ALTERING CARDIOPULMONARY RESUSCITATION (CPR) EDUCATION FOR ALLIED HEALTH CARE PROVIDERS BASED ON SELF-REPORTED EXPERIENCES WITH RECERTIFICATION

A Dissertation
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Kassiann Deen Landin

In Partial Fulfillment of the Requirements
for the Degree of
DOCTOR OF PHILOSOPHY

Major Program:
Exercise Science and Nutrition

June 2021

Fargo, North Dakota

North Dakota State University
Graduate School

Title

ALTERING CARDIOPULMONARY RESUSCITATION (CPR) EDUCATION FOR ALLIED HEALTH CARE PROVIDERS BASED ON SELF-REPORTED EXPERIENCES WITH RECERTIFICATION

By

Kassiann Deen Landin

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

DOCTOR OF PHILOSOPHY

SUPERVISORY COMMITTEE:

Katie Lyman
Chair

Joe Duetsch

Bryan Christensen

Justin Wageman

Approved:

June 10, 2021
Date

Dr. Yeong Rhee
Department Chair

ABSTRACT

Health care providers (nurses, athletic trainers, and emergency medical services [EMS] personnel) are expected to perform high-quality cardiopulmonary resuscitation (CPR) regardless of their confidence. Also, regardless the design of CPR recertification courses, it is expected that health care providers perform high-quality CPR. The first goal of the study pertained to self-efficacy. This research investigated health care professionals reports of self-efficacy of CPR performance with the current CPR guidelines for a specific amount of time as well as over athletic equipment. Secondly, this research explored differences in recertification expectations and educational approaches between professions. Ninety-nine health care professionals (36 nurses, 36 athletic trainers, and 27 EMS personnel) completed a self-efficacy questionnaire and a CPR recertification questionnaire. For investigation one, raw data and, a 3X2 ANOVA model was estimated to test for differences between the professional groups and for the condition of athletic equipment in place. For investigation two, descriptive statistics, means, standard deviations, and frequencies were utilized to analyze the differences between professions in CPR recertification components. Health care providers claimed to have high levels of self-efficacy for CPR performance over an extended period of time, but a low level of self-efficacy when asked about performing CPR for an extended period of time over athletic equipment (40.09% of health care providers agreed/strongly agreed they could perform CPR for an extended period of time over athletic equipment). Nurses reported a lower total score for self-efficacy for CPR performance over protective athletic equipment when compared to athletic trainers and EMS personnel. Six percent of surveyed health care providers reported they trained on high-fidelity equipment in their most recent certification. Ninety-seven percent indicated that feedback directly from a manikin enhanced their ability to perform high-quality CPR. Only 41% of

reported participation in booster sessions with 38% of nurses reporting participation every 3 months and 45% of athletic trainers never participated in booster session. The relationship between confidence and CPR quality must be explored further to ensure CPR education is revised. Also, because results provide baseline data clarifying differences between specific health care professions, deliberate practice specific to professionals for CPR education can occur.

ACKNOWLEDGMENTS

Tanner John Landin, thank you for loving me through the long nights of writing, the travels to Fargo, the frustrations I had with limited sleep from the kids and wanting to finish. Without you I would not have persevered and I am lucky you are my teammate. I love you.

Henry and Cash, you both won't remember mommy being on her computer, but thank you for sleeping so I could write. Education is an investment in our ability to critically analyze the world, and I hope one day you also will see the value in what I was able to do while you both were so young.

Mom and Dad, thank you for always encouraging me to continue to go to school and better myself. The sacrifices from you both have not gone unnoticed and I am thankful for your support.

Kendall Grimm, thank you for letting me live with you Tuesday-Thursday for those two years. You are the best friend I could ask for. One who understands the value of the time and energy we put in to finish our degrees. Thank you for loving me and supporting me from the first day on the softball field to now.

Dr. Katie Lyman, there are not enough smart kid words in the world to thank you, but I will try. Early in my educational experience I always heard people say, "there will always be one teacher you will never forget." I assumed that would have been my 5th grade teacher because she was simply fun, I have since changed my mind. You are my favorite; you have impacted me so much in a positive way. In my education by encouraging me to continue past my masters, and in my personal life by supporting my family during this long fruitful process. So, thank you, thank you for investing in me, and encouraging me. Oh, and you are fun too. I am so thankful for you and your guidance.

To my committee who has been so supportive of me. Thank you Dr. Deutsch, Dr. Christensen, and Dr. Wageman. I am continually awed by each of your abilities to adapt to the world of higher education, and by the way you have formed a team to support me and encourage me. Thank you for your investment in me, albeit a long one, I am so appreciative of you.

Thank you to the department of HNES for providing me with a graduate assistantship and the support from all of the individuals who make up our great department.

Dan Nygard, the Microsoft word wizard. Thank you so much for your help with my faulty formatting. It takes someone with great patience to do your job, and you do it well. So, thank you.

Thank you to my participants. I was dumbfounded by the amount of you who reached out to help me by either taking our survey or sending it to someone you knew would take it. The Fargo fire department, Spring Lake Park/Blaine/Mounds View fire department, my auntie Margo, my UMaine family, Ringdahl Ambulance, and NDSU athletic trainers, you all and countless others have shown your support not only to me, but to your professions. Thank you for making it possible to gain data that hopefully only benefits you long term.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Overview of the Problem

While it is recognized by the medical community that cardiopulmonary resuscitation (CPR) is the best medical intervention for a patient in cardiac arrest, the American Heart Association (AHA) has not yet implemented best teaching practices for practitioners to refine their skills.[1, 2] Parameters of CPR performance, such as compression rate and depth, have become more specific through the years, best educational practices remain unclear.[2] The conventional design of initial CPR certification as well as for recertification courses is controversial due to the low quality of psychomotor performance and subsequent retention of CPR skills.[3] Best educational approaches are unclear and lack specificity for particular professionals, specifically in nursing, athletic training, and Emergency Medical Services (EMS). More recent AHA updates identify the use of deliberate feedback devices as being useful in skill acquisition during CPR education yet there is limited data and direction clarifying the optimal timing and provision of the feedback.[2] Likewise, data from health care providers (nurses, athletic trainers, and EMS) regarding deliberate practice and feedback within CPR education is also limited.

Furthermore, there is inadequate data recognizing psychological barriers and perceived confidence in rescuers' ability and the effects on CPR performance. While the national average for ambulance arrival in an urban environment is 8 minutes and 59 seconds, most research exploring CPR performance is analyzed for a shorter period of time with the standard being approximately two minutes.[4-6] Thus, more data investigating the confidence of rescuers performing CPR skills for a longer period of time is necessary. Additionally, data is unclear regarding nurses', athletic trainers', and EMS professionals' perceived ability to perform high-quality CPR over protective athletic equipment.[7-9] Without more data on the topic of CPR being performed over protective equipment and for proper amount of time, best recommendations and subsequent decisions regarding CPR education cannot be made.

Statement of Purpose

The purpose of this study was to investigate nurses', athletic trainers', and EMS professionals' reports of self-efficacy of CPR performance with the current CPR guidelines for a specific amount of time. In addition, we explored professionals' self-efficacy pertaining to performing CPR over athletic equipment. A secondary purpose was to clarify and compare feelings regarding the certification, recertification, and educational design specifically from the aforementioned professionals. The first investigation was devoted to self-efficacy of nurses, athletic trainers, and EMS and their perceived ability to perform CPR in accordance with current CPR guidelines for 8 minutes and 59 seconds, as well as over protective athletic equipment. The second investigation explored the possible differences in recertification expectations and educational approaches between professions. In conjunction with educational information, the second survey sought to explore the use of deliberate feedback manikins and debriefing during training sessions compared across professions. In summary, the purpose of this survey research was to gain a better understanding of self-efficacy related to possible external factors that may impede CPR performance. Finally, we aimed to explore the differences in educational format across professions.

Research Questions

The research was designed to answer the following questions for investigation 1: An analysis of CPR self-efficacy between emergency professionals related to external factors.

Q1: What is the relationship between nurses, athletic trainers, and firefighter/EMTs self-efficacy and their ability to perform CPR for 8:59?

Q2: What is the relationship between nurses, athletic trainers, and EMS self-efficacy and their ability to perform CPR over protective athletic equipment?

This research was designed to answer the following questions for investigation 2: Investigating the differences among professions in components of recertification experiences.

Q1: What are the differences in recertification requirements between medical professionals?

Q2: What are the differences between professions related to training on various deliberate feedback devices?

Q3: What are the differences between professions related to booster sessions?

Definitions

Cardiopulmonary Resuscitation (CPR): a medical procedure involving repeated compression of a patient's chest, performed in an attempt to restore the blood circulation and breathing of a person who has suffered cardiac arrest [10]

Emergency Medical Services (EMS): first responders, EMT basic, EMT Advanced, paramedic, firefighter[11]

Self- Efficacy: a person's belief in his/her ability to succeed in a particular situation [12]

Low-fidelity manikin: manikin with limited physical similarity to a realistic environment[13]

Medium-fidelity manikin: manikin that allows for realistic practice but does not provide physical findings concurrent with programmed condition [13]

High-fidelity manikin: demonstrates functions of physical findings such as heart and lung/breath sounds, pulses, chest rise and fall, and vital signs that correlate with physical findings of a programmed condition and paired with feedback [2]

Deliberate practice: repetitive performance of the intended skills, paired with a skills assessment and subsequent feedback resulting in improved practice [14, 15]

Limitations

Limitations of the first study regarding self-efficacy included subjective reports of self-efficacy while performing CPR for an extended period of time and over protective equipment. Researchers did not examine CPR psychomotor performance to ensure that participants performed high-quality CPR in accordance with current guidelines.

Limitations of the second study regarding education and deliberate practice included subjective reporting of CPR certification and educational design. Researchers did not confirm educational design formats from employers or certifying bodies.

Delimitations

Delimitations for both studies included a limited participant population comprised of nurses, athletic trainers, individuals in EMS because we are interested in the emergency population. We were able to compare the results more effectively because the professions all provide emergency medical procedures and may encounter similar patient groups.

Additionally, participants' responses were based on their recollection of their most recent recertification experience; we did not confirm responses with employer policies, procedures, or practices. More information regarding CPR self-efficacy reported by health care professionals, as well as CPR education practices is needed before further exploratory research can be properly conducted. There is a need for this foundational knowledge to guide experimental designs in the future.

Assumptions

Assumptions for both studies that were made were that participants honestly reported their perceived ability to perform high quality CPR. Additionally, it was assumed that participants honestly and, to the best of their knowledge, answered the survey regarding components of CPR recertification

Variables

The independent variables in the first study included participants' profession, length of performance, and equipment. Dependent variables included the scores regarding the self-reported ability to perform high quality CPR on the modified Basic Resuscitation Skills Self-Efficacy Scale (BRE-SES).[16]

Descriptive statistics were calculated for components of study two. Frequencies of responses were reported.

Significance of the Study

Existing research that explores self-efficacy specifically related to emergency care professionals related to performance of CPR for extended period of time and over athlete equipment is sparse. Thus, the current study contributes further data to support potential changes in guidelines and best educational practice. Also, since there is little data comparing educational experiences between professions, it is difficult to make appropriate suggestions for certification and recertification programs. The first study aimed to identify differences in the self-efficacy of CPR performance for an extended period of time as well as over protective athletic equipment in different allied health professions. Researchers anticipated that findings from this study will provide valuable information to assist with potential changes in CPR education and training within specific professions.

The second study aimed to identify differences between and perceptions of educational experiences including recertification courses, deliberate feedback paired with fidelity equipment, and booster sessions, as reported by nurses, athletic trainers, and EMS professionals. We anticipated that the results of this study contribute to the body of literature that identifies the need for changes in CPR education. The results support the notion that one format of education may not be best for all professions.

COMPREHENSIVE REVIEW

The History of CPR

Throughout history, cardiopulmonary resuscitation (CPR) knowledge and psychomotor techniques have progressed simultaneously with the advancements in medicine. The evolution of CPR knowledge and practice has occurred due to changes in technology as well as a broader understanding of cardiac emergency etiology. Research and active scenarios have created the opportunity to support and develop best-practice guidelines with a focus on the emergency care techniques of CPR. One of the first recorded instances of CPR dates back to the 1700's, where a form of mouth-to-mouth resuscitation was recommended for drowning victims.[17] During this time, Dr. Peter Safer had been credited with founding the head-tilt-chin-lift and jaw thrust technique to maintain a proper airway in unconscious victims.[17, 18] Records at that time also indicated that William Tossach utilized artificial breaths by means of mouth-to-mouth breathing to resuscitate unconscious coal miners.[18, 19] In 1775, the English Humane Society Annual reported inflation of lungs for resuscitation purposes as 'useful.' Lung inflation was described as closing the patient's nostrils while inflating the lungs and chest utilizing the breath of the rescuers going into the patient's mouth. Then, expiration of the air occurred by manually compressing the chest to mimic breathing.[20]

In the 1800's, there was documentation of sternal compressions, described as external or closed cardiac massage, for the treatment of cardiac victims. These compressions were described as being performed at approximately 12 compressions per minute with no guidelines as to the depth a rescuer must provide. Freidrich Maass was credited with the first successful positive outcome utilizing closed cardiac massage on a human.[18, 20] Prior to closed cardiac massage, open cardiac massage consisted of the physical compression or manipulation of the heart in an effort to preserve the necessary cardiac rhythm to promote blood flow though this was not a commonly used intervention.[18]

Approximately 100 years later, William Kouwenhoven, an electrical engineer, began investigating the effects of electricity on the cardiac cycle. He, along with other researchers, found that utilizing electrical current to stop an arrhythmia allowed for normal cardiac rhythm to be reestablished. These findings led to the invention of the modern day defibrillator.[21] Kouwenhoven also further investigated closed chest cardiac massage suggesting that forceful chest compressions produced respectable arterial pulses.[17] In 1960, Kouwenhoven and his team maintained adequate circulation in dogs for approximately 30 minutes when the chest was compressed in a rhythmic fashion.[20] Based on the findings of animal research , Kouwenhoven and researchers enlisted the Red Cross to demonstrate to the public the potential positive effects closed cardiac chest massage had on dogs.[21] The new findings and demonstrations to the public piqued the interest of Asmund Laerdal who created a mannequin to facilitate psychomotor practice on humans for CPR education.

By 1966, the first CPR guidelines were created but were not recommended for use by the general public. These guidelines, created by the National Research Council of the National Academy of Sciences, were established to standardize training and performance in CPR.[17, 18] The guideline recommendations from 1966 are outlined in Table 1. The parameters included; compression depth of 4-5 cm, 60 compressions per minute, a compression to ventilation ration of 15:2 for one rescuer and 5:1 for two rescuers, ventilation volume of approximately twice the amount the patient normal breathes and a rate of 12 breaths per minute (Table 1).[22]

Table 1. 1966 CPR Guidelines

Rate (compressions per minute)	60
Depth	4-5 cm
Ratio (single rescuer)	15:2
Ratio (two rescuer)	5:1
Ventilation Volume	2x the amount the patient normally breathes
Ventilation Rate (breaths per minute)	12

As CPR methods have evolved, updated guidelines have been developed and introduced into practice for professionals as well as for the lay population to increase survival rates from an out-of-hospital cardiac event. Layperson education for CPR formally began in 1974, but the American Heart Association (AHA) did not introduce the chain of survival concept until 1991.[18] The chain of survival acted as a guide describing the most efficient way for resuscitation efforts to occur providing the victim the best chance of survival. The chain of survival was published as; early access to the victim, early CPR, early defibrillation and then advanced care.[23, 24] The chain of survival simplified is described as; early access/recognition and call 911, early CPR to slow the rate of brain and heart deterioration, early defibrillation to restore perfusion rhythm, and lastly early advanced support to medical care to stabilize the patient.[25] In addition, lay population was taught an algorithm to remember proper CPR. The algorithm was the commonly known standard of A-B-C. The A-B-C standard consisted of airway check, introducing breaths, and then compressions for CPR.[17]

A defining moment for CPR education and research occurred in 1992 when the International Liaison Committee on Resuscitation (ILCOR) was founded. The development of this committee created unification of resuscitation efforts worldwide. The ILCOR created objectives that integrated resuscitation organizations and began making evidence-based recommendations for best practices in CPR. The ILCOR echoed the 1991/1992 guidelines that in utilizing the chain of survival, victims would have the best chance for survial.[17, 24, 26] Finally, in

1999, the first task force on first aid and CPR was appointed. The First International Conference on Guidelines for CPR and Emergency Cardiovascular Care (ECC) created a universal set of standards for CPR education and performance. At this conference, new guidelines were created, which were supported by science and international collaboration further merging CPR educational efforts. As a result, the 2000 International CPR and ECC guidelines were published.[17, 18] The history of the development of CPR as well as the different agencies that study CPR have shaped an opportunity for change to occur within the guidelines. As more teaching methods and patient outcomes are studied and researched, aspects of CPR remain standardized by ILCOR and are updated approximately every five years.[24, 26]

The CPR guidelines from the European Resuscitation Council in 1992 recommended providing a chest thump to terminate cardiac arrest and then continue with three attempts of defibrillation. In the 1990's the compression to ventilation ratio was recommended to be 5:1 for 10 sequences until the next attempt at defibrillation.[27, 28] At that time there was limited evidence supporting that the success of CPR was directly influenced by the rate of compressions. Thus, the range for compression rate was from 60 to 100 compressions per minute suggesting the rate of 80 compressions per minute was ideal. The 1992 guidelines also recommended that to circulate the oxygenated blood throughout the body, ventilations must be combined with a chest compression depth of four to five centimeters. The exact timing of the ventilations was not critical to the success of CPR; thus, simply waiting for the chest to fall after a ventilation was reported to be adequate.[28] In 1993 there was an interest in utilizing scientific-based information to offer appropriate guidelines for basic and advanced life support.[29] In addition to ensuring guidelines were developed with evidence-based information, a goal was set to ensure international resuscitation guidelines were as consistent as possible by the year 2000.[30]

CPR: Guidelines 2000's

The objectives of the Guidelines 2000 Conference on CPR and ECC were to produce international guidelines, revise past recommendations, publish new recommendations for teaching knowledge and skills of ECC and BLS, and lastly, utilizing evidence-based guidelines for the development of these revisions.[30, 31] The conference consisted of an international collaboration between the American Heart Association (AHA), the European Resuscitation Council, the Heart and Stroke Foundation of Canada, the Australian Resuscitation Council, the Resuscitation Councils of Latin America, and many others. This was the first conference that utilized widespread findings to create new recommendations for CPR and ECC.[30, 31] Similar to the 1992 guidelines, a high priority for cardiac arrest victims was rapid defibrillation, which was noted by the addition of the "D", or defibrillation, to the standard sequence of A-B-C (airway, breathing, compressions).[17, 32] The 2000 guidelines also emphasized a high-frequency rapid compression rate was the best technique for CPR. High frequency was defined as compressions occurring at more than 100 compressions per minute. This contradicted the 1992 guidelines that called for compression rates between 60-100 compressions per minute.[28, 30, 32] The chain of survival for the layperson did not change from the 1992 standards, which consisted of early access, early CPR, early defibrillation and early ACLS.[32]

2000 Pulse Check Removal

One change for lay rescuer CPR from the 1992 guidelines to the 2000 guidelines was elimination of the pulse check. The reasoning behind eliminating the pulse assessment included the amount of time required for laypersons to assess as well as the inaccuracy of their diagnosis. The delay in start to compressions due to the time required for the pulse check could have a potential negative outcome for success rates. Evidence supports elimination of the pule check due to the inability of healthcare professionals to detect the presence or absence of a carotid pulse within 10 seconds; this finding would also suggest that lay rescuers would likely be unable to correctly detect a pulse.[33-36] Table 2 delineates supporting studies for the removal of the pulse check from the 2000 guidelines.

Table 2. Supporting Research for Pulse Check Removal

<table>
<tr><th>Authors</th><th>Purpose</th><th>Participants</th><th>Design</th><th>Outcomes</th><th>Limitations</th></tr>
<tr>
<td>Mather et.al (1995)[35]</td>
<td>- Record the amount of time it took for ACLS trained Anesthetists to palpate and identify carotid, radial, brachial, and femoral pulses in anaesthetized patients.</td>
<td>- Data were collected by hospital anesthetists on 554 patients undergoing general anesthesia.</td>
<td>- Data were recorded with a stopwatch, starting when there was finger-tip contact with the skin to the moment the anesthetist indicated they had found the pulse.

- If there was no pulse found within 30 seconds, timing was halted.</td>
<td>- Of the 554 patients, pulses were identified on all except 22 (4.0%). These failures included the femoral pulse (12 of 22), the carotid pulse (8 of 22) and the radial pulse (2 of 22).

<table>
<tr><th>Pulse</th><th>Percentage identified within five seconds (CI 95%)</th><th>Percentage identified within 10 seconds (CI 95%)</th></tr>
<tr><td>Radial</td><td>97.8 (96.6-99.0)</td><td>99.3 (98.6-100)</td></tr>
<tr><td>Brachial</td><td>91.0 (88.6-93.4)</td><td>99.9 (99.6-100)</td></tr>
<tr><td>Femoral</td><td>82.1 (78.9-85.3)</td><td>97.1 (95.7-98.5)</td></tr>
<tr><td>Carotid</td><td>81.5 (78.3-84.7)</td><td>96.7 (95.2-98.2)</td></tr>
</table>
</td>
<td>- Timing was abandoned at 30 seconds, resulting in the 4% failure rate. This did not provide for a true failure rate.

- The number of anesthetists was not recorded; thus, it is unknown if results are a true representation of the ability of the general population of anesthetists to correctly palpate pulses.</td>
</tr>
</table>

Table 2. Supporting Research for Pulse Check Removal (continued)

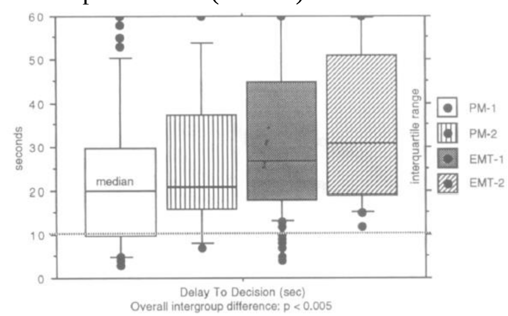
Authors	Purpose	Participants	Design	Outcomes	Limitations
Eberle et al. (1996)[37]	- To evaluate if four groups of first responder with different levels of CPR training (student EMTs with 4 hours of BLS, EMT's with practical instruction with BLS training, paramedic students with BLS and ACLS training, and certified paramedics) could accurately and quickly asses the carotid pulse	- Collected pulse check data from 206 first responders on 16 patients undergoing coronary artery bypass surgery during spontaneous circulation or a non-pulsatile bypass time-period	- Single blinded, random, left carotid pulse assessment in anaesthetized patients during spontaneous circulation or during non-pulsatile cardiopulmonary bypass. - Palpated the artery and when felt the pulse they were to count aloud (told to voice pulselessness ASAP if that was their conclusion).	- For all participants, sensitivity of pulselessness was almost 90% but specificity was only 55%. - Between participant groups, both sensitivity and specificity increased with increased levels of trainings - Median time to decision was must sooner when participants were sure they had found a pulse (15 ±3-28 seconds) and the largest differences in time to decision can be noted between EMTs in training and certified paramedics (P < .02)  *box plot taken from Eberle et al. (1996)[37] - Only 16.5% of participants were able to reach a diagnosis within 10 seconds	- 147 assessments were performed with a pulse present and 59 with no pulse, so the pulse to no pulse ratio was not even for those attempting to locate a pulse. A more equally distributed number may have shown different results for finding pulselessness.

Table 2. Supporting Research for Pulse Check Removal (continued)

<table>
<tr><th>Authors</th><th>Purpose</th><th>Participants</th><th>Design</th><th>Outcomes</th><th>Limitations</th></tr>
<tr>
<td>Bahr et al. (1997)[38]</td>
<td>- Evaluate the skills of lay people in checking the carotid pulse directly after a first aid course, as well as one group of lay people prior to attending a first aid course</td>
<td>- 449 people: 168 volunteers tested after 16 hours of training, 202 volunteers after 8 hours of training, 79 volunteers tested prior to the attendance of a first aid course</td>
<td>- In both courses, palpation training was performed via demonstration and by having individuals palpate their own carotid pulse, and during CPR practice palpations were performed on a manikin with no simulate pulse.

- For the study participants were asked to check the carotid pulse on a young, healthy, non-obese person lying on the floor, they were to count aloud when they found the pulse while an investigator simultaneously checked the radial pulse for accuracy.</td>
<td>- The average amount of time for participants to find a pulse was 9.46 seconds.
- No significant difference in the amount of time to pulse detection between groups receiving differing amounts of training.

- At five seconds, only 47% of participants found the pulse, within 10 seconds, only 74% found the pulse and by 35 seconds 95% of participants found the pulse correctly.

