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Evaluation of skills acquisition using a new tool for CPR self-training

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Abstract

Introduction: In sudden cardiac arrest, early cardiopulmonary resuscitation (CPR), with emphasis on chest compressions, is a fundamental step in the Chain of Survival. Due to irregular training and low skill retention, CPR can be performed ineffectively. Simulation can be a useful resource for training resuscitation. Feedback on performance is a crucial component of the learning processes associated with simulation and has been shown to improve CPR quality during simulated cardiac arrest on manikins.

Aim: The general aim of this study is to evaluate skills acquisition using a new tool for CPR self-training, by assessing its efficiency and effectiveness when compared to the standard training methods. The prototype is expected to facilitate regular training and improve long-term knowledge.

Methods: This study was carried out at the Biomedical Simulation Center of the Faculty of Medicine, University of Porto and consisted in the comparison of two homogeneous groups of medical students, undergoing Basic Life Support (BLS) training. For training BLS skills, the control group used a standard task-trainer and received feedback from an instructor. The intervention group used a standard task-trainer coupled to the CPR Personal Trainer providing automated performance feedback (with no instructor). Students' knowledge and skills were assessed before and after the course, through theoretical and practical pre and post-tests. After both theoretical and practical training courses the intervention group was also asked to assess the usability of the CPR Personal Trainer.

Results: Theoretical and practical tests in both groups presented an increase in the score between the pre and the post-test with statistical significant difference. The inter group comparison showed, for all tests no statistically significant differences indicating no differences between groups. The pre and post-test comparison for the overall and all individual compressions related parameters present a statistical significant increase, in both groups. Considering the practical test results for the parameters not related to compressions (such as adequate ventilations or shout for help), an overall improvement is observed in both groups, but with a greater difference in the control group.

The usability test global score was 75, which is considered above the average. The three most commented positive aspects were: real-time feedback, rapid learning curve, and correct evaluation of compression's parameters. The three most mentioned aspects that needed improvement were: compression's depth assessment, ventilation parameters assessment, and information on the algorithm.

Discussion and conclusions: This study corroborates the hypothesis that low-cost tools with feedback for CPR self-training can provide an alternative or a complementary extension to the traditional methods, applied to both skills' acquisition and maintenance. Despite some limitations, the proposed tool proved to be effective in the acquisition of compressions related skills, with similar outcomes as the traditional instructor-based method. The most pressing future work of this project is related to overall technical improvement of the CPR Personal Trainer, repeating the study with a larger sample (and groups with different background) and comparing the training outcomes of the low cost CPR Personal Trainer with other feedback tools existing on the market but with a higher cost.

Keywords: Cardiopulmonary Resuscitation, CPR Personal Trainer, Simulation, Basic Life Support.

Resumo

Introdução: Em caso de paragem cardiorrespiratória súbita, a reanimação cardiorrespiratória precoce, com destaque nas compressões torácicas, é um passo fundamental na cadeia de sobrevivência. Devido à formação irregular e à baixa retenção de competências, a reanimação cardiorrespiratória pode ser realizada de forma ineficaz. A simulação pode ser um recurso útil para o treino em reanimação. O *feedback* sobre o desempenho é um componente crucial dos processos de aprendizagem associados à simulação e tem sido demonstrado que melhora a qualidade da reanimação cardiorrespiratória durante situações simuladas de paragem cardiorrespiratória em manequins.

Objetivo: O objetivo geral deste estudo é avaliar a aquisição de competências utilizando uma nova ferramenta para a autoaprendizagem em reanimação cardiorrespiratória, avaliando a sua eficiência e efetividade quando comparada com os métodos de treino padrão. O protótipo é suposto facilitar a formação regular e melhorar o conhecimento a longo prazo.

Métodos: Este estudo foi realizado no Centro de Simulação Biomédica da Faculdade de Medicina, Universidade do Porto e consistiu na comparação de dois grupos homogéneos de estudantes de medicina, submetidos a formação em Suporte Básico de Vida. Para o treino das competências em Suporte Básico de Vida, o grupo de controlo utilizou um torso padrão e recebeu *feedback* de um instrutor. O grupo de intervenção utilizou um torso padrão acoplado ao *CPR Personal Trainer* com *feedback* automatizado de desempenho (sem instrutor). Os conhecimentos e competências dos alunos foram avaliados antes e depois do curso, através de pré e pós-testes teóricos e práticos. Depois dos cursos de formação teórica e prática o grupo de intervenção realizou a avaliação da usabilidade do *CPR Personal Trainer*.

Resultados: Os testes teóricos e práticos em ambos os grupos apresentaram um aumento no *score* entre o pré e o pós-teste, com diferenças estatisticamente significativas. A comparação entre os grupos demonstra que para todos os testes não ocorreram diferenças significativas, indicando não existirem diferenças entre os grupos. A comparação entre o pré e pós-teste para os parâmetros gerais e individuais das compressões apresenta um aumento estatístico significativo, em ambos os grupos. Considerando-se os resultados dos testes práticos, para os parâmetros não relacionados com compressões (como ventilações

adequadas ou pedido de ajuda), observou-se uma melhoria global em ambos os grupos, mas com uma diferença maior no grupo de controlo.

O *score* global do teste de usabilidade foi de 75, o que é considerado acima da média. Os três aspetos positivos mais comentados foram: *feedback* em tempo real; curva de aprendizagem rápida; correta avaliação dos parâmetros das compressões. Os três aspetos mais citados que precisam de melhoria foram: avaliação da profundidade das compressões; avaliação dos parâmetros da ventilação; informações sobre o algoritmo.

Discussão e conclusões: Este estudo corrobora a hipótese de que as ferramentas de baixo custo para a autoaprendizagem em reanimação cardiorrespiratória podem fornecer uma alternativa ou ser uma extensão complementar aos métodos tradicionais, relativamente à aquisição e manutenção de habilidades. Apesar de algumas limitações, a ferramenta proposta provou ser eficaz na aquisição de habilidades relacionadas com as compressões, com resultados semelhantes aos do método tradicional com instrutor. O trabalho futuro mais iminente deste projeto está relacionado com a melhoria técnica global do *CPR Personal Trainer*, repetindo o estudo com uma amostra maior (e grupos com diferente *background*) e comparar os resultados do treino com a ferramenta de baixo custo, o *CPR Personal Trainer*, com outras ferramentas de *feedback* existentes no mercado, mas com um custo mais elevado.

Palavras-chave: Reanimação Cardiorrespiratória, *CPR Personal Trainer*, Simulação, Suporte Básico de Vida.

Preamble

I am a graduate student in Nuclear Medicine by the *Escola Superior de Tecnologia da Saúde de Lisboa* (ESTESL) of the *Instituto Politécnico de Lisboa*, since 2011. In 2014, I joined the master's degree in Medical Informatics.

Moreover, since 2009, I am a volunteer firefighter. In this sense, the empathy for the area of cardiopulmonary resuscitation led to embark into this thesis' project.

Due to specific training needs in CPR and its importance in the survival rate of the population, I embraced the opportunity to evaluate the educational impact of a new low-cost CPR training system for self-guided training on chest compressions, under development at the Faculty of Medicine, University of Porto. The results of this work are presented here.

During the development of this work, an abstract was submitted and accepted for oral presentation at the Annual Meeting of the Society in Europe for Simulation Applied to Medicine (oral presentation on June 15th, 2016). This work was also invited for presentation at the Annual Symposium of the master's degree in Medical Informatics of the Faculty of Medicine, University of Porto (oral presentation on September 24th, 2016).

Contents

Abbreviations and acronyms

AED	Automated External Defibrillator
BLS	Basic Life Support
CPR	Cardiopulmonary Resuscitation
ECG	Electrocardiogram
ERC	European Resuscitation Council
SBL	Simulation-Based Learning
SCA	Sudden Cardiac Arrest

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1. Introduction

This initial chapter comprises a global approach of this thesis, and outlines the research problem and question, the objectives proposed, the contributions this work brings to the scientific research community and the thesis' structure.

1.1 Motivation

Cardiac events are a leading cause of death worldwide. Sedentary lifestyle, obesity, hypertension, diabetes, smoking and stress are risk factors for the existence of cardiovascular problems that can lead to cardiac arrest (Hopstock, 2008).

Anyone can get into cardiac arrest, so it can be of crucial importance to know how to act in such situation where the survival rate decreases quickly with every minute, and the possibility to suffer brain damage increases if there is no immediate cardiopulmonary resuscitation (CPR) (Bullock, 2000; Pozner et al., 2011).

Research results show that rescuer's skills deteriorate within months after training and skills are poorly acquired. So, it is important to frequently update theoretical knowledge and practical training as well as keep up with the current research to adapt new and improved training methods (Pozner et al., 2011).

Simulation is a good option as it allows regular training in CPR. Properly conducted simulation scenarios create an ideal educational environment because learning activities can be predictable, consistent, standardized, safe, and reproducible. This environment encourages learning through experimentation, trial and error with the ability to rewind, rehearse, and practice without negative patient outcomes, allowing students and trainees to achieve their goals without putting patient's lives at risk (Perkins et al., 2008).

For all these reasons it becomes increasingly important to conduct studies and research in the field of medical simulation applied to cardiopulmonary resuscitation training, involving both healthcare professionals and general population (Nishiyama, Iwami, Kawamura, & Ando, 2010).

Healthcare professionals' training in CPR is already associated with the use of simulation equipment however, this equipment is usually expensive and only available in Simulation Centers.

The development and evaluation of innovative and low cost systems for the simulation of CPR becomes increasingly relevant (Gaba, 2004). With this purpose, a new training tool for self-training of CPR skills (CPR Personal Trainer) was developed at the Biomedical Simulation Centre of the Faculty of Medicine of University of Porto.

This study evaluates if the use of this new tool improves knowledge and technical skills of medical students when compared to the standard training methods.

1.2 Aim and objectives

The general aim of this study is to evaluate skills acquisition using a new tool for CPR self-training, by assessing its efficiency and effectiveness when compared to the standard training methods.

The specific objectives are:

- To measure and evaluate the acquisition of knowledge and technical skills of self-training when compared with the traditional method;
- To identify potential limitations of the self-training system when compared to the traditional method;
- To evaluate system's usability.

1.3 Thesis structure

The thesis is organised in five chapters, outlined as follows:

- Chapter one – Presents the motivation, the project aims and objectives and thesis outline;
- Chapter two – Introduces basic concepts of CPR and describes the CPR training based on simulation;
- Chapter tree – Describes the study design and implementation;
- Chapter four – Reports the results of the implementation;
- Chapter five– Discusses the obtained results, some limitations of this work and proposes recommendations and directions of future work.

2. Background

2.1 Cardiopulmonary resuscitation

One of the leading causes of death in Europe is the sudden cardiac arrest (SCA), affecting about 55–113 per 100,000 inhabitants per year (Hopstock, 2008).

Cardiac arrest is a sudden stop in effective blood circulation due to the failure of the heart to contract effectively or at all. It occurs in a quarter to a third of patients with myocardial ischemia within the first hour after the onset of chest pain (Kwok, Coult, Drton, Rea, & Sherman, 2015).

