**Study III** showed a higher total score for training with a preparatory web-based education, instructor-led and film-based instructions with a feedback device on chest compressions and reflective questions when compared with the standard training in BLS. Since the differences overall were small and as well as when the standard training was compared with the self-learning training with additional interventions, the clinical relevance of the findings needs to be further investigated. However, there are some implications, as follows.

- The clinical implication is to plan for and conduct further studies in the field of blended learning and different learning activities in BLS, targeted to workplaces.
- A web-based education, feedback device on chest compressions and reflective questions can be used in both instructor-led training and self-learning training in BLS at workplaces.

**In Study IV**, the overall learning aspect of OHCA at workplaces was that the adjusted 30-day survival was 22 per cent. The probability of survival was lower at all other locations outside hospital, apart from crowded public places, than at workplaces. A shockable cardiac rhythm was detected more often at workplaces and the OHCA patients at workplaces were defibrillated more frequently than at other places. Moreover, a shockable cardiac rhythm was a strong predictor of survival from OHCA at workplaces, followed by female gender. Finally, no bystander CPR at workplaces displayed a lower chance of survival when private office was excluded from the analysis and this may indicate that survival from OHCA at workplaces has the potential to improve even further.

The clinical implications are as follows.

- A shockable cardiac rhythm can be detected more often at workplaces and the patients can be defibrillated more frequently than at other places outside hospital.

- Survival to 30 days at workplaces can be higher than at other places outside hospital.

- Workplaces have the opportunity for regular training in BLS and, in the event of an OHCA, to perform high-quality BLS in a timely manner before the arrival of EMS.

In conclusion, the interpretation of the results in **Studies I-IV**, regarding learning aspects of OHCA at workplaces and different learning activities for laypersons at workplaces, reveals that the differences are small, and the clinical relevance of the findings is unknown. However, this is the findings from the studies and the only thing that we can say with any certainty is that the data indicate a change in the right direction, which means potential for improvement.

# Future perspectives

Clinical implications for the future are that different learning activities and strategies for learning in BLS can be highlighted at workplaces for an overall increase in educational level and efficiency and the quality of performed BLS. A blended learning approach with a preparatory interactive web-based education, instructor-led and film-based practical training, a CPR feedback device for self-regulation, reflection in collaboration at work and spaced training, can be recommended for implementation at workplaces. If no instructor-led training is available or between training times, practical self-regulated training, with a preparatory interactive web-based education and with a feedback device, can be recommended as an alternative. With more educated laypersons performing high-quality CPR in the event of an OHCA, the survival rate may hopefully increase.

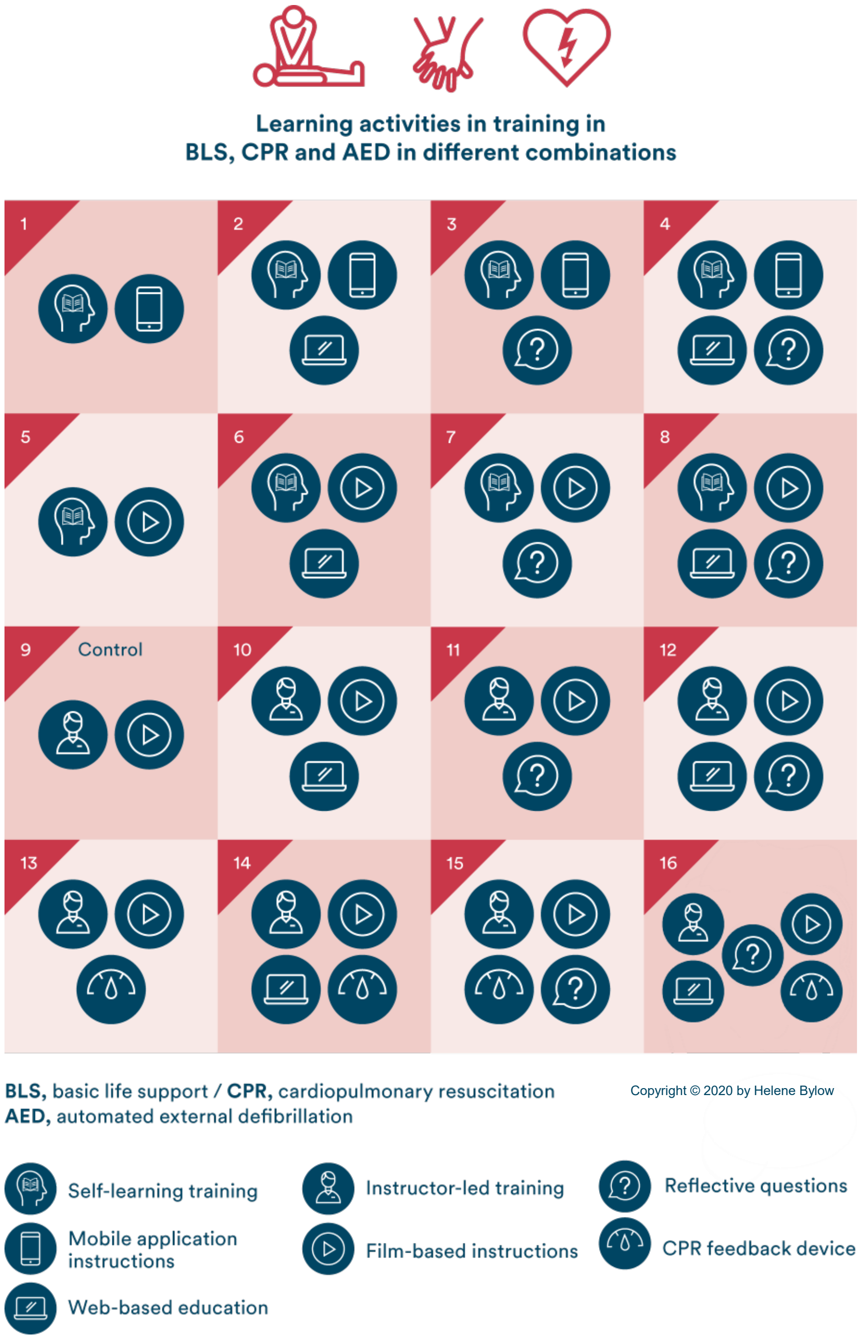
Workplaces have the potential for even greater survival from OHCA, since workplaces are a common and organised location for education in BLS. Moreover, the patients who suffer from OHCA at workplaces are more likely to be younger and more often found in a shockable cardiac rhythm than at other places outside hospital, and both of these factors are predictors for an increased chance of survival.