Percentages of pulses detected within five or 10 seconds
<table>
<tr><th></th><th>Within 5 seconds</th><th>Within 10 seconds</th></tr>
<tr><td>After 16-hour course</td><td>51.8</td><td>73.8</td></tr>
<tr><td>After 8-hour course</td><td>42.1</td><td>72.8</td></tr>
<tr><td>No course</td><td>44.7</td><td>74</td></tr>
</table>
</td>
<td>- Participants found a pulse on a healthy individual, which would not translate into an emergent situation.

- Participants were tested immediately after a training course thus a learning effect likely occurred.</td>
</tr>
</table>

Table 2. Supporting Research for Pulse Check Removal (continued)

<table>
<tr><th>Authors</th><th>Purpose</th><th>Participants</th><th>Design</th><th>Outcomes</th><th>Limitations</th></tr>
<tr>
<td>Ochoa et al. (1998)[36]</td>
<td>- Investigate the proportion of emergency room intensive care staff able to accurately locate the carotid pulse in less than five seconds.

- Identify potential variables that could alter the ability to locate a pulse (previous CPR training, scene (floor or stretcher), and the neck position (neutral or extended)</td>
<td>- 72 participants (37 physicians, 35 nurses) located the carotid pulse in a healthy, aware male with normal blood pressure</td>
<td>- Participants randomly selected from nurses/physicians in ICU and ER

- Located carotid pulse in four positions (lying on floor with neutral neck, lying on floor with extended neck, lying on stretcher with neutral neck, lying on stretcher with extended neck)

- Variables studied included: age of participant, previous CPR training, time to detect pulse, and neck positions</td>
<td>- The probability that those with no previous training required more than 5 seconds was nine times greater than those with training

<table>
<tr><th>Patient Position</th><th>Mean time ± standard deviation</th><th>% of participants unable to detect pulse before five seconds</th><th>% of participants unable to detect pulse before 10 seconds</th></tr>
<tr><td>Stretcher + neck extended</td><td>2.74 ± 1.32</td><td>5.6</td><td>0</td></tr>
<tr><td>Stretcher + neck in neutral</td><td>4.26 ± 3.56</td><td>15.3</td><td>1.4</td></tr>
<tr><td>Floor + neck extended</td><td>2.64 ± 1.67</td><td>6.9</td><td>2.8</td></tr>
<tr><td>Floor + neck in neutral</td><td>3.78 ± 2.19</td><td>15.3</td><td>4.2</td></tr>
</table>
</td>
<td>- This study was completed using physicians and nurses, who have experience finding pulses, so the results are not generalizable to a lay population or even to those simply trained in BLS.</td>
</tr>
</table>

Based on the published literature related to checking for a pulse, three studies should be noted for their inclusion of medical professionals as the participants.[35-37] The guidelines prior to 2000 stated for the location of the pulse to be checked at the carotid artery and to last no longer than 10 seconds. Findings suggest that even well-trained medical professionals did not have consistent success in finding the carotid pulse in the proposed time frame. It should be highlighted that none of the studies that included medical professionals included emergent situations where accurate diagnosis in a short time frame was critical. The inability to find the pulse correctly in a controlled environment in a reasonable time frame during research was deemed concerning.

According to the findings from Mather et al., health care professionals had the most success in finding the radial pulse with 97.8% of participants finding it within five seconds. Interestingly, only 87.5% of participants in that study found the carotid pulse within five seconds.[35] In comparison, only 52.8% of participants in Ochoa et al.'s study that utilized emergency room care staff found the carotid pulse accurately within five seconds.[36] Within 10 seconds, health care professionals in Mather et al.'s study found the carotid pulse 96.7% of the time.[35] Yet, according to Eberle et al., only 16.5% of participants found the pulse within the 10 second time frame.[37] The differences in these numbers alone show how inaccurate and time consuming the pulse check aspect of CPR may be. In these studies, researchers concluded the length of time it takes to determine a pulse was dependent on factors such as pulse rate, blood pressure, and anatomical variance. These factors suggest the amount of time spent to identify pulses or the absence of a pulse may result in delayed care. The potential delay in care was deemed notable by Mathers et al. who reported the carotid pulse appeared to be the most difficult to find yet was the recommended pulse check site from Advanced Cardiac Life Support (ACLS) courses.[35]

While the previously mentioned data supports the removal of the pulse check, there remains a gap in the literature regarding the lay person's ability to correctly and quickly find a pulse. Bahr et al. discussed the amount of time it took lay people who had just been trained to accurately find the pulse was too long. Ninety-five percent of participants in their study took 35 seconds to correctly detect the carotid pulse. The lack of significance between groups who had training and those who did not is key in supporting the removal of the pulse check in the guidelines.[38] The lack of statistical significance indicates the education/certification did not properly train participants to correctly find the carotid pulse. Additionally, the pulse that they were searching for in the Bahr et al. study was on a healthy individual with a strong, consistent pulse. In an emergent scenario, the pulse may not be as easily detected due to the underlying cause of the condition causing distress. Therefore, the amount of time it takes to correctly analyze the pulse may increase, thereby causing a significant delay of initiation of rapid CPR.[38] Overall, the inability of both lay people and highly trained medical personnel to efficiently check the carotid pulse supports the change in guidelines for the removal of pulse check. While findings indicate that medical personnel are not proficient in finding a pulse, the pulse check aspect remained in the ACLS guidelines. The value of the pulse check may not be greater than the potential advantages of the rapid initiation of CPR.

2000 Compression to Ventilation Ratio Changes

In 1992, the compression to ventilation ratio was 5:1 for 10 sequences, but in 2000 was changed to 15:2 for both single- and two-person CPR.[28] This recommendation was proposed by the AHA because it was thought that more than five compressions without disruption were needed to achieve adequate blood flow and oxygen delivery and the potential for return of spontaneous circulation (ROSC). In addition, the change of compression to ventilation ratio increased the number of chest compressions per minute while reducing the number of times per minute there was an interruption in compressions.[30] Table 3 organizes core research studies and their findings to support the change in compression to ventilation ratios within the guidelines.

Table 3. Supporting Research for the Change in Compression to Ventilation Ratios

Authors	Purpose	Participants	Design	Outcomes	Limitations
Dunkley et al. (1998)[39]	-Compare standard (compression to ventilation ratio of 5:1) and modified (compression to ventilation ratio of 15:2) CPR	- Sixty CPR certified participants, who were medical students, nurses, paramedics, or operating department staff	- Randomly assigned to provide standard two person CPR (5:1) or modified one rescuer CPR (15:2) for 4 minutes -Respiratory rate, tidal volume, minute volumes, compression rate and depth for all four minutes of CPR	- No significant difference in compression rate between two ratios - Significant difference ($P < .01$) in compression rate, with the modified (15:2) group compressed more quickly per minute (82±8 compressions per minute) when compared to the standard CPR (5:1) group (65±11 compressions per minute)	- Qualities of compressions were not discussed. Rate and depth were recorded but it was not stated if there was clinical significance regarding rate even though there was not statistical significance
Kinney and Tibballs (1999)[40]	- Identify the ideal chest compression to ventilation ratio utilizing three ratios (5:1, 10:2 and 15:2)	- 18 nurses who had been CPR trained within the past 5 months	- Nurses were instructed to perform CPR at all 3 ratios, with their compressions in unison with a metronome set at 100 compressions per minute. - All ratios were performed for 1 minute, (with one-minute breaks between ratios) while number of compressions, percentage of effective chest compressions, number of breaths and tidal volume were recorded	- 85% of compressions were performed effectively across all three ratios - No significant differences in quality of compressions when comparing the ratios ($p > .9$)	- Only performed each ratio for 1 minute, which is not an adequate time frame for in depth CPR data - The use of a metronome to guide pulse rate removed the opportunity to measure and analyze differences between pulse rate between the ratios

Table 3. Supporting Research for the Change in Compression to Ventilation Ratios (continued)

<table>
<tr><th>Authors</th><th>Purpose</th><th>Participants</th><th>Design</th><th>Outcomes</th><th>Limitations</th></tr>
<tr>
<td>Greingor (2002)[41]</td>
<td>- Explore the quality of compressions over a 5-minute time period for two compression to ventilation ratios (5:1 and 15:2)</td>
<td>- Twenty-one male first responders participated

- All participants performed both compression to ventilation ratios</td>
<td>- ResusciAnne with Skillmeter recorded: rate of compression, number of compressions per minute, depth of compressions and location of compressions.

- Each participant performed 5 minutes of chest compressions for each ratio while their partner performed ventilations (aspects of ventilation quality were not measured)</td>
<td>- Participants performed 14.5% more compressions at the 15:2 ratio compared to the 5:1 ratio, however the number of properly performed compressions was significant in the 5:1 ratio (p = .0002)

- Compression quality declined as the duration of the study continued

Compression data for 15:2 and 5:1 compression to ventilation ratios
<table>
<tr><th></th><th colspan="2">15:2</th><th colspan="2">5:1</th></tr>
<tr><td>Mean rate of compressions</td><td colspan="2">112</td><td colspan="2">103.5</td></tr>
<tr><td rowspan="5">Mean number of correct compressions per minute</td><td>Minute 1</td><td>59</td><td>Minute 1</td><td>58</td></tr>
<tr><td>Minute 2</td><td>41</td><td>Minute 2</td><td>55</td></tr>
<tr><td>Minute 3</td><td>40</td><td>Minute 3</td><td>53</td></tr>
<tr><td>Minute 4</td><td>47</td><td>Minute 4</td><td>60</td></tr>
<tr><td>Minute 5</td><td>34</td><td>Minute 5</td><td>56</td></tr>
</table>
</td>
<td>- No comment on if performances were randomized, so it is unknown if fatigue was attempted to be controlled

- Manikin study</td>
</tr>
</table>

Table 3. Supporting Research for the Change in Compression to Ventilation Ratios (continued)

Authors	Purpose	Participants	Design	Outcomes	Limitations
Dorph, Wik and Steen (2002)[42]	- Evaluate the effectiveness of 5:1 and 15:2 compression ratios during a simulated single rescuer CPR attempt	- Fourteen individuals in attendance of a BLS course and were taught basic pediatric life support (per the 2000 guidelines), as well as trained to perform CPR at a compression to ventilation ratio of 15:2	- Participants were instructed to provide single rescuer CPR to a junior manikin by applying compressions to the lower half of the sternum at a depth of 1/3 chest depth, at a rate of 100/min - the study began with participants checking for responsiveness, and following proper ABC's -provided compressions and ventilations for 4 minutes for each of the ratio sets (15:2 and 5:1)	- No significant difference in mean compression rate between the ratios - Average number of compressions was 48±15% higher in the 15:2 group (60±9 compressions per minute for 15:2 compared to 41±7 for 5:1 ((p = .001)).	- Testing occurred immediately after training so a learning effect may have occurred

Table 3. Supporting Research for the Change in Compression to Ventilation Ratios (continued)

Authors	Purpose	Participants	Design	Outcomes	Limitations
Babbs and Kern (2002)[43]	-Identify the optimum compression to ventilation ratio utilizing equations in which oxygen delivery and blood flow were functions of compressions and ventilations	- Non-human research - Desired result was oxygen delivery so utilizing equations which altered flow of blood via compressions as well as oxygen saturation helped to deduce the ideal compression to ventilation ratio - Included time to deliver breaths (16 seconds for 2 breathes)	- Utilized equations which described oxygen delivery and blood flow as functions of compressions and ventilations over time - Changed amount of time between compressions ending and ventilations beginning - Fick Principal: Oxygen delivery is equal to cardiac output multiplied by arteriovenous difference in oxygen content - Altered the flow of blood in equations utilizing compression and oxygen saturation (ventilations) to change oxygen delivery	- When utilizing the average ventilation time of 5 seconds/2 breaths, maximal oxygen delivery corresponded with a 20:2 or 40:2 compression to ventilation ratio - When utilizing the true average ventilation time of 16 seconds/2 breaths, maximal oxygen delivery corresponded with a 25:1 or 50:2 compression to ventilation ratio - According to their equational findings, Babbs and Kern state that by converting from a 15:2 to a 50:2 compression to ventilation ratio, there would be a potential 26% improvement in oxygen delivery, thus potentially delaying ischemia and improving CPR outcomes	- Non-human research - When discussing the desired result (oxygen delivery), a successful resuscitation attempt was not discussed

Table 3. Supporting Research for the Change in Compression to Ventilation Ratios (continued)

Authors	Purpose	Participants	Design	Outcomes	Limitations
Valenzuela et al. (2005)[44]	-Determine the proportion of time spent doing chest compressions during resuscitation attempts	-61 cases of OHCA who were treated by EMS with ECG and voice recording AEDs	-CA incidence and survival rates were tracked over a 10-year period for a comparison with newly implemented guidelines	- In the first 5 minutes of CPR, chest compressions were performed only 40±21% of the time - Throughout the entire effort of CPR, chest compressions were only performed 43±18% of the time - When compared to past data, survival to hospital discharge increased from 6% to 7%	- Selective, subgroup analysis (may not be representative of whole population with relatively small N)

The success of CPR is dependent on many factors with a vital element being the rescuers' ability to provide sufficient blood flow utilizing chest compressions with the goal of ROSC and favorable neurological outcomes. Based on the available literature regarding compression to ventilation ratios from the 2000 guideline alterations, the previously mentioned five studies support the change for an increase in compressions. Researchers all utilized both the suggested 15:2 compression to ventilation ratio as well as the 5:1 ratio in their studies. Findings across the studies completed by Dunkley et al., Greingor, and Dorph, Wik and Steen all indicate there was an increase in compressions with the 15:2 ratio. Interestingly, it should be noted that the quality of compressions appeared to decline as the duration of the study continued.[39, 41, 42] Greingor found that participants performed 14.5% more compressions at the 15:2 ratio compared to the 5:1 ratio, while Dorph, Wik and Steen found that the average number of compressions was approximately 48% higher with the 15:2 ratio.[41, 42] While these percentages show a wide range of increased compressions from the 15:2 ratio, it is important to note that the quality of the compressions performed may not have been up to standard. At this time, the quality aspects of compressions, such as rate, depth, and chest recoil, were not well defined, so it was thought that simply increasing the number of compressions in the CPR sequence would benefit a victim.

While Babbs and Kern did not utilize humans for their research, their findings indicated that a higher compression to ventilation ratio would be beneficial for increased oxygen delivery and blood flow. Their equations even suggested increasing the compression to ventilation ratio to 50:2 creating a potential 26% improvement in oxygen delivery. That ratio does not account for human error or fatigue, so utilizing the average ventilation time of 5 seconds for the delivery of two breaths maximum oxygen delivery was shown to correspond with 20:2 compression to ventilation ratio.[43] Regardless of the population studied, the research studies supported the increase in compression to ventilation ratio due to the increase in number of compressions given to the victim.

2000 Educational Changes

A final alteration to the 2000 guidelines was the concept of changing education and training for CPR. The idea of instructor-centered course was discussed as a potential issue due to discrepancies in training and teaching methods regardless of training manuals. The Introduction to the International Guidelines 2000 for CPR and ECC explained instructor-centered courses consisted of traditional lecture, skill demonstration, skill checklists, and evaluation utilizing checklists. Though programs were developed and sponsored by similar BLS and ECC organizations, discrepancy between instructors remained. The overall consensus in the 2000 guidelines was CPR needed to be simplified in an effort to create a greater focus on skills and retention of those skills for more successful patient outcomes.[31] Table 4 outlines the supporting studies for the advancement of adult pedagogy.

Table 4. Supporting Research of 2000 CPR Education Guideline Changes

Authors	Purpose	Participants	Design	Outcomes	Limitations
Brennan and Braslow (1995)[45]	- Evaluate skill levels of individuals who took an American Red Cross Adult, single rescuer CPR course	- 46 hotel employees (not medical personnel) completed the study	- CPR courses were taught in the traditional 4-hour format using a video format for skill demonstrations versus instructor guided skills - No first aid techniques were included in this course - Classes and skill sessions were videotaped -once trainees passed instructor conducted skills tests, they went and performed a skill check on a manikin - Evaluated using a 14-point modified check list and global performance scale - Performance scale assigned one of five ranks (outstanding to not competent)	- Based on the global rating scale, 46% of the trainees were classified as questionably competent or non- competent - no trainees in the outstanding category - 17% fell within the very good category which allowed for minor errors during the skill exam -Compression and ventilation skill quality results fell short of the standards, with only 11.8% of compressions being delivered correctly - 19% of compressions were too deep -45% of compressions were too shallow -13.9% of compressions were not fully released	- Skill retention was not tested -Instructors corrected trainees' errors during testing, but allowed them to continue, thus trainees did not string together all skills to emulate real-life CPR scenario
Brennan and Braslow (1995)[45]	-Interviewed trainees on the evaluation of skill practice times and confidence levels of their skills	- 46 hotel employees (not medical personnel) completed the study	- After training and all testing (see above), trainees completed a subjective class evaluation which included questions such as: did you have enough time to practice? How confident are you in your ability to perform correct CPR skills?	- 89% indicated they had ample time for practice - 6% of trainees indicated they had too much time while 4% indicated they did not have enough time - 64% of trainees stated that they were "very confident" that they could perform CPR, while the rest indicated that they were "somewhat confident	- Unknown if the confidence scale used was validated to similar research

Table 4. Supporting Research of 2000 CPR Education Guideline Changes (Continued)

Authors	Purpose	Participants	Design	Outcomes	Limitations
Kaye and Mancini (1998)[46]	-Review of literature between 1992 and 1996 that evaluated CPR training and retention	- Asked the following questions of CPR training programs for both lay people and medical professionals: 1. Are the programs effective? 2. Do trainees learn? 3. Does training affect actual resuscitations? 4. Is survival improved?	- Literature search utilizing key words: Cardiopulmonary resuscitation (CPR) education, resuscitation training, basic life support, AED training, and ACLS	- Regardless of population being evaluated or which course was being taught, basic resuscitation knowledge and psychomotor skills were poor - Little time in hands on practice occurred in training courses - Overall slow rate and inadequate depth of compressions occurred - To improve CPR courses, the curriculum and standards should be based on minimum criteria to save a life - Eliminate excess material in these courses - Essential components as follows: 1. Assess consciousness 2. Call 911 3. Defibrillate 4. Initiate CPR - Emphasis on skills with repetitive practice - Each student should have their own manikin to practice on	- Survival data was extremely limited - Data regarding real time resuscitation attempts was also limited in this search time period

While it is obvious that CPR education goals should be focused on ensuring trainees properly learn CPR, not all courses are formatted in ways that encourage CPR competence. The lack of purposeful formatting could foster incorrect skill learning, thereby creating the opportunity for participants to ineffectively perform CPR and subsequently producing poor patient outcomes. By and large, having instructors control the training environment could be detrimental to promoting proper skills due to the ratio of instructor to student, variations of content being shared, and corrections made in skill sessions. A statement made by Kaye and Mancini clarified the purpose of CPR education should be to ensure that classroom performance and knowledge translate into successful clinical practice. By analyzing review studies, Kaye and Mancini discussed the effectiveness of CPR training programs and proposed future directions, which assisted with the guideline change in 2000.

Researchers acknowledged that actual performance and retention of skills were poor regardless of the population who was being evaluated.[46] Results indicate that although trainees had the opportunity to practice CPR skills while indicating a high confidence level in their skill ability, a mastery level skill performance was not obtained. Only 8.5% of trainees performed half the compressions according to the published standards, yet 65% of the trainees said they were very confident in their ability to properly perform CPR.[45] In discussion, Brennan and Braslow agree with previously published research in questioning the competence of instructors in assisting with the acquisition and evaluation of CPR psychomotor skills.[47] The study completed by Brennan and Braslow appears to agree in challenging the effectiveness and quality control of the course content provided by instructors, consequently encouraging alterative teaching techniques for CPR psychomotor skill acquisition. Brennan and Braslow stated that the effectiveness of training methods should be considered to achieve proper levels of performance with the intent of increasing survival rates.[45] Yet, based on findings, it is evident that not only are the quality of skills acquired in the course poor, there seems to be a false sense of confidence in those skills. It is vital to note that the push for education changes began 20 plus years ago, and yet the AHA and ARC are still trying to create a course that ensures proper CPR motor skill acquisition and retention.

CPR: 2005 Guidelines

The 2005 Consensus Conference was focused on the idea that novice bystanders needed to learn CPR. In addition, those who were already certified likely need remedial training to perform high-quality CPR. One goal of the 2005 guideline changes was to simplify the basic life support sequence. This change provided an opportunity to minimize differences between the ages of the victim, such that more lay rescuers were confident in acting in the event of an emergency. The 2005 guidelines differentiated slightly between lay rescuer and health care provider responsibilities. In 2005, the first universal compression to ventilation ratio of 30:2 was introduced and recommended for single rescuer CPR for adult, child, and infants.[48] The main priority for the 2005 guidelines was to simplify CPR for the lay rescuer to reduce hesitation and enhance likelihood of providing care. The 2005 guidelines are noted below in table 5.

Table 5. 2005 Cardiopulmonary Resuscitation Guidelines for The Lay Rescuer

2005 Guidelines	Adult	Child	Infant
Rate (compressions per minute)		~ 100	
Depth	1 ½ -2 inches	1/3-1/2 chest depth	1/3-1/2 chest depth
Ratio (single rescuer)		30:2	
CPR Sequence		A-B-C-D	

The 2005 guidelines were the first to recommend instructing certain skills respective to professional experience. For example, rescue breathing without chest compressions was no longer recommended to be taught to lay rescuers. As mentioned in the 2000 guidelines, lay rescuers were not taught to assess pulse, which remained in the 2005 guidelines. The lay rescuer was instructed to begin with two ventilations and then begin chest compressions. Lay rescuers and lone healthcare providers were instructed to perform compressions hard and fast at a rate of 30 compressions to 2 ventilations. Another highlight of the 2005 guidelines for compressions was ensuring the chest fully recoiled after each compression and ensuring that compressions were not interrupted. Table 6 displays supporting research for the simplification of the 2005 guidelines for lay rescuers.

Table 6. Supporting Research for 2005 Guideline Changes for Lay Rescuers

Authors	Purpose	Participants	Design	Outcomes	Limitations
Nagao et. al (2007)[49]	- Assessed the effect of lay person delivered compression only resuscitation on adults who had an out-of-hospital cardiac arrest. - Compared neurological outcomes in patients who received no CPR, conventional CPR, and compression-only CPR.	- Analyzed data from 4,068 adults who had OHCA witnessed by bystanders and were transported by paramedic to a hospital included in the study.	- Prospective, multicenter, observational design - Paramedics observed technique of lay rescuers and were asked additional questions to define lay rescuer CPR as: cardiac-only, conventional CPR, pulmonary-only, unidentified technique or compressions not documented - End point was a favorable neurological outcome 30 days after OHCA	-11% received cardiac-only resuscitation, 18% received conventional CPR and 72% did not receive any bystander resuscitation - The groups who had any resuscitation attempt had better neurological outcomes than those who did not receive bystander resuscitation. - Cardiac-only resuscitation group had significantly higher favorable neurological outcomes at 30 days in many subgroups (apnoea [P= .0195], ventricular fibrillation [P=.041]), when compared to patients who received conventional CPR - Cardiac-only resuscitation resulted in higher proportions of favorable outcomes at 30 days when observing the relationship of the time between first resuscitation attempt and AED analysis in patients with a shockable rhythm (P =.0086) - Likelihood of favorable neurological outcomes decreased for every minute from resuscitation attempt to AED analysis for both cardiac-only (P=.0105) and conventional CPR (P=.0003)	- No randomization -no control group -Characteristics of patients may be like other large populations

Table 6. Supporting Research for 2005 Guideline Changes for Lay Rescuers (continued)

Authors	Purpose	Participants	Design	Outcomes	Limitations
Iwami et al (2007)[50]	- Observe the effectiveness of bystander cardiac-inly CPR in patients with OHCA	- 783 patients received conventional CPR -544 patients received cardiac-only resuscitation	-Prospective, population based observational study using documented CPR attempts from 1998 to 2003 -Primary outcome was neurologically favorable survival at 1 year	- Findings indicate that cardiac-only CPR had a higher rate of 1-year survival when compared to no CPR (4.3%), while conventional CPR also had a similar rate of survival compared to no CPR (4.1%)	-Few data points were analyzed (such as quality of CPR provided) - EMS providers responsibility is to give care, not evaluate bystanders' effectiveness
Bohm et al (2007)[51]	Compared the 1-month survival rates of OHCA patients who were given bystander CPR (standard or chest compression-only CPR)	- 11275 patients between 1990 and 2005 who had OHCA and received bystander CPR and who were reported to the Swedish Cardiac Arrest Register were included in this study	-Retrospective design -73% of patients received standard CPR -10% received Chest compression only CPR	- No significance between compression-only CPR (20%) and standard CPR (19.6%) for being hospitalized alive -No significant difference between compression-only CPR (6.7) and standard CPR (7.2) being alive after 1 month.	- Potential lack of sample size for compression-only CPR group (only 1145 compared to 8209 for standard CPR) - Did not say which standard CPR guidelines were utilized

Simplification of the CPR process was a key aspect of the 2005 guideline changes for lay people. Medical experts hypothesized if CPR was made easier for lay people to perform, more people would attempt to help someone suffering from an OHCA. While there is limited data comparing effectiveness between the 2000 guidelines and the 2005 guidelines, the previously mentioned studies lend support for the guideline simplifications for lay people. The increase in compressions, from a 15:2 compression to ventilation ratio to 30:2, appeared to provide better rates of survival and neurological outcomes for OHCA victims who received lay people-initiated CPR.