Immediately following cardiac arrest, blood flowing to the brain is reduced to virtually zero, causing a lack of oxygen and glucose in the brain, which then results into abnormal or absent breathing (Kwok et al., 2015). Cardiac arrest is a medical emergency that, in certain situations, is potentially reversible if treated early, otherwise it can lead to death within minutes (Kwok et al., 2015). The treatment for cardiac arrest is immediate defibrillation if a "shockable" rhythm is present, while cardiopulmonary resuscitation is the solution to provide circulatory support and/or to induce a "shockable" rhythm (Kwok et al., 2015; Perkins, 2007).

The early CPR is a central step in the chain of survival (Figure 1) in case of cardiopulmonary arrest with an emphasis on chest compressions (component of CPR that seems to make the greatest difference in most cases)(Monsieurs et al., 2015). It is recommended to be started as soon as possible and interrupted as little as possible. This procedure allows then the preservation of intact brain function, restoring the partial flow of oxygenated blood to the brain and heart, delaying the tissue's death (Kwok et al., 2015; Perkins, 2007).

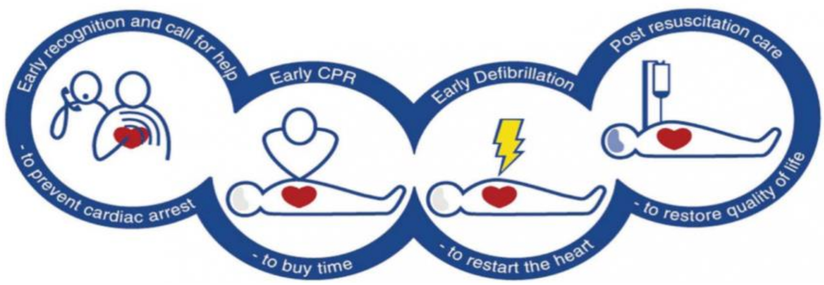

Figure 1: Chain of survival. Adapted from the ERC guidelines (Monsieurs et al., 2015)

CPR comprises the execution of chest compressions and breaths/ventilations with a ratio of chest compressions to ventilations of 30:2. When providing rescue breaths/ventilations, there should be spent approximately 1 second in inflating the chest with sufficient volume to ensure the chest rises visibly. The chest compressions should not be suspended for more than 10 seconds to provide ventilations (Monsieurs et al., 2015).

According to manikin studies, to emphasize the priority of chest compressions, it is recommended that adults' CPR should start with chest compressions rather than initial ventilations (Neset et al., 2010).

When performing chest compressions it is important to take into account parameters such as hand's position, compression depth, compression rate and chest wall recoil (Monsieurs et al., 2015).

Additionally, when performing chest compressions and to have better hemodynamic responses, the position of the hands should be on the lower half of the sternum. The heel of one hand should be in the center of the chest with the other hand on top as is shown at Figure 2 (Monsieurs et al., 2015; Wang et al., 2015).

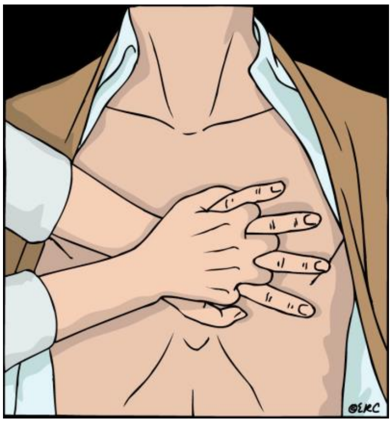

Figure 2: Hands' position. Adapted from the ERC guidelines (Monsieurs et al., 2015)

The European Resuscitation Council (ERC) considers that it is reasonable to aim for a chest compression depth of approximately 5 cm but not more than 6 cm in an average sized adult (Monsieurs et al., 2015).

Chest compression rate is defined as the actual rate of compressions being given at any one time and differs from the number of chest compressions in a specific time period, which takes into account any interruptions in chest compressions. The ERC recommends that chest compressions should be performed at a rate of 100–120 min^{-1} (Monsieurs et al., 2015).

After each compression it is important to allow for complete chest recoil, which may cause better venous return to the heart and may improve the effectiveness of CPR. Therefore, CPR providers should avoid leaning after each chest compression (Monsieurs et al., 2015). The 2015 CPR Algorithm for the adult is presented in Figure 3.

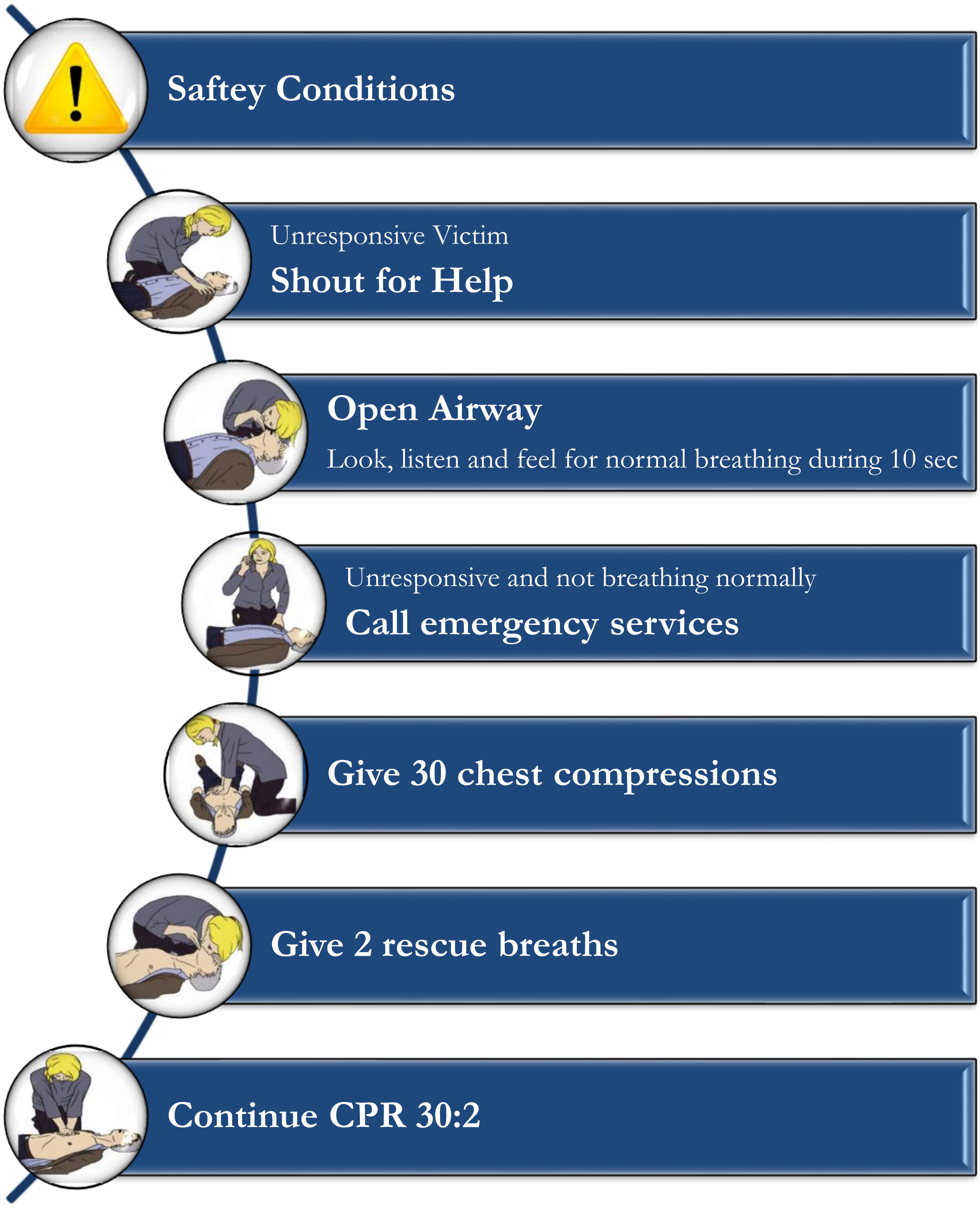

Figure 3: CPR algorithm. Adapted from the ERC guidelines (Monsieurs et al., 2015)

High quality cardiopulmonary resuscitation remains essential to improving outcomes. Several studies have shown that sometimes the CPR is performed ineffectively, possibly due to irregular training and low skill retention (Hopstock, 2008; Pozner et al., 2011; Perkins, 2007).

2.2 CPR training

The training interventions should ensure that rescuers acquire and retain skills that allow them to act correctly in case of CPR and improve the survival rate of victims. The traditional acquisition and retention of skills in CPR is based in a theoretical and practical training in a mannequin or task-trainer, given by one instructor according to the following sequence: theoretical background in CPR, chain of survival, correct CPR performance with emphasis on chest compressions, automated external defibrillator (AED) use and correct positioning of the victim after recovery (European Resuscitation Council, 2008; Maria et al., 2014).

The course includes a standardized assessment of performance (given by the instructor), either during the course in the form of continuous assessment, or at the end of the course during which the key learning outcomes of the course have to be successfully demonstrated (European Resuscitation Council, 2008; Maria et al., 2014).

As an alternative to classical training led by trainers, training models based on short videos of self-learning may be used combined with practical training sessions with minimal intervention from instructors. Other alternative that seems to improve the CPR skills is the use of one automated voice advisory manikin that is able to increase skill level by means of continuous verbal feedback during individual CPR training without an instructor (Perkins, 2007).

In this sense, simulation seems to be an essential part of training in resuscitation, providing a learning opportunity for controlled clinical training without putting patients or others at risk (Perkins, 2007).

2.3 Medical simulation

Education is a learning process which deals with unknown outcomes, with circumstances which require a complex synthesis of knowledge, skills and experience to solve problems (Vantini & Benini, 2008; Mba, Ed, Hons, & Ed, 2007).

Beyond the many existing learning methods in the field of medicine in recent years' simulation-based learning (SBL) has been increasingly used in health care training and especially in medical education. Given that cognitive psychology has shown that facts and concepts are better remembered and put into practice when they are taught, practiced and assessed in the context in which they will be used, the simulation has sparked great interest in medical education (Ziv, Wolpe, Small, & Glick, 2003; Dourado & Giannella, 2014).

SBL can be the way to develop health professionals' knowledge, skills, and attitudes, whilst protecting patients from unnecessary risks. SBL has been used as a methodology which is characterized by active learning in risk-free environment to build the knowledge, technical skills, communication, leadership and team work. In this context, the medical simulation is presented as a potential instruction strategy by allowing learning to occur in a secure environment, enabling the display of multiple pathologies and facilitating the knowledge and skills such as are experienced in clinical practice (Lateef, 2010).

Simulation is a technique to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner; or a generic term that refers to the artificial representation of a real world process to achieve educational goals via experimental learning (Gaba, 2004).

A simulator is defined as a device that enables the operator to reproduce or represent under test conditions phenomena likely to occur in actual performance. In health care the term "simulator" usually refers to a device that presents a simulated patient (or part of a patient) and interacts appropriately with the actions taken by the simulation participant (Ziv et al., 2003).