Describing the number of BLS-educated employees at all larger workplaces in one or several regions of Sweden, could be the subject of a further study, to be able to compare the survival rate with the number of educated employees. There might be a knowledge gap in terms of evidence of training in BLS at workplaces. Additionally, the outcome after OHCA at workplaces described as 30-day survival could be complemented with information on cerebral function, PROMs, such as quality of life, and return to work. The variable in the SRCR describing the level of education of the laypersons who perform bystander-CPR can be further highlighted to be reported and registered by the EMS.

Future research on how the competence and skills in BLS should be assessed is another research area. In the Work Environment Act [130], there are regulations about safety, prevention for occupational illness and accidents and recommendations for training in first aid, BLS, and crisis support. The recommendations for training in BLS could be mandatory for all employees with a minimal level of training every year, including feedback and assessment and short spaced training every six months.

The impact of training in BLS could also be the subject of a further study by describing the trainees' experiences not yet analysed from the questionnaires in Studies I-III. Experienced learning and benefits from the training in BLS, perceptions of how it would be to intervene in a real-life situation and the motivation and willingness to perform CPR could be described using qualitative research methodology, content analysis, for example. A further study of experiences of learning in training in BLS and preparedness to intervene in a real-life OHCA situation, among laypersons at workplaces, using a phenomenographic approach and interviews, is another important study area. Phenomenography focuses on conceptions of the world and could be useful in describing the impact of training in BLS and in designing of new educational approaches [366, 381, 382].

The present thesis has discussed learning aspects of OHCA and different learning activities in BLS for laypersons at workplaces. Today, I have the time and motivation for learning. Let us choose learning activity number 16 below and reflect on the fact that education is life itself and that we learn by reflecting on experiences [150].


Learning activities in training in
BLS, CPR and AED in different combinations
1
2
3
4
5
6
7
8
9
Control
10
11
12
13
14
15
16
BLS, basic life support / CPR, cardiopulmonary resuscitation
AED, automated external defibrillation
Copyright © 2020 by Helene Bylow
Self-learning training
Mobile application instructions
Web-based education
Instructor-led training
Film-based instructions
Reflective questions
CPR feedback device

# Acknowledgements

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My mother of life, Marita Bylow, thanks for everything!
Now we can walk by the sea, side by side.

With all my love, from Helene

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# Supplementary files

## Questionnaire directly after training in BLS

Questionnaire for all study participants in the BLS research project 2014-2016, directly after intervention relating to training in basic life support.

ONE response option to each question. When SEVERAL options are available, this is indicated. When no options are presented, the question is open ended, and the respondent is free to write as much as he/she likes.

Background factors
1) Participant, personal code number:
2) Training intervention; year, month, day and time:
3) Follow-up, directly after intervention; year, month, day and time:

Background factors regarding previous practical training in BLS, CPR and AED
4) Have you previously trained in:
a) chest compressions? Yes < 5 years ago/Yes > than 5 years ago/No, never
b) ventilations? Yes < 5 years ago/Yes > than 5 years ago/No, never
c) automated external defibrillator? Yes < 5 years ago/Yes > than 5 years ago/No, never

Background factors regarding previously experienced real-life situations
5) Have you ever been involved when someone suffered a:
a) suspected stroke? Yes/No/Do not know
b) suspected heart attack (acute myocardial infarction)? Yes/No/Do not know
c) suspected sudden cardiac arrest? Yes/No/Do not know

Self-assessed knowledge, confidence, and willingness to act
Self-assessed importance of learning in BLS
6) Do you think it is important to learn basic life support, cardiopulmonary re-suscitation and to use an automated external defibrillator? Yes/No/Do not know