Findings from Iwami et al. and Nagao et al. indicate that both cardiac-only CPR and conventional (with ventilations) CPR, provided better clinical outcomes when compared to groups who had no intervention.[49, 50] And while those findings may seem obvious, it is important to note that simply having someone provide compressions is valuable when compared to doing nothing at all. There was no statistical significance in the study completed by Bohm et al., yet survival between groups, standard CPR and compression-only CPR, at arrival at the hospital and alive at one month were similar.[51] By creating simple steps for lay people to complete proper CPR, the likelihood for OHCA victims to be treated by lay people could increase, potentially improving survival to discharge rates.

2005 Guidelines Change for Health Care Providers

Meanwhile, health care providers were instructed to base the sequence of their response on the assumed etiology.[48] Health care providers were instructed to deliver rescue breaths and then attempt to locate a pulse for no more than 10 seconds. If no pulse was felt, compressions and ventilations were to begin. In an unwitnessed collapse, health care providers were instructed to perform five cycles of CPR prior to calling 911 and attaching and AED on an unresponsive victim of any age.[52, 53] If the collapse was witnessed, healthcare providers were instructed to utilize the AED immediately. For two-rescuer CPR with an advanced airway already placed, the concept of cycles of compressions with pauses for ventilations was eliminated. The compressing rescuer was instructed to deliver 100 compressions a minute continuously while the ventilation rescuer simultaneously delivered 8-10 breathes a minute.[48, 52] Health care providers performing two-person CPR were instructed to utilize a compression to ventilation ratio of 30:2 for adults and 15:2 for children.[52] [48] Table 7 highlights supporting research studies and findings for the guidelines changes for health care providers.

Table 7. Supporting Research for 2005 Health Care Providers Guideline Changes 2005

Authors	Purpose	Participants	Design	Outcomes	Limitations
Mellor and Woolard (2009)[54]	- Compare pre- and post-skill acquisition from BLS training (with 2005 guidelines) in a sample of health care workers	- Data from 34 medical staff who were attending a mandatory two-hour BLS course using the 2005 guidelines	- Participants were asked to manage a standardized simulated cardiac scenario immediately prior to training and again right after - Performed 2 minutes of BLS on a recording manikin - Outcome measures: differences in number of correct compressions, average compression depth, rate, and average number of compressions delivered	- Proportions of participants correctly performing outcome measures increased significantly in these areas: total number of compressions (prior to training:103, after training: 177, $p < .001$), total number of correct compressions (prior to training: 3, after training: 41, $p < .001$), compression rate per minute (prior to training: 123, after training: 147, $p < .001$), average depth of compressions (prior to training: 36mm, after training: 40 mm, $p = .006$, - Proportion of providers giving correct compression to ventilation ratio (prior to training: 32%, after training: 59%, $p = .033$)	- Small sample size - Relied on volunteers so may not be an accurate representation of the population working at that hospital - Calm, and controlled environment which may not translate to an emergent situation
Olasveengen et. al (2009)[55]	-Evaluated if the quality of CPR improved after the 2005 CPR guidelines were implemented for EMS providers	-Resuscitation data from 435 patients before 2005 guidelines implementation, and 481 patients after the implementation of the 2005 guidelines - ECG data for 64% of patients before and 76% of patients after the guidelines were implemented	- Retrospective observational study of adult cardiac arrest patients 2 years prior to and 2 years after the 2005 guidelines were implemented - Standard LIFEPAK12 defibrillators were used in this study to record the following: time without spontaneous circulation, time without compressions, hands-off time, compression rate, actual number of compressions and ventilations per minute	-Data from 64% of cases prior to new guidelines were utilized and 76% of cases after the guidelines were implemented - Survival with favorable neurological outcome was 10% pre and 12% post guideline change - No statistical significance in quality aspects of CPR, but overall CPR application time increased from 19, to 21 minutes, hands off intervals decreased with the guideline change (.23±0.13 to .14±0.09), compression per minute increased from 90±16 pre, to 96±13 post implementation of guidelines -The quality of CPR improved, yet only a weak trend towards improved survival to hospital discharge occurred	-Observational, uncontrolled study -Power based on true population of those who endured OHCA - Lost data due to ECG not recording properly

Table 7. Supporting Research for 2005 Health Care Providers Guideline Changes 2005 (continued)

Authors	Purpose	Participants	Design	Outcomes	Limitations
Hinchey et al. (2009)[56]	- Evaluate survival to discharge from OHCA after implementation of new 2005 guidelines	-1365 cardiac arrest patients with similar demographic data, clinical data, and emergency medical services - All patients received CPR by an EMS provider	- Four phase before-after design over 46 months - base line (16-month duration where all patients were treated with 2000 AHA guidelines- 15:2 compression to ventilation ratio, 3 shocks with no chest compression interruptions) - New CPR (12-month duration, minimal chest compression interruptions) - Impedance threshold device (6 months) - Full implementation of guidelines including out-of-hospital-induced hypothermia (12-month duration) -Primary outcome was survival to discharge - Secondary outcome measures: pulse on emergency department arrival, survival to hospital admission, and neurologic status at discharge	- When comparing baseline phase to the successive phases, there were increased rates of initial CPR, and shorter EMS response intervals - Statistically significant improvements between full implementation phases and baseline phases - Survival to hospital discharge for all groups combined improved by 7.3% (p=.0002)	- Potential changes in care over time that were not reported - Potential increase in survival rates because increased attention to resuscitation care due to knowledge of the study

With an increased emphasis on quality of CPR for health care professionals, the implementation of the 2005 guidelines would have procured improved skills when compared to skill performances from previous guidelines. Upon examination, findings from Mellor and Woolard as well as Olasveengen et al. indicate that the quality of certain aspects of CPR performance improved after participants were instructed from the 2005 guidelines. These aspects included: total number of correct compressions, compression rate, compression depth and hands off time decreased.[55, 57] Interestingly, Mellor and Woolard found statistical significance of the previously mentioned aspects of CPR improving while Olasveengen et al. did not have statistical significance when analyzing aspects of CPR performance. Although Olasveengen et al.'s results were not statistically significant, clinical significance was noted with the survival to discharge percentage improving from 10 to 12% when compared to survival to discharge data using previous guidelines.[55] Hinchey et al. found that there was a 7.3% improvement rate from OHCA to hospital discharge when the 2005 guidelines were adhered.[56] These improved survival to discharge rates after the implementation of the 2005 guidelines appeared to have a positive role in successful patient outcomes, thereby indicating the change in guidelines were more effective when compared to past protocols.

CPR: 2010 Guidelines

Although the 2005 guidelines focused on specific attributes of CPR compressions, the 2010 AHA Guidelines for CPR and ECC included recommendations addressing the issues of continued improvement of compressions, survival variability with out of hospital cardiac arrest cases, and lack of bystander action. The changes between the 2005 guidelines and the 2010 guidelines included changing the wording for compression rate. The 2005 guidelines stated that the compression rate should be approximately 100 compressions per minute while the 2010 guidelines claimed they should be at least 100 compressions per minute.[1, 58] Table 8 illustrates the 2010 guidelines.

Table 8. 2010 Guidelines

2010 Guidelines	Adult	Child	Infant
Rate (compressions per minute)		At least 100	
Depth	At least 2 inches	1/3 of diameter of chest (2 inches)	1/3 of diameter of chest (1 ½ inches)
Ratio (single rescuer)		30:2	
Ratio (2 or more rescuers)	30:2	15:2	15:2
CPR Sequence		C-A-B	

The 2010 guidelines emphasized that compressions are vital to the success of positive outcomes, thus all rescuers, regardless of training, should provide compressions to the victim no matter the age of the victim.[58] Since the quality of CPR was a focal point, the 2010 guidelines stressed providing compressions at an adequate depth. The 2010 guidelines detailed that the correct depth for adult CPR was at least 2 inches, while the 2005 guidelines instructed that the correct depth was 1.5-2 inches. The child and infant depth also changed in the 2010 guidelines stating that instead of 1/3-1/2 the depth of the chest, the compression depth for infants should be 1.5 inches and 2 inches for children.[1, 58]

Prior to 2010, the order of action was commonly recognized as airway, breathing, then compressions, or A-B-C. This included first opening the airway, checking for normal breathing using the "look, listen and feel" technique, delivering two rescue breaths, and finally continuing the cycle of CPR; 30 compressions and 2 breathes. In the 2010 guideline update, the sequence was changed to compressions, airway, and then breathing, which is now recognized as C-A-B.[1, 58] Additionally, the focus on high-quality compressions and rapid defibrillation prompted the elimination of the "look listen and feel" technique to observe if there was breathing. The 2010 guidelines recommended responders should simply deliver 30 compressions and then 2 breathes. The delivery of two breathes created an opportunity for the rescuer to check for breathing in conjunction with their compressions and ventilations thus limiting interruptions in care.[1, 58] Table 9 outlines supporting research for supporting the change in the A-B-C, to C-A-B sequence.

Table 9. Supporting Research for C-A-B Sequence

Author	Purpose	Participants	Design	Outcomes	Limitations
Lubrano et al. (2012)[59]	- Identify and verify if the amount of time for intervention in pediatric CPR between C-A-B and A-B-C sequences	- 340 participants certified in healthcare provider BLS were paired into two-person teams to perform CPR with both C-A-B and A-B-C sequences	-Training courses were conducted for participants to ensure education was uniform - Two-rescuer CPR was performed for both A-B-C and C-A-B sequences three times each - All performances were video, and audio recorded - Mean values from all 3 attempts were obtained - Resuscitation efforts were halted if a supervisor identified a serious mistake, such as incorrect sequence or ineffective maneuvers resulting in a compromised performance	- 11 teams were excluded because of major faults - Seven major mistakes were detected in the A-B-C sequence, and four in the C-A-B (not statistically significant) - Respiratory and cardiac arrest were diagnosed earlier using the C-A-B sequence ($p < .05$) - Compressions began earlier with the C-A-B sequence ($p < .05$)	- Learning effect from review of training sequences prior to study occurring
Sekiguchi, Kondo, Kukita (2013)[60]	- Evaluate if there was time saved by initiating compressions and evaluate if there was significance with the 2010 guidelines	- 40 health care providers trained in both 2005 and 2010 guidelines	- Measured: time spent on rescue breathing, time taken to initiate chest compression, and time taken to initiate compressions with no rescue breathing - Participants performed both A-B-C sequence and C-A-B sequence on a manikin	- When A-B-C sequence (2005 guidelines) was followed, time to initiate chest compressions was 36 ± 4.1 seconds, but when using C-A-B sequence (2010 guidelines) time to initiate chest compressions was 15.4 ± 3 seconds ($p < .001$)	- Manikin research -Stopwatch usage (potentially inconstant between subjects)

Table 9. Supporting Research for C-A-B Sequence (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Marsch et al. (2014)[61]	- Time to completion of first resuscitation cycle when comparing A-B-C approach and B-A-C approach	- 108 teams consisting of two-physicians each	- Prospective randomized single-blinded - Randomized to receive a display of either A-B-C sequence or C-A-B sequence and then treated a simulated cardiac arrest accordingly - Participants were all given instruction regarding the simulator they would be using (palpable pulses, spontaneous breathing etc.)	- Time to completion of the first CPR cycle (30 compressions to 2 breaths) for A-B-C was 63 ± 17 seconds, and in the C-A-B group 48 ±10 seconds ($P < .0001$)	- Simulator based study
Wang et al (2017)	- Assess the efficacy of the 2010 guidelines	- Code team members in a hospital who were certified to provide BLS and ACLS for IHCA - 1538 adult patients received chest compressions for two minutes or more between 2006 and 2014	- Patients who received CPR between 2006 -2010 received CPR according to the 2005 guidelines and the rest received CPR according to the 2010 guidelines - Outcome was favorable neurological status at discharge	- When analyzing CPR duration, patients who received CPR in accordance with the 2010 guidelines underwent CPR for a short time (23 min) compared to those who were resuscitated with the 2005 guidelines (30) ($p < .001$)	- Observational study - Can only observe independent and dependent variables, no causation

With updated data regarding improved outcomes from high-quality compressions, it is not surprising that the 2010 guidelines changed the algorithm from A-B-C to C-A-B. When evaluating if there was time saved by beginning compressions right away versus analyzing the airway and initiating breathing prior to delivering compressions, Sekiguchi et al., Lubrano et al. and Marsch et al. all found that there was significant time saved.[59-61] Marsh et al. found that the time from the initial approach of CPR to completion for the first round of CPR (30 compressions to 2 breaths) was significant when comparing the A-B-C sequence and C-A-B sequence. The C-A-B sequence saved approximately 15 seconds from the arrival of rescuers to the end of the first round of CPR.[61] These findings, paired with the previously mentioned findings regarding the inability of rescuers to identify the carotid pulse, endorse the transition to the C-A-B format. The guarantee that compressions occur sooner in the sequence could increase favorable outcomes due to the potential for ROSC, thereby deeming the change from A-B-C to C-A-B in the 2010 guidelines an appropriate alteration from previously published guidelines.

When comparing patients who received CPR according to the 2005 and 2010 guidelines, Wang et al. found the 2010 group had better neurological outcomes at hospital discharge. Since Wang et al.'s study occurred in a hospital setting, the amount of time from initial cardiac event to the beginning of treatment was minimal. Based on the small amount of time between event and treatment occurring, researchers inferred that significance in the study was due to the different guidelines (2005 versus 2010) instead of the potential amount of time assessing the patient once they went in distress. With the improved neurological outcomes in the 2010 guidelines group, victims also underwent CPR for significantly less time compared to the 2005 guidelines group ($p < 0.001$).[62] Because Wang et al.'s study was an observational study with no direct interventions, the authors discussed the difficulty of identifying specific parameters of CPR. Wang et al. stated that the updated revisions benefited victims needing CPR in a hospital setting. However, based on their findings, the sequence from A-B-C to C-A-B may not have been the only reason the 2010 guidelines provided better neurological outcomes. Regardless of the cause of these improved outcomes, better compression qualities, the C-A-B sequence, or both, the changes in the 2010 guidelines made large impacts in CPR performance constructing more favorable outcomes for an in-hospital cardiac arrest setting.

2010 Compression-only CPR

The overarching theme of improving survival rates and favorable neurological outcomes at discharge from cardiac emergency was at the forefront of the 2010 guideline changes, thereby ensuring lay rescuers with no training provided some care to assist with resuscitation was vital. Another change from the 2005 update was the untrained lay rescuer providing compression-only CPR. According to the 2010 guidelines, dispatch was able to provide clear instructions for lay rescuers to "push hard and fast." Previously, emergency dispatch instructed lay rescuers on how to perform CPR with breaths but found many bystanders did not want to perform ventilations.[58] Table 10. highlights the research that supports compression-only CPR for the lay rescuer.

Table 10. Research Supporting Training Lay People Using Compression-only CPR

Author	Purpose	Participants	Design	Outcomes	Limitations
Bobrow, et al. (2010)[63]	- Investigate survival of OHCA patients when compression-only CPR was used compared to conventional CPR	- 4415 OHCA, not observed by medical personal were utilized in this study	- Prospective, observational study of survival in patients with OHCA over a 4-year time period - In the 4- year time period, the community offered compression-only CPR trainings to the public - EMS coded bystander CPR for this study, so CPR performance from by standers with medical training were excluded	- Proportion of patients who received by stander compression-only CPR increased from 19.6% in the first year to 75.8% in the fourth year of the study ($p < .001$) - Survival increased over time form 3.7% in the first year to 9.8% in the last year of the study ($P < .001$) - When analyzing heart rhythm, survival increased over time in the group who provided compression-only CPR with a shockable rhythm (10.8% in the first year, to 30.4% in the last, $p < .001$)	- No randomization occurred - The decision to perform conventional or compression only CPR was up to the bystander - Quality aspects of CPR were not measured
Cabrini et al. (2010)[64]	- Systematic review and meta-analysis of randomized control trials regarding compression-only CPR and standard CPR with outcome measure of survival at hospital discharge	- Searched published literature of OHCA (non-traumatic) that compared compression-only CPR and standard CPR	- Three studies met inclusion criteria set forth by Cabrini et al. (2010) - Study time frames took place between 1992-1998, 2004-2009 and 2005-2009 - Standard CPR consisted of either 15:2 or 30:2 compression to ventilation ratio and all included compression-only CPR	- Overall analysis indicated that compression-only CPR was associated with increased survival (11.5%) compared to standard CPR (9.4%)	- No use of the 2010 guidelines - Retrospective data

Table 10. Research Supporting Training Lay People Using Compression-only CPR (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Panchal et al. (2013)[65]	- Evaluated the relationship of lay person compression-only CPR and survival for OHCA	- 4913 cardiac-related OHCA and 880 non-cardiac related OHCA, with complete data and who received compression-only CPR by a non-medically trained person were included in this study	- Prospective, observational analysis of OHCA in a state-wide CPR program - Primary outcome measures were survival to hospital discharge and type of lay rescuer CPR provided	- Survival to hospital discharge was significantly lower in the non-cardiac caused OHCA group (3.8%) when compared to the cardiac related OHCA group (7%) ($p < .001$) - No significance on survival to discharge when observing CPR type (Conventional CPR, 3.8%, or compression-only CPR 2.7%; $P = .85$)	- Observational with no randomization - Too low of statistical power for non-cardiac OHCA's
Yang et al. (2014)[66]	- Investigate the quality of chest compression during compression-only CPR in lay people using 2010 and 2005 guidelines	-86 volunteers with experience in basic life support or CPR training participated	- Prospective, randomized controlled study - 2005 and 2010 compressions- only CPR was performed - All volunteers endured a 4-hour course, took the exam, and then performed a skills scenario where participants performed 8 minutes of compression-only CPR in accordance with the guidelines they were taught	- When comparing chest compression depth and rate, participants who performed compressions in accordance with the 2010 guidelines performed more compressions per minute at the correct depth and rate ($p < .01$ for minutes one, two and three, and $p < .05$ for minutes four through eight)	- Chest recoil and participant hand placement were not observed - Manikin study

When investigating the relationship between compression-only CPR performed by lay rescuers and survival to hospital discharge from OHCA, Panchal et al. (2013) and Bobrow et al. both found that compression-only CPR improved survival rates when compared to no-intervention.[63, 65] Panchal et al. found no significant difference between conventional CPR and compression-only CPR at survival to discharge (3.8% and 2.7%, respectively).[65] The lack of significance is important to note because it shows that doing something, even if no ventilations occur, is better than nothing at all. The adage of "push hard and fast" should be encouraged for lay rescuers. Also, in the meta-analysis presented by Cabrini et al., compression-only CPR was associated with increased survival when compared to standard CPR.[64] With clinical significance resulting from the use of compression-only CPR, the support for the guidelines change is unequivocal. According to the abovementioned findings, compression-only CPR is an adequate intervention for lay people who may be unable to provide standard CPR in an emergent scenario.

With the increase in chest compression rate and depth, chest compression quality may be more difficult to establish. Understanding if it was possible to achieve high-quality chest compressions during compression-only CPR was important to Yang and team. Results from their study indicate that during eight minutes of compression-only CPR, compression depth and rate in the group who learned compressions according to the 2010 guidelines were both higher than in the group who performed compressions according to the 2005 guidelines.[66] While one limitation to their study was that they did not measure chest recoil or hand placement, it is important to note that compression rate and depth did improve when individuals were trained using the updated guidelines. Therefore, high-quality CPR performance can be achieved with compression-only CPR. Thus, the lay rescuer change in the 2010 guidelines was an advantageous alteration from prior years.

2010 Education Changes

To encourage quality CPR performance, the 2010 guidelines included an education section. The first aspect of CPR education that was addressed involved the two-year certification period. The 2010 guidelines stated that although the certification period for BLS and ACLS is two years, there should be an added assessment within those two years. The added assessment should include reinforcement or supplementary information if deemed necessary based on a separate needs assessment. The 2010 guidelines confirmed that the two-year certification period may not be optimal and should continue to be investigated. Basic life support psychomotor skills can and should be learned with practice-while-watching scenarios. The guidelines elaborated that practice-while-watching experiences should include the use of high-fidelity manikins because of the potential for realistic practice. High-fidelity manikins should include chest expansion, breath sounds, accurate pulse, and blood pressure. At the time of publication, the 2010 guidelines noted there was not enough evidence to recommend these manikins to be required in CPR courses. Although there was insufficient evidence to make the aforementioned recommendation, the 2010 guidelines did suggest that feedback devices may be useful for training individuals in CPR, as well as useful for the overall strategy to improve CPR outcomes.[58] Table 11 introduces the core research studies that supported the newfound focus on education during the 2010 guideline changes.

Table 11. Research Supporting the CPR Education Changes

Author	Purpose	Participants	Design	Outcomes	Limitations
Mieure et al. (2009)[67]	- Determine if a designed and implemented ACLS human patient simulator enhanced understanding of ACLS and improved the learning experience	- 119 third year pharmacy students	- Revised ACLS workshop which consisted of a pre-session lecture, a calculation exercise, and a 40-minute simulator - These workshops included pharmacological measures for advanced cardiac life support - Survey instrument was used to evaluate student's perceptions of the ACLS workshops and HPS and a knowledge quiz after workshops	- 99.2% of students agreed that the HPS experience enhanced their understanding - 98.3% of students strongly agreed the simulator enhanced their understanding of ACLS - Simulation assisted with proper skill acquisition but did not appear to benefit the students regarding the knowledge quiz	- Non graded assessment, so quality of ACLS were not recorded (unknown if high quality CPR was provided with patient simulation instruction)
Hughes et al. (2010)[68]	Explore the proportion of first- time pass grades of instructor led, and peer led CPR students	- 132 students - 74 in a peer-led course, 58 in an expert-led course - Peers were final-year medical students who had taken the course previously and had taken an Advanced Life Support course - Participants in the study were fourth year medical students undergoing BLS	- Seven-week course with teaching aims of: 1. Assessing a collapsed victim (breathing and circulation) 2. Perform basic CPR 3. Initiate advanced resuscitation efforts 4. Correct use of a defibrillator (AED) -Practical skills session lasted 90-120 minutes with a 40-minute lecture of etiology of arrest and treatment - Skills were tested in an objective structured clinical exam	- 97% of students in the peer led group passed - 98% of students in the instructor led group passed - When observing a "high pass" which was a perfect score, 58% of instructor led students passed and 42% of peer led students passed with a "high pass"	- Medical students have a background in anatomy and potentially have previously learned some life saving techniques - Peer led scenarios are not always appropriate

Table 11. Research Supporting the CPR Education Changes (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Meaney et al. (2012)	- Evaluate acquisition and retention of different training methods for CPR: instructor led, limited instructor with manikin feedback, and self-directed learning	- Data from 170 In-hospital health care providers was analyzed in the initial study - Data from 89 participants at 3 months - Data from 72 participants at 6 months	- prospective, quazi-randomized intervention trial to determine the effectiveness of AHA CPR training in a resource limited setting - 2005 BLS exam was taken, and single-rescuer simulated scenario for infant and adult was completed prior to training - Knowledge and skills were tested immediately following training and at the 3- and 6-month marks - Traditional 2005 BLS course, instructor to student ratio 6:1 (5 hours of instruction with DVD and no feedback device) - Limited instruction with feedback consisted of BLS DVD instruction with instructor ratio18:1 with feedback from the manikin - Self-directed learning was heart code BLS with no instructor and using the feedback from a manikin	Cognitive assessments: - Acquisition pre training score was 63% and after rose to 84% ($p < .01$) Skill Assessments: - CPR Skill baseline 32% for infant CPR and 28% for adult skill retention compared to baseline at 3 months: infant 70% from 39% ($p < .01$) Adult 51% from 34% ($p = .02$) - Skill retention 6 months compared to baseline for infants 67% from 38%, ($p < .01$) Adult 37% from 30% ($p = .5$) - Low cognitive scores and need for skill remediation impacted CPR performance but instruction method may not have significant impact	- No patient outcomes were studies - Loss of participants for follow up - Study completed in English language but only 53% of participants reported English fluency (even though 99% of them reported being comfortable participating)

The 2010 guidelines indicated that CPR skills can be learned with non-traditional formats such as "practice while watching," when compared to the traditional, instructor-led, course. Also, the guidelines state that written assessments should not be the only assessment used when determining if the course was effective. Pairing instructor-led courses with the use of manikins that provide quality feedback for learning psychomotor skills, CPR education should encourage CPR psychomotor skill acquisition. When observing skill assessment scores from training methods that used manikin feedback, it was notable that there was significance in the study completed by Meany et al. They found that in three groups of hospital workers (instructor led, limited instructor led with manikin feedback, and self-directed learning), the cognitive assessment, skill assessments, and skill retention assessments all were improved when compared to a baseline test ($p < .01$, $p < .01$ and $p < .01$, respectively). Findings indicated statistical significance between baseline and at three ($P= .02$) and six ($P = .5$) months in regard to retention, which shows that the traditional course for CPR may not be the only education option, especially as it pertains to health care providers.[69]

In the study completed by Mieure et al., pharmacy students indicated that using feedback devices not only enhanced their understanding of ACLS but ensured proper skill acquisition. Based on students' feedback, Mieure et al. shared that an active learning environment was beneficial not only to ensuring knowledge was learned but also that skill acquisition and performance was improved.[67] Similar to Mieure et al, Hughes et al. also used allied health care professionals as their sample population. In exploring the proportion of first-time passing grades between an expert- and a peer-led course, they found a one percent difference.[68] The lack of significant difference between the proportion of passing grades between the two teaching methods is crucial because it gives the opportunity for altered course formats, as long as learning and skill objectives are still met. In this case, medical students were able to adequately learn and acquire the proper skills in a peer-led setting. The potential for different formats in CPR education is evident based on the previously mentioned findings.