Medical simulation can be defined as the use of a device or series of devices to emulate a real patient situation for the purposes of education, evaluation, or research (Binstadt et al., 2007). According to Dr. David Gaba medical simulation is defined as an instructional process that substitutes real patient encounters with artificial models, live actors, or virtual reality patients (Gaba, 2004). In other words, simulation-based medical education can be defined as any educational activity that uses simulation to replicate clinical patient care scenarios in a realistic environments for the purpose of feedback and assessment (Gaba, 2004; Ziv et al., 2003).

The interest in simulation for health care has derived in large measure from the long experience and heavy use of simulation for training and other purposes in non-medical industries (Ziv et al., 2003). Nowadays, medical simulators are becoming a staple of educational services offered to medical students, residents, fellows, nursing staff, ancillary health care professionals and practicing physicians throughout the world (Kunkler, 2006).

There is some diversity of simulation tools ranging from the simple to complex, existing desktop software platforms, part-task trainers, full-body high fidelity simulators and live actors acting as standardized patients (Okuda et al., 2009).

Desktop software simulators are programs to train and assess clinical knowledge and decision making, e.g., perioperative critical incident management, problem-based learning, physical diagnosis in cardiology and acute cardiac life support (Ziv et al., 2003).

Software platforms include anatomic simulators such as the Visible Body, Hemodynamic Simulator, the virtual rat, and some that are "created in-house". Software such as the Visible Body is now available and improves on the traditional teaching methods in anatomy (Eason, 2013).

Part task trainers consist of parts of the human body to teach a particular skill, as the pelvic trainers. Part-task trainers may be simple anatomical models of body parts in their normal state or representing pathologies (Rosen, 2008).

The most famous part-task trainer was born in 1960 and was called Resusci Annie. This product was one of the first significant events in the history of medical simulation. She was initially designed for the practice of mouth-to-mouth breathing. Her face was based on the death mask of the Girl from the River Seine, a famous French drowning victim. Later, Annie evolved to incorporate a spring in her chest for the practice of cardiopulmonary resuscitation (Rosen, 2008)

Full-body high-fidelity simulators consist of mannequins that are anatomically and physiologically accurate representations of real patients. They also come with clinical interfaces such as monitors that provide real-time clinical data such as electrocardiogram (ECG) tracings and vital signs (Kunkler, 2006). In the last years, full-body high-fidelity simulators evolved and nowadays can represent breathing, blinking, exhibit a heartbeat and pulse, and can be hooked up to lines to provide bleeding. These simulators can be used for the training of complex and high-risk clinical situations in a life-like team training setting, promoting the training of technical and non-technical skills (such as teamwork, decision making, leadership, etc.)(Al-elq, 2010).

Standardized patients are actors used to educate and evaluate history taking and physical examination skills, communication, and professionalism. These human actors interact with the learners with complaints seen with particular disease presentations. Through these interactions, students can see the clinical implications of pathophysiology (Eason, 2013).

There are several advantages of using medical simulation, such as: practicing hands-on of invasive procedures; the ability to allow errors to continue to their natural conclusion; risks to patients and learners are avoided; the opportunity for the same scenario to be accessed multiple times and by multiple students providing similar learning opportunities; immediate feedback during debriefing sessions; the use of real medical equipment (Al-elq, 2010).

The cost of simulators can be a major limitation to widespread simulator use. The cost-effectiveness of potentially expensive simulation-based medical education and training should be examined in terms of improvement of clinical competence and its impact on patient's safety. Perhaps, with the adoption of simulation as a standard of training and certification, health care systems will be viewed as more accountable by the population (Al-elq, 2010; Ziv et al., 2003).

Considering this, the future of medical simulation may be more sustainable with the development of dedicated centers and low-cost equipment (Al-elq, 2010).

2.4 Simulation-based training in CPR

In cardiopulmonary resuscitation the goal of saving more lives relies not only on solid and high quality science but also on the effective education of both lay people and healthcare professionals (Pozner et al., 2011).

Developing and retaining practical skills is an essential component of professional life. Once a skill has been learnt, application and correct performance become the key issues (European Resuscitation Council, 2008). Mortality and morbidity in a cardiac arrest victim are directly affected by the ability of lay persons and health professionals to apply CPR knowledge and appropriate skills (Bullock, 2000). Simulation training seems to be an integral part of resuscitation training and showed improvement in knowledge and skill performance compared to training without simulation (Monsieurs et al., 2015; Sahu & Lata, 2010).

Several studies (Hopstock, 2008; Pozner et al., 2011; Abella et al., 2007) have demonstrated that the quality of CPR performance during actual cardiac arrest is poor, even when resuscitation efforts are conducted by healthcare professionals during both in-hospital and out-of-hospital cardiac arrest. These CPR discrepancies occur despite clearly stipulated published guidelines for CPR delivery and well-established programs for resuscitation training and certification (Abella et al., 2007).

One possible solution to this problem is the use of monitoring and feedback systems during CPR to detect and correct deficiencies in real-time.

The features of simulation which best facilitate learning include the ability to provide feedback, the repetitive practice, the curriculum integration and the ability to range the difficulty levels (Lateef, 2010).

For this progress to be achieved, active cooperation is required in addition to the prior acquisition of knowledge and basic skills, it is important to have feedback and/or debriefing after the simulation sessions. These are, in fact, elements that facilitate learning. Feedback is justly considered the most important constituent element of good practices, often cited in the literature (Perkins, 2007; Lateef, 2010).

Feedback on performance is a crucial component of the learning processes associated with simulation and has been shown to improve CPR quality during simulated cardiac arrest on manikins (Abella et al., 2007). Feedback technology supports the rescuer in real-time with vocal or visual information on CPR quality to improve guideline adherence (Pozner et al., 2011).

Educational feedback also appears to slow the decay of acquired skills and allows learners to self-assess and monitor their progress toward skill acquisition and maintenance. Sources of feedback may either be “built-in” to a simulator, given by an instructor in “real time” during educational sessions, or provided post hoc by viewing a videotape of the simulation-based educational activity (Issenberg, McGaghie, Petrusa, Gordon, & Scalese, 2004).

There is evidence that instructors provide poor feedback including correction of skills in performing chest compressions (Wang et al., 2015). In this way a variety of feedback systems have been developed in the course of the last few years, namely devices that measure hemodynamically important components of CPR and provide rescuers with real-time CPR feedback (Pozner et al., 2011).

Feedback devices can be divided into two groups: on one hand, there are the so-called stand-alone devices and typically small, portable devices with feedback on chest compressions only; on the other hand, there are defibrillators with built in feedback technology. These contain everything that is needed for effective basic treatment of cardiac arrest: feedback on chest compressions to ensure effective CPR and defibrillation (Gruber, Stumpf, Zapletal, Neuhold, & Fischer, 2012).

Previous studies have compared the quality of CPR training with feedback devices with the traditional CPR training. A literature review (detailed description in Appendix I) retrieved 7 previous studies that were analyzed and compared (Table 1).

Almost all the studies analysed aimed to determine the effects of CPR feedback systems in the quality of CPR training. The parameters evaluated in the studies were the compressions rate, compressions frequency, chest recoil, hands positioning, and one of the studies evaluated the ventilations.

The outcomes of the studies confirm that some feedback systems improve significantly the quality of chest compressions, in a simulated cardiac arrest scenario. However, there are a few studies (Zapletal et al., 2014; Kurowski, Szarpak, Bogdański, Zaśko, & Czyżewski, 2015) that indicate that CPR feedback devices needs to be thoroughly investigated.

All these findings were considered relevant, and shaped the decisions made for present study methodology, as explained in the following chapters of this thesis.

Table 1: Summary of characteristics of included studies

Identification (Author, Year; Publication)	Sample Size	Type	Devices	CPR Providers	Design	Aim	Methodology	CPR Parameters Evaluated	Outcomes
(Allan, Wong, Aves, & Dorian, 2013); Resuscitation Journal	n=298	Manikin study Two rescuers	ZOLL R series: feedback defibrillator ZOLL M series: standard no feedback defibrillator	Medical and nursing students	Randomized 3-arm study	Determine the impact of a training method for basic life support with the incorporation of a defibrillator feedback during simulated cardiac arrest on the quality and retention of CPR skills	3 groups received a 2h training session followed by a simulated cardiac arrest test scenario. Group 1: feedback training/testing Group2: feedback training; no feedback testing Group 3: control group, no feedback	Depth, rate, compression fraction and ventilations were compared between control vs. Group 1 and control vs. Group 2	Using real-time CPR audio-visual feedback combined with review of quantitative CPR data obtained from the defibrillator improved CPR quality metrics as well as the retention of these skills compared to standard training
(Yeung, Davies, Gao, & Perkins, 2014); Resuscitation Journal	n=103	Manikin study Single rescuer	Pressure sensor/metronome device (CPREzyT); An accelerometer device (Phillips Q-CPR);	Healthcare providers	Blinded, randomised controlled trial	Compare the effect of three CPR prompt and feedback devices on quality of chest	Participants were randomised in blocks of 4 into groups: control, CPREzy,	Primary outcome of the study was chest compression depth.	The use of pressure sensor feedback device improved chest

Table 1: Summary of characteristics of included studies (cont.)

		Simple metronome		compressions amongst healthcare providers	QCPR and metronome. The participants were asked to perform continuous chest compressions without any device for 2 min on a manikin as baseline performance. After 1 h of rest, participants were asked to perform another 2 min of continuous chest compressions on a manikin using their allocated devices	Secondary outcomes were compression rate, proportion of chest compressions with inadequate depth and incomplete release and user satisfaction scores of each device	compression depth and rate, but did not improve incomplete release. Whilst real time prompt and feedback devices may be able to give objective assessment of our CPR performance, they will not replace high quality effective training and timely refresher updates.

Table 1: Summary of characteristics of included studies (cont.)

(Kurowski et al., 2015); Kardiologia Polska Journal	n=167	Manikin study Single rescuer performing hands only CPR	TrueCPR™ CPR Assistant Zoll PocketCPR®	Paramedics	Randomised controlled study	Compare the effectiveness of CPR during standard manual chest compressions(SMCC) and with the use of TrueCPR and Pocket CPRfeedback devices	The participants were randomised to perform SMCC, CPR using the TrueCPR device, and CPR using a smartphone with the PocketCPR application in a crossover study	Compression depth, compression rate, incomplete chest relaxation rate and inappropriate hand position on the chest surface	The highest effectiveness of chest compression was found for TrueCPR, and the lowest for PocketCPR
(Zapletal et al., 2014) Resuscitation Journal	n=240	Manikin study 8 min of single rescuer CPR	Zoll PocketCPR®; Laerdal CPRmeter®; iPhone app Zoll PocketCPR®	Medical Students	Prospective, randomized, controlled parallel group study	Investigate the effect of various CPR feedback devices on CPR quality. Compared three CPR feedback devices with standard BLS without feedback in a simulated scenario	Participants were randomized in four groups of 60. They performed 8 minutes of single-rescuer CPR with mouth-to-mouth ventilation according to the prompts	Compression rate, flow time fraction and ventilation parameters were compared between the four groups	None of the devices achieved an improvement in chest compression quality compared to standard BLS without feedback. The performance of further improved CPR

Table 1: Summary of characteristics of included studies (cont.)

							given by their CPR feedback device		to be thoroughly investigated
(Krasteva, 2011) IOPScience Journal	n=63	Manikin study Single rescuer performing hands-only CPR	Cardio compression (CC) control device applied on a standard training manikin	Lay persons	Prospective study	Contribute to the scarce data available about the abilities of untrained lay persons to perform hands-only CPR on a manikin and the improvement of their skills during training with an autonomous CPR feedback device.	All participants received a BLS debriefing and performed 2 consecutive 3 min trials of hands-only CPR on a manikin with 3 min resting period between. In trial 1 participants did not receive a feedback from the CC-Device. In trial 2 they received visual feedback and audio guidance from the CC-Device	Compression depth, rate and complete chest recoil	This study demonstrates the use of the CC-Device as a tool for effective training of lay persons in hands-only CPR

Table 1: Summary of characteristics of included studies (cont.)