Self-assed theoretical and practical knowledge
7) Do you think your theoretical knowledge and practical skills are sufficient to perform:
a) chest compressions? Yes/No/Do not know
b) ventilations? Yes/No/Do not know
c) instructions from an automated external defibrillator? Yes/No/Do not know

Self-assessed confidence
8) Do you feel more confident after the intervention than before, to intervene and act in a real-life sudden cardiac arrest situation? Yes/No/Do not know

Self-assesses willingness to act and start CPR – friend or relative
9) Imagine a situation at home. How do you think you would act if a close friend or a relative suffered a sudden cardiac arrest?
-I would not dare or want to intervene or act
-I would perform chest compressions, only
-I would perform ventilations, only
-I would perform both chest compressions and ventilations

10) If you answered that you would NOT dare or want to perform chest compressions, indicate possible reasons why: (SEVERAL options are possible)
a) Lack of knowledge
b) Afraid of hurting the person
c) Afraid of transmissible/contagious disease
d) Other reasons
If other reasons, describe which (*open ended)*:

11) If you answered that you would NOT dare or want to perform ventilations, indicate possible reasons why: (SEVERAL options are possible)
a) Lack of knowledge
b) Afraid of hurting the person
c) Afraid of transmissible/contagious disease
d) Other reasons
If other reasons, describe which (*open ended)*:

Self-assessed willingness to act and start CPR – unknown person
12) Imagine a situation at a bus stop. How do you think you would act if an unknown person suffered a sudden cardiac arrest?
-I would not dare or want to intervene or act
-I would perform chest compressions, only
-I would perform ventilations, only
-I would perform both chest compressions and ventilations

13) If you answered that you would NOT dare or want to perform chest compressions, indicate possible reasons why: (SEVERAL options are possible)
a) Lack of knowledge
b) Afraid of hurting the person
c) Afraid of transmissible/contagious disease
d) Do not want to touch a stranger
e) Other reasons
If other reasons, describe which (*open ended)*:

14) If you answered that you would NOT dare or want to perform ventilations, indicate possible reasons why: (SEVERAL options are possible)
a) Lack of knowledge
b) Afraid of hurting the person
c) Afraid of transmissible/contagious disease
d) Do not want to touch a stranger
e) Other reasons
If other reasons, describe which (*open ended)*:

Self-assessed willingness to use an AED
15) Imagine a situation at work. How do you think you would act in a situation in which your colleague was performing cardiopulmonary resuscitation, the ambulance was not yet present, and the workplace had an automated external defibrillator on site? Would you use the automated external defibrillator? Yes/No/Do not know

16) If you answered that you would NOT dare or want to use the automated external defibrillator, indicate possible reasons why: (SEVERAL options are possible)
a) Lack of knowledge
b) Afraid of hurting the person
c) Other reasons
If other reasons, describe which (*open ended)*:

Self-estimated experienced learning factors for practical skills dependent on the training
17) If the education made you feel that you can start cardiopulmonary resuscitation and use an automated external defibrillator, what was it that specifically contributed, in the education (*open ended)*:

Self-estimated missing learning factors for practical skills dependent on the training
18) If the education did NOT make you feel that you could start cardiopulmonary resuscitation and use an automated external defibrillator, what would have been needed for you to intervene and feel that you could start cardiopulmonary resuscitation and use an automated external defibrillator (*open ended)*:

Stroke symptoms
19) Which symptoms often occur, regarding a stroke?
a) Pain on one side of the body: Yes/No/Do not know
b) Pain on both the left and the right side of the body: Yes/No/Do not know
**c) Weakness on one side of the body: Yes**/No/Do not know
d) Weakness on both the left and the right side of the body: Yes/No/Do not know
e) Symptoms occur slowly: Yes/No/Do not know

**f) Symptoms occur quickly: Yes**/No/Do not know
**g) Difficult to speak or slurred speech: Yes**/No/Do not know

Acute myocardial infarction symptoms
20) What symptoms often occur, regarding a heart attack (acute myocardial infarction)?
**a) Discomfort or pain in the right arm: Yes**/No/Do not know
**b) Discomfort or pain in the left arm: Yes**/No/Do not know
**c) Discomfort or pain in the chest: Yes**/No/Do not know
d) Discomfort or pain in the right leg: Yes/No/Do not know
e) Discomfort or pain in the left leg: Yes/No/Do not know
**f) Discomfort or pain in the back: Yes**/No/Do not know
**g) Discomfort or pain in the stomach: Yes**/No/Do not know
h) Headache: Yes/No/Do not know
**i) Nausea: Yes**/No/Do not know

Theoretical knowledge of the first action if stroke or acute myocardial infarction
21) If symptoms of a stroke or heart attack (acute myocardial infarction) occur, what is your first action?
-Call the medical on-call service, 1177
-Call the health centre
**-Call the emergency services, 112**
-Wait fifteen minutes to see if the symptoms disappear
-Do not know

Theoretical knowledge of first action if cardiac arrest
22) What is your **first** action if you find a person that has a cardiac arrest?
-Start cardiopulmonary resuscitation
-Find and bring the nearest automated external defibrillator
-Place the victim in the recovery position
-**Call 112**
**-**Do not know