CPR: 2015 Guidelines

The 2015 guidelines continued to emphasize compressions as a priority for quality CPR. The basis for this emphasis was the additional data showing high-quality CPR improves survival rates from sudden cardiac arrest. The 2015 guidelines advocate that high-quality CPR is composed of chest compressions occurring at an adequate rate, adequate depth, allowing for full chest recoil between compressions, minimized interruptions during compressions, and finally excessive ventilation is avoided.[70] The updated 2015 guidelines can be found in Table 12. The major changes that should be noted from 2010 to 2015 include a change in wording for an upper limit of compression rate, from "at least 100 compressions per minute" to 100-120 compressions per minute and a change for adult compression depth to an upper limit of 2.4 cm instead of at least 2 inches. While these changes may seem insignificant, they are important to note due to the potential increase in survival to discharge resulting the implementation of high-quality CPR guidelines.

Table 12. 2015 CPR Guidelines

Aspects of CPR	Adult	Child	Infant
Rate (compressions per minute)		100-120	
Chest Compression Depth	At least 2 inches no more than 2.4 inches	1/3 of diameter of chest (2 inches)	1/3 of diameter of chest (1 ½ inches)
Compression to ventilation ratio (single rescuer)		30:2	
Compression to ventilation ratio (2 or more rescuers)	30:2	15:2	15:2
Ventilations when the rescuer is not trained		Compressions only	
CPR Sequence		EMS activation then C-A-B	

2015 Guidelines Compression Rate

With the focus on high-quality CPR, the 2015 guidelines updated specific aspects of CPR to create evidence-based standards potentially improving patient outcomes. Chest compressions should be performed at a rate of at least 100 compressions per minute but based on new evidence at the time the 2015 guidelines were written, the optimal rate for manual chest compressions was at least 100 compressions per minute with an upper limit of 120 compressions a minute. The rate of 100-120 compressions per minute range seemed to be associated with an improvement in survival.[70] Research supporting the change from at least 100 compressions per minute to 100-120 compressions per minute can be found below in Table 13.

Table 13. Research Supporting 2015 CPR Guidelines Compression Rate

Author	Purpose	Participants	Design	Outcomes	Limitations
Idris et al. (2015)[71]	-Determine the relationship between CPR compression rates and survival	-Data from 10371 patients treated by EMS for OHCA	- Prospective, observational study - Used data from OHCA that had been monitored by defibrillators for the first five minutes of an EMS providing CPR - Logistic regression assessed odds ratio for compression rate categories: <80, 80-99, 100-119, 120-139, >140	- Statistical analysis provided with a significant relationship between the compression rate group of 100-119 and survival (P =.02)	- No intervention - Amount of time from when victim was found/911 called and when EMS began CPR was unknown for many victims
Kilgannon et al. (2017)[72]	-Test the association between chest compression rate, ROSC, and good neurological outcome at hospital discharge in victims who have had in hospital cardiac arrest	- Prospective observational study in a medical center	- Analyzed chest compression rate in 222 in-hospital cardiac arrest victims - Data were analyzed using defibrillation electrodes - Multivariable logistic regression to determine odds ratios for ROSC by three compression rate categories: 100-120, 121-140 and greater than 140	- Mean compression rate of 121-140 had the highest odds ratio for ROSC, 5.17 (95% CI 1.38-19.45) (P = .01)	- The reference range used was 100-120, but this group had the smallest data set at only 10% of the overall data
Kaminska et al 2018)[6]	- Identify factors (demographic data, fat mass, trunk muscle mass, arm muscle mass) that influence chest compressions during BLS in accordance with the 2015 guidelines	- Prospective observational design	- 72 Participants participated in CPR training in accordance with the 2015 guidelines -Body composition was assessed (fat mass, predicted muscle mass, total body water, fat-free mass - All participants performed two minutes of single person CPR on a Resusci-Anne which recorded: chest compression depth, rate, percentage of correct compressions, and recoil	- No measured factors in this study significantly affected chest compression rate	- It is unknown if these demographic characteristics influenced chest compression quality for a prolonged rescue attempt (more than two minutes in this case)

A chest compression rate of 100-120 compressions per minute provides the most optimal conditions for high-quality CPR and subsequently the potential for survival. Data obtained prior to the 2015 guidelines indicted the lower limit of 100 compressions per minute was attainable by rescuers, but an upper limit had not been well established. Interestingly, results from Indris et al. and Kilgannon et al. were conflicting regarding an upper limit for compression rate. Idris et al. found significant correlation between survival and a compression rate of 100-120 compressions per minute, while Kilgannon et al. found a positive correlation between ROSC and a compression rate of 121-140 compressions per minute.[71, 72] While the compression rate range of 121-140 appeared to have success regarding ROSC, it is important to note that authors attributed the success of the higher rate to a chest compression fraction between 81 and 100% and not solely to the higher compression rate itself. Kilgannon and team acknowledge that while the 121-140 range is out of the suggested 100-120 range put forth by the guidelines, a compression rate on the higher end of the 100-120 may produce better neurological outcomes in those who undergo CPR.

2015 Guidelines Compression Depth

At the time of the 2015 guidelines conference, evidence suggested that compression depths of approximately 5 cm were associated with positive outcomes.[70] There seemed to be limited evidence supporting an upper threshold for compression depth, but the guidelines mentioned the risk for associated injuries when compressions were deeper than 6 cm. The updated 2015 guidelines called for rescuers to perform chest compressions to at least 2 inches (or 5 cm), but no more than 2.4 inches (or 6 cm) to avoid complications with injury as well as gas exchange during compressions. Table 14 highlights research supporting the chest compression depth upper limit guideline alteration.

Table 14. Research Supporting 2015 CPR Guidelines Compression Depth

Author	Purpose	Participants	Design	Outcomes	Limitations
Vadeboncoeur et al. (2014)[73]	- Assess the relationship between chest compression depth and OHCA survival	- of 593 OHCA, 136 patients achieved ROSC and 63 survived, 50 patients had favorable functional outcomes	- Prospective, before-after cohort study of patients aged 18 and older with OHCA treated with CPR between 2008 and 200 - Baseline data were recorded from 2008-2010, then an education initiative (2 hours of didactic teaching and 2 hours of psychomotor practice with real-time audio-visual feedback according to 2010 guidelines) occurred in the location of the study. - Phase two of the study began in 2010 after the education training was completed - Data were collected during resuscitation	- Mean chest compression depth was 49.8 m - Chest compression depth was significantly deeper in survivors compared to non-survivors (53.6 mm 95% CI 50.5–56.7) versus 48.8 mm 95% CI 47.6–50.0) - Odds of survival increased 1.29 times for every 5 mm of chest compression depth	- Observational design does not allow researchers to determine true cause of OHCA survival and favorable outcome at discharge

Table 14. Research Supporting 2015 CPR Guidelines Compression Depth (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Mayrand, Fischer and Ten Eyck (2015)[5]	- Assess factors that may impact chest compression depth including: Bed height, step stool use, rescuers arm/shoulder position relative to chest compression point, and rescuer demographics Main outcome measure: compression depth from utilizing a step stool and lowering the bed (to increase depth)	- Fifty-six medical student trainees (physician assistant, emergency medicine residents) participated	- Participants were randomly assigned to either the control (n= 28) or intervention group (n =28) - Demographic data was taken (gender, height, weight) - Two minutes of chest compressions were performed, manikin software recorded mean compression depth in 10-second segments - Use of a step stool was allowed - Arm/shoulder position was analyzed in both groups and the bed was locked in a specific position	- Mean compression depth for intervention group was 39.3 mm compared to a control group of 34.6 (P=.11) -The correlations between compression depth and participant height, weight and gender were all statistically significant (p <.0001) - Mean compression depth for males was greater than females (P=.0001) -When analyzing data from intervention and control groups with arm angle of 90 degrees and less than 90 degrees, there was significance (p < .003) - The correlation between proper shoulder angle and step stool usage was also significant (p <.02)	- Majority of participants did not utilize the stop stool - Relatively small sample

Table 14. Research Supporting 2015 CPR Guidelines Compression Depth (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Kaminska et al. (2018)[6]	- Identify factors that influence chest compression depth during BLS in accordance with the 2015 guidelines	- 72 Participants participated in CPR training in accordance with the 2015 guidelines	- Prospective observational design -Body composition was assessed (fat mass, predicted muscle mass, total body water, fat-free mass - All participants performed two minutes of single person CPR on a Resusci Anne which recorded: chest compression depth, rate, percentage of correct compressions, and recoil	- The following were positively correlated with chest compression depth: trunk muscle mass (P = .023), right (P= .013) and left (P = .015) arm muscle mass, and fat-free mass (P = .023) were all positively correlated with compression depth (all p < .05) - When compared to males, females have significantly less compressions at the correct depth (p= .042)	- It is unknown if these demographic characteristics influence chest compression quality for a prolonged rescue attempt (more than two minutes in this case)

While it is known that chest compression depth is an integral aspect of quality CPR, ensuring chest compressions are consistently performed at the correct depth is difficult. There are multiple studies contributing data to identifying factors that influence chest compression depth. Both Kaminska et al. and Mayrand, Fischer and Ten Eyck had participants perform two minutes of CPR. Researchers found correlations indicating gender, height, and weight were factors that influenced compression depth.[5, 6] According to their findings, females provide chest compressions at a lesser depth when compared to males. Furthermore, Kaminska et al. identified that arm muscle mass and trunk muscle mass were positively correlated with compression depth, i.e. the larger amount of muscle mass the deeper the compressions. Based on their results, Kaminska and team deduced that body composition and physical fitness are important factors when ensuring proper chest compression depth is be achieved.[6]

Additionally, research supporting the upper limit of chest compression depth should be highlighted. Vadeboncoeur et al. found that in survivors, chest compression depth was deeper (at least 51 mm) when compared to non-survivors who had a mean depth of 48.8 mm.[73] A limitation to Vadeboncoeur et al.'s study was that an upper limit of depth was not measured, therefore researchers deduced the deeper the compressions the more likely for survival to hospital discharge, yet were unable to discuss potential negatives associated with the deep compression depth. Supplementary injuries associated with chest compressions, such as rib fractures, were not included in their study but should be noted when discussing an upper compression depth limit.

<u>2015 Guidelines Chest Recoil</u>

Another aspect of high-quality CPR is allowing full recoil in the chest after chest compressions are performed. The 2015 guidelines defined full recoil as allowing the sternum to return to its neutral position during the decompression phase of CPR. The 2015 guidelines express that rescuers should avoid leaning on the chest between compressions to allow for full recoil of the chest. This full recoil of the chest allows for positive venous return and cardiopulmonary blood flow, i.e., reoxygenation of the available blood. Leaning on the chest negatively influences resuscitation outcomes due to lack of cardiac output from compressions and limited oxygenation occurring in that cardiac flow.[70, 74] Evidence supports high-quality compressions being associated with positive patient outcomes but also suggests that the components of compressions are interrelated. Support for full chest recoil can be found in Table 15.

Table 15. Research Supporting 2015 CPR Guidelines Chest Recoil

Author	Purpose	Participants	Design	Outcomes	Limitations
Yannopoulos et al. (2005)[75]	- Investigate if incomplete chest wall recoil caused an increase intrathoracic pressure (calculated coronary perfusion pressure [CCP])	- 9 pigs in ventricular fibrillation for 6minutes were treated with an automated compression/decompression device	- Pigs were treated with a compression rate of 100 per minute, at a rate of 15:2 compressions to ventilations with 100% decompression for 3 minutes - Then decompressions were reduced to 75% for 1 minute and then restored again to 100 % for 1 minute - Coronary profusion pressure (CCP) was calculated, pressures were analyzed, and systolic and diastolic pressures were measured and analyzed	- When 100% decompression occurred the calculated CPP was 23.3 mmHg - When 75% decompression occurred the CPP was 15.1 mmHg and only mildly recovered with an increase to 16.6 mmHg during the second phase of 100% decompression (P = .003) - Systolic pressure decreased with incomplete chest recoil (75%) but recovered when complete decompression occurred (P= .01)	- Cerebral and coronary blood flow was not measured - Animal study - Findings from one minute of 75% or incomplete chest recoil may not specify the full impact incomplete recoil has on overall survival to discharge

Table 15. Research Supporting 2015 CPR Guidelines Chest Recoil (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Aufderheide et al. (2005)[76]	- To determine if changing CPR technique (hand placement: standard and 3 alternative CPR approaches) would improve chest recoil	-30 EMS providers performed 3 minutes of CPR on a manikin	- Clinical observation study - 30 EMS providers performed 3 minutes of CPR on a skill reporting manikin using standard hand position - Then performed 3 minutes of CPR using different techniques (random order) 1. Two-finger fulcrum technique (lifting the heel of the hand off the chest but keeping contact with the thumb and little finger) 2. Five-finger fulcrum, lifting heel off but all fingers slightly stay on chest and lastly 3: hands off technique	- Hands off technique achieved the highest rate of chest recoil ($P < .0001$) and was 129 times more likely to provide complete chest recoil when compared to the standard hand position	- Testing was completed on a manikin - Only 3 minutes of CPR was performed, so this study does not address chest recoil in relation to fatigue

Table 15. Research Supporting 2015 CPR Guidelines Chest Recoil (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Fried et al. (2011)[77]	- Evaluate if leaning (incomplete chest recoil) worsens over time due to rescuer fatigue	- 108 cardiac arrest episodes consisting of 112,569 chest compressions (between 2007 and 2009)	- Observational clinical cohort study at an academic medical center - allowed defibrillator to provide corrective feedback during CPR performances - every segment of 120 seconds or more of chest compressions was analyzed and broken down into 30 second segments (fatigue in the last segment versus first)	- Leaning was present in 91% of the cardiac arrests - 12% of total chest compressions did not have full recoil (no statistical significance) - Feedback caused a significant reduction in leaning ($p < .001$)	- Real time corrective feedback was used so measuring a correlation between non-corrected compressions and fatigue did not occur - Hospital staff had focused years on improving CPR compression quality so may not have been the best sample population to generalize to other settings for CPR performance
Cheskes et al. (2015)[78]	- Explore the relationship between chest compression release velocity (CCRV) and survival to hospital discharge	- 1137 treated resuscitations with compression data from EMS with chest compression rate, depth, chest compression fraction, and shock-pause duration collection, and CCRV extracted and analyzed were included in this study	- Retrospective observational study - 10 minutes of compression data was utilized	- Chest compression depth and CCRV were significantly associated with survival to discharge ($P = .01$ and $P > 0.001$) - There was no significant association between CCRV and clinical outcomes when observing increased (per 10 mm) of chest compression release velocity	- Rapid response times in the region that the study took place - CCRV measurements may have been impacted or altered by the surface which compressions were performed on (i.e. bed versus cement floor)

The 2015 guidelines encouraged CPR providers not to lean on the chest, thereby allowing for complete recoil of the chest during CPR performance. The support for full chest recoil is indicated in Cheskes et al.'s study with results stating that chest compression depth and chest compression release were significantly associated with survival to hospital discharge.[78] Data published in 2011 indicated that 12% of total chest compressions did not have full recoil.[77] While that percentage was not statistically significant in Fried et al.'s study, it is vital to note that chest recoil does not happen in most rescue attempts. Fried stated that leaning was present in 91% of total cardiac arrests that were evaluated. Aufderheide et al. explored different CPR hand placements to identify whether chest recoil improved. When compared to the standard hand position, they found that the hands-off technique, which consisted of completely removing the hands from the victim's chest after a compression, achieved the highest rate of recoil ($p < .0001$).[76] A pitfall of the hands-off technique could be an alteration to chest compression rate and depth, but other aspects of chest compression quality were not addressed by Aufderheide et al. The potential for full chest recoil with the hands-off technique should be acknowledged, especially in cases where chest recoil is compromised due to rescuer fatigue. Yet the 2015 guidelines do not state the optimal way to achieve full chest recoil.

<u>2015 Guidelines Chest Compression Fraction</u>

The recommended chest compression fraction (CCF), or the proportion of time that compressions are performed during cardiac arrest, prior to 2010 was at least 60% but changed to 80% in 2010. Prior to 2010, the effect quality compressions had on the potential for survival to hospital discharge was grossly underestimated. The amount of time spent on compressions was low compared to more recent guidelines. The pause in compressions for the delivery of ventilations should be less than 10 seconds in an effort to minimize compression interruptions and subsequent increase CCF.[2, 70] A consensus statement by the AHA in 2010 on improving resuscitation outcomes in- and out-of-hospital stated that the ideal CCF is 80%; this CCF was also reiterated in the 2015 guideline update.[2, 69, 70] Improved survival from OHCA is associated with the performance of high-quality CPR, specifically aspects of compressions and limited interruptions of compressions. Table 16 shows research supporting the 80% CCF.

Table 16. Research Supporting 2015 CPR Guidelines Compression Fraction

Author	Purpose	Participants	Design	Outcomes	Limitations
Christenson et al. (2009)[79]	- Investigate the effect of increasing CCF during CPR on survival to discharge in patients with ventricular fibrillation or pulseless ventricular tachycardia	- 506 cardiac arrest victims qualified for the study	- Prospective observational cohort study of adult patients with confirmed ventricular fibrillation or ventricular tachycardia with no defibrillation prior to EMS arriving, with recorded CPR and a confirmed outcome - Chest compression fraction was categorized by 5 sections (in percentages); 0-20, 21-40,41-60, 61-80, 81-100	- The 61-80% CCF proposed the highest proportion of patients at survival to hospital discharge with 28.7% of patients surviving - The effect of increasing CCF remained significant after adjusting for known determinants of survival (age, gender, if bystander CPR was provided) and the linear effect on the odds ratio for every 10% change in CCF the increased potential for survival was 1.11%	- Only able to establish associations, not causal relationships - Potential selection bias with exclusion criteria
Krarup et al. (2011)[80]	- Evaluate the quality of CPR provided by basic life support (BLS) provider and EMS (ACLS) in a nationwide OHCA case	- 191 cases of OHCA with follow up of one year or death were analyzed	- Prospective observational study of OHCA - No flow time was observed as time without compressions and time without ROSC - Compression data recorded on defibrillator	- No flow time was significant between ALS capable groups and BLS capable groups ($p < .001$, time in seconds 331 and 774, respectively)	- Compression depth was not evaluated which could have provided valuable insight to the quality of CPR provided

Table 16. Research Supporting 2015 CPR Guidelines Compression Fraction (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Cheskes et al. (2017)[81]	- Explore if CCF, compression rate, depth and pre-shock pause are associated with improved survival from OHCA	- 19,568 defibrillator records were collected over a 4-year period	- Secondary analysis of prospectively collected data - Divided rescues into 2015 guideline compliant and non-guideline compliant groups - Guideline compliance was: CCF > 0.8, compression rate of 100-120/min, depth 50-60 mm, and pre-shock pause < 10 s. - Survival to discharge was assessed	- In the group that was compliant with guidelines mean CCF of > 0.8 occurred 94.8% of the time (compared to 70.9% in the non-compliant group) - CCF alone was not significantly associated with survival to hospital discharge	- Only observational data occurred, not intervention research - CPR guideline compliant group was limited in power

Table 16. Research Supporting 2015 CPR Guidelines Compression Fraction (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Wik et al. (2016)[82]	- Identify the effect of confounding variables on CCF to predict survival to hospital discharge - Confounding factors include age, gender, witnessed arrest, public location, number of shocks, shockable rhythm, bystander compressions and treatment duration	-1997 patients who received manual compressions were included in this study	- Multi-center randomized clinical trial - CCF was defined as the percentage of time when the patient received compressions - Electronic defibrillator recorded resuscitations	- When using multivariate regression controlling for confounding factors significantly associated with CCF, a higher CCF was associated with survival (OR 6.34; 95% CI 1.02-39.5) - When using logistic regression, CCF was inversely related with survival (OR 0.07; 95% CI 0.01-0.36)	- The data used in this study was a secondary analysis of a subset of patients from a different study. - CCF was calculated by human reviewers, thus error is sure to ensue - Compression rate was the only other quality metric of CPR recorded thus based on this study it is unknown how depth could change prediction of CCF on survival to hospital discharge

The reiterated 80% CCF by the 2015 guidelines was recommended as best practice and has evidence supporting the percentage. Numerous studies show associations between a high CCF and survival to hospital discharge. Wik et al. found that when controlling for factors such as age, gender, and bystander compressions, survival was significantly associated with a higher CCF (odds ratio 6.34; (95% CI 1.02-39.5).[82] Christenson et al. also controlled for factors like age, gender, and the provision of bystander CPR and found that the proportion of patients at survival to hospital discharge had a 61-80% CCF during their rescue attempt. Additionally, results indicated that for every 10% increase in CCF, the potential for survival was increased by 1.11% until a CCF of 80% was obtained. Findings from Wik et al. and Christenson et al. support the 2015 guidelines encouragement of maintaining a CCF of at least 80%.

Moreover, in comparing the quality of CPR provided by BLS and ACLS trained rescuers, researchers found that the no flow time, which was the time observed without compressions and without ROSC, was significant between the groups. The BLS group had larger gaps of no flow time.[80] Unfortunately, survival to hospital discharge and compression depth were not evaluated in Krarup et al.'s study; thus, the significance of their results does not translate to clinical outcomes. Also, a limitation to the study completed by Kraruep et al. was the usage of the 2010 guidelines. The 2010 guidelines stated that chest compression interruptions should be limited to 10 seconds or less but did not directly state that the CCF should be at 80%. Therefore, findings from Cheskes et al, which utilized the 2015 guidelines regarding CCF, may be more beneficial to discuss when supporting the 2015 guidelines change. Researchers divided defibrillator records from 19,568 cardiac emergencies into two groups: 2015 guideline compliant group and a non-guideline compliant group. The purpose of the study was to evaluate if aspects of CPR, when performed according to the guidelines, impacted survival from OHCA. Findings indicated that a

CCF of > .8 occurred in 94.8% of the resuscitation attempts in the guideline compliant group and only 70.9% of the time in the non-compliant group. Authors did not find any significance with CCF as a sole predictor of survival to hospital discharge.[81] While there was no intervention in this study, results support the 2015 guidelines thus reiterating that the CCF should be at least 80% of the attempted rescue to endorse the potential of increases survival to hospital discharge in OHCA.

2015 CPR Guidelines Education Changes

The 2015 education guidelines utilize evidence-based strategies to make best recommendations for education to improve provider psychomotor skill retention as well as cognitive aspects of CPR. With improved training, quality of CPR performance and clinical outcomes should also improve. The key changes in the 2015 guidelines when compared to the 2010 educational recommendations include the use of high-fidelity manikins, the utilization of CPR feedback devices for psychomotor skill acquisition, and again the questioning of the two-year certification period. The 2015 guidelines discuss the utilization of experiential learning in CPR education. In utilizing best education practices, as well as specific scenarios, learners' knowledge can be transferred to real-life situations. The core educational principles presented by the AHA in the 2015 guidelines include simplification, consistency, context (relevance), hands-on-practice, practice to mastery, debriefing, assessment, and lastly program evaluation. According to the 2015 guidelines, the key aspect of skill acquisition included deliberate, hands-on practice paired with feedback improved students' overall skill development.[83] Table 17 shows the research supporting the 2015 CPR changes for education.