(Skorning et al., 2010); Resuscitation Journal	n=93	Manikin study Single rescuer	Feedback device (prototype by Laerdal, Stavanger, Norway)	Healthcare Professionals	Randomized cross-over study	Evaluate a new feedback system in simulated cardiac arrest based on improvement in ECC performance and acceptance by healthcare workers	All participants were tested on a manikin in identical mock cardiac arrest scenario and asked to perform 2min of continuous external chest compression (ECC). Group A: ECC with device first, followed by ECC without device a minimum of 45min later; group B: vice versa	Compressions rate and depth	The visual feedback device described here is able to significantly improve performance of ECC by professional healthcare workers in simulated cardiac arrest in terms of compression rate and depth as well as overall ECC sufficiency
(Semeraro et al., 2013); Resuscitation Journal	n=93	Manikin study	CPR feedback system (Mini-VREM)	Nurses physicians (CPR experts) and lay people	Prospective, randomised cross-over design	Evaluate a new CPR feedback system designed to improve chest compression during training	The participants were divided in two groups. All subjects performed a 2 min of chest compression (CC) trial, 1 h	Compressions rate and depth	The Mini-VREM system was able to improve significantly the quality of chest compressions,

Table 1: Summary of characteristics of included studies (cont.)

	pause and a second 2 min CC trial. The first group performed CC with Mini-VREM feedback followed by CC without feedback. The second group performed vice-versa	in terms of compression rate and depth, performed by healthcare professionals and lay people in a simulated cardiac arrest scenario

3. Study design and methodology

3.1 Overview

The present work was developed as part of the Master degree in Medical Informatics at the Faculty of Medicine, University of Porto, and consisted in the evaluation of a new training tool for self-guided learning of CPR skills, by assessing its efficacy and effectiveness when compared to the standard training methods.

In order to promote a better knowledge about CPR, and according to the recent learning and educational trends described in the previous chapters, a low cost CPR self-guided tool was developed for the training – CPR Personal Trainer (Figure 4).

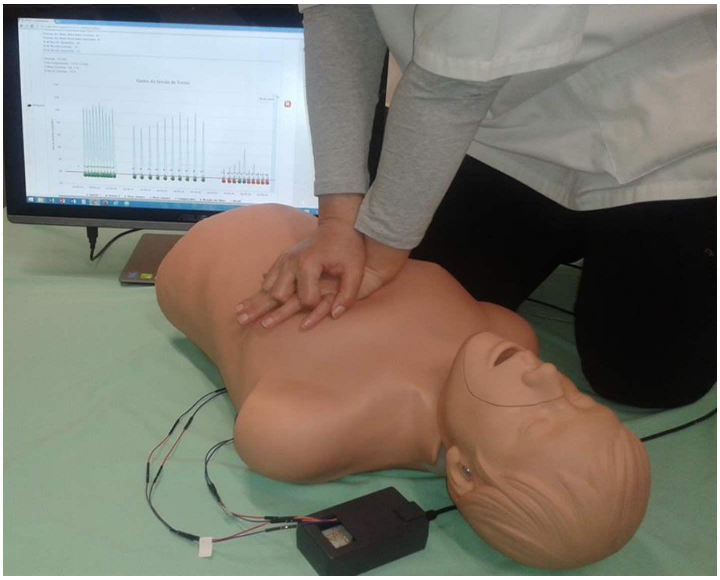

Figure 4: CPR Personal Trainer

The CPR Personal Trainer consists in a standard CPR training manikin instrumented with off-the-shelf piezoresistive sensors connected to an electronic pre-processing unit and information system. The total cost of the mannequin add-on is around 150€. The pre-processed signal is analyzed, extracting relevant data regarding the performed chest compressions and scoring them on three different factors associated with compression quality: hand position, compression rate, and chest recoil. The depth of the compressions is still under development and will be included in a near future.

The software is connected to a user-friendly online Graphical User Interface (GUI), which manages the workflow of the training and provides reports for each training session, the overall progression along the sessions and the performance evolution of the trainee. Figure 5 shows an extract of the CPR Personal Trainer Interface, representing two training sessions of a student.

The tool was intended to be evaluated for its efficacy and effectiveness through a control trial, using as data collection instruments individual pre and post-tests (both theoretical and practical), and a satisfaction questionnaire. The usability of the tool was also accessed through a validated questionnaire: System Usability Questionnaire (SUS).

This study was approved by the *Comissão de Ética para a Saúde do Centro Hospitalar de São João*. Written informed consent was obtained from all participants before the study.

Figure 5: Print-screen of the CPR Personal Trainer interface.
Feedback to trainee is presented visually and numerically. Top image: Students feedback shows need for improvement in all parameters (red labels). Visual and audible aids are available to help the position of hands and the frequency of the compressions. Bottom image: Student feedback shows all parameters performed correctly (green labels).

3.2 Target population and sampling strategy

The target population of this study was basic years (1st - 3rd) medical students of the Faculty of Medicine, University of Porto. The restriction to students of basic years was to avoid students with recent CPR training.

The target population was invited to participate in the study, through announcements and posters from the student's association. The students were invited to voluntarily register for the study. Only registered students constituted the sample of this study.

3.3 Study design and implementation

On Day 1, registered students that were present for the study were given information and clarifications about the study and an informed consent (Appendix II) to read and sign.

Of the 34 registered students only 28 attended Day 1. The 28 students were submitted to the pre-test evaluation, including both theoretical and practical components (detailed description of the evaluation can be found in the section 3.4).

After the evaluation, students were divided into two groups with 14 students each. The two groups were randomized and allocated to the control or the intervention group. The study was blinded, meaning that students from both groups only knew at the day of the course to which group they were allocated. After the evaluation, students received the latest CPR guidelines and algorithm and were advised to review them.

On Day 8, the control group received training with an experienced basic life support (BLS) instructor and a mannequin. The intervention group received training with the feedback of CPR Personal Trainer (without instructor). The training time was equivalent for both groups. Students from the intervention group also answered a questionnaire on the usability of the CPR Personal Trainer System (Appendix III). There were two drop-outs in this group.

On Day 15, both groups were submitted to the post-test evaluation, including again both theoretical and practical components.

The study protocol is graphically present in Figure 6.

3.4 Pre- and post-tests

The knowledge and technical skills of the participants were evaluated through a theoretical and practical test, before and after the CPR training course.

- **Theoretical tests**

  The theoretical test consisted in 14 different questions about CPR with emphasis on chest compressions (Appendix IV).

  Theoretical tests were made available using Moodle platform (http://www.moodle.org). Each student accessed the platform through their individual credentials and answered all the questions online.

- **Practical tests**

  The practical tests were performed individually and consisted in executing 2 minutes of the BLS algorithm. All performances were video recorded for later evaluation.

  The evaluation of the correct application of BLS algorithm and correct CPR performance of each student was made through visualization of each video by an independent expert, with the use of a checklist (Appendix V).

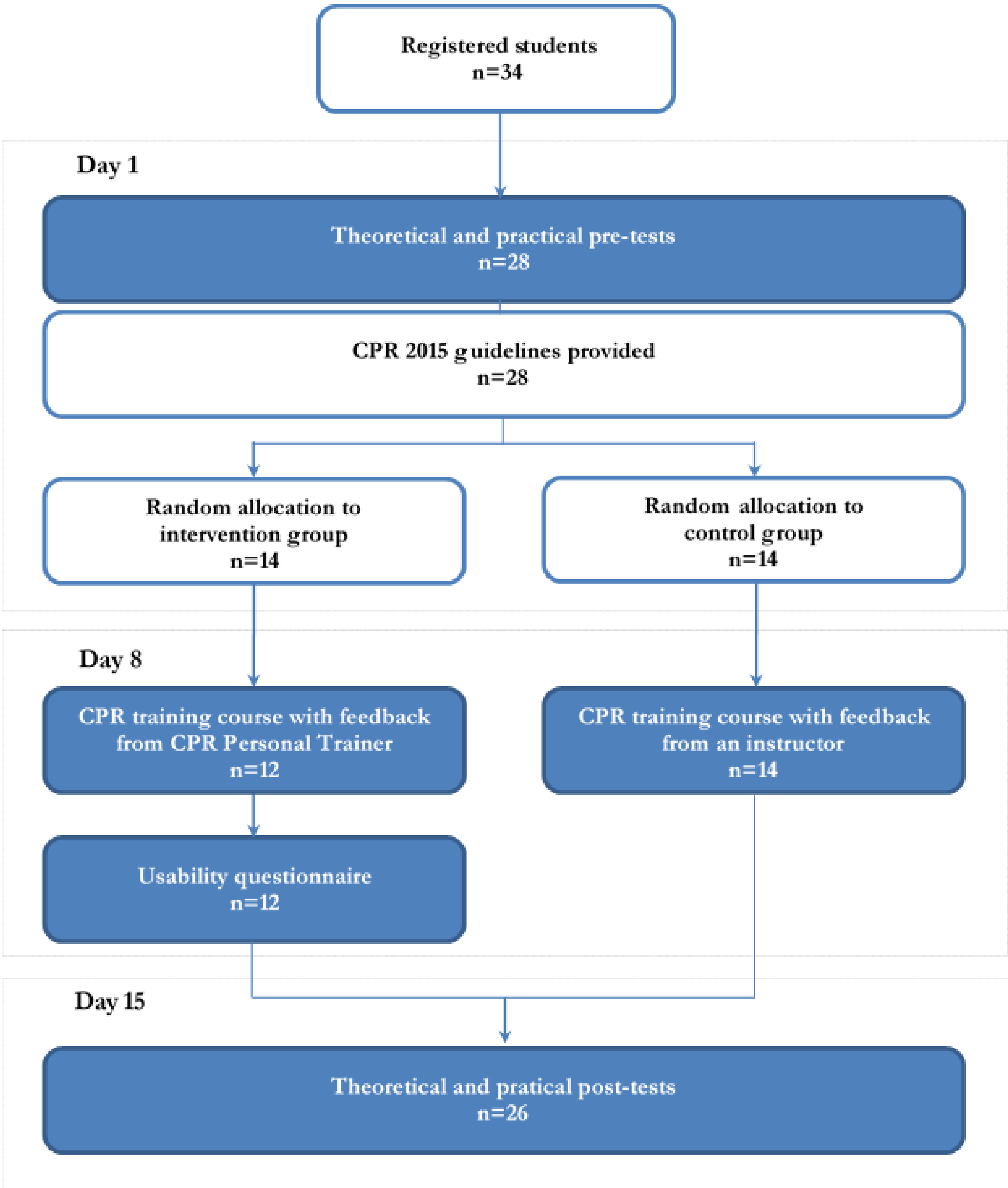

Figure 6: Study protocol

The checklist aimed to evaluate the following parameters:

- call for help;
- check normal breathing;
- chest compressions and rescue breaths in a ratio of 30:2;
- compressions frequency;
- hand positioning;

- chest recoil;
- compressions depth;
- 2 deep breaths;
- breaths in less than 10 seconds;
- head extension.