Theoretical knowledge of healthy lifestyle factors
23) Which of the following living habits are regarded as healthy lifestyle factors?
**a) Regular physical exercise: Yes**/No/Do not know
b) Smoking: Yes/No/Do not know
**c) Eating fruit and vegetables daily: Ye**s/No/Do not know
d) Being mostly sedentary daily: Yes/No/Do not know
**e) Eating fish two or three times a week: Yes**/No/Do not know
**f) Daily exercise such as walking or cycling: Yes**/No/Do not know

Background factors
Background factor language

24) Is your mother tongue (the first language you learned) Swedish? Yes/No/Do not know
-If NO, do you consider that you are able to read and understand Swedish without difficulty? Yes/No/Do not know

Background factor of CVD
25) Do you have any known cardiovascular disease? Yes/No/Do not know
-If YES, can you briefly describe the kind of disease (*open ended)*:

26) Have any close relatives or other related person any known cardiovascular disease?
Yes/No/Do not know?
-If YES, can you briefly describe the kind of disease (*open ended)*:

Background factor education
27) What is your highest level of education?
a) Have not attended school
b) Primary/elementary school (about age 6-16)
c) Secondary/high school (about age 17-20)
d) College/university (from about age 21)

Background factor occupation
28) Occupation (*open ended)*:

Background factor year of age
29) Age:

Background factor gender
30) Gender:

Background factor weight
31) Weight:

Background factor height
32) Height:

Overall comments
33) Other comments (*open ended)*:

# Questionnaire six months after training in BLS

Questionnaire for all study participants in the BLS research project 2014-2016, six months after intervention relating to training in basic life support.

ONE response option to each question. When SEVERAL options are available, this is indicated. When no options are presented, the question is open ended, and the respondent is free to write as much as he/she likes.

Background factors
1) Participant, personal code number:
2) Training intervention; year, month, day and time:
3) Follow-up six months after intervention; year, month, day and time:

Theoretical and practical benefits of the intervention/training
4) After the intervention and training in BLS, have you experienced theoretical or practical benefits from the training on:
a) chest compressions? Yes/No/Do not know
b) ventilations? Yes/No/Do not know
c) automated external defibrillator? Yes/No/Do not know
If yes, describe how (o*pen ended)*:

Backgrounds factors on previously experienced real-life situations
5) After the intervention have you been involved when someone suffered a:
a) suspected stroke? Yes/No/Do not know
b) suspected heart attack (acute myocardial infarction)? Yes/No/Do not know
c) suspected sudden cardiac arrest? Yes/No/Do not know

Self-assessed knowledge, confidence, and willingness to act
Self-assessed importance of learning in BLS training
6) Do you think it is important to learn basic life support, cardiopulmonary re-suscitation and to use an automated external defibrillator? Yes/No/Do not know

Self-assessed theoretical and practical knowledge
7) Do you think your theoretical knowledge and practical skills are sufficient to perform:
a) chest compressions? Yes/No/Do not know
b) ventilations? Yes/No/Do not know
c) instructions from an automated external defibrillator? Yes/No/Do not know

Self-assessed confidence
8) Do you feel more confident after the intervention than before, to intervene and act in a real-life sudden cardiac arrest situation? Yes/No/Do not know

Self-assessed willingness to act and start CPR – friend or relative
9) Imagine a situation at home. How do you think you would act if a close friend or a relative suffered a sudden cardiac arrest?
-I would not dare or want to intervene or act
-I would perform chest compressions, only
-I would perform ventilations, only
-I would perform both chest compressions and ventilations

10) If you answered that you would NOT dare or want to perform chest compressions, indicate possible reasons why: (SEVERAL options are possible)
a) Lack of knowledge
b) Afraid of hurting the person
c) Afraid of transmissible/contagious disease
d) Other reasons
If other reasons, describe which (*open ended)*:

11) If you answered that you would NOT dare or want to perform ventilations, indicate possible reasons why: (SEVERAL options are possible)
a) Lack of knowledge
b) Afraid of hurting the person
c) Afraid of transmissible/contagious disease
d) Other reasons
If other reasons, describe which (*open ended)*:

Self-assessed willingness to act and start CPR – unknown person
12) Imagine a situation at a bus stop. How do you think you would act if an unknown person suffered a sudden cardiac arrest?
-I would not dare or want to intervene or act
-I would perform chest compressions, only
-I would perform ventilations, only
-I would perform both chest compressions and ventilations

13) If you answered that you would NOT dare or want to perform chest compressions, indicate possible reasons why: (SEVERAL options are possible)
a) Lack of knowledge
b) Afraid of hurting the person
c) Afraid of transmissible/contagious disease
d) Do not want to touch a stranger
e) Other reasons
If other reasons, describe which (*open ended)*:

14) If you answered that you would NOT dare or want to perform ventilations, indicate possible reasons why: (SEVERAL options are possible)
a) Lack of knowledge

b) Afraid of hurting the person
c) Afraid of transmissible/contagious disease
d) Do not want to touch a stranger
e) Other reasons
If other reasons, describe which (*open ended)*:

Self-assessed willingness to use an AED
15) Imagine a situation at work. How do you think you would act in a situation in which your colleague was performing cardiopulmonary resuscitation, the ambulance was not yet present, and the workplace had an automated external defibrillator on site? Would you use the automated external defibrillator? Yes/No/Do not know

16) If you answered that you would NOT dare or want to use the automated external defibrillator, indicate possible reasons why: (SEVERAL options are possible)
a) Lack of knowledge
b) Afraid of hurting the person
c) Other reasons
If other reasons, describe which (*open ended)*:

Self-estimated experienced learning factors for practical skills dependent on the training
17) If the education made you feel that you can start cardiopulmonary resuscitation and use an automated external defibrillator, what was it that specifically contributed, in the education (*open ended)*:

Self-estimated missing learning factors for practical skills dependent on the training
18) If the education did NOT make you feel that you could start cardiopulmonary resuscitation and use an automated external defibrillator, what would have been needed for you to intervene and feel that you could start cardiopulmonary resuscitation and use an automated external defibrillator (*open ended)*:

Stroke symptoms
19) Which symptoms often occur, regarding a stroke?
a) Pain on one side of the body: Yes/No/Do not know
b) Pain on both the left and the right side of the body: Yes/No/Do not know
**c) Weakness on one side of the body: Yes**/No/Do not know
d) Weakness on both the left and the right side of the body: Yes/No/Do not know
e) Symptoms occur slowly: Yes/No/Do not know
**f) Symptoms occur quickly: Yes**/No/Do not know
**g) Difficult to speak or slurred speech: Yes**/No/Do not know

Acute myocardial infarction symptoms
20) What symptoms often occur, regarding a heart attack (acute myocardial infarction)?
**a) Discomfort or pain in the right arm: Yes**/No/Do not know
**b) Discomfort or pain in the left arm: Yes**/No/Do not know
**c) Discomfort or pain in the chest: Yes**/No/Do not know
d) Discomfort or pain in the right leg: Yes/No/Do not know
e) Discomfort or pain in the left leg: Yes/No/Do not know
**f) Discomfort or pain in the back: Yes**/No/Do not know
**g) Discomfort or pain in the stomach: Yes**/No/Do not know
h) Headache: Yes/No/Do not know
**i) Nausea: Yes**/No/Do not know

Theoretical knowledge of the first action if stroke or acute myocardial infarction
21) If symptoms of a stroke or heart attack (acute myocardial infarction) occur, what is your first action?
-Call the medical on-call service, 1177
-Call the health centre
**-Call the emergency services, 112**
-Wait fifteen minutes to see if the symptoms disappear
-Do not know

Theoretical knowledge of first action if cardiac arrest
22) What is your **first** action if you find a person that has a cardiac arrest?
-Start cardiopulmonary resuscitation
-Find and bring the nearest automated external defibrillator
-Place the victim in the recovery position
**-Call 112**
**-**Do not know

Theoretical knowledge of healthy lifestyle factors
23) Which of the following living habits are regarded as healthy lifestyle factors?
**a) Regular physical exercise: Yes**/No/Do not know
b) Smoking: Yes/No/Do not know
**c) Eating fruit and vegetables daily: Ye**s/No/Do not know
d) Being mostly sedentary daily: Yes/No/Do not know
**e) Eating fish two or three times a week: Yes**/No/Do not know
**f) Daily exercise such as walking or cycling: Yes**/No/Do not know

Background factors
Background factor language
24) Is your mother tongue (the first language you learned) Swedish? Yes/No/Do not know

-If NO, do you consider that you are able to read and understand Swedish without difficulty? Yes/No/Do not know

Background factor of CVD
25) Do you have any known cardiovascular disease? Yes/No/Do not know
-If YES, can you briefly describe the kind of disease (*open ended)*:

26) Have any close relatives or other related person any known cardiovascular disease?
Yes/No/Do not know?
-If YES, can you briefly describe the kind of disease (*open ended)*:

Background factor education
27) What is your highest level of education?
a) Have not attended school
b) Primary/elementary school (about age 6-16)
c) Secondary/high school (about age 17-20)
d) College/university (from about age 21)

Background factor occupation
28) Occupation (*open ended)*:

Background factor year of age
29) Age:

Background factor gender
30) Gender:

Background factor weight
31) Weight:

Background factor height
32) Height:

Background factors other sources of information
33) Have you completed the web-based education called Help-Brain-Heart?
-No, never
-Yes, once
-Yes, several times
-Do not know
-If YES, what do you think about it (*open ended)*:

34) Have you recommended the web-based education called Help-Brain-Heart to someone else and, if yes, who (for example relatives or friends, *open ended)*:

35) Have you looked at and read the mobile application called Rädda hjärtat (Save the heart):
-No, never
-Yes, once
-Yes, several times
-Do not know
-If YES, what do you think about it (*open ended)*:

36) Have you recommended the mobile application named Rädda hjärtat (Save the heart) to someone else and, if yes, who (for example relatives or friends) (*open ended)*:

Self-estimated expected experience to intervene
37) *How would it be for you to intervene in a real-life acute situation? How do you think? How do you feel?* (*open ended):*

Self-reported overall experience of the intervention and training
38) Here, you can make other comments on your overall experience of the education (*open ended)*:

# The Cardiff Test of basic life support and external defibrillation

Description of the modified version of the Cardiff Test of basic life support and external defibrillation, according to ERC guidelines 2010 and the national Swedish guidelines 2010.