Table 17. Research Supporting 2015 CPR Guidelines Education Changes

Author	Purpose	Participants	Design	Outcomes	Limitations
Fried et al. (2011)[77]	- Evaluate if leaning (incomplete chest recoil) worsens over time due to rescuer fatigue and used real-time corrective feedback to alter CPR performance	- 108 cardiac arrest episodes consisting of 112,569 chest compressions (between 2007 and 2009)	- observational clinical cohort study at an academic medical center - Allowed defibrillator to provide corrective feedback during CPR performances - Every segment of 120 seconds or more of chest compressions was analyzed and broken down into 30 second segments (fatigue in the last segment versus first)	- Leaning was present in 91% of the cardiac arrests - Feedback caused a significant reduction in leaning ($p < .001$)	- Real time corrective feedback was used so measuring a correlation between non-corrected compressions and fatigue did not occur - Hospital staff had focused years on improving CPR compression quality so may not have been the best sample population to generalize to other settings for CPR performance
Bobrow et al. (2013)[84]	- Assess if scenario-based training with real-time audiovisual feedback improved CPR quality (for professional rescuers) and increased survival from OHCA	- 484 OHCA patients were included (phase one before training occurred included 232 patients and phase 2; after training with feedback had 252 patients)	- Before- after study of OHCA with data obtained from a monitor defibrillator during resuscitation - Phase 2 intervention consisted of 2 hours psychomotor practice using scenario based training and real-time audiovisual feedback on the defibrillator	- Survival increased from 8.7% in phase one to 13.9% after phase 2 (adjusted OR 2.72 [95% CI 1.15-6.41])	- No randomization occurred - Unknown confounders may have led to improved outcomes

Table 17. Research Supporting 2015 CPR Guidelines Education Changes (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Yeung et al. (2014)[85]	- Compare the effect of three CPR feedback devices on quality of chest compression in health care providers	- 101 health care providers who were trained in CPR and able to perform CPR for 2 minutes participated in the study	- Single Blinded randomized control trial - Compared 1. Pressure sensor/metronome device 2. Accelerometer device and 3. a metronome on the quality of chest compressions by trained rescuers - Main outcome measure was compression depth - Secondary measures were rate, proportion of compressions with inadequate depth, incomplete release, and satisfaction	- The pressure sensor device significantly improved chest compression depth when compared to baseline (P= .02). - Accelerometer use decreased depth significantly when compared to baseline (P = .04) - Feedback devices all led to compression rates closer to 100 compressions per minute when compared to baseline (pressure sensor P= .001, accelerometer P= .072, and metronome P = .009). - Metronome and accelerometer feedback devices were well received by participants	- Manikin training environment - Health care professionals who may perform CPR often: results may not be applicable to laypeople - Only 2 minutes of CPR was measured

Table 17. Research Supporting 2015 CPR Guidelines Education Changes (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Liu et al. (2018)[86]	- Investigate the effects of a CPR feedback device on the quality of chest compressions during compression-only CPR	-124 lay people participated in this study	- Participants were dividing into three groups 1. 2010 guidelines 2. 2015 guidelines with no feedback, 3. 2015 guidelines with feedback device - Participants underwent CPR training and then performed 2 minutes of compression-only CPR for 2 minutes - Quality of CPR was recorded: chest compression depth, rate, recoil and CCF per 20 seconds	- When comparing the feedback group to the 2015 guidelines group there was statistical significance in minute one and two of the following: compression depth ($P = .008$, $P =.002$), correct ratio of compressions ($p < .001$, $p <.001$), compression rate ($P = .008$, $p= .009$) and CCF ($p = .026$)	- Volunteers were young - Fatigue was not measured - Hand placement was not assessed

With the renewed focus on deliberate practice for CPR psychomotor skill acquisition, researchers strived to investigate the effects of feedback devises during CPR education. Previous to the 2015 guidelines, corrective feedback of CPR skills often came from instructors instead of from a device that records analytics of CPR compressions and ventilations. By utilizing feedback devices, students can properly correct CPR skills that are being completed incorrectly potentially leading to more positive clinical outcomes. Bobrow et al. investigated real-time audiovisual feedback with scenario-based training in health care professionals. The outcome measure of the study was survival rate from OHCA. When comparing the group who underwent a traditional CPR course to the group who received real-time, audio-visual feedback, survival rates increased from 8.7% to 13.9%.[84] Of course, it is not reasonable to provide real-time feedback to rescuers during every cardiac incident, but this study is important for recognizing that CPR psychomotor skills need to be corrected during training to ensure better outcomes, and the provision of feedback can be beneficial in correcting errors in performance.

Yeung et al. also utilized health care providers as a sample population. They compared the effect of feedback devices on the quality of chest compressions. When compared to baseline, all three of their feedback devices (a pressure sensor/metronome device, and accelerometer and a simple metronome device) led to compression rates closer to 100 compressions per minute when compared to baseline, and the pressure sensor device led to significant improvement in chest compression depth. Unfortunately, only two minutes of CPR was measured, which does not represent a typical CPR rescue attempt.[85] The implication of the results from Yeung et al. is that feedback devices, even if not in the form of visual prompts, can be beneficial for properly correcting the quality of chest compressions.

The goal of altering education guidelines is to ensure CPR skills are reinforced and implemented correctly. For example, the 2015 guidelines encouraged an upper limit for CPR compression rate when compared to the 2010 CPR guidelines (100-120 compressions per minute versus at least 100 compressions per minute). By encouraging the use of feedback devices in CPR education, rescuers gain the ability to learn and subsequently perform metrics of CPR properly. Liu et al. compared CPR performance with chest compression rate, depth, recoil and CCF between three groups of lay people. One group was trained according to the 2010 guidelines and the other two groups were trained in accordance with the 2015 guidelines. One of the 2015 groups also utilized feedback in their training. When comparing the feedback group to the others, there was statistical significance in all of the aspects of chest compressions except for recoil.[86] Interestingly, Fried et al. analyzed if corrective feedback changed the amount of leaning (chest recoil) in rescuers who were fatigued, and found that those who received feedback had a statistically significant reduction in leaning.[77] The recommendation of utilizing feedback devices to ensure proper CPR psychomotor skills are learned and performed is a valuable adjustment to the 2015 guidelines. The education component of CPR needs to continue to improve so that CPR psychomotor skills are performed at a higher quality, thus improving CPR outcomes.

Conclusion

Understanding the history and evolution of CPR guidelines and education is imperative to making future recommendations. While great strides have occurred by utilizing evidence-based findings to improve guidelines and patient outcomes, CPR performance quality and education must continue to improve. Ensuring health care professionals as well as lay personal are prepared to assist and are confident during a cardiac incident should continue to be a focus going forward.

Variables That Can Affect CPR Performance

Self-efficacy

When analyzing variables that affect CPR performance, self-efficacy is a key factor in determining performance. The construct of self-efficacy is described by psychologist Albert Bandura as a person's belief in his/her ability to succeed in a particular situation. He further suggested the beliefs regarding an individual's potential success play a large role in how they think, behave, act and feel. Additionally, Bandura emphasized in his theory that the initiation of a behavior is highly dependent on said individual believing that he/she will perform in a way that will meet the preferred outcome successfully.[12, 87] For example, if a person is not confident that their ability to perform adequate CPR skills will actually help save someone during a cardiac emergency, that individual would be unlikely to attempt to perform CPR. Therefore, it is only logical that perceived self-efficacy plays a role in CPR performance quality. Table 18 indicates research highlighting the associations between CPR quality and self-efficacy.

Table 18. Research Highlighting Associations Between Self-efficacy and CPR Quality

Author	Purpose	Participants	Design	Outcomes	Limitations
Kallestedt et al. (2012)[88]	- Examine if there were changes in attitudes in health care professionals to start CPR and the impact of training on attitudes	- 3097 health care professionals were divided into two groups	- Group 1: 2152 people taking part in CPR training - Group 2: 945 participants taking part in training and had performed CPR in real life - Both groups were subdivided into four subgroups: 1. Physicians 2. Nurses 3. Other educated staff (physiotherapists, occupational therapists, psychologists) 4. Assistant nurses/aids - Training program consisted of a 4-hour course - Questionnaire was used to collect information about attitudes and experiences performing CPR	- Training significantly influenced attitudes among nurses and assistant ($p < .001$) - Physicians attitudes of feeling securing CPR knowledge were similar to nurses (not significant) - All healthcare providers increased positive answers regarding how to use and AED after training (from 24-67%, $P < .01$).	- Population based prospective study with only subjective data - Uneven groups - Did not discuss number of times CPR trained
Rho et al. (2012)[89]	- Develop and evaluate the Resuscitation Self-Efficacy Scale for nurses	- 124 Nursing students were tested in a one-group post-test only study	- 30-minute lecture regarding current CPR guidelines was attended, then an hour-long hands-on CPR training took place. Following the training participants took a two-item perceived self-efficacy assessment consisting of a five-point Likert scale to rate their confidence in performing chest compressions and ventilations - Participants also completed a 10-item quiz assessing CPR knowledge - They then performed CPR on a manikin with CPR quality data being recorded	- Significant negative correlations between compressions skills and self-efficacy, participants who reported high self-efficacy for compressions, were likely to perform compressions correctly ($P = .008$) - Compression and ventilation skills were not correlated with knowledge of either compressions or ventilations ($P = .510$ and $P = .257$) - Statistical significance between self-efficacy and total CPR knowledge ($p < .001$)	- Small number of items on assessment tools for both self-efficacy and knowledge - Duration of skills exam was not noted - Limited demographic data was reported

Table 18. Research Highlighting Associations Between Self-efficacy and CPR Quality (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Gonzi et al. (2015)[4]	- Assess the relationship between the perception of the ability to perform quality CPR	- 320 medical professionals (45% nurses and 43 % physicians, remainder was other allied health care professionals)	- All participants attended a five-hour BLS courses prior to the study being completed. - Participants performed a five-minute CPR simulation to measure CPR quality (compression rate and depth) - Participants completed a 10-point Likert scale regarding their perceived self-efficacy (prior to- and after the CPR simulation)	- No statistical significance between pre-test self-efficacy CPR performance for overall chest compression quality ($p > .05$), chest compression rate ($p > .05$), or chest compression fraction ($p > .05$) - Statistical significance occurred at post- self-efficacy test and CPR performance for overall chest compression quality ($p <.05$), chest compression rate ($p < .01$), or chest compression fraction ($p <.01$)	- Simulation may not have been the most realistic - In-hospital CA most likely would be responded to differently than OHCA, thus self-efficacy may not be the same for both situations
Ro et al. (2016)[90]	- Test association between CPR at capacity at the community level and survival after OHCA utilizing indexes of CPR capacity	- Of the 29,052 eligible OHCA sampled, there was 11,079 that received bystander CPR	- Cross sectional study using nationwide OHCA registry - Community CPR capacity factors were explored using a community health survey - EMS treated OHCA with cardiac etiology were analyzed and those treated initially by bystanders were included - Indexes of community CPR capacity included: CPR awareness, CPR-Any training, recent CPR training, CPR manikin training and CPR self-efficacy	- Adjusted odds ratio of bystander CPR and self-efficacy was 1.14 (95% CI 1.02-1.28) - Adjusted odds ratio for survival to discharge and self-efficacy was 1.71 (95% CI 1.64-2.96) - Statistically significant findings in survival outcomes in those who claimed any self-efficacy ($p < .01$)	- Population based observational study with no intervention - Self-report with no objective measures of self-efficacy -Selection bias

Table 18. Research Highlighting Associations Between Self-efficacy and CPR Quality (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Riggs, Franklin and Saylany (2019)[91]	- Determine if training history, knowledge, self-efficacy, training history, knowledge and willingness are associated with CPR psychomotor skills in lay people in an OHCA setting	- 34 articles with a total of 35421 participants included - Literature search included adult laypersons	- Studies that were included had to assess training, willingness, self-efficacy, or knowledge and did not include health professionals or health care professional students. - Studies had to make an association between the interventions and outcomes - Training included activities designed to improve CPR performance, training history, number of times trained and the amount of time since the last training - Willingness was defined as the perceived likelihood of performing CPR - Self-efficacy was defined as the self confidence in the ability to perform CPR correctly - Knowledge was a person's understanding of CPR technique	- Regarding self-efficacy manikin studies did not report associations between self-rated confidence, self-rated competence, and psychomotor skills - Odds ratios for survival to discharge following OHCA was 1.08 (95% CI 1.03-1.13) per 10% increase in self-efficacy at the community level - Weak evidence supporting self-efficacy was associated with improved psychomotor skills and performance	- Objective manikin recorded outcomes and subjective human judgements were used

Table 18. Research Highlighting Associations Between Self-efficacy and CPR Quality (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Binkhorst et al. (2020)[92]	- Evaluate BLS related self-efficacy of medical students who were trained by expert instructors or near-peer instructors	- 213 fifth-year medical students preparing for the pediatric internship	- Randomized control trial (non-blinded) - Two pediatricians who were certified instructors and medical school instructors were the expert instructors for a pediatric BLS course - Near-peer instructors were certified first aid instructors with at least 3 years of teaching BLS to students, they were also all 5th or 6th year medical students who had already completed their pediatric internship - Half of the trainings were completed by the expert instructor and the other half by the near-peer instructor (content was all the same) - Demographic data and previous experience with BLS were documented - 2-hour courses with a 1:15 instructor to student ratio, then the first questionnaire was given - A videotaped BLS exam on a manikin occurred and then another questionnaire was given	- Near-peer trained participants indicated higher self-efficacy than expert trained participants (P =.007)	- Limited number of expert instructors - Baseline self-efficacy was not measured - No blinding occurred - Near-peer instructors and participants may have had external relationships affecting results

Table 18. Research Highlighting Associations Between Self-efficacy and CPR Quality (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Lammert et al. (2020)[93]	- Investigate the relationship between self-efficacy and CPR quality in certified athletic trainers	- Fifty certified athletic trainers participated in this study	- A 1-minute proficiency exam was completed then a 14- item self-efficacy questionnaire was completed. - Once the questionnaire was complete, participants performed 8 minutes and 59 seconds of single rescuer CPR in accordance with the 2015 guidelines on a Resusci Anne® QCPR manikin, quality aspects of CPR were recorded - Participants then re-took the self-efficacy questionnaire	- Athletic trainers self-reported that they were efficient in CPR - Performing CPR did not change the self-efficacy scores (p=.792) - Participants reported high confidence in hand position even when they may have had incorrect hand position during CPR (P=.07 at the 10% level) - Chest recoil was reported with high self-efficacy, but results indicated that there was a statistical significance between emergency care self-efficacy and chest recoil (P=.038)	- CPR was performed in a controlled environment with no scenario-based simulation - Population was small - Convenience sample was recruited

Research exploring the correlation between self-efficacy and CPR performance is limited; thus, definitive conclusions regarding self-efficacy and CPR quality are difficult to make. Based on findings from Rho et al., rescuer reported self-efficacy may be a better predictor of CPR psychomotor skill performance as opposed to a written exam (knowledge). Rho et al. did not find a correlation between CPR skills and knowledge ($P = .510$) but did find significant correlation between CPR compression skills and self-efficacy. For example, participants who reported a high level of self-efficacy for chest compressions had minimal errors in compression quality during their skills exam ($P= .008$).[89] Similar to findings from Rho et al., results from Gonzi et al., indicate that CPR knowledge may not predict quality of CPR psychomotor skills but self-efficacy may. When analyzing overall compression quality, rate, and fraction, Gonzi et al. found statistical significance with all three variables and self-efficacy reports ($p < .05$, $p <.01$, and $p <.01$, respectively).[4] It is important to note that in both studies, Rho et al. and Gonzi et al., confounding variables such as fatigue and BMI were not accounted for when analyzing skill quality. Another limitation was the use of manikins for research purposes. A rescuer may claim high self-efficacy for performance of CPR in a scenario-based setting, yet a real-life cardiac arrest emergency may yield a different response.

Additionally, self-efficacy questionnaires were completed immediately follow a CPR training session. Thus, results may not be generalizable after a certain time frame due to learning effect. Interestingly, when exploring self-efficacy prior to and after training, Kallestedt et al. found that healthcare workers' attitudes became more positive after training, and nurses and nursing assistants reported higher self-efficacy regarding CPR skills after education ($p < .001$).[88] Gonzi et al. had similar findings in regards to an increase in self-efficacy after a training session.[4] A limitation to both Kallestedt et al. and Gonzi et al.'s study was the lack of report of demographic data such as how many times participants had been previously trained in CPR. Both studies utilized health care professionals as a sample population. The sampled professionals most likely had been trained in CPR multiple times, yet the additional trainings may not have been factored into the current results. However, according to findings from Lammert et al., the number of years participants had been CPR certified did not have significant correlations with self-efficacy (P= .356).[93] According to the literature, it appears that self-efficacy does influence the quality of CPR skill performance. Yet, based on the limitations of the previously mentioned research, there appears to be room for improvement in CPR training to ensure skills are properly acquired thereby resulting in higher levels of self-efficacy and CPR performance.

Profession and Experience

It is widely known and expected that health care professionals are trained to perform high-quality CPR.[94] Employers of health care professionals may all have different recertification programs within their system, yet individuals must adhere to their professional standards regarding CPR certification. Additionally, CPR certification and recertification must occur for professionals regardless of how often they perform CPR in their clinical setting. In essence, the level and amount of training does not change based on the amount of experience an individual has performing CPR on patients. Based on expected responsibilities of specific health care professionals in their work environment could result in performing CPR often or rarely. Thus, it is important to consider profession as a factor when considering CPR education requirements.

Nurses

The success of CPR is dependent on factors such as timeliness of provision of care, quality of care provided (including aspects of CPR such as compression rate, depth, fraction, chest recoil), and self-efficacy. Those in the nursing profession have been trained in CPR and lifesaving techniques and are expected to be knowledgeable about all components based on their education. Nonetheless, something that is not often discussed is the how the real-life experience of nurses with performing CPR correlates with their ability to perform quality CPR. Additionally, years of experience in the profession could play a significant role in the ability to perform components of CPR. Table 19 highlights research regarding the nursing profession and the relationship with CPR.

Table 19. Research Analyzing the Nursing Profession Experience and Quality of CPR Performed

Author	Purpose	Participants	Design	Outcomes	Limitations
Kallestedt et al. (2012)88	- Examine if there were changes in attitudes in health care professionals to start CPR and the impact of education on attitudes	- 3097 health care professionals were divided into two groups	- Group 1: 2152 people taking part in CPR training - Group 2: 945 participants taking part in training and had performed CPR in real life - Both groups were subdivided into four subgroups: 1. Physicians 2. Nurses 3. Other educated staff (physiotherapists, occupational therapists, psychologists) 4. Assistant nurses/aids - Training program consisted of a 4-hour course - Questionnaire was used to collect information about attitudes and experiences performing CPR	- Training significantly influenced attitudes among nurses and assistant (p < .001) - Physicians attitudes of feeling securing CPR knowledge were similar to nurses (not significant) - All healthcare providers increased positive answers regarding how to use and AED after training (from 24-67%, P < .01). - After training all health care professionals' knowledge in CPR increased significantly (p <.0001) - After training nurses, assistant nurses, physiotherapists, psychologists, and other staff all claimed they knew what to do if cardiac arrest occurred (p <.001), while there was not significance for physicians in that category	- Population based prospective study with only subjective data - Uneven groups - Did not discuss number of times CPR trained
Roshana et al (2012)95	- Explore the knowledge of and attitude towards BLS in medical and paramedical professionals	- 121 responders who were on duty in different departments of the hospital where the study took place (clinical faculty members, nurses, dental professionals, health assistants)	- Participants took a questionnaire which consisted of: Demographics and professional qualifications Experience in BLS/CPR and attitudes towards BLS/CPS Theoretical and practical knowledge of BLS based on the 2005 European Resuscitation Council BLS guidelines	- Mean knowledge score was higher in those who had had CPR training within the past 5 years compared to those who had training more than five years ago (P= .001) and those who had no training (p <.001). - No association between knowledge score and duration of clinical work in years) (P = .91)	- No intervention - Relatively small sample of professions - CPR psychomotor skill quality was not recorded

Table 19. Research Analyzing the Nursing Profession Experience and Quality of CPR Performed (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Citolino et al. (2015)96	- Identify the main factors affecting the quality of CPR according to nurses	- 49 nurses working in inpatient units at a hospital that specialized in cardiology and pneumology	- Descriptive, exploratory study - Questionnaire distributed to the nursing staff - Variables included in the questionnaire were: The number of professionals caring for a patient Presence of a leader in the scenario Team relationship Lack of material/equipment failure Lack of familiarity to emergency trolly Presence of family during CPR Personal stress Stress of other team members	- 75.5% of nurses stated that above 6 professionals acting during CPR was too many, and disturbed the care of the patient (P = .664) - 93.9% of nurses surveyed stated that having someone act as a leader improved the quality of care (P= .273) - No significance between the average of professional experience and the variables related to care	- Nurses only sampled from one institution - Small sample size - Sample from a cardiopulmonary unit, so resuscitation occurs often compared to other areas of the hospital
-Navalopotro-Pascual, Blanco-Blanco, and Torre-Puente (2018)97	- Aimed to discover the meanings that healthcare professionals attach to CPR behaviors	- 7 respondents with a minimum of 10 years of experience	- Interviews took place consisting of questions and discussions pertaining to: Personal Factors: Knowledge, thoughts, emotions, actions Situational Factors: Teams, patient, environment, family - Utilized these factors to identify what facilitated and impeded the delivery of CPR	- Healthcare professionals have had ample CPR training, yet have a fear of not knowing what to do if they do not practice - All healthcare professionals referred to CPR as an experience and not just a life-saving technique indicating emotions play a role in the performance, and subsequently the outcome - Having a team leader during CPR application reduces anxiety and improves performance according to health care professionals	- Results are conditional to the participants experiences

Table 19. Research Analyzing the Nursing Profession Experience and Quality of CPR Performed (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Silverplats et al. (2020)98	- Evaluate if in-hospital healthcare professionals' knowledge of CPR and self-assessed ability to perform CPR	- 3044 healthcare professionals were surveyed on their self-assessed ability and given a knowledge test	- Cross-sectional survey with data collected at a secondary care hospital - Physicians, nurses, nursing assistants and other university educated health care professionals were surveyed - Theoretical knowledge was measured using nine multiple choice questions - Self assessed ability was measured using two questions that contained a Likert scale regarding compressions, ventilations, defibrillations, and leadership	- Passing of the knowledge exam was defined as 7 of the 9 questions being correct and only 41% of participants passed - Low positive correlation between score of abilities and the number of correct answers ($p < .001$). - Nurses and physicians had higher knowledge and higher self-assessed ability to perform CPR when compared to non-physician and non- nurse participants, additionally those who recently attended a CPR training (within 6 months of test) scored higher on knowledge and assessed their own ability as higher as well - Years in the profession did not show significance in any category	- Selection bias - Questions of self-reported leadership ability may have been poorly worded - No actual experiences in CPR situations were evaluated

As nurses progress in their profession, recertification and training in CPR continues to occur. Thus, those who have been in the profession for an extended period of time would be trained and retrained numerous times. One would hypothesize that the more opportunities to participate in training would result in better performance. However, several external factors may actually be barriers to an increase in performance. Citolino et al. evaluated the common factors that affected the quality of CPR in a nursing population. They found that 75.5% of nurses who were surveyed agreed that having more than six rescuers attempting to perform CPR was too many and disturbed the care of the patient ($P = .664$). Approximately 94% of nurses stated that having someone act as a leader improved the quality of care ($P = .273$). Navalopotro-Pascual and team had similar findings in that having a team leader during CPR reduced nurses' anxiety and improved overall care for the patient.[97] Citolino et al. did not find a significant correlation between the average time of professional experience and the quality of care given during CPR.[96] Similar to findings from Citolino et al., Silverplats et al. also found that years of experience in the nursing profession did not have significant correlations with self-assessed ability to correctly perform aspects of CPR.[98] Limitations of all three mentioned studies was that no intervention occurred, nurses were surveyed using a questionnaire, and the quality of psychomotor skills were not examined. Therefore, limited inferences regarding CPR skill quality and years of experience can be made with respect to the profession of nursing.[96, 98]

Meanwhile, when observing the impact of CPR education on nurses and other health care professionals' attitudes, Kallestedt et al. found that training significantly improved attitudes among nurses and nursing assistants ($p < .001$).[88] Roshana et al. found that an increase in the option for health care professionals to partake in trainings improved attitudes regarding BLS and CPR. Interestingly, the amount of experience in years nurses had been in the profession did not hold significance in the attitudes towards CPR. Unfortunately, comparable to the previously described studies, Roshana et al. did not record CPR psychomotor quality data to correlate with years of experience.[95] Overall, there is little data exploring if experience in real CPR scenarios correlates with the ability to perform quality CPR psychomotor skills.

Physicians

Anecdotally, the lay public would assume that physicians would be proficient in CPR skills based on their extensive education and expected continuing education in BLS. While the application of high-quality CPR is known to improve survival, the factors that alter physicians' ability to perform at an expert level are unknown. Additionally, it is not widely understood if physicians' experience with performing CPR outside of learning simulations correlates directly with the quality of CPR performed. Table 20 details research outlining the quality of CPR physicians provide as well as factors that affect CPR quality.