For each item a score of 0, 1 or 2 was given: 0 if performed incorrectly, 1 if insufficiently performed, and 2 if performed correctly.

3.5 The CPR course: control vs intervention

Both groups (control and intervention) were divided into smaller groups of four to five elements. The control groups received from the instructor, some theoretical information about CPR, followed by training with feedback from the instructor. The intervention groups just performed the practical training. All groups had the 2015 CPR algorithm displayed, near the training station. Each session lasted 1-hour, for both control and intervention groups.

For training the CPR skills, the control group used a standard task-trainer (as shown in Figure 7), and received feedback from an experienced BLS instructor.

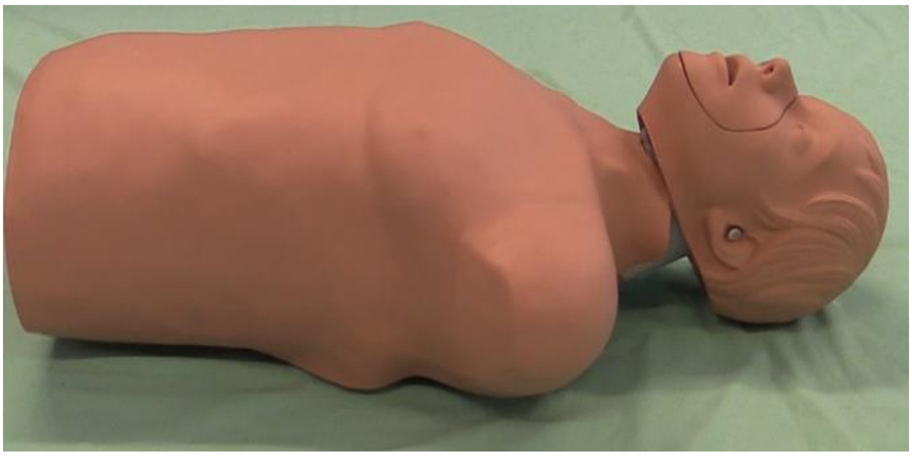

Figure 7: Standard task-trainer torso

The intervention group used a standard task-trainer (identical to the one used in the control group) instrumented with a hardware/software component (Figure 4: CPR Personal Trainer) that measures specific parameters and provides performance feedback (with no instructor) to the student. The intervention group received performance feedback regarding hands' position, frequency and recoil from the CPR Personal Trainer system. Two aids were included in the CPR Personal Trainer to guide the student in the training: an audio sample of a metronome at 100 bpm to help in the compressions frequency and an image of the correct hands position. These aids were shown to the student when presenting the feedback of his/her performance.

3.6 Usability questionnaire

A preliminary assess of CPR Personal Trainer usability was performed with the students from the intervention group. For that, a Portuguese translation of the System Usability Scale (SUS) questionnaire, proposed by Brooke (Brooke, 1996) and used by Simões &Moraes (Simões & Moraes, 2012), was used.

The SUS questionnaire is a reliable tool for usability assessment, consisting in 10 questions, to be rated in a 5-point Likert scale (from strongly agree to strongly disagree), among which five are positive statements and the rest are negative. It has been found to be a remarkably robust measure of system usability (Bangor, Kortum, & Miller, 2008; Lewis & Sauro, 2009; Tullis & Stetson, 2004), even with a small sample size (Tullis & Stetson, 2004).

The SUS score (Simões & Moraes, 2012) is calculated by summing up all individual items. For items 1, 3, 5, 7, and 9 (positive statements) the score contribution is the scale position minus 1. For items 2, 4, 6, 8 and 10 (negative statements), the contribution is 5 minus the scale position. The overall value for each student is obtained by multiplying the sum of the scores by 2.5. The global SUS score has a range of 0 to 100 and represent the median of the sample. A global score higher than 70 is considered above the average and higher than 80 is considered good (Bangor, Kortum, & Miller, 2009).

3.7 Statistical analysis

Statistical analysis was performed in IBM SPSS Statistics® software, version 23.0. Both descriptive and inferential analyses were performed. To evaluate knowledge and skills differences, intra- and inter-groups non-parametric tests were used, considering a significance level of 5%. The choice of non-parametric tests can be justified by the reduced sample size.

4. Results

4.1 Sample description

Considering demographic variables, globally within 26 individuals, 18 are female and 8 are male. Regarding the control group there are 4 male individuals and 10 female individuals. In the intervention group there are 4 male individuals and 8 female individuals.

In the intervention group the mean age of students is 20.58 and in the control group the mean age is 20.93.

Both groups were compared for age and gender and no statistical differences were found between groups (p-value>0.05), confirming their homogeneity (Table 2).

Table 2: Demographic characterization of the sample

	Intervention (n=12)	**Control (n=14)**	**p-value****
Gender, n			
Male	4	4	0.797
Female	8	10	
Age, mean±SD	20.58±2.31	20.93±2.84	0.792

** Difference between groups, Mann Whitney U-test, 2-tailed, (α=0.05)

4.2 Pre and post test results

Total scores of the pre and post theoretical tests and total and partial scores of the pre and post practical tests were calculated and compared. For the practical tests, partial scores representing the compressions related parameters and other parameters of CPR algorithm were calculated, analyzed and presented separately.

4.2.1 Theoretical and practical total score

Theoretical tests in both groups presented an increase in the score between the pre and the post-test with statistical significant differences. Similar results were found for the practical tests, with statistical significant differences between the pre and post-tests.

The inter group comparison shows, for all tests, no statistically significant differences indicating no differences between groups (Table 3).

Table 3: Comparison between the pre and post-test mean scores, for the theoretical and practical tests. Scores presented as Mean ± SD

		Intervention (n=12)	Control (n=14)	*p-value***
Theoretical Score (0-100%)	Pre-test	72±13	71±13	*0.662*
	Post-test	82±9	85±7	*0.442*
	*p-value**	***0.004***	***0.002***	
Practical Score (0-2)	Pre-test	0.98±0.23	0.98±0.25	*0.839*
	Post-test	1.51±0.30	1.84±0.16	*0.560*
	*p-value**	***0.002***	***<0.001***	

* Pre-post test difference, Wilcoxon signed rank test, 1-tailed (α=0.05)

** Difference between groups, Mann Whitney U-test, 2-tailed (α=0.05)

4.2.2 Pre and post practical score: compressions related parameters

The pre and post-test comparison for the overall and all individual compressions related parameters present a statistical significant increase, in both groups. Table 4 presents the detailed results and comparisons.

Table 4: Comparison between pre and post-test compressions related measurements mean scores. Scores (0-2) presented as Mean ± SD

		Intervention (n=12)	Control (n=14)	*p-value***
Hands position	Pre-test	0.83±0.72	1.36±0.50	***0.049***
	Post-test	1.75±0.45	1.79±0.43	*0.083*
	*p-value**	***0.005***	**0.*007***	
Frequency	Pre-test	0.75±0.97	0.86±0.77	*0.638*
	Post-test	1.67±0.65	1.67±0.50	*0.678*
	*p-value**	***0.025***	**0.*003***	
Recoil	Pre-test	1.25±0.45	1.21±0.43	*0.083*
	Post-test	1.75±0.45	1.86±0.36	*0.498*
	*p-value**	***0.017***	**0.*002***	
Depth	Pre-test	1.33±0.45	1.29±0.47	*0.841*
	Post-test	1.75±0.45	1.79±0.43	*0.833*
	*p-value**	***0.013***	***0.004***	
Total	Pre-test	1.02±0.53	1.18±0.30	0.259
	Post-test	1.73±0.29	1.78±0.27	0.744
	*p-value**	***0.005***	***<0.001***	

* Pre-post test difference, Wilcoxon signed rank test, 1-tailed (α=0.05)

** Difference between groups, Mann Whitney U-test, 2-tailed (α=0.05)

No differences between groups were found in the compression related parameters, with the exception of the hands position were the control group score is higher in the pre-test.

4.2.3 Pre and post practical score: other CPR algorithm parameters

In the control group, the pre and post-test comparison for the overall and other CPR algorithm parameters present a statistical significant increase in all parameters, with the exception of the "ventilations in less than 10 sec" parameter. Table 5 presents the detailed results and comparisons.

Table 5: Comparison between pre- and post-test mean scores of CPR measurements without compressions. Scores (0-2) presented as Mean ± SD

		Intervention (n=12)	**Control (n=14)**	***p-value*****
Shout for help	Pre-test	0.50±0.80	0.50±0.86	*0.899*
	Post-test	1.00±0.95	2.00±0.00	***0.001***
	*p-value**	*0.051*	**<0.001**	
Check breathing	Pre-test	0.83±0.84	0.57±0.76	*0.400*
	Post-test	1.42±0.90	2.00±0.00	***0.022***
	*p-value**	*0.051*	**<0.001**	
Ratio 30:2	Pre-test	1.67±0.65	1.57±0.65	*0.612*
	Post-test	2.00±0.00	1.93±0.27	*0.355*
	*p-value**	*0.051*	**0.030**	
2 Deep ventilations	Pre-test	0.75±0.62	0.43±0.51	*0.180*
	Post-test	1.17±0.72	1.71±0.47	*0.037*
	*p-value**	*0.052*	***0.001***	
Ventilations in less than 10s	Pre-test	1.83±0.39	1.86±0.36	*0.869*
	Post-test	1.92±0.29	2.00±0.00	*0.280*
	*p-value**	*0.159*	*0.079*	
Head extension	Pre-test	0.08±0.29	0.14±0.36	*0.642*
	Post-test	0.67±0.89	1.71±0.47	*0.003*
	*p-value**	***0.019***	***<0.001***	
Total	Pre-test	0.94±0.38	0.85±0.36	0.480
	Post-test	1.36±0.41	1.89±0.14	**0.001**
	*p-value**	*0.006*	***<0.001***	

* Pre-post test difference, Wilcoxon signed rank test, 1-tailed (α=0.05)

** Difference between groups, Mann Whitney U-test, 2-tailed (α=0.05)

In the intervention group, although there was an increase in the overall and other CPR algorithm parameters, there were no significant differences between the pre and post-test scores, with the exception of the "Head extension" parameters.

In the between groups comparison, no significant statistically differences were found in the pre-test scores. On the post-test differences can be observed in the overall and in the other CPR algorithm parameters, with the exception of "ratio 30:2" and the "ventilations in less than 10 sec" parameters.

4.2.4 Pre and post practical score: results' compilation

For an easier comparison and analysis of the pre and post-test results, between groups and parameters, a graphical compilation of the results is presented (Figure 8).