The practical BLS test lasted for three minutes in order optimally to identify the cardiac arrest for no more than 30 seconds, call for help and perform cardiopulmonary resuscitation (CPR) and about two minutes for using the automated external defibrillator (AED). The AED was delivered three minutes after the start of the scenario. The test was terminated after one shock and the resumption of CPR. The practical part was filmed by a mounted visible video camera on the wall after personal information and a signed informed consent from the participant. The test was started after a simulated sudden out-of-hospital cardiac arrest (OHCA) scenario was described by the assessor to the participant who was sitting in a chair in a regular living room beside a dressed manikin, lying on the floor.

> *"You are at work. A colleague looks pale, puts her/his hand in the middle of her/his chest and says, I have chest pain and then suddenly collapses in front of you. Act as if it was a real-life situation!"*

The environment was as close as possible to a real-life situation and equally for all assessments. Registrations from the Laerdal PC Skill Reporting System was automatically measured. The Cardiff Test score sheet was marked manually from direct observation and checked by the videotape/film after the test. All the variables were then entered into a database system.

| **Modified version of the Cardiff Test of basic life support and external defibrillation** | |
|---|---|
| **Description of variables in the Cardiff Test**<br>Maximum score 70 — minimum score 19 | **Points**<br>(70-19) |
| **1. Checks responsiveness—by talking**<br>2 points: Yes<br>1 point: No<br>**Description: Responsiveness—talk**<br>The participant must check responsiveness by some verbal communication, talking, saying "Are you all right", for example. If performed, a yes was marked, if not, a no was marked by direct observation and registration on the Cardiff Test score sheet. | **(2-1)** |

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| **2. Checks responsiveness—by shaking**<br>3 points: Yes<br>2 points: No<br>1 point: Potentially dangerous<br>**Description: Responsiveness—shake**<br>The participant must check responsiveness by gently shaking the victim's shoulders. If performed, a yes was marked, if not, a no was marked and, if the shaking was violent, potentially causing injuries, the lowest score was marked by direct observation and registration on the Cardiff Test. | **(3-1)** |
| **3. Opens airway—head tilt and chin lift**<br>5 points: Perfect as instructed<br>4 points: Acceptable<br>3 points: Attempted other<br>2 points: Attempted visible but fails or only one element<br>1 point: No<br>**Description: Open airway—head tilt and chin lift**<br>For perfect as instructed, the participant must clearly and visibly place one hand on the victim's forehead, tilt the head back and lift the chin with the fingertips on the hard bone to open the airway. For acceptable the manoeuvre must open the airway as instructed, close to perfect. If attempting technique other than that described by ERC guidelines, it must be similar to as instructed. If the participant failed or only used one element, the next lowest score was marked. No was marked when no attempt to open the airway was made at all. Direct observation and registration on the Cardiff Test were used even if the PC Skill Reporting System also registers it. | **(5-1)** |
| **4. Checks breathing—look, listen and feel**<br>2 points: Yes<br>1 point: No<br>**Description: Breathing—look, listen and feel**<br>Yes, was marked if the participant performed open airway together with look, listen and feel correctly and for no more than ten seconds. No was marked if no attempt to check breathing was made. Direct observation, a stopwatch and registration on the Cardiff Test were used. | **(2-1)** |
| **5. Calls 112—or asks for help calling 112**<br>2 points: Yes<br>1 point: No<br>**Description: Call 112**<br>For yes, the participant had to call to 112 or ask someone else to call 112 (the national emergency number) within the first minute from the scenario start. If not, no was marked on the Cardiff Test | **(2-1)** |

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| using direct observation, a stopwatch and registration on the Cardiff Test. | |
| **6. Send someone for AED**<br>2 points: Yes<br>1 point: No<br>**Description: Send for AED**<br>For yes, the participant had to ask someone to bring the AED within three minutes. If not, no was marked. Direct observation, a stopwatch and registration on the Cardiff Test were used. | **(2-1)** |
| **7. Starts CPR—compression/ventilation ratio**<br>4 points: 30:2 (28-32:2)<br>3 points: Another ratio<br>2 points: Compressions only<br>1 point: Ventilations only<br>**Description: Start CPR**<br>For the highest score, the participant had to start with thirty compressions (28-32 were accepted), two ventilations and then continue the ratio 30:2. Some misses in the ratio were accepted, such as 28-32 for compressions and failed ventilations. Another ratio was marked if a different ratio from 28-32:2 was used, for example, 2:30. Compressions and ventilations only were marked if the participant intended to perform only one of them. For the CPR ratio, we used 30:2 for six points, as the maximum according to ERC guidelines for trained, five points for another ratio, as the national education teaches both compressions and ventilations, and three points for compressions only, as this was an educational intervention. Direct observation, registration from the Laerdal PC Skill Reporting System were used directly and transferred after the test to the Cardiff Test score sheet. The time from scenario start to first compression was counted by a stopwatch and from the PC Skill Reporting System, marked on the Cardiff Test score sheet. | **(4-1)** |
| **8. Hand placement compressions**<br>4 points: Correct<br>3 points: Other wrong<br>2 points: Too low<br>1 point: Not attempted<br>**Description: Hand placement for compressions**<br>The correct hand position according to a previous validated Cardiff Test means that all compressions must be correct for the highest score. They must all be placed according to ERC guidelines, with the heel of one hand on the centre of the victim's chest, on the lower half of the breast bone, the heel of the other hand on top of the first hand and with interlocked fingers. Wrong | **(4-1)** |