Table 20. Research Analyzing Physicians Experience and Quality of CPR Performed

Author	Purpose	Participants	Design	Outcomes	Limitations
Kallestedt et al. (2012)[88]	- Examine if there were changes in attitudes in health care professionals to start CPR and the impact of education on attitudes	- 3097 health care professionals were divided into two random groups	- Group 1: 2152 people taking part in CPR training - Group 2: 945 participants taking part in training and had performed CPR in real life - Both groups were subdivided into four subgroups: 1. Physicians 2. Nurses 3. Other educated staff (physiotherapists, occupational therapists, psychologists) 4. Assistant nurses/aids - Training program consisted of a 4-hour course - Questionnaire was used to collect information about attitudes and experiences performing CPR	- Training significantly influenced attitudes among nurses and assistant (p <.001) - Physicians attitudes of feeling securing CPR knowledge were like nurses (not significant) - All healthcare providers increased positive answers regarding how to use and AED after training (from 24-67%, p <.01). - After training all health care professionals' knowledge in CPR increased significantly (p <.0001) - After training nurses, assistant nurses, physiotherapists, psychologists, and other staff all claimed they knew what to do if cardiac arrest occurred (p <.001), while there was not significance for physicians in that category	- Population based prospective study with only subjective data - Uneven groups - Did not discuss number of times CPR trained -Did not discuss previous experiences performing CPR in real-life
Sayee and Mccuskey (2012)[99]	- Assess CPR skills of first year resident physicians and highlight factors that influence performance	- 34 first year resident physicians participated in the study (18 males, 16 female)	- Participants were grouped by gender and were asked to perform 3 minutes of CPR using a compression to vent ratio of either 15:3 or 30:2 (randomly assigned) They then rested for five minutes and performed 3 minutes of the other ratio - Data were recorded by the Laerdal Resusci-Anne Skills reporter	-Male physicians performed significantly more quality compressions than females with both compression ratios; 15:2 (P = .008), 30:2 (P= .005) - Greater number of physicians met a CCF of >80% when using the 15:2 compression to ventilation ratio (not significant, but notable) - Approximately 29% of physicians performing the 15:2 ratio were rated ineffective and 38% of those performing the 30:2 ratio	- Effectiveness was rated by CPR instructors (not equipment) - Demographic data such as real-life CPR experience was not included - Relatively small sample sizes

Table 20. Research Analyzing Physicians Experience and Quality of CPR Performed (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Navalopotro-Pascual, Blanco-Blanco, and Torre-Puente (2018)[97]	- Aimed to discover the meanings that healthcare professionals attach to CPR behaviors	- 7 respondents with a minimum of 10 years of experience	- Interviews took place consisting of questions and discussions pertaining to: • Personal Factors: Knowledge, thoughts, emotions, actions • Situational Factors: Teams, patient, environment, family - Utilized these factors to identify what facilitated and impeded the delivery of CPR	- Healthcare professionals have had ample CPR training, yet have a fear of not knowing what to do if they do not practice - All healthcare professionals referred to CPR as an experience and not just a life-saving technique indicating emotions play a role in the performance, and subsequently the outcome - Having a team leader during CPR application reduces anxiety and improves performance according to health care professionals	- Results are conditional to the participants experiences - No quantitative data
Silverplats et al. (2020)[98]	- Evaluate if in-hospital healthcare professionals' knowledge of CPR and self-assessed ability to perform CPR	- 3044 healthcare professionals were surveyed on their self-assessed ability and given a knowledge test	- Cross-sectional survey with data collected at a secondary care hospital - Physicians, nurses, nursing assistants and other university educated health care professionals were surveyed - Theoretical knowledge was measured using nine multiple choice questions - Self assessed ability was measured using two questions that contained a Likert scale regarding compressions, ventilations, defibrillations, and leadership	- Passing of the knowledge exam was defined as 7 of the 9 questions being correct and only 41% of participants passed - Low positive correlation between score of abilities and the number of correct answers ($p < .001$). - Nurses and physicians had higher knowledge and higher self-assessed ability to perform CPR when compared to non-physician and non- nurse participants, additionally those who recently attended a CPR training (within 6 months of test) scored higher on knowledge and assessed their own ability as higher as well - Years in the profession did not show significance in any category	- Selection bias - Questions of self-reported leadership ability may have been poorly worded - No actual experiences in CPR situations were evaluated

The ability for physicians to perform quality CPR should not be a unique skill set based on their education and assumed experience in the healthcare field. The literature gap is large when analyzing the quality of CPR performed by physicians, specifically factors that affect their ability to perform quality compressions. Sayee and McCluskey found that first-year physicians performed effective CPR, but factors such as gender and BMI affected the quality of compressions. Additionally, Sayee and McCluskey's results indicate that approximately 29% of physicians performing the 15:2 compression to ventilation ratio were rated ineffective and 38% of those performing the 30:2 ratio were also rated to be ineffective. While there was not statistical significance with those numbers, it is important to recognize that the sample size was relatively small. Authors stated that 10 of 34 and 13 of 34 physicians (at respective compression to ventilation ratios) could be performing CPR ineffectively.[99] Meanwhile, findings from Kallestedt et al. indicate that physicians' attitudes towards their ability to perform proper CPR did not change after a training experience. Physicians surveyed were confident in their ability to perform quality CPR at baseline.[88] Incongruously with their ratings from psychomotor performances, physicians are claiming confidence in their ability to perform. Limitations to the studies by Kallestedt et al., and Sayee and McCluskey was the lack of reporting the number of times individuals had been trained in CPR as well as the number of real-life CPR experiences.[88, 99]

A qualitative study completed by Navalopotro-Pascual et al. explored personal factors and situational factors that affected attitudes and behaviors toward CPR. This study was interesting because it did not include any quantitative data. Researchers indicated that CPR was referred to as an experience. Consequently, emotions experienced during an emergency play a role in the quality of their performance. Thus, quality of CPR may be affected by extenuating factors surrounding the emergency.[97] A core limitation to the study completed by Navalopotro-Pascual et al. other than lack of quantitative data, was that the results are conditional to each participant's experiences. Thus, the results cannot be generalized to physicians as a whole. Based on the notion that individuals' emotions play a role in the quality of performance during CPR, professional experience may also contribute to the quality of CPR. Silverplats et al. found that while physicians had higher levels of knowledge and self-assessed ability to perform CPR than non-physicians, years in the profession did not hold statistical significance in the ability to perform CPR. A limitation to the study completed by Silverplats et al. was that no CPR situations or simulations were evaluated, therefore no quantitative inferences regarding experience and quality of performance are available.[98] Future research regarding experience in a profession as well as CPR scenarios should occur to help control for factors that contribute to the quality of CPR performed.

Fire Fighters and EMS Personnel

Early CPR by prehospital rescuers is vital to positive neurological outcomes at survival to discharge. While it is expected that Emergency Medical Technicians (EMTs) and paramedics perform quality CPR when they implement the potential lifesaving technique, literature shows quality performance is not always the case. While the goal of advanced emergency medical care is to reduce mortality from emergent scenarios, the success of CPR is still highly dependent on the performer (outside of cardiac rhythm and other factors).[100] Similar to nurses and physicians, objective data specific to EMTs and paramedics is limited even though these individuals have a greater expectation for producing quality medical interventions. Table 21 highlights research regarding CPR quality in EMTs and paramedics.

Table 21. Research Analyzing EMTs and Paramedics Experience and Quality of CPR Performed

Author	Purpose	Participants	Design	Outcomes	Limitations
Eisenberg, Bergner and Hallstrom (1979)[101]	- Identify factors associated with successful resuscitation from OHCA	- 604 OHCA were analyzed	- 604 OHCA were analyzed with the following data obtained: 1. Patient identification 2. Prehospital Care (EMT or Paramedic) 3. Time from collapse to initiation of CPR 4. Time from collapse to definitive care 5. CPR duration 6. Response time of emergency agency 7. Witnessed or unwitnessed event 8. Weight of patient 9. ECG rhythm 10. Outcome	- Prehospital care had a significant effect on successful outcomes, 39% of paramedic treated patients were admitted to the hospital while only 17 in non-paramedic treated victims 9 P < .01) - 27% of paramedic treated victims were discharged alive while only 6% non-paramedic treated (p < .01)	- Quality of CPR was not analyzed - Previous CPR experience in Paramedics and EMTs was not recorded or analyzed - Years in profession + recertification years were also not included
Ko et al. (2005)[102]	- Evaluate prehospital CPR performance and its impact on outcomes in EMS	- 52 patients in ventricular fibrillation who did not achieve ROSC immediately and needed CPR were included in the study	- Retrospective analysis of prospectively acquired AED data was used to determine the quality of prehospital CPR - Adequate CPR was defined as 1. Noticeable deflection of electrocardiography with chest compressions 2. Supplemented rhythmic verbal counting 3. Compressions per minute greater than 50 4. If CPR was resumed after the AED prompt 5. No more than 30 second interruptions during transport	- The quality of CPR on scene and during transport was deemed adequate in 29% of cases and 71% inadequate - Those with adequate CPR care had higher survival to discharge rates (53% versus 8%) (P =.001)	- Limited compression quality data was recorded - Only patients with shockable rhythms were included - No demographic data regarding EMTs was analyzed so it is unknown if experience plays a role in quality of care - No delineations were made between EMT and paramedic, thus educational aspects cannot be analyzed

Table 21. Research Analyzing EMTs and Paramedics Experience and Quality of CPR Performed (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Brown et al. (2006)[103]	- Explore the relationships between knowledge of CPR guidelines and performance	- 60 professional EMTs (basic life support and ACLS) were sampled	- Cross sectional observational study - Recording manikin and video model used to assess performance in standardized scenario paired with a survey to assess guideline knowledge - Participants performed three minutes of single rescuer CPR on a recording Resusci Anne manikin - Compression rate, depth, compression to ventilation ratio and ventilation volume were assessed - Demographic data was also taken (age, gender, years of experience, and if they had performed CPR in the last 6 months)	- Years of experience was not related to correct performance - Accurate knowledge of the guidelines was associated with better performance • Compression Rate OR 4.6 (95% CI 1.2-18.1) • Compression Depth OR 1.7 (95% CI0,4-6.5) • Compression to ventilation ratio OR 4.5 (95% CI 1.1-18.5) • - ACLS EMTs were more likely to perform compressions at a correct rate	- Manikin model - Participants reported multiple rescuer CPR is performed, not single rescuer which may affect quality of CPR in this scenario -Number of trainings and recertifications was not analyzed
Lin et al. 2016[104]	- Identify factors associated with the performance of high-quality CPR using a manikin-based method for EMTs	-95 EMTs from two county fire departments	-Post hoc analysis using data from a manikin survey of CPR quality in volunteer EMTs - Demographic data were taken, including if they had taken any CPR courses within the past 3 months - Quality aspects of CPR recorded included: hand position, chest recoil, compression depth, rate, and hands on time -EMTs were grouped based on if they performed high quality CPR or not (rate of at least 100 compressions per minute, depth of at least 5 cm) and then factors with different groups were identified	- Of the 95 EMTs, 36 were assigned to the high-quality CPR group. - Characteristics that differed significantly between groups were: EMT levels (P= .01), BMI (P =.029) and factors associated with exercise (frequency; P = .001, and duration P =.005) - No statistical significance between those who had been trained in the past 3 months and those who had not been	- Years of experience was not included in demographic data - Real CPR experience was not included - Voluntary participants from two fire departments may be selection bias, thus results may not be generalizable.

Results of CPR performed by EMTs and paramedics is difficult to record due to environmental considerations. However, such data proves invaluable to understanding where deficiencies occur during treatment and care of cardiac victims. Findings from Lin et al., Eisenberg, Berngner and Hallstrom and Brown et al., suggest that the level of training, EMT basic, intermediate, or paramedic, influences the quality of CPR performed. Lin et al. found statistical significance between EMT levels (P = .01) and the ability to perform high-quality CPR, with paramedics and EMT intermediate performing higher quality than EMT basic.[104] Dating back to 1979, Eisenberg, Berngner and Hallstrom also found that paramedics performed higher quality CPR based on discharge rate. In their study, they reported 27% of victims treated by paramedics were discharged compared to 6% of patients treated by an emergency care professionals with less training (i.e., EMT-basic).[101]

Limited data comparing the quality of CPR between training levels in EMS providers exists. Yet, Brown et al. reported that those who were trained in ACLS versus BLS were more likely to perform compressions at the correct rate. A limitation to Lin et al. and Brown et al.'s studies was that they were manikin based with single-rescuer CPR occurring. Brown et al. discussed that in the field, EMT's would be providing two-rescuer CPR or team CPR, thus would be able to maintain focus on providing quality compressions instead of both compressions and ventilations.[103]

It is widely known that early CPR and defibrillation are key to increase survival in cardiac emergencies and yet the quality of CPR in EMS providers is not well understood. Ko et al. stated that CPR during transport was deemed adequate in only 29% of the analyzed cases. One limitation to the study was compression quality data was limited in that it was not broken down by specific quality but rather based on hands on time and length of interruptions.

Additionally, there was no delineation between certification of EMS personnel; therefore, training and education levels were not incorporated in the study.[102] More data regarding the specific aspects of compression quality in EMS personnel could be beneficial in analyzing overall CPR performance.

Of the analyzed studies, Brown et al. was the only that investigated whether years of experience correlated with quality of performance. Findings indicated that years of experience did not have any effect on the quality of performance. Interestingly, while experience does not seem to effect CPR quality, recent training may not either.[103] Lin et al. found no statistical significance between EMTs who had been trained within a three-month time frame of the study and those who were not recently recertified or trained.[104] Based on these findings, experience and recertification time frames do not alter CPR quality. However, there may not be enough data to make inferences regarding experience and recertification timelines and the relationship with CPR quality in EMS personnel.

Athletic Trainers

One of the five domains of athletic training is the immediate and emergency care domain.[105] Athletic trainers are expected to act in any situation and must be prepared to assess and treat not only orthopedic and skeletal muscle injury but also catastrophic injuries and conditions. These catastrophic injuries include the need for athletic trainers to be able to recognize and treat life threatening conditions such as sudden cardiac arrest and respiratory failure.[106] To ensure good standing with the Board of Certification®, athletic trainers must maintain an up-to-date emergency care and cardiac care certification, which currently consists of reeducation every two years.[105] Unfortunately, research regarding the ability of athletic trainers to perform quality aspects of CPR properly and effectively is limited and can be seen in table 22.

Table 22. Research Analyzing Athletic Trainers Experience and Quality of CPR Performed

Author	Purpose	Participants	Design	Outcomes	Limitations
Waninger et al. (2014)[8]	-Evaluate CPR quality during simulated cardiac arrest of football players with equipment on (does equipment impede CPR performance in athletic trainers?)	- 30 athletic trainers (certified and students) and 6 ACLS EMTs	- Each participant performed three, two-minute bouts of CPR on a SimMan 3G manikin (chest compression rate and depth were recorded) - First bout of CPR was baseline collection with no football pads, second was with football pads and third was with football pads, but the subject performed CPR under the pads - CPR was performed in accordance with the 2010 guidelines	- No statistical significance in baseline data between athletic trainers and EMTs so groups were combined for analysis - Compressions were significantly deeper when performed under pads when compared to over (P = .002) but adequate depth was not reached in either situation - No statistical findings for compression rate, and rate was adequate for all bouts of CPR	- No baseline data was reported by researcher - Could not differentiated between certified athletic trainers and athletic training students - No experience or history of previous training was recorded or analyzed

Table 22. Research Analyzing Athletic Trainers Experience and Quality of CPR Performed (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Lammert et al. (2020)[107]	- Investigate the relationship between self-efficacy and CPR quality in athletic trainers	- Fifty certified athletic trainers participated in this study	- A 1-minute proficiency exam was completed then a 14- item self-efficacy questionnaire was completed. - Once the questionnaire was complete, participants performed 8 minutes and 59 seconds of single rescuer CPR in accordance with the 2015 guidelines on a Resusci Anne® QCPR manikin, quality aspects of CPR were recorded - Participants then re-took the self-efficacy questionnaire	- Athletic trainers self-reported that they were efficient in CPR - Performing CPR did not change the self-efficacy scores (P=.792) - Participants reported high confidence in hand position even when they may have had incorrect hand position during CPR (P=.07 at the 10% level) - Chest recoil was reported with high self-efficacy, but results indicated that there was a statistical significance between emergency care self-efficacy and chest recoil (P=.038) - None of the reported variable other than hand position showed statistical significance, but the trend was the greater self-confidence, the worse the performance was. - 70% of participants achieved a satisfactory CPR rating - Only 46% of participants maintained a compression rate of 100-120 compressions per minute	- CPR was performed in a controlled environment with no scenario-based simulation - Population was small - Convenience sample was recruited - Low incidence of SCA in the athletic population so this sample may not have real life experience, thus other athletic trainers in other setting may have higher reported self-efficacy.

Table 22. Research Analyzing Athletic Trainers Experience and Quality of CPR Performed (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Lyman, Landin and Guggisberg (2017)[108]	- Compare the quality of compression-only CPR among students enrolled in allied health care programs and students in non-allied health care programs	- 60 participants (40 non-allied health and 20 allied health)	- Participants were divided into three groups: (1) 20, declared allied health care students. And 40 non-allied health care students randomized into two groups of 20: (2) non-allied health, no intervention, (3) non-allied health students who were taught compression-only CPR via a 2-minute video and received feedback as they practiced compressions on the high-fidelity manikin - All participants performed 2-minutes of compression-only CPR while quality of compressions was recorded - Data included the following aspects of compressions: overall score, mean rate, mean depth, % compressions fully released, and % compressions with appropriate depths.	- Overall score mean differences between groups were statistically significant (P < .001) - Statistical significance between groups 1 and 2 occurred (P =.006), groups 1 and 3 (P < .001) and groups 2 and 3 (P < .001)	- Only 2-minutes of CPR was performed - Data regarding number of times trained and experience with true cardiac emergencies for allied health care students was not analyzed or included - Delineation between profession allied-health care students were in was not included in results

Table 22. Research Analyzing Athletic Trainers Experience and Quality of CPR Performed (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Estabrooks et al. (2018)[108]	- Determine if certified athletic trainers were able to provide high-quality chest compressions over hockey shoulder pads	- 50 certified athletic trainers (25 male and 25 female who were already CPR certified	- Athletic trainers performed a 1-minute proficiency (at least 80% overall) test to ensure high quality CPR was performed in accordance with the 2015 AHA CPR guidelines - CPR quality was recorded on a Resusci Anne Skills reporter (overall score, chest compression rate, depth, chest compression fraction, % chest recoil, % compressions with appropriate depth, % of ventilations that were adequate) - Participants then performed single-rescuer CPR for 8 minutes and 59 seconds on a manikin wearing hockey should pads - No feedback was provided to participants during testing with shoulder pads	- Regarding compression depth, there was significant correlation between gender and mean compression depth with males compressing deeper than females ($p < .01$) with hockey should pads on the manikin - Only 44% of participants were able to compress at the recommended depth with shoulder pads on the victim -Other traits of athletic trainers such as years in the profession, level of education and BMI were not significant predictors of CPR performance	- CPR performed on a QCPR Anne manikin -Small population limited to Midwest region - Only one brand of hockey pads
Skaro et al. [109]	- Determine if certified athletic trainers were able to deliver high-quality CPR over football shoulder pads	- 27 certified athletic trainers	- Athletic trainers performed two sessions of CPR in accordance with the 2015 AHA CPR guidelines - Session one consisted of performing compressions over football shoulder pads - Session two consisted of timing the equipment removal and performance of compressions under the shoulder pads - Each session was performed for 4-minutes totals with a five-minute rest period	- Overall CPR scores with chest compressions performed over and under the shoulder pads were 43.88% and 77.17%, respectively ($p<.001$). - On average, the ATCs were able to achieve a mean depth of 39.41 mm over the shoulder pads, and 54.05 mm under the pads ($p<.001$).	- Controlled setting for CPR - Relatively short CPR performance - Only two types of shoulder pads utilized in the study - Small population limited to Midwest region

The skill set of athletic trainers is rather broad, thus the assumption that athletic trainers are be able to perform high-quality CPR is still valued. Similar to other health care professions, athletic trainers must maintain CPR certification and yet data shows that regardless of the certification, quality performance is lacking. When discussing specific aspects of CPR quality, Waninger et al. found that compression depth was deeper when compressions were performed under football pads when compared to over the pads ($P = .002$). It should be highlighted that adequate depth was not obtained in either scenario. Baseline compression rate and depth quality was not reported, so it is unknown if the lack of adequate compression depth can be attributed to the football pads or if participants simply did not perform compressions properly.[8] Meanwhile, Skaro et al. found that the mean chest compression depth performed by athletic trainers was significant when compressions were performed under football pads versus when football pads were still on the victim ($p < .001$).[109] Additionally, compression depth was significant when Estabrooks et al. analyzed demographic data such as gender, in the sample of athletic trainers studied. Males compressed deeper than females when hockey shoulder pads were in place ($p < .01$).[7]

While the chest compression rate was adequate in the Waninger et al. study, Lammert et al. indicated that only 46% of athletic trainers maintained a compression rate of 100-120 compressions per minute. It should be noted compressions outside that rate were not in accordance with the guidelines and contributed to an unsatisfactory performance of CPR. When discussing self-efficacy, Lammert et al. reported that athletic trainers indicated that they were efficient in CPR, yet the data trend indicated that the higher an individual's confidence, the worse their CPR performance.[93] A limitation to Lammert et al. and Waninger et al.'s studies was that the CPR scenario was in a controlled environment, thus not reflecting a real-life experience.

While traits of athletic trainers such as years in profession, level of education, and BMI were not significant predictors of CPR performance, there is little data indicating what traits could be significant in predicting CPR performance.[7] Furthermore, more data regarding the performance of CPR while equipment is still on versus the removal of equipment must be analyzed to ensure best practices occur for athletic trainers. Estabrooks et al. found that only 44% of athletic trainers were able to compress the chest to the appropriate depth with the shoulder pads on, while Waninger et al reported that chest compressions were significantly deeper when football pads were still in place.[7, 8] The conflicting findings make it difficult to ensure athletic trainers are providing the best care to their equipment-laden athletes. More research must occur in the field of athletic training to ensure athletic trainers are able to perform high-quality CPR at any time in their career.

Equipment

As indicated in the previous section, a factor that may affect the quality of CPR is an equipment-laden athlete. Many rescuers remove the equipment, but in an effort to save valuable time, it may be more important to start compressions immediately directly over the equipment. Nonetheless, a lack of direction and guidelines from CPR organizations creates confusion for rescuers and medical directors who oversee patient care. Though there is limited research regarding the efficacy of CPR over athletic equipment, some valuable inferences can be made. Table 23 outlines research regarding CPR performance with and without athletic equipment over the chest while performing CPR.