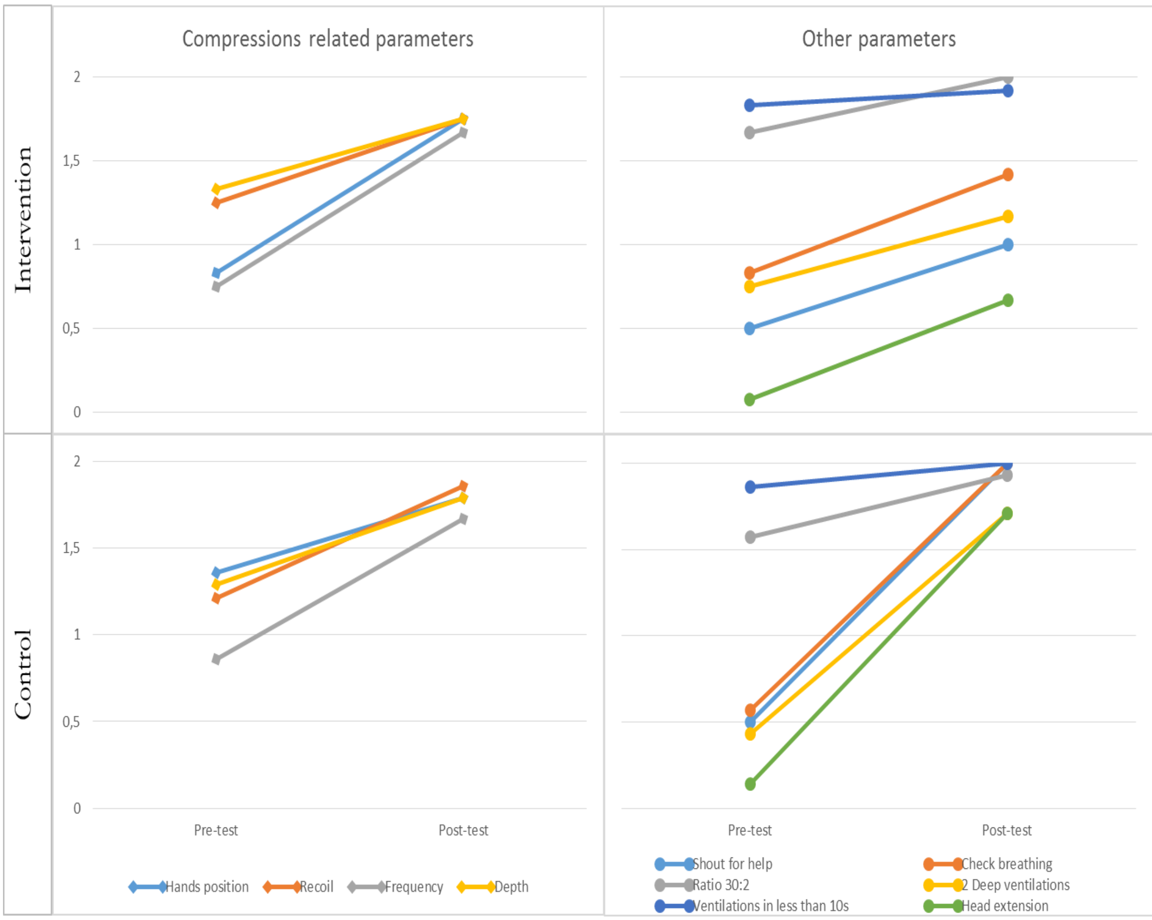

Figure 8: Comparison between pre- and post-test mean scores of CPR measurements with and without compressions.

Figure 8 show the progression of scores, between the pre and post-test, for each compression related parameters and for the other CPR Algorithm parameters, in both groups.

4.3 System's usability assessment questionnaire

The students who performed the CPR training course with the CPR Personal Trainer (intervention group) answered to the System's Usability Questionnaire.

The individual scores were calculated for each student and from those the global score (median of the sample), Table 6. The global SUS score of the CPR Personal Trainer is 75.

Table 6: Individual and global SUS scores

Students	**Individual Scores***
Student 1	57.5
Student 2	60
Student 3	67.5
Student 4	70
Student 5	70
Student 6	75
Student 7	75
Student 8	80
Student 9	82.5
Student 10	90
Student 11	92.5
Student 12	92.5
Global SUS score	**75**

*SUS score of each student

The SUS questionnaire included two open-questions on the "positive" and "needs improvement" aspects of the CPR Personal Trainer (Table 7).

Table 7: Positive aspects of CPR Personal Trainer and those that need improvement

Positive aspects	**Answers (%)**	**Need improvement aspects**	**Answers (%)**
Real-time Feedback	58	No compression's depth assessment	42
Rapid learning curve	42	No ventilation parameters assessment	25
Correct evaluation of compression's parameters	42	No information on the algorithm	25

The three most commented positive aspects were: real-time feedback; rapid learning curve and; correct evaluation of compression's parameters.

The three most mentioned aspects that needed improvement were: compression's depth assessment; ventilation parameters assessment and; information on the algorithm.

Table 7 presents the students' answers, including the percentage of students that suggested each item.

5. Discussion and conclusions

This study investigates and compares the acquisition of knowledge and technical skills related to chest compressions in CPR manoeuvres, when using an automated CPR feedback tool and when receiving standard CPR training.

According to the literature review aforementioned in Chapter 2, the quality of CPR depends on the training. Simulation is a good option that allows regular training in CPR because it creates an ideal educational environment with predictable, consistent, standardized, safe, and reproducible learning activities.

In the various studies reported in the literature, it was verified the existence of other tools providing feedback for self-guided CPR training with positive results on skills improvement. However, no evidence was found regarding studies related to low-cost tools for self-guided CPR training.

This study indicates that a low-cost tool with feedback for self-guided training in CPR may provide an alternative or be a complementary extension to the traditional training methods based on an instructor.

5.1 Discussing the results

Sample analysis confirms that both intervention and control groups are homogeneous, reducing the potential bias or discrepancies in the results.

The theoretical tests showed an improvement in the scores from the pre to the post-test, both in the intervention and in the control group. Although the intervention group had no theoretical support from an instructor, the content made available, revealed to be sufficient to increase their knowledge to a similar range as for the control group. No statistical significant differences were observed between the groups.

The practical tests (total score) showed an improvement between the pre and the post-test for both groups, although the control group presented a higher difference (0.53 versus 0.86) but with no statistical significance. The higher improvement in the control group is related to the fact that this practical total score includes all the CPR parameters, including the parameters that the CPR Personal Trainer does not provide feedback (such as ventilation related parameters). For each compression's related parameters (hands position, recoil, frequency and depth), an increase in scores is observed, between the pre and the post-test, in both groups. The intervention group presented a higher total score difference

(0.71 versus 0.60) but with no statistical significance. This result corroborates our initial hypothesis, indicating that the CPR Personal Trainer provides the acquisition of skills similarly to the traditional method.

Observing each compression's related parameters in detail, similar conclusions can be withdrawn. Moreover, in the hands position parameter the improvement observed in the intervention group was higher than in the control group (0.92 versus 0.43). In the intervention group the pre-test results scored significantly lower than for the control group. These results indicate that the proposed feedback tool levels the skills of the participants, independently of their baseline.

An interesting result was on the depth parameter, where similar improvement can be observed in both groups, although the CPR personal trainer does not provide feedback on this. This improvement can be attributed to the relationship between depth and recoil, providing feedback for the later may lead to a potential indirect depth performance impact.

Considering the practical test results for the parameters not related to compressions, an overall improvement is observed in both groups, but with a greater difference in the control group (0.42 versus 1.04). Of mention is that, in three parameters (shout for help, check breathing, ventilations in less of 10 s), the control group scored in the post-test 2.0 with a SD of 0.0, indicating that all students in this group correctly executed these tasks. The same was observed for the intervention group for the parameter "Ratio 30:2". The notorious improvement in the control group compared to the intervention group in parameters not related to compression was expected and justified by the involvement of the instructor in the training. Nevertheless, in the intervention group the mean scores for all parameters have increased from the pre to the post-test, although not statistically significant.

Of mention is that the results show that the initial objectives proposed for this work were reached. It was observed that CPR Personal Trainer is effective when compared with the traditional method. The intervention group showed improvements regarding skills acquisition and the CPR Personal Trainer allowed to achieve a similar level of knowledge when compared with the control group. Also, it was found that the system is efficient as it may reduce the need for a permanent presence of an instructor, specifically for the training of chest compressions, allowing a more regular training outside formal training courses.

Regarding the usability of the CPR Personal Trainer , the SUS global score was 75 which, based on the literature (Bangor et al., 2009)(Simões & Moraes, 2012), is considered above average. However, there were three students scoring below average (<70). One explanation could be the fact that some of the questions are presented using a negative sentence which may have confused the respondents when translated to its Portuguese version. Future work can be done in reassessing the validation of the SUS questionnaire and ensuring the unambiguousness of the questions. Also, it could be useful to provide some space for the respondents to explain their answers, as this would clarify some contradictions.

Regarding the open-questions, "the real-time feedback" parameter was considered by the respondents as the most positive aspect of the system. The users also considered that the system has a "Rapid learning curve" and that provides a "Correct evaluation of compression's parameters".

On the other hand, the respondents stated that the aspect that needs most improvement is the "no compression's depth assessment". This was expected as there was no time to include a feature that would objectively measure this value. This work is in progress and measuring compressions' depth will be available in the next version of the system.

5.2 Limitations

The main challenge of this work was the time available to carry out the study. In fact, if the time was not a constraint, the sample could have been extended, and it could even include students from other backgrounds (non-health sciences students, for example), allowing the comparison of students with different interests and baseline knowledge. Also refrained by the time limit was the re-assessment at least one month after the CPR training course to measure the skills retention.

An important limitation was the reduced sample. Due to time limitations, students' availability and other logistic constraints, the sample used was considerably small which may influence some results of this work.

Another potential bias can emerge from the practical evaluation, which was performed by a single evaluator. Although the evaluator was blind to the study, used the video recordings and a standard checklist, the intrinsic subjectivity of the human nature could be reduced if other evaluators were included. This can be easily done as all video recordings of the students' performance are available, depending only on the availability of experienced evaluators.

The SUS questionnaire used to assess the usability of CPR Personal Trainer could benefit of some revision. Misinterpretation of some questions may have led to some lower scores. This questionnaire was only available in English and the limited timeframe unable the validation of the Portuguese version. Of notice is that no similar questionnaire already validated and adapted to our system in Portuguese was found in the literature, which suggests that this task can be considered as future work.

Finally, an important limitation is related to the under developing features of the CPR Personal Trainer, namely the assessment of the depth of compressions and ventilations. This leads to an incomplete assessment of the effectiveness of CPR Personal Trainer in the CPR training. These features require a relative complex technical approach and further studies are needed to validate the accuracy of these measurements.

5.3 Conclusions

Cardiac arrest is a serious public health problem that relies on people's CPR skills to act in such situations. The CPR training has a key role in the improvement of the survival rate. Low-cost tools for self-guided CPR training are an alternative to traditional training, which requires an instructor, as it can offer the opportunity of learning and continuous training to the entire population, with a low cost associated.