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| was recorded for compressions too high up on the breast bone, to the right or to the left of the breast bone, if the participant used too much of the hand or had very large hands or used his/her fist. Too low compressions were recorded if just one compression was too low on the breast bone. If no compressions were performed, not attempted was marked. Direct observation, registration from the Laerdal PC Skill Reporting System were used and transferred to the Cardiff Test score sheet. | |
| **9. Average compression depth**<br>6 points: 50-59 mm<br>5 points: ≥ 60 mm<br>4 points: 35-49 mm<br>2 points: < 35<br>1 point: Not attempted<br>**Description: Average compression depth**<br>According to previous research, the highest score for compression depth was six points for 40-50 mm. The ERC guidelines updated the compression depth to 50-60 mm. To adjust to the updated guidelines, we decided to keep the score when adding the new depth. The PC Skill Reporting System version, 2.4.1, only measured up to 60 mm and, for this reason, we decided to score 50-59 mm. Those who performed compressions 60 mm or more received the next highest score. Even if the guidelines emphasise "not more than 60 mm", some previous studies discuss the fact that the bystander tends to perform compressions that are too shallow [228] and, together with previous scores, this is the reason why we kept it as the next highest score. The optimal depth has been reported as 45.6 mm [16], but the rescuers tend to compress below the target [228] and this consolidates the scores in the Cardiff Test. To adjust for the deeper depth and keep the score as in the validated previous research with six points, we also had to deduct three points from the score. Direct observation, registration from the Laerdal PC Skill Reporting System were used and transferred to the Cardiff Test score sheet. | **(6-1)** |
| **10 Average compression rate**<br>6 points: 100-120<br>5 points: 121-140<br>4 points: 80-99<br>3 points: > 140<br>2 points: < 80<br>1 point: Not attempted<br>**Description: Average compression rate**<br>The six-level scoring scale was kept for the compression rate to make the relationship between the different steps in the Cardiff | **(6-1)** |

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| Test like those in the previous Cardiff Test. We used the same level as compression depth to be consistent. Both the exact value for the average compression rate from the Laerdal PC Skill Reporting System and the Cardiff Test points were noted on the sheet. | |
| **11. Total compressions counted**<br>6 points: 140-190<br>5 points: > 190<br>4 points: 121-139<br>3 points: 81-120<br>2 points: 1-80<br>1 point: Not attempted<br>**Description: Total compressions counted**<br>Total compressions were counted for three minutes. This was the time from the scenario start to when the AED was delivered to the participant. The time included for optimally identifying the cardiac arrest, calling for help, asking for an AED, compressions and ventilations. The total number of counted compressions are therefore dependent on how much time the participant took for each step. Data from the Laerdal PC Skill Reporting System were transferred to the Cardiff Test score sheet both as the exact value and as the Cardiff Test points. | **(6-1)** |
| **12. Average ventilation volume**<br>5 points: 500-600 ml<br>4 points: 1-499 ml<br>3 points: > 600 ml<br>2 points: 0 ml<br>1 point: Not attempted<br>**Description: Average ventilation volume**<br>Like previous studies, we kept the five-level scale for ventilation volume. Two points was marked if the participant attempted ventilations but failed, the chest did not rise and no volume was registered in the Laerdal PC Skill Reporting System. For one point, ventilations were not performed at all. Direct observation, registration from the Laerdal PC Skill Reporting System were used directly and transferred after the test for scoring to the Cardiff Test score sheet, both as the exact value and as the Cardiff Test points. | **(5-1)** |
| **13. Total ventilations counted**<br>5 points: 8-12<br>4 points: 1-7<br>3 points: > 12<br>2 points: 0<br>1 point: Not attempted | **(5-1)** |