Table 23. Research Analyzing Athletic Equipment and Other Barriers That Affect the Quality of CPR Performed

Author	Purpose	Participants	Design	Outcomes	Limitations
Del Rossi et al. (2011)[110]	- Determine the effect of athletic equipment on the initiation of CPR also the feasibility of performing compressions over the chest protector to save time	- 47 participants (athletic trainers)	- Prospective randomized crossover study - Two scenarios 1. Removal of football facemask and chest protector 2. Removal of facemask but deliver chest compressions over chest protector - Participants performed 4 minutes of CPR in accordance with the 2005 guidelines with each cycle consisting of a compression to ventilation ratio of 30:2 - Data recorded included: • Time to first breath and compression • Total number of compressions • Depth of compressions • Hand placement • Time needed to expose the chest	- Adequate chest compression depth was attained more frequently by rescuers when chest protector was left on ($p < .0001$) - Chest recoil was negatively impacted with chest protector left on ($p < .0001$) - It took over two minutes from time of collapse to first compression when chest protector was left on ($P = .08$)	- Scenario was not in a realistic chaotic environment - Participants reviewed scenario prior to CPR performance which may have increased response times
Waninger et al. (2014)[8]	-Evaluate CPR quality during simulated cardiac arrest of football players with equipment on (does equipment impede CPR performance in athletic trainers?)	- 30 athletic trainers (certified and students) and 6 ACLS EMTs	- Each participant performed three, two-minute bouts of CPR on a SimMan 3G manikin (chest compression rate and depth were recorded) - First bout of CPR was baseline collection with no football pads, second was with football pads and third was with football pads, but the subject performed CPR under the pads - CPR was performed in accordance with the 2010 guidelines	- No statistical significance in baseline data between athletic trainers and EMTs so groups were combined for analysis - Compressions were significantly deeper when performed under pads when compared to over ($P = .002$) but adequate depth was not reached in either situation - No statistical findings for compression rate, and rate was adequate for all bouts of CPR	- No baseline data was reported by researcher - Could not differentiated between certified athletic trainers and athletic training students - No experience or history of previous training was recorded or analyzed

Table 23. Research Analyzing Athletic Equipment and Other Barriers That Affect the Quality of CPR Performed (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Boergers et al. (2018)[111]	- Assess the effect of lacrosse shoulder pads on the ability to provide quality chest compressions	- 36 certified athletic trainers	- Crossover study in a simulation laboratory - Two sets of shoulder pads used - Participants were paired then watched a short informational video which reviewed high quality CPR aspects - Participants performed a baseline skills training exam consisting of 2 minutes of CPR (2-rescuer), they also had to meet an 80% pass rate to move to simulations - If they did not achieve an 80% pass rate, they were able to practice for up to 30 minutes to achieve the pass rate - 7 days after the training session participants performed CPR for 6 trials (so each person performed 3 trials of compressions) with different equipment present	- Hand placement accuracy among the 3 shoulder-pad conditions was statistically significant (P=.004). - No significance with compression rate - Statistical difference in mean compression depth between should pad conditions; shallower depths during Warrior brand when compared to no shoulder pads (P= .02) but no significance with the Stx brand pads	- Only studied two brands of pads - Data collected on a firm surface in a controlled setting - Only two minutes of CPR occurred which is not realistic to clinical application
Bowman et al. (2020)[112]	- Determine the time to first chest compression and AED show in two exposure procedures with two different pad types	- 36 certified athletic trainers	- Crossover design - Participants worked in pairs to provide 2-rescuer CPR during a simulation on a QCPR manikin that had lacrosse pads and a helmet on - Chest exposure procedures included 1. Removal of helmet with CPR initiated over the pads, then removal of pads for AED application and 2. Removal of helmet and pads to begin compressions and AED application - Both procedures occurred with two different styles of pads	- Removal of the helmet with CPR initiated over the pads was statistically significant for both styles of pads compared to removal of the helmet and the pads (P =.004) - Time to first AED shock was not different between equipment procedure or pad type	- Quality of CPR compressions were not analyzed - Conducted in a controlled setting - Position of injured athlete was not considered nor was a cervical spine injury

Table 23. Research Analyzing Athletic Equipment and Other Barriers That Affect the Quality of CPR Performed (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Estabrooks et al. (2018)[7]	- Determine if certified athletic trainers were able to provide high-quality chest compressions over hockey shoulder pads	- 50 certified athletic trainers (25 male and 25 female who were already CPR certified	- Athletic trainers performed a 1-minute proficiency (at least 80% overall) test to ensure high quality CPR was performed in accordance with the 2015 AHA CPR guidelines - CPR quality was recorded on a Resusci Anne Skills reporter (overall score, chest compression rate, depth, chest compression fraction, % chest recoil, % compressions with appropriate depth, % of ventilations that were adequate) - Participants then performed single-rescuer CPR for 8 minutes and 59 seconds on a manikin wearing hockey shoulder pads - No feedback was provided to participants during testing with shoulder pads	- Regarding compression depth, there was significant correlation between gender and mean compression depth with males compressing deeper than females ($p < .01$) with hockey should pads on the manikin - Only 44% of participants were able to compress at the recommended depth with shoulder pads on the victim -Other traits of athletic trainers such as years in the profession, level of education and BMI were not significant predictors of CPR performance	- CPR performed on a QCPR Anne manikin -Small population limited to Midwest region - Only one brand of hockey pads
Skaro et al. [109]	- Determine if certified athletic trainers were able to deliver high-quality CPR over football shoulder pads	- 27 certified athletic trainers	- Athletic trainers performed two sessions of CPR in accordance with the 2015 AHA CPR guidelines - Session one consisted of performing compressions over football shoulder pads - Session two consisted of timing the equipment removal and performance of compressions under the shoulder pads - Each session was performed for 4-minutes totals with a five-minute rest period	- Overall CPR scores with chest compressions performed over and under the shoulder pads were 43.88% and 77.17%, respectively ($p<.001$). - On average, the ATCs were able to achieve a mean depth of 39.41 mm over the shoulder pads, and 54.05 mm under the pads ($p<.001$).	- Controlled setting for CPR - Relatively short CPR performance - Only two types of shoulder pads utilized in the study - Small population limited to Midwest region

Protective equipment worn by athletes may hinder chest compression quality during CPR, yet the amount of time saved by providing compressions prior to equipment removal may be significant in survival for cardiac emergencies. Findings from Boergers et al. indicate that compression depth was dependent on the brand of lacrosse chest protector worn, thus indicating that more research regarding chest protectors and the relationship with compression depth needs to occur. Interestingly, Del Rossi et al. found that correct chest compression depth was more likely when the football chest protector was still in place ($p < .0001$) but chest recoil was negatively impacted by the protector ($p < .0001$).[110] In contrast, findings from Skaro et al. suggest that athletic trainers had a better performance when football shoulder pads were removed ($p < .001$).[109] Additionally, when analyzing chest compression quality over ice hockey pads, Estabrooks et al. reported that only 44% of participants were able to compress at the recommended depth.[7] A limitation of both Boergers et al. and Del Rossi et al.'s study was participants only performed CPR for a short amount of time (two minutes), which is not realistic in a true CPR emergency.[110, 111]

While performing chest compressions over athletic equipment does save time in regards to collapse to first compression, athletic equipment must still be removed to ensure AED placement can occur. Del Rossi et al. found it took over two minutes from the time of collapse to compressions when equipment was removed, therefore deducing that rescuers should perform high-quality CPR over the pads immediately to ensure prompt care occurs.[110] CPR education and training, especially for individuals who work with an athletic population who wear protective equipment should ensure they practice quality skills with equipment on to ensure proper performance.

Conclusion

Despite an increase in research concerning the quality of CPR performance in health care professionals and factors that could affect performance, definitive answers are still unclear. While we know that the provision of high-quality CPR is ideal and encouraged in allied health care professionals, the trend seems to be that high-quality performance is lacking regardless of the profession or the amount of experience one has. Because of the need to perform high-quality CPR to mitigate the effects of cardiac arrest, more research should be completed to understand the factors that reduce CPR effectiveness.

Education

Cardiopulmonary resuscitation education and psychomotor skills training are essential components of health care provider clinical skills, and yet since the introduction of CPR guidelines, there is limited clarity on best education practices. Over time the format of CPR education courses has evolved from a traditional four-hour, lecture-based course to shortened video and app-based course approaches. These updated options are often paired with scenario-based psychomotor trainings, which utilize real-time feedback equipment to provide the opportunity for participants to expand their skill quality based on the provided feedback. To date, CPR certifications are valid for two years with no additional training requirements. However, retention of CPR psychomotor skills decline around 6 months after the initial training.[83]

The key recommendations in the 2015 CPR education guidelines include the use of high-fidelity manikins for training. Additionally, the use of CPR feedback devices and more frequent trainings in BLS and ACLS during the two-year certification time period may be helpful for ensuring the provision of high-quality CPR. Additionally, with the goal of skill mastery, there has been a shift from simply meeting minimum standards to creating an educational experience that provides authentic-practice experiences.[83] The shift from meeting minimum standards to the goal of mastery creates the opportunity for deliberate practice to occur regarding CPR psychomotor skills.[14] Deliberate practice paired with high-fidelity equipment equates to high-quality, objective feedback. Ensuring students understand the complexities of all components of CPR provides the best-case scenario for providing care during an emergency.

Format of Course

Current CPR guidelines indicate that high-level scientific evidence regarding the optimal CPR education method is scarce. Therefore, the current guidelines still maintain that face-to-face education remain as the gold standard for initial and recertification [2] To date, there are limited BLS CPR courses that offer a CPR credential without a skills assessment by a certified instructor. Most courses offered by the AHA are the traditional course for CPR and first aid instruction but some are multimodal. Traditional CPR courses are instructor-led and classroom based over an approximate four-hour period. Additionally, instructors administer the hands-on skill practice and examination aspect of the course.

While other CPR education options exist such as multimodal or blended learning, CPR guidelines regarding educational standards are still unclear on best education practice. Blended learning is comprised of online learning and a hands-on skill session with a certified instructor. An additional education option is e-learning, which does not include hands-on skills but rather focuses on cognitive knowledge. Data supporting contemporary formats are not clear regarding psychomotor skills acquisition and retention. Foundational knowledge of the cardiopulmonary system provides background information specific to CPR. However, the intricacies of CPR are often advanced for lay public. By spending too much time on the cognitive component, less time is available for practice and adapting performance for specific situations a rescuer may encounter. The amount of research regarding CPR education is vast, and yet best practices regarding CPR education are still relatively unknown. Traditional course formats are being questioned based on the amount of time it takes to train individuals who appear to perform CPR at subpar levels. Table 24 highlights research regarding the format of CPR courses and best way to ensure psychomotor skills are acquired.

Table 24. Research Analyzing the Format of CPR Courses

Author	Purpose	Participants	Design	Outcomes	Limitations
Einspruch et al. (2007)[113]	- Evaluate performance levels from a traditional heart saver CPR course and a 30-minute self-training video, initial skills and two-month retention of skills	- 285 adults between the age of 40 and 70 years old with no CPR training within the past 5 years (185 participants returned for follow up)	- Experimental design with one untrained control group, a traditional heart saver trained group, three self-training groups (self-train alone, self-train with instructor facilitation, self-train with peer facilitation) - All groups had to perform a CPR skills exam - Self-training consisted of a 22-minute practice while watching video with a CPR compression coach - Test scenario occurred within 1.5 hours of training - Secondary testing occurred 2 months after initial training - Sensored manikins captured ventilation volume, compression rate and depth and hand placement	- Overall performance declined from 42% to 30% for heart saver subjects and from 60% to 44% for self-taught subjects - Mean percent of compressions with proper hand placement was higher in the self-training groups at initial and 2month follow up when compared to the heart saver group - Heart saver performed better than the control (P = .019) and self-taught also performed better compared to the control ($p < .001$)	- Short retention interval - Older population so not generalizable to younger population - Previous training limited to the last 5 years, but profession and additional previous training was not recorded
Nishiyama et al. (2015)[114]	- Evaluate long-term effectiveness of a 15-min BLS training following a 45-min compression-only BLS training	- 112 participants completed the study - 71 assigned to refresher training - 69 assigned to control group	- Randomized control trial - 45-min chest compression training consisted of DVD education and a personal manikin that provided corrective feedback - Participants were then assigned to a refresher BLS group (6 months after training consisting of 15 minutes) or a control group consisting of no refresh - Participants performed a 2-minute scenario test 1 year after initial training - Primary outcome was the number of appropriate chest compressions during the 2-minute test period	- Greater number of appropriate chest compressions in the refresher group compared to the control (P = .009) -Short amount of time compressions were not occurring in the refresher group compared to the control ($p <.001$) - No statistical significance in the amount of time to begin compressions and AED use	- Scenario-based - Effects of repetitive training were lacking - No blinded training assignments

Table 24. Research Analyzing the Format of CPR Courses (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Nord et al. (2016)[115]	- Compare practical CPR skills after a 30-min mobile app training versus a 50-min DVD based training	- 1232 seventh grade students (approximately 13 years of age)	- Cluster Randomized trial - Students classes were randomized to either the DVD based education intervention or the app-based intervention - CPR skills were assessed directly after training as well as at 6 months - All participants used an individual training manikin - App-based method students practiced independently using 8 images with related text (took approximately 30 minutes total) - DVD based method the whole class practiced together based on instructions from a 31-minute DVD with an additional 20 minutes of practice (14 cycles of compressions and ventilations were carried out) - Assessment included quantitative data recorded from a Laerdal PC Skill reporting system (compression-ventilation ratio, hand position, compression rate, compression depth, total number of compressions, ventilations and volume, hands-off time and incomplete release) - Skills exam was 3-minutes long -Participants also took a questionnaire with demographics and willingness to act questions - Investigator was blind to the training method of the students	- The DVD group performed significantly better in terms of total score at baseline ($p < .001$) and at 6 months ($p < .001$) - The DVD group performed significantly better in regard to compression/ventilation ratio at baseline ($p< .001$) and at 6 months ($p < .001$), compression depth at baseline 6 months ($P = .031$), total number of compressions at baseline ($p < .001$) and at 6 months ($p < .013$), ventilation volume and total ventilations ($p < .001$), and hands off time at baseline ($p < .001$) and at 6 months ($P= .018$).	- App-based training gave students the opportunity to skip sections if they wanted whereas DVD training was still teacher lead - 30 minutes versus 50 minutes of training - Risk that instructor's enthusiasm and experience affect learning - Young sample age who may understand app/phone-based trainings differently than other age groups

Table 24. Research Analyzing the Format of CPR Courses (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Beniot et al. (2017)[116]	- Determine if participants passively exposed to an ultra-brief video perform CPR better than those unexposed	- 100 participants who were non-patients in an emergency department waiting room - 50 control and 50 experimental in brief video group	- No information about CPR was provided during pre-intervention period - During intervention, an ultra-brief CPR video was on a large TV in the waiting room of the emergency room - Video was slightly longer than one minute and was shown 3-6 times per hour (the average stay of patients in the ED was 6 hours so those in the waiting room had ample opportunity to see the video) - Note the intervention was passive exposure to the video - Demographics regarding prior CPR experience was collected - Participants were then asked what they would do if they saw someone collapse and then performed compression-only CPR with a single research coordinator evaluating their performance - Correct performance was defined as: • Check for responsiveness • Call for help • Begin compressions within 10 seconds • Hand placement • Correct compression rate (90-110 [guidelines stated at least 100 at the time of the study]) • Correct depth (manikin had audible click)	- 20% of exposure to video group performed all actions correctly (compared to 0% of the control) ($p < .001$) - Exposed compression rate occurred in 44% of participants compared to only 22% in the control ($P = .019$) - Compression depth was properly performed in 15% of the exposed group and only 10% of the control ($p= .012$)	- Research coordinator who assessed outcomes was not blinded - No knowledge measurement was taken additionally its unknown if the information gained from the video is retained after a certain amount of time - Research occurred in an emergency department where individuals may be more apt to learning new medical information, or distracted due to a family medical emergency

Table 24. Research Analyzing the Format of CPR Courses (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Lau et al. (2018)[117]	- Evaluate the effectiveness of digital CPR training in improving knowledge and skill compared to traditional CPR training	- 20 randomized control trails	- Data were extracted by two reviewers - The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) system was utilized to assess overall strength of the evidence	- Regarding knowledge scores, digital CPR training showed increases compared to traditional CPR training (P =.04) - When comparing skill performance scores between digital CPR training and traditional training there was no statistical significance (p= .28) - Trainees who underwent digital training had significantly slower compression rates than those who underwent traditional training (p < .001)	- Small sample size - Only included studies in English which may have provided a publication bias - Wide variation in digital training
McCoy et al. (2019)[118]	- Compare the effectiveness of high-fidelity simulation training vs standard manikin training for medical students	- 70 fourth year medical students	- Prospective Randomized study - Simulation group learned CPR via an hour session that included a lecture with training on a high-fidelity simulator - Standard training included a power point lecture with training on a low-fidelity manikin - Primary outcome measures were based on the AHA guidelines of high-quality CPR: • Compression rate • Compression depth • Recoil • CCF	- Sim group students performed CPR more closely adhered to AHA guidelines of compression depth and compression fraction - Mean depth was 4.57cm for the sim group and 3.89cm for the standard training group (P =.02) -CCF in sim group was 0.724 and .0679 (P=.01) - No significance for rate or recoil	- Medical students may have previously encountered high-fidelity simulation - Retention was not studied - Past experience with CPR education and real-life experience were not included

Table 24. Research Analyzing the Format of CPR Courses (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Chien et al. (2020)[119]	- Develop an alternative training format that was comparable to a traditional training in terms of CPR quality and knowledge, but would be more time saving and cost-effective (lay people)	- 832 participants who had not been CPR certified within the last year were divided and randomly assigned to the traditional group or the blended program - 372 in the traditional group attended a one year follow up and 364 in the blended group attended a one year follow up	- Participants underwent a traditional CPR course or a blended program (18 minutes versus 60 minutes) - Traditional learning consisted of a 60-minute CPR knowledge lecture and a 30-minute hands-on session for compression-only CPR - Blended program was an e-learning module (18 minutes) with a 30-minute session of compression only CPR - After training all participants performed CPR and took a knowledge skills exam - Participants returned at 6 months and a year later and retook the exam and skills exam - Knowledge was assessed by a written exam consisting of 15 multiple choice questions - CPR was assessed with examiner rated and manikin feedback (compression depth, rate, chest recoil)	- Results of CPR performance in the blended group were comparable to the traditional group with no significant difference in skills at the initial exam other than in compression depth (mean depth in traditional group was 5.21 cm and in the blended group 5.24 cm P= .0006) - No significant difference in retention of skills between groups	- Selection bias (location of study had mandated areas of AEDs installed) - No demographic data was taken at follow-up, so it was unknown if participants reviewed skills and knowledge for the follow-up exams - Unknown if participants received feedback during their hands-on training

Traditional CPR course formats are being questioned based on the amount of time it takes to train individuals, especially when the potential for high volumes of people being trained in shorter time frames appears to be possible. When comparing the effectiveness of traditional courses to digital courses, Lau et al. and Chien et al. found that there was no significant statistical difference in overall skill performance.[117, 119] Meanwhile, Nord et al. found that the DVD group in their study, which consisted of a 30-minute DVD, paired with 20 minutes of hands-on practice with feedback, performed significantly better than the shorter app-based training group ($P < .001$).[115]

When analyzing specific metrics of CPR, Lau et al. found that the digital group had significantly slower compression rates when compared to the traditional group ($p < .001$).[117] Regarding compression depth, Chien et al. found that the non-traditional group performed compressions deeper than the traditional group ($P =.0006$).[119] McCoy et al. compared the effectiveness of a shortened training paired with high-fidelity equipment to a traditional CPR training and found that similar to Chien et al., compressions were significantly deeper in the non-traditional group when compared to the traditional group ($P= .02$).[118, 119] McCoy et al. also indicated that the non-traditional group performed CPR more closely to the AHA guidelines of compression depth and chest compression fraction when compared to the traditional group.[118] Einspruch et al. concluded that participants in a shortened 30-minute, self-training course performed chest compressions with the correct hand placement more frequently than those who took a traditional heart saver BLS course. Additionally, both the shortened 30-minute training and traditional training groups performed statistically better when compared to a control group with no training. Based on the previously mentioned findings, it is clear that some type of training, or even exposure to CPR training is better than nothing. Yet, clarity has not been determined as to which training method is best for the acquisition of skills to perform high-quality CPR.

A limitation to the studies completed by Lau et al., McCoy et al., and Nord et al., included a lack of demographic data regarding previous training or previous experience with CPR.[115, 117, 118] While Chien et al., excluded participants if they had been CPR certified in the past year, participants' previous experiences with CPR education were not documented.[119] Einspruch et al., excluded participants if they had been trained within the past five years, yet did not differentiate between participants who had any previous training and those who did not.[113] Additionally, the convenience samples from McCoy et al., Nord et al., Beniot et al., and Einspruch et al., make the generalizability of their finding difficult to include in overarching education decisions and changes.[115, 116, 118, 120] For example, Einspruch et al. utilized an older population, while McCoy et al. utilized fourth-year medical students. Therefore, research must continue to determine the most efficient and beneficial way for people to be trained to perform high-quality CPR in accordance with their profession or goal in the training.

Feedback

According to the 2015 CPR guidelines, the key aspect of skill acquisition included deliberate, hands-on practice paired with feedback to improve students' overall skill development. To properly train CPR psychomotor skills, feedback should be given during CPR education skills training sessions. Feedback can be presented in forms such as verbal from an instructor or auditory, i.e., clicking on a manikin. It is well known that any feedback proves beneficial during skill acquisition to improve performance, yet the most beneficial type of feedback, as well as the timing and quantity of feedback, is not conclusive.[2] Options on timing of feedback includes real-time feedback, which occurs during the skill performance as opposed to terminal feedback that occurs at the end of a skills performance. Feedback quantity is for either the whole session or just a specific part of a skills performance. The feedback type, timing, and quantity all potentially play a role in the quality of CPR skills acquisition and subsequent performance. Table 25 highlights associated research with CPR feedback and the associations between traditional training with limited or no feedback and the potential for improved skill development due to feedback.

Table 25. Research Analyzing Feedback and the Quality of CPR Performed

Author	Purpose	Participants	Design	Outcomes	Limitations
Yeung et al. (2014)[85]	- Compare the effect of three CPR feedback devices on quality of chest compression in health care providers	- 101 health care providers who were trained in CPR and able to perform CPR for 2 minutes participated in the study	- Single Blinded randomized control trial - Compared a 1. Pressure sensor/metronome device 2. Accelerometer device 3. a metronome on the quality of chest compressions by trained rescuers - Main outcome measure was compression depth - Secondary measures were rate, proportion of compressions with inadequate depth, incomplete release and satisfaction	- The pressure sensor device significantly improved chest compression depth when compared to baseline (P = .02) - Accelerometer use decreased depth significantly when compared to baseline (P = .04) - Feedback devices all led to compression rates closer to 100 compressions per minute when compared to baseline (pressure sensor P= .001, accelerometer P= .072, and metronome P = .009) - Metronome and accelerometer feedback devices were well received by participants	- Manikin training environment - Health care professionals who may perform CPR often: results may not be applicable to laypeople - Only 2 minutes of CPR was measured
Buleon et al. (2016)[121]	- Determine the impact of a feedback device on chest compression quality	- 60 professional rescuers (physicians, nurses, ambulance personnel)	- Randomized control crossover study - Rescuers were randomized to two groups: feedback and no feedback group - They practice performed 2 sets of 10 minutes of continuous compressions with 4 hours of rest between the sets to reduce fatigue - Feedback was given via the CPRmeter, included data on rate, depth recoil and force	- Feedback group performed compressions at a rate and depth greater than the no feedback group (p< .0001, p <.0001) respectively) - Overall compression quality was greater in the feedback group when compared to the no feedback group (p <.0001)	- Manikin study - Compression sessions were performed in a low stress environment - Utilized health care professionals for population so CPR training had occurred in the past - Did not discuss previous CPR experience

Table 25. Research Analyzing Feedback and the Quality of CPR Performed (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Martin et al. (2013)[122]	- Identify if chest compression quality was improved from real-time feedback	-69 European Pediatric life support CPP certified rescuers	-Intervention included a feedback or no feedback group to perform infant compression only CPR on a manikin using either the two-finger or two- thumb method - Randomized to the feedback or no feedback group and then were randomized to the thumb group or the finger group - Participants performed continuous chest compressions for 60 seconds (baseline), then rested and performed 60 seconds of continuous compressions (experimental) again - Chest compression quality was defined by the proportion of compressions that achieved the targets (rate, depth, release, and duty cycles)	- Overall compression quality in the feedback group was significantly higher than the non-feedback group ($p < .0001$) - Chest compression depth was significantly deeper in the feedback group ($p < .001$) - Chest compression rate was performed too quickly, but resolved with feedback significantly ($p < .001$)	- All participants were already certified in pediatric life support CPR thus results are not generalizable to populations without that certification - Manikin study - Real life experience was not factored into study

Table 25. Research Analyzing Feedback and the Quality of CPR Performed (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Spence et al. (2016)[123]	-Evaluate the effectiveness of video compared to verbal feedback in CPR performances	- 135 final year medical students	- Participants were divided into groups of 4 and further divided into group with video or verbal feedback, and performed rescue scenarios in those groups (feedback as based on group not on individuals) - Groups performed 10 minutes of CPR utilizing the same scenario for all the groups -Group A then received verbal feedback on their performance while group B received video feedback (no verbal) - Participants returned 4 weeks later to preform again - CPR evaluation was completed by a check list tool, highlighting areas performed well and poorly, providing appropriate criticism. Additionally, the video group received video analysis so each group could view their performance objectively with the score associated	- Students who received video feedback has significantly greater improvement in overall score compared to those with verbal feedback (P = .006) - Video feedback group also improved significantly from initial session to return session (P = .004)	- Compression quality was not discussed - Individuals only group were assessed, so it is unknown based on this study the effectiveness of video or verbal feedback on an individual basis - CPR history and experience were not discussed - Retention was discussed yet it was only a 4 week return period

Table 25. Research Analyzing Feedback and the Quality of CPR Performed (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Lin et al. (2018)[124]	- Compare the effectiveness of distributed CPR training with real-time feedback with conventional BLS training for CPR skills in pediatric health care providers	- 87 health care providers (control n=41, intervention n=46)	- Randomized into either an annual BLS training (control group) or distributed training with real-time feedback - Intervention group practiced CPR for 2 minutes while receiving real-time feedback at least one a month - Control group was asked to not practice CPR during the study period - Excellent CPR was defined at 90% guideline-compliant for compression rate, depth, and recoil - CPR performance occurred every 3 months for the duration of the 12-month period (compared between groups)	- At 12 months the intervention group was superior for overall CPR (p<.001) - Intervention group superior for compression depth (P=.003) - Intervention group superior for compression rate (P= .003) - Intervention group superior for compression recoil (P=.002) - Intervention group significantly improved at 3 months for all compression metrics (depth, p < .001; rate p < .001; and recoil, p < .001)	- Only two minutes of CPR was performed - Testing effect from being tested every 3 months - No ventilations were measured
Akuzkui et al. (2019)[125]	- Clarify the influence of feedback frequency and timing on CPR skills	- 68 first year college students in the department of health sciences	- Participants were randomized to one of four groups for each sex: concurrent - 100%, concurrent-50%, terminal-100% and terminal 50% feedback groups - Study consisted of instruction using DVD and then a pre-test, practice session with assigned feedback, post-test (24 hours after practice session) and a follow-up test (3 months after practice session) -Practice sessions consisted of six 2-minute CPR sessions in accordance with the group they were assigned using manikins and feedback devices - Terminal feedback was provided at the conclusion of the session and concurrent was during the session - 100% was for the entirety of the session and 50% was for only half of the session	- No statistically significance for overall score at follow-up between the four groups (P = .173) - Concurrent feedback was statistically significantly superior to terminal condition for sessions 1 (p < .001), 2 (p < .001) 4 (P= .01) and 5 (P=.036) for overall score - Regarding overall compression score ANOVA indicated a significant effect of feedback timing (p < 0.001) and feedback frequency (P = .035) with concurrent feedback being superior to terminal - For overall ventilation score concurrent feedback was superior to terminal (P= .002)	- Short duration of CPR performed (only 2 minutes per session) - Short follow up time frame (only 3 months)

While a key focus to the current CPR guidelines includes feedback, the guidelines are limited in clarifying the type and frequency of feedback that should be given to those participating in CPR education and psychomotor skills trainings. Based on published literature, it is clear that feedback does improve the quality of CPR skills. When further analyzed, data suggests that real-time feedback is the most significant when compared to alternative types of feedback such as verbal or no feedback at all. When comparing groups who received real-time video feedback to groups with no feedback, the feedback groups performed CPR significantly better.