CPR Personal Trainer is a simulation-based tool for CPR training with a feedback system that improves technical skills and reinforces knowledge. The repetitive self-training allows the trainees to improvement skills at their own rhythm. The feedback feature provides objective, reliable and standardized assessment of the skills' acquisition and, as opposed to the subjective evaluation of an instructor, potentially boosting the trainee confidence in performing CPR correctly. Despite some limitations, this tool proved to be effective in the acquisition of compressions related skills, with similar outcomes as the traditional instructor-based method.

Due to budget restrictions associated with the current economic context, CPR Personal Trainer may be the next trend for education in CPR, by improving the skills of both professionals and laypeople, and consequently improving patient safety.

In conclusion, this study corroborates the hypothesis that low-cost tools with feedback for CPR self-training can provide an alternative or a complementary extension to the traditional methods, applied to both skills' acquisition and maintenance.

5.4 Future work

The most pressing future work of this project is related to overall technical improvement of the CPR Personal Trainer, mainly to allow performance feedback of compression's depth and ventilation. The interface should also be improved with other features such as evolution of the trainee and the inclusion of a tutorial with current CPR guidelines and quizzes.

Related to the work of this project, it is important to repeat the study with a larger sample, including groups with different background groups, such as firefights, health professionals, and laypersons, among others.

In a more challenging long-term perspective, it would be interesting to analyse knowledge retention both theoretical and technical and compare the training outcomes of the low cost CPR Personal Trainer with other feedback tools existing on the market but with a higher cost.

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7. Appendices

Appendix I: Literature review

In order to understand how previous studies have compared the quality of CPR training with feedback devices with the traditional CPR training, a literature search on PubMed and Google Schoolar was performed. The query used was: CPR compressions [All Fields] AND (feedback devices [All Fields] OR self-guided devices [All Fields]).

The articles where selected in two phases: the first phase was based on the analysis of the title and abstract of the articles found in the initial search. The inclusion or exclusion of the articles was made according to its relevance to the research question. The second phase was the analysis of the full papers.

Articles were included if they reported studies with CPR feedback devices, with manikins or studies related with basic life support. Studies were excluded if they did not satisfy the selection criteria, if they were published prior to 2010, if they were written in English, if they were duplicates, not available in free access or if they were meta-analyses or systematic reviews.

The initial search using the previously described query was made on the 1st of November of 2015. Figure I represents the flow chart of the selection process.

Seven studies were retrieved from this search. The work carried out by (Zapletal et al., 2014) was not found during our search, but it was present in the references of the study proposed by (Kurowski et al., 2015). Given its relevance, it was included in the final list of papers.

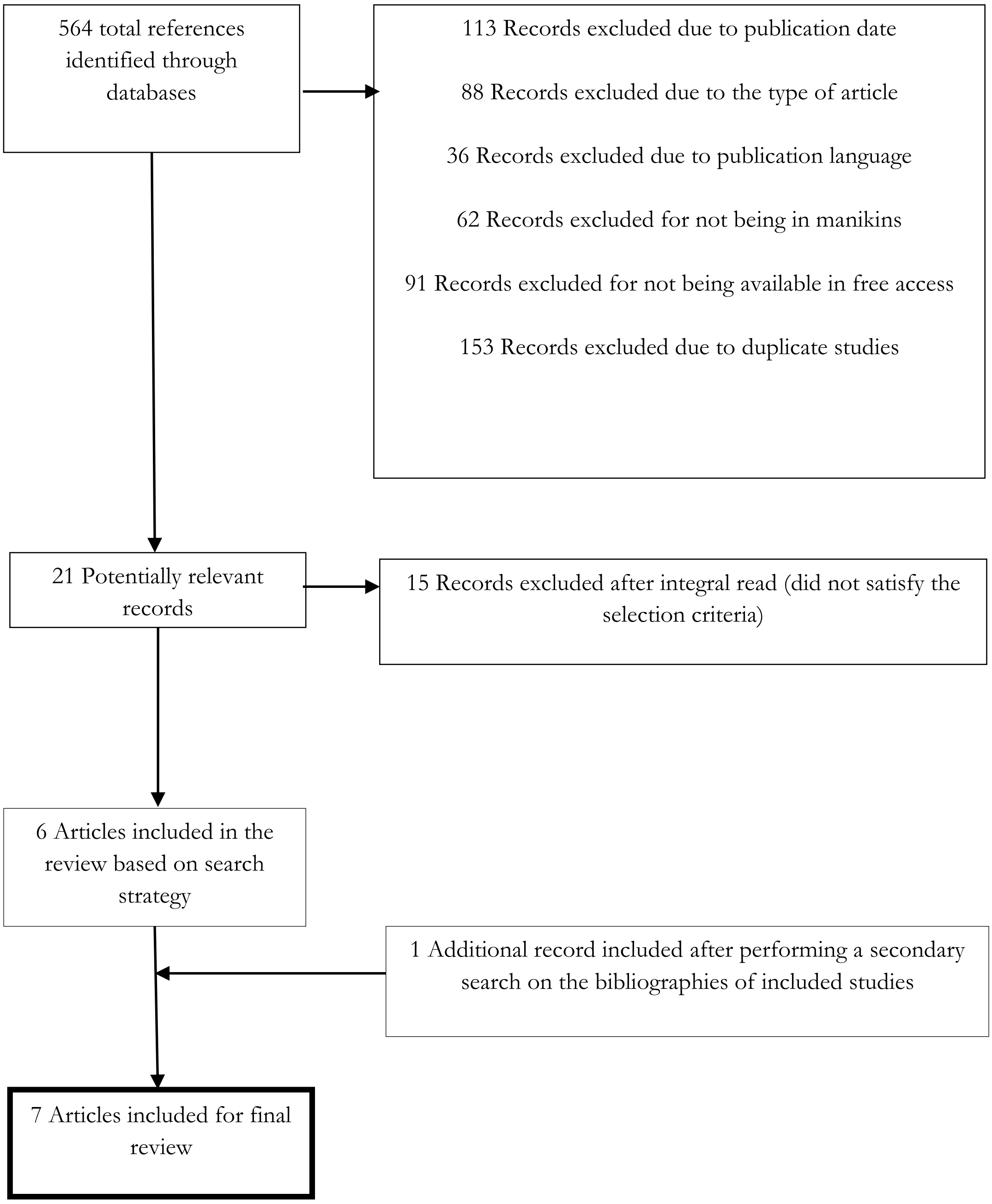

Figure I: Study selection flow chart

Appendix II: Informed consent

CONSENTIMENTO INFORMADO, LIVRE E ESCLARECIDO PARA PARTICIPAÇÃO EM INVESTIGAÇÃO

de acordo com a Declaração de Helsínquia[1] e a Convenção de Oviedo[2]

Por favor, leia com atenção a seguinte informação. Se achar que algo está incorrecto ou que não está claro, não hesite em solicitar mais informações. Se concorda com a proposta que lhe foi feita, queira assinar este documento.

Título do estudo: **Avaliação de um novo sistema de feedback e scoring para uma ferramenta low-cost de treino em reanimação cardiopulmonar.**

Enquadramento: O estudo decorrerá na Unidade de Simulação Biomédica do Departamento de Educação e Simulação Médica da Faculdade de Medicina da Universidade do Porto. Este estudo é realizado no âmbito da unidade curricular de Dissertação do Mestrado em Informática Médica da Faculdade de Medicina da Universidade do Porto, pela estudante Diana Almeida (diana.almeidafi@gmail.com), com a orientação da Doutora Carla Sá Couto (csacouto@med.up.pt), do Doutor Pedro Marques (pmarques@med.up.pt) e da Doutora Ana Ferreira (amlaf@med.up.pt). Este estudo foi aprovado pela Comissão de Ética para a Saúde (CES) do Centro Hospitalar de S. João – EPE.

Explicação do estudo: O estudo pretende comparar dois métodos de treino em SBV, relativamente à aquisição e retenção de competências em contexto de cenário simulado de emergência, por estudantes de pré-graduação. A avaliação da aquisição e retenção de competências será realizada objetivamente. Esta avaliação só será usada no âmbito deste estudo e de forma anonimizada. Proceder-se-á à gravação dos cenários, de modo a permitir uma avaliação rigorosa e objetiva dos critérios relativos às competências em estudo. As gravações serão acedidas por um número muito restrito de avaliadores, sendo que serão eliminadas imediatamente após a realização do estudo, não sendo utilizadas para mais nenhum fim adicional.

Cada estudante será randomizado num dos grupos de estudo. Cada estudante compromete-se a participar em três sessões distintas: pré-avaliação e formação teórica (dia 1), treino e primeira pós-avaliação (dia 2) e segunda pós-avaliação (dia 3). Os estudantes receberão um certificado de participação emitido pelo Centro de Simulação Biomédica da FMUP, após a presença nas três sessões. O abandono a meio do estudo não trará quaisquer implicações para o estudante (apenas não será emitido o certificado de participação).

A amostra de participantes será de conveniência, sendo convidados a participar todos os estudantes inscritos na formação desenhada para o estudo.

Condições e financiamento: A participação no estudo é de caráter voluntário.

Confidencialidade e anonimato: Os coordenadores do estudo garantem a confidencialidade e uso exclusivo dos dados recolhidos para o presente estudo; Todos os participantes serão mantidos em anonimato e a sua identificação nunca será tornada pública; As imagens recolhidas serão visualizadas exclusivamente pelos investigadores deste estudo e não sendo de forma alguma tornadas públicas.

[1] http://portal.arsnorte.min-saude.pt/portal/page/portal/ARSNorte/Comiss%C3%A3o%20de%20%C3%89tica/Ficheiros/Declaracao_Helsinquia_2008.pdf

[2] http://dre.pt/pdf1sdip/2001/01/002A00/00140036.pdf

<u>Assinaturas dos investigadores responsáveis</u>: … … … … … … … … … .. … … … …... … … … … .