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| **Description: Total ventilations counted**<br>Total ventilations were counted for three minutes. This was the time from the scenario start to when the AED was delivered to the participant. The time included for optimally identifying the cardiac arrest, calling for help, asking for an AED, compressions and ventilations. The total number of counted ventilations are therefore dependent on how much time the participant took for each step. Direct observation, registration from the Laerdal PC Skill Reporting System were used directly and transferred after the test for scoring to the Cardiff Test score sheet, both as an exact value and as the Cardiff Test points. | |
| **14. Total hands-off time**<br>4 points: ≤ 60 second<br>3 points: 61-90 seconds<br>2 points: 91-135 seconds<br>1 points: > 135 seconds<br>**Description: Total hands-off time**<br>When no compressions were performed in the scenario, the total hands-off time was measured from the Laerdal PC Skill Reporting System. The data was transferred to the Cardiff Test scoring sheet, both as an exact value and as the Cardiff Test point. | **(4-1)** |
| **15. Switch on AED**<br>2 points: Yes<br>1 point: No<br>**Description: Switch on AED**<br>After three minutes from the scenario start, the assessor placed the AED next to the manikin and started the stopwatch. If the participant switched the AED on, a yes was marked. The time for delivering the AED was set as the research was created for the public, outside the hospital. The most common thing is that someone has to be sent for an AED and bring it. Three minutes are calculated as the minimal time. The participant has enough time to do CPR and then decide to use the AED or not. Direct observation with registration was used directly and transferred to the Cardiff Test score sheet. | **(2-1)** |
| **16. Attach electrode pads**<br>6 points: Both electrodes completely in areas<br>5 points: One electrode completely in area and one crossing the border of area<br>4 points: One electrode completely in area and one electrode outside the area<br>3 points: Both electrodes crossing the area<br>2 points: Both electrodes outside the areas<br>1 point: Electrodes not attached or plugged into AED | **(6-1)** |

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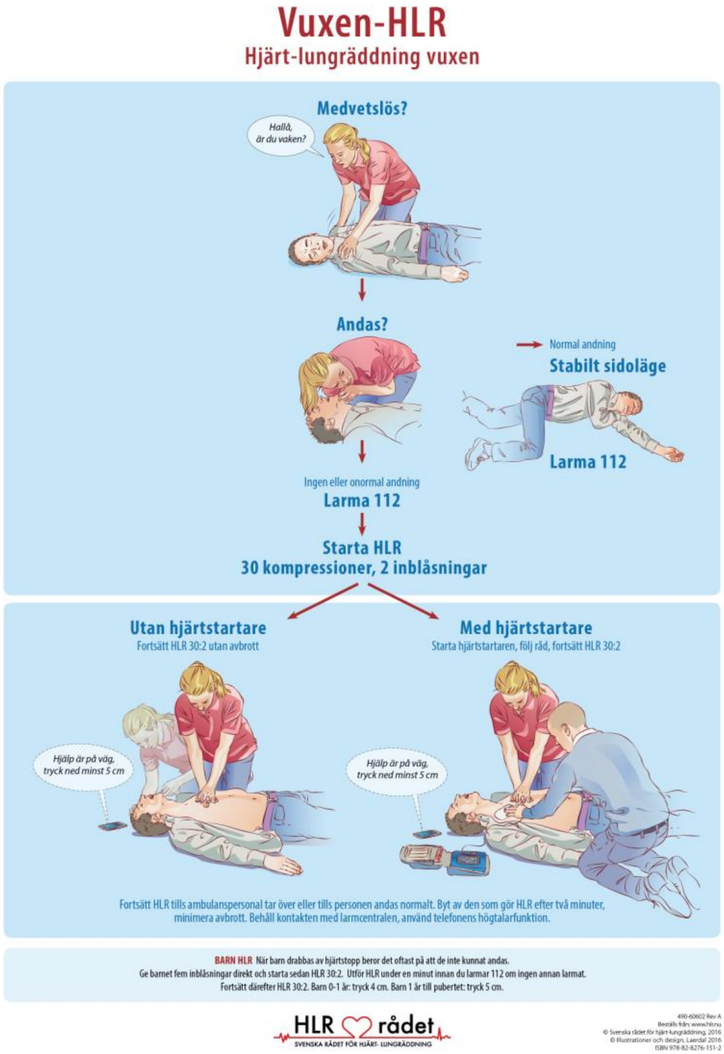
| **Description: Attach electrode pads**<br>Previous studies with pictures and text were used for the scoring system for the correct position for the electrode pads on the victim's bare chest. Direct observation with registration was used directly and transferred to the Cardiff Test score sheet. | |
| **17. Checks safety before shocking**<br>2 points: Yes, performed<br>1 point: No, not performed<br>**Description: Checks safety of bystanders and him/herself before shocking**<br>The participant must ensure that nobody or him/herself is in contact with the victim using a verbal and visual check and communicating, for example, with "stand clear", before the shock button is pushed. No was marked if the participant did not check for safety. | **(2-1)** |
| **18. Deliver shock as directed from the AED**<br>2 points: Yes<br>1 point: No<br>The time from when the AED was placed next to the manikin to the first shock was counted using a stopwatch and marked on the Cardiff Test score sheet. | **(2-1)** |
| **19. Continues CPR directly after shocking, as directed from the AED**<br>2 points: Yes<br>1 point: No<br>**Description: Continues CPR directly after shocking**<br>After shocking, the voice prompt from the AED told the participant to continue CPR. Direct observation with registration was used directly and transferred to the Cardiff Test score sheet. | **(2-1)** |
| **Maximum points 70**<br>**Minimum points 19** | **(70-19)** |

# Adult CPR and AED algorithm
# Swedish Resuscitation Council




The BLS, CPR and AED algorithm by the SRC was the same during the training period 2014-2016
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