Buleon et al. found that the compression rate and depth were both performed significantly better than the no feedback group ($p < .0001$ and $p < .0001$, respectively).[121] Additionally, overall compression quality was significantly greater in the feedback group compared to the no feedback group ($p < .0001$). These findings were concurrent with previous findings from Martin et al. who stated that overall compression quality for pediatric CPR was significantly higher in the feedback group compared to the no feedback group ($p < .0001$).[122] Findings from Lin et al. also were similar in that in the feedback group, stating that overall CPR was superior when compared to the control ($p < .001$).[124]

A limitation of the previously discussed studies was that they were all low stress scenario, manikin studies, which may not translate to high quality CPR in real life. Also, participants in all of the previously mentioned studies were health care providers who not only had been previously trained in CPR, but also may have used high fidelity, real-time feedback scenarios. It should be reiterated that inclusion of allied health care providers limits the ability to generalize the findings to non-health care providers. Regarding frequency and timing of feedback, Akuzkui et al. found that concurrent feedback was statistically superior to terminal feedback for overall CPR score. Also, concerning frequency, Akuzkui et al.'s findings indicate that the 100% feedback condition (mean: 92.0%, 95% CI: 89.8–94.1) was superior to the 50% feedback condition.[125] Similar to Lin et al., participants only performed two minutes of CPR. Thus, longer performances need to be evaluated to determine the effectiveness of feedback frequency and timing. Overall, findings indicate the provision of real-time feedback throughout the entire CPR education experience provides the opportunity for increased quality of overall CPR skill performance. Research should continue to deduce optimal feedback formats for populations outside of medical professionals.

Recertification and Retention

Throughout the years, CPR education has had a renewed focus regarding psychomotor skills acquisition and subsequent retention. The 2015 guidelines education section discusses how when examining retention of skills, there is a decline in CPR performance from initial training, especially when there is the absence of retraining. Additionally, the 2015 CPR guidelines education section questions the two-year recertification time frame by stating that it may be reasonable for training to be completed more often by individuals who are more likely to encounter a cardiac arrest scenario, such as health care providers. Moreover, the education guidelines focus more attention to promoting CPR education scenarios regarding adequate timing and duration to create an environment best suited for learning.[83] Currently, CPR certification is valid for two years, indicating that an individual should be able to perform CPR adequately the day after they were initially trained or the day before their certification expires. However, research indicates that CPR psychomotor skills decline within six months from the initial training.[3] Table 26 highlights appropriate research and findings supporting additional trainings during the two-year certification to improve CPR psychomotor skill retention.

Table 26. Research Analyzing Recertification Period and Retention for CPR Psychomotor Skills

Author	Purpose	Participants	Design	Outcomes	Limitations
Oermann et al. (2011)[126]	-Examined the effects of brief monthly practice on CPR psychomotor skills performance	-606 nursing students	- Students complete either a Heart code BLS or instructor-led course and then were randomly assigned to an intervention group practice schedule - Intervention group consisted of a month practice for 6 minutes a month - Control group consisted of no practice after initial training - Retest every 3 months - Outcome measures were compression rate, depth, percent of compressions with adequate depth, hand placement, ventilation rate and volume	- Control group had significant loss in compression depth between 9 and 12 months (P =.004) while practice group maintained adequate compression depth over the 12-month period - Mean compression rate was significantly higher in the control when compared to the experimental group at baseline (P= .0009) but mean compression rate increased with training significantly (p <.0001) - At the final test there was no significance between groups for compression rate (P=.98)	- Student volunteers with a motivation to learn - High rate of attrition

Table 26. Research Analyzing Recertification Period and Retention for CPR Psychomotor Skills (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Mpotos et al. (2014)[127]	- Investigate if repetitive sessions of formative self-testing results in skill levels comparable to formative self-testing with additional practice	- 196 third year medical students	- Medical students were randomized to the self-testing group or the self-testing with additional practice group in a self-learning station -Practice sessions included chest compression depth, release, rate and ventilation volume recorded with feedback - At the beginning of the session participants were asked to resuscitate a victim for two minutes with the previously mentioned metrics recorded -To be considered competent students had to achieve a 70% assessment score - They were also provided feedback on the screen with suggestions on how to improve in the future - In the additional practice group, student were shown their previous results and feedback and then were given the option to re-test or practice for up to 30 minutes with voice assisted manikin practice, prior to re-testing - All students were expected to achieve competence within 6 weeks using as many sessions as it required - Testing occurred again at the 6-month mark	- At 6 weeks the success rate in both groups was 96% - At 6 months there was not statistical significance, but results indicated that the group with additional practice retained skills better than just the self-test group for compression rate	- Amount of time in self-learning was unknown, the test itself only lasted 2 minutes but could be repeated as often as a student liked -Sample size may have contributed to the statistical insignificance at the 6-month retention mark

Table 26. Research Analyzing Recertification Period and Retention for CPR Psychomotor Skills (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Nishiyama et al. (2015)[114]	-Evaluate the long-term effectiveness of a 15-minute refresher BLS training following a 45-minute chest compression-only CPR training	-112 participants from a university setting	- All participants partook in the 45-minute chest compression-only CLS training which consisted of an instructional DVD, and a compact personal resuscitation manikin which provided auditory feedback for adequate chest compression depth - Participants were randomized into the 15-minute refresher group which was given 6 months after the initial training - Refresher training consisted of 1 minute of overview, emergency call and cardiac arrest recognition, 5 minutes of chest compressions, 5 minutes of AED use and a question ending -Testing occurred again after 1 year where 2-minutes of compression-only CPR occurred -Primary outcome measure was the number of appropriate compressions -Secondary outcomes included the number of total compressions, proportion of appropriate chest compressions and time without chest compressions, and AED information	-The refresher group showed statistical significance in calling for an AED when compared to the control (P=.027) - For total number of chest compressions, the refresher group showed statistical significance when compared to the control ($p<.001$) -The number of appropriate chest compressions was greater in the refresher group at one year when compared to the control ($p < .001$) - Time without chest compressions was significantly shorter in the refresher training group ($p< .001$)	- Short bout of CPR was performed - No blinded training assignment -Demographic data regarding additional CPR courses or training was not analyzed
Au et al. (2019)[3]	-Evaluate the literature on interventions that improve skill retention following CPR training for health care professionals	-16 studies with a total of 1192 participants were included in the final analysis	-Literature search utilizing the words/phrases: CPR, resuscitation, advanced cardiac life support, basic life support, advanced trauma life support, learning, education, retention, memory, skill retention, and task performance - Studies that included a randomized controlled design, investigated skill retention in healthcare professionals, and reported skill outcomes were included	-Skill retention at 6 months was the most used endpoint -Psychomotor skills decay rapidly between 3-6 months after initial training -Simulation with debriefing seemed to improve skill retention at the 5-month mark -Booster sessions indicate that skill improvement is possible	-Time intervals and metrics used to determine skill retention varied - Different guidelines were utilized throughout the studies thus retention of quality skills was difficult to determine

Table 26. Research Analyzing Recertification Period and Retention for CPR Psychomotor Skills (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Anderson et al. (2019)[128]	- Determine the training interval associated with the highest quality CPR performance at one year	- 167 nurses who worked in an ICU, operating room, emergency room or surgical ward	- Participants were randomized to a 1-month, 3-month, 6-month and 12-month training interval over the 12-month study - Practice sessions included 2-minjute CPR sessions with visual feedback from the manikin and verbal coaching until excellent CPR was achieved - Excellent CPR was defined as at least 90% of session was compressions, a depth of 50-6-mm, a compression rate of 100-120 per minute and complete chest recoil -All participants were assessed at the 12-month mark with the primary outcome being the number of participants who achieved an excellent score per group - Assessments were comprised of two-minutes of CPR with no feedback	-Participants who were trained monthly had a significantly higher proportion of excellent CPR performance compared to the 3-month group (P=.008), the 6-month group (P=.002), and the 12-month group (P < .001).	- Fixed physical environment which may not translate to a realistic clinical environment - Large dropout rate in monthly training group -Did not include analysis of how many times a participant was involved in the management of a cardiac emergency during the study - Cost-effectiveness was not analyzed for monthly training but should be considered

Table 26. Research Analyzing Recertification Period and Retention for CPR Psychomotor Skills (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Oermann et al. (2020)[129]	-Compare nursing students CPR skills with 4-different spaced training intervals (daily, weekly, monthly and quarterly)	- 475 nursing students in the first year of their program who had already been trained in BLS	- Students were randomly assigned to one of the four training intervals, with outcome measures of compression quality and ventilations measured on the resuscitation quality improvement station software on a Laerdal Resusci Anne manikin - Baseline data was taken by having students perform 60 compressions and 12 BVM ventilations with no feedback (this test occurred at the beginning of every training session as well) - Training sessions were not focused on CPR sequence but on CPR compression and ventilation quality -Participants watched a brief video that reviewed key points of technique and reviewed a card at the testing station. - Participants then performed 60 compressions and 12 BVM ventilations with real-time feedback -They then rested for 4-10 minutes and retested with no feedback -The video, card, and testing + practice process was the same for daily, weekly, monthly and quarterly practice and testing	- Overall compression score showed significant difference between pretest scores between daily and quarterly training ($P = .044$) - Pretest scores for the percentage of compressions with adequate depth increased significantly from session 1 to 4 for all training intervals - For ventilations with adequate volume significant differences between the daily and quarterly practices ($P = .020$), and weekly and quarterly sessions ($P = .012$) occurred - In students who had daily training overall ventilation score increased from pretest in session one by session 4 ($P < .001$)	- Authors stated that 47 of the students had additional CPR training during the study that was not included in the analysis - Participants only performed 60 compressions and 12 ventilations and not in a simulated event - Learning effect may have taken place -Retention at 1 year was not analyzed

With the two-year CPR certification period in question, it is vital to understand the retention of CPR psychomotor skills and factors that could increase retention. Cardiopulmonary psychomotor skills decay rapidly at the six-month mark after initial training, and literature supports the addition on booster sessions to slow the decay of skills.[3] Multiple studies have analyzed the effect of intermittent training intervals throughout the two-year certification time frame to understand whether the quality of CPR psychomotor skills are retained or improved. Findings from Anderson et al. indicate that monthly skill trainings produced a significantly higher proportion of excellent CPR performance at a year when compared to those who had trainings every three months, six months and a single refresher at 12 months ($p = .008$, $p = .002$, and $p < .001$, respectively).[128] Similarly, Oermann et al. provided an intervention of six minutes of practice every month for a group of nursing students and compared their psychomotor skills to a control group who had no practice after initial training. Results from Oermann et al. suggested that the control group had significant loss in compression depth between nine and 12 months ($P = .004$) while the practice group maintained adequate depth over the 12-month period. Additionally, mean compression rate increased significantly in the training group from the initial test session to the final 12-month session ($p < .0001$).[126] Meanwhile, Mpotos et al. also had an intervention of practice sessions with feedback to achieve CPR competence. Their findings were intriguing because at the six-month interval, there was not statistical significance between the control and the practice group. Authors stated that although results were not statistically significant, the group with additional practice retained skills related to compression rate better than those who did not practice.

There are some limitations to the studies completed by Oermann et al., Mpotos et al., and Anderson et al. All CPR test sessions occurred for only two minutes, which is not a realistic time frame for CPR. Also, the participants in the studies were medical professionals or students who may have a high motivation to learn and may have already been CPR certified multiple times.[126-128] Overall, the research supports adding psychomotor booster skills sessions throughout the two-year certification period to ensure rescuers can perform high-quality CPR. However, data regarding retention levels past twelve months with additional trainings is sparse. More research should occur regarding optimal training and skill practice sessions to determine psychomotor skill retention past one year, especially if the CPR certification remains valid for two years.

<u>Deliberate Practice</u>

In the 2015 guidelines education section, a core AHA emergency cardiovascular care concept is practice to mastery. In this section, the guidelines state, "learners should have opportunities for repetitive performance of key skills coupled with rigorous assessment and informative feedback in a controlled setting. This deliberate practice should be based on clearly defined objectives and not time spent, to promote student development toward mastery."[83(p.563)] Deliberate practice is defined by Macnamara and team as structured activities created specifically to improve performance in a specific domain.[14] Macnamara et al. derived this definition from psychologist K. Anders Ericsson. Ericsson's professional contributions included the study of expert performance and provided further knowledge in the domain of deliberate practice. Deliberate practice was explained as repetitive performance of the intended skills, paired with a skills assessment and subsequent feedback resulting in improved practice. Ideas in the sphere of deliberate practice changes the old saying of "practice makes perfect," to "perfect practice makes perfect" instead.[15]

In the realm of CPR education, deliberate practice would be ensuring that CPR scenarios are as similar to what a real CPR experience would be like for a rescuer. This not only includes quality aspects of CPR but factors such as the manikins that are used, the scenario script, and potential changes in the surface in which CPR performance may occur. For example, a scenario in which a rescuer provides CPR for only two minutes is not realistic to what they would do in a real cardiac emergency. Thus, they should practice similar to how they would perform so that the acquired psychomotor skills can be properly performed no matter the environment. Table 27 summarizes research regarding deliberate practice in CPR education and the potential effects associated.

Table 27. Research Analyzing Deliberate Practice in CPR Education

Author	Purpose	Participants	Design	Outcomes	Limitations
Oermann et al. (2011)[126]	-Examined the effects of brief monthly practice on CPR psychomotor skills performance	-606 nursing students	- Students complete either a Heart code BLS or instructor-led course and then were randomly assigned to an intervention group practice schedule - Intervention group consisted of a month practice for 6 minutes a month - Control group consisted of no practice after initial training - Retest every 3 months - Outcome measures were compression rate, depth, percent of compressions with adequate depth, hand placement, ventilation rate and volume	- Control group had significant loss in compression depth between 9 and 12 months (p =.004) while practice group maintained adequate compression depth over the 12-month period - Mean compression rate was significantly higher in the control when compared to the experimental group at baseline (p= .0009) but mean compression rate increased with training significantly (p <.0001) - At the final test there was no significance between groups for compression rate (P=.98)	- Student volunteers with a motivation to learn - High rate of attrition
Sawyer et al. (2011)[130]	- Evaluate the effectiveness of deliberate practice using simulation on improving neonatal resuscitation	- 30 pediatric and family medicine residents (15 teams of 2)	-Pre-test/Post-test design - Participants were randomly paired into 15 teams of 2 - Each team completed a series of three standardized neonatal resuscitation simulations followed by a debriefing session that was facilitated - Simulation scenarios were based on previously published neonatal codes and followed a pattern of increasing difficulty - Debriefing sessions were timed and limited to 20 minutes	- First year residents scored lowest on pre-test and experienced the largest improvement in post test scores (17.6% increase), but they were not statistically significant - Post test scores indicated statistically increases in positive-pressure ventilations (P =.043) and overall neonatal resuscitation performance (P= .024)	- No control group - Higher than expected baseline performance - Scoring instrument included the elements of decision making and was not just based on skills

Table 27. Research Analyzing Deliberate Practice in CPR Education (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Lin et al. (2018)[124]	- Compare the effectiveness of distributed CPR training with real-time feedback to conventional BLS training	- 87 health care providers	-Healthcare providers were randomized into a control group that receiving annual BLS training (no real-time feedback but instructor evaluation) or the intervention group which distributed training with feedback - Feedback in the intervention group included chest compression rate, depth, and recoil -Practice consisted of chest compressions for 2 minutes with real-time feedback at least once a month - Assessment occurred for both control and intervention at 3 months during the study period (final assessment at 12 months) - Outcome measure was excellent CPR which was meeting at least 90% of AHA standards for chest compression rate, depth and recoil	- Baseline assessment showed no difference in CPR between the groups - Intervention group significantly improved at the 3-month mark for compression assessment ($p < .001$), rate ($p < .001$) and recoil ($P = .002$) - Intervention group performance was retained over the course of the study and control group skills decayed at the 3-month assessment 9 ($P = .03$)	- 2-minutes of CPR was performed with no distraction -potential testing effect with assessment every three months - Participants were mainly female nurses in an emergency department with active simulation which may influence the generalizability

Table 27. Research Analyzing Deliberate Practice in CPR Education (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Bhalala et al. (2019)[131]	- Determine if rapid cycle deliberate practice is superior to the conventional video debriefing for improving hands-on CPR skills	- 120 pediatric providers participated	- Prospective randomized interventional study comparing two methods, rapid cycle deliberate practice and video debriefing of hands-on skill training (60 participants in each group) - True CPR device which captured compression depth, rate and fraction was used with the rapid cycle deliberate practice additionally they were coached to improved hands on CPR skills - Video debrief went over their recorded scenario to learn and change CPR skills - End points were chest compression quality, time to defib, and confidence levels	- Rapid cycle deliberate practice group had a greater improvement in chest compression depth compared to baseline ($p < .0001$) - Rapid cycle deliberate practice did not appear to be superior or inferior to video debrief for improving chest compression rate, fraction time to shock or confidence levels	- Examined providers who were previously trained in CPR - 83% of providers had experiences with defibrillation in real or simulated scenarios

Table 27. Research Analyzing Deliberate Practice in CPR Education (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Diederich et al. (2019)[132]	- Identify if manipulated hands-on practice versus reflective debriefing for CPR skills supported learning task work or teamwork better	- 131 first year residents who held a current AHA BLS certification	- Randomized comparison trial with pre and post-test design - Participants were split into teams of 5 to 6 learners and were randomized to either drill or scrimmage type of 2-hour training - Teams were told the learning objectives (provide high-quality CPR and work as a coordinated team) -Pretest occurred and then training and lastly post test - Drill training consisted of three 25-minute stations representing the phases of CPR (first response, initial role assignment, and compression quality) - Hands on time for practice was approximately 60 minutes - Scrimmage training began with a debrief after the pretest and then they completed 3 full scenarios each with a unique case. After each scenario the team debriefed with two facilitators, total hands on time was approximately 18 minutes with 50 minutes of debrief	- Both drill and scrimmage teams improved from pre-test significantly for average compression quality (P=.01) and percent correct depth of compressions (P=.01) - No significant difference between groups except in the use of compression adjuncts (i.e., utilizing a step stool, lowering the bed or using a backboard) the drill team was favored in this compared to the scrimmage team (P=.03)	- Teams not individuals were analyzed - Participants already held a CPR certification and may have already had deliberate practice within their education - There was no control group of individuals who held a traditional BLS certification and did not undergo an intervention

Cardiopulmonary resuscitation education should include deliberate practice by ensuring participants practice psychomotor skills in scenarios similar to a cardiac arrest scenario. Unfortunately, simulation of CPR scenarios is difficult to create because cardiac emergencies do not discriminate based on what rescuers are possibly ready for. Additionally, deliberate practice can be defined as instructor-led debriefing after practice sessions such that rescuers can adjust their performance. When analyzing whether deliberate practice simulation and debriefing sessions were effective in resuscitation, Sawyer et al. found that post-test scores for overall resuscitation performance significantly increased when compared to participants baseline scores ($p = .024$).[130] Similarly, the intervention group, which consisted of real-time feedback with practice at least once a month during the study duration, significantly improved at the three-month mark for compression assessment when compared to the control group who received no real-time feedback ($p < .001$), rate ($p < .001$) and recoil ($p = .002$) in Lin et al.'s study.[124] A limitation to Lin et al. and Sawyer et al.'s studies include participants who had previous experience with CPR and CPR education, thus their baseline scores may have been higher than expected. Additionally, test scenarios were controlled and calm, which is often not the case in a realistic CPR situation.

With a focus on the debriefing part of deliberate practice, Bhalala et al. and Diederich et al. examined health care providers who had been previously CPR certified. Bhalala et al. found that while the deliberate practice group had greater improvements in chest compression depth compared to baseline ($p = .0001$), the overall mean scores of chest compression rate, fraction and time to shock were consistent with the video-debrief group.[131] Unfortunately, in Diederich et al.'s study, all participants worked in teams, so individual analytics of CPR were not analyzed. Based on team scores, there was no significant difference between the groups who had manipulated hands-on practice as a team or reflective team debriefing.[132] Findings from both studies indicate that a combination of interventions, such as deliberate, manipulated hands-on practice paired with debriefings as an individual or as a rescue team is beneficial in CPR performance. The lack of control group with a simple BLS certification from a traditional CPR course in both studies makes it difficult to project findings that are conclusive for education changes.[131, 132] Yet, with the knowledge that deliberate practice does not create an environment where skills are inferior compared to baseline, education design and practices should include deliberate practice scenarios paired with feedback and debriefing sessions.

Fidelity in CPR Education

The 2015 AHA guidelines for CPR education section includes an updated section regarding manikin fidelity. The guidelines state that the use of high-fidelity manikins can encourage learners to engage more, thereby creating the opportunity for students to become fully submerged in the experiential learning environment.[83] Prior to the distinction between high- and low-fidelity equipment for medical simulation, Schoenherr and Hamstra explain that fidelity was defined in lesser words as the extent to which a simulator resembles the task of equipment in context.[13] Currently there are difficulties in clearly defining high- and low- fidelity simulators, and yet in the context of CPR, a high-fidelity manikin is described by the AHA as a manikin with the ability to provide physical findings. Physical findings include heart sounds, breath sounds, pulses, chest rise and fall, blinking eyes, and the potential for vital signs to coincide with physical findings and treatments.[83] Schoenherr and Hamstra also explain that low-fidelity models are considered, in the case of CPR education, as manikins with limited physical similarity to the training environment to develop a basic understanding of the potential clinical environment. For example, a manikin for compressions that give no or limited feedback regarding performance would be considered low-fidelity (no clicking noises, and no visual feedback).[13] Previously in CPR education, the distinction between low- and high-fidelity manikins and simulation was not in question, but currently, the 2015 AHA guidelines encourage the use of high-fidelity equipment to ensure the highest potential for the acquisition of high-quality CPR knowledge and psychomotor skills.[133]

Low- and Medium-Fidelity

When discussing the use of low- and medium-fidelity equipment for CPR education, the distinction between the two is rather difficult based on current literature. The most descript delineations of low-fidelity is by Schoenherr and Hamstra who state that low-fidelity models contain limited physical similarity to the training environment. These simulators are to ensure a basic understanding of the clinical environment. Low-fidelity simulation does not provide quality feedback nor life-like simulations in CPR practice. Low- and medium-fidelity manikins are much more cost effective for training when compared to high-fidelity.[13] The 2015 CPR guidelines education update discusses that although high-fidelity manikins are beneficial for improving CPR skills performance at the conclusion of courses, it is unknown if the increased cost is realistic for all training due to the uncertainty of skill performance in the long term.[83] Table 28 encompasses associated research regarding low- and medium-fidelity manikins and CPR education.

Table 28. Research Analyzing Low- and Medium-fidelity Manikins in CPR Education

Author	Purpose	Participants	Design	Outcomes	Limitations