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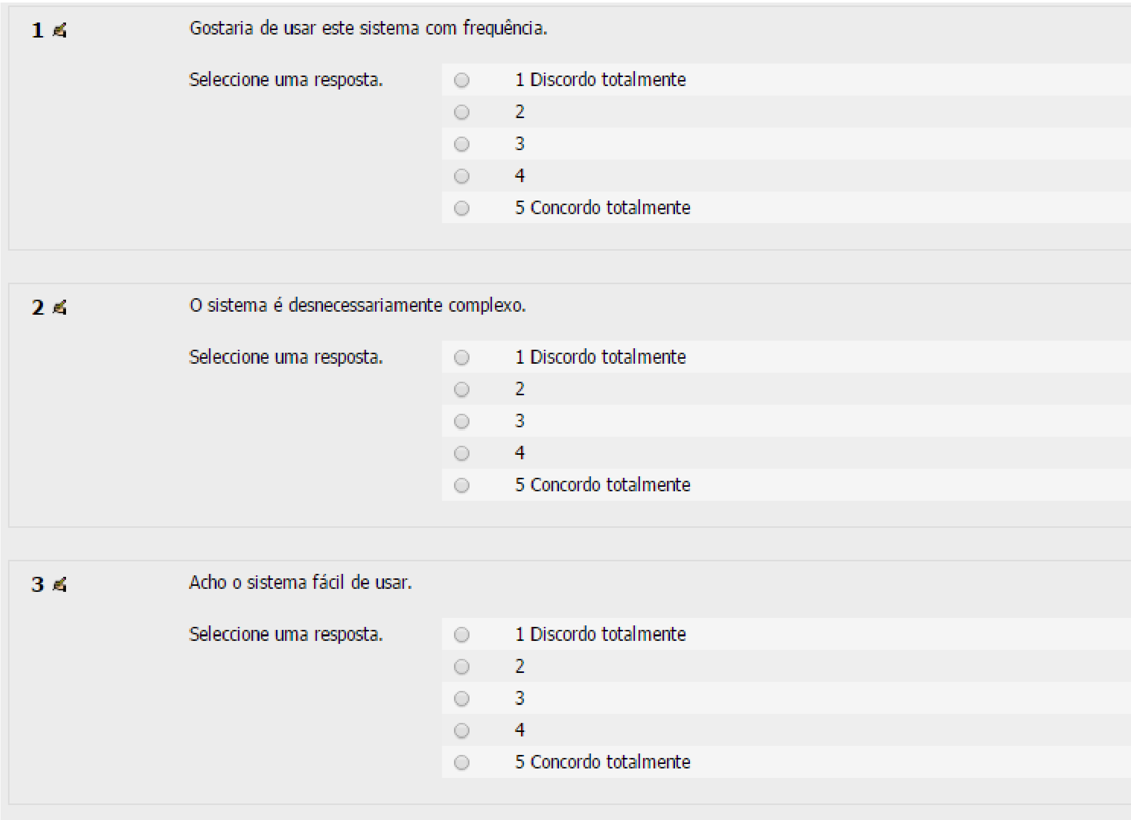
Declaro ter lido e compreendido este documento, bem como as informações verbais que me foram fornecidas pelas pessoas que acima assinam. Foi-me garantida a possibilidade de, em qualquer altura, recusar participar neste estudo sem qualquer tipo de consequências. Desta forma, aceito participar neste estudo e permito a utilização dos dados que de forma voluntária forneço, confiando em que apenas serão utilizados para esta investigação e nas garantias de confidencialidade e anonimato que me são dadas pelos investigadores.

Nome: … … … … … … … …... … … … …... … … … … … … … … … … … … …

Assinatura: … … … … … … … …... … … … … .. … … … … … … … … … … … … …

Data: …… /…… /………..

Appendix III: Usability questionnaire



1

Gostaria de usar este sistema com frequência.

Seleccione uma resposta.

- 1 Discordo totalmente
- 2
- 3
- 4
- 5 Concordo totalmente

2

O sistema é desnecessariamente complexo.

Seleccione uma resposta.

- 1 Discordo totalmente
- 2
- 3
- 4
- 5 Concordo totalmente

3

Acho o sistema fácil de usar.

Seleccione uma resposta.

- 1 Discordo totalmente
- 2
- 3
- 4
- 5 Concordo totalmente

4 Acho que preciso do apoio de uma pessoa especializada para ser capaz de usar este sistema.

Seleccione uma resposta.

- 1 Discordo totalmente
- 2
- 3
- 4
- 5 Concordo totalmente

5 Acho que as várias funções deste sistema estão bem integradas.

Seleccione uma resposta.

- 1 Discordo totalmente
- 2
- 3
- 4
- 5 Concordo totalmente

6 Acho que existe muita inconsistência neste sistema.

Seleccione uma resposta.

- 1 Discordo totalmente
- 2
- 3
- 4
- 5 Concordo totalmente

7 Imagino que a maioria das pessoas aprende a usar este sistema muito rapidamente.

Seleccione uma resposta.

- 1 Discordo totalmente
- 2
- 3
- 4
- 5 Concordo totalmente

8 Acho o sistema muito incómodo de usar.

Seleccione uma resposta.

- 1 Discordo totalmente
- 2
- 3
- 4
- 5 Concordo totalmente

9 Senti-me muito confiante a usar o sistema.

Seleccione uma resposta.

- 1 Discordo totalmente
- 2
- 3
- 4
- 5 Concordo totalmente

10 Preciso de aprender muitas coisas antes de começar a usar este sistema.

Seleccione uma resposta.

- 1 Discordo totalmente
- 2
- 3
- 4
- 5 Concordo totalmente

11 Indique o(s) aspeto(s) **positivo(s)** do sistema:

Resposta:

12 Indique o(s) aspeto(s) **negativo(s)** do sistema:

Resposta:

13 Comente quanto ao tipo / qualidade / completude de feedback exibido pela aplicação.

Resposta:

Appendix IV: Pre and post-test

1
Pontuações: 1

Selecione **a(s)** resposta(s) **errada(s)** em relação às compressões torácicas:

Escolha pelo menos uma resposta

- ☐ Mantêm o fluxo de sangue para o coração, o cérebro e outros órgãos vitais
- ☐ Devem ser realizadas de forma a comprimir o esterno 5 a 6 cm
- ☐ Devem ser realizadas de forma rítmica a uma frequência de pelo menos 100 por minuto, mas não mais do que 120 por minuto
- ☐ Devem ser interrompidas mais de 10 segundos

2
Pontuações: 1

Indique **qual(ais)** dos seguintes procedimentos **não faz(em)** parte do Suporte Básico de Vida do adulto:

Escolha pelo menos uma resposta

- ☐ Pesquisar a respiração normal - VOS durante 5 segundos
- ☐ Realizar 5 insuflações antes de serem iniciadas as compressões torácicas
- ☐ Avaliar o estado de consciência da vítima
- ☐ Permeabilizar a via aérea
- ☐ Iniciar trinta compressões torácicas, seguidas de duas ventilações
- ☐ Administrar fármacos para estabilizar a vítima

3
Pontuações: 1

Segundo o algoritmo de **Suporte Básico de Vida**, qual o rácio de compressões/insuflações que deve ser instituído, no adulto?
(assinale **a** alínea **correcta**)

Seleccione uma resposta.

- ○ 5:1
- ○ 3:1
- ○ 5:2
- ○ 30:2
- ○ 15:2

4
Pontuações: 1

Em relação à posição das mãos na realização de compressões torácicas, estas devem ser colocadas:

Seleccione uma resposta.

- ○ Nenhuma das opções
- ○ Na porção inferior do esterno
- ○ Na porção superior do esterno
- ○ No centro do esterno

5
Pontuações: 1

Quais os **riscos** que podem resultar da execução das compressões torácicas ?
(indique qual(ais) **a(s)** alínea(s) **correta(s)**)

Escolha pelo menos uma resposta

- ☐ Provocar lesões na grelha costal pela pressão exercida fora do esterno
- ☐ Provocar uma pressão sanguínea que permita a perfusão
- ☐ Nenhuma das opções
- ☐ Provocar fratura do apêndice xifóideo, se a compressão for exercida sobre este

6
Pontuações: 1

Ordene (sem repetições) os procedimentos relativos à realização de compressões torácicas:

Colocar a outra mão sobre a primeira entrelaçando os dedos	Escolha... ▾
Certificar-se que a vítima está deitada de costas, sobre uma superfície firme e plana	Escolha... ▾
No final de cada compressão garantir a reexpansão total do tórax, aliviando toda a pressão sem remover as mãos do tórax	Escolha... ▾
Braços e cotovelos esticados, com os ombros na direção das mãos	Escolha... ▾
Colocar a base de uma mão no centro do tórax, entre os mamilos	Escolha... ▾
Afastar/remover as roupas que cobrem o tórax da vítima	Escolha... ▾
Posicionar-se ao lado da vítima	Escolha... ▾
Aplicar compressão sobre o esterno deprimindo-o	Escolha... ▾

7
Pontuações: 1

Estabeleça a correspondência correta, relativa ao comando **VOS**:

V	Escolha...
O	Escolha...
S	Escolha...

8
Pontuações: 1

Indique a frequência com que devem ser realizadas as compressões torácicas:

Seleccione uma resposta.
- 120 a 140 por minuto
- 100 a 120 por minuto
- Cerca de 60 a 70 por minuto (frequência cardíaca normal de um adulto)
- Até 100 por minuto

9
Pontuações: 1

Numa vítima em paragem cardiorrespiratória, pretende-se que as compressões torácicas (indique a resposta mais correta):

Seleccione uma resposta.
- Preservem os batimentos cardíacos e forneçam energia ao coração
- Transmitam ao coração movimentos mecânicos capazes de ativar o ciclo cardíaco
- Garantam a circulação do sangue, promovam a hematose pulmonar e evitem a morte das células, principalmente do cérebro e do coração
- Garantam o fornecimento de oxigénio aos pulmões de modo que seja normalizada a hematose pulmonar

10
Pontuações: 1

Indique **a** alínea **correcta** nas seguintes questões relacionadas com compressões torácicas:

Seleccione uma resposta.
- As compressões torácicas numa vítima com 19 anos devem ser efetuadas com uma mão
- As compressões torácicas no adulto devem ser efetuadas no centro do tórax entre os mamilos
- As compressões torácicas no adulto devem ser efetuadas ao ritmo de 60 por minuto
- As compressões torácicas no adulto devem provocar uma depressão do tórax cerca de 6 a 8 cm

11
Pontuações: 1

No final de cada compressão torácica deve-se:

Seleccione uma resposta.
- Permitir a reexpansão total do tórax, aliviando toda a pressão sem remover as mãos do tórax
- Permitir a reexpansão total do tórax, aliviando toda a pressão removendo as mãos do tórax
- Evitar a reexpansão total do tórax, não aliviando toda a pressão

12
Pontuações: 1

Para a permeabilização da via aérea deve-se:

Seleccione uma resposta.
- Colocar a máscara na face da vítima
- Efetuar a extensão da cabeça e elevação do queixo
- Tocar, abanar a vítima e perguntar "sente-se bem?"
- Ver, ouvir e sentir durante 10 segundos

13
Pontuações: 1

As compressões torácicas devem ser aplicadas sobre o esterno, deprimindo-o:

Seleccione uma resposta.
- 5 a 6 cm
- 4 a 5 cm
- 6 a 7 cm
- Mais de 7 cm
- Nenhuma das opções

14
Pontuações: 1

Selecione **a(s)** resposta(s) **certa(s)**:

Escolha pelo menos uma resposta
- Se forem realizadas apenas compressões estas devem ser continuas com cerca de 180 por minuto
- Se forem realizadas apenas compressões estas devem ser interrompidas no momento correspondente às ventilações
- Se não existirem condições de realização das ventilações realizam-se apenas as compressões
- Se forem realizadas apenas compressões estas devem ser continuas com cerca de 100 por minuto

Appendix V: Checklist

Classificação:
2 - Correto
1 -Insuficiente
0 - Incorreto

PRE-TESTE Prático/ P0S-TESTE Prático

				Compressões				Insuflações			
ID	Chamar ajuda	VOS	Racio 30:2	Frequência	Posicao das Maos	Recoil	Profundidade	2 Profundas	Em menos de 10s	Extensão da cabeça	Observações
Aluno1											
Aluno2											
Aluno3											
Aluno4											
Aluno5											
Aluno6											
Aluno7											
….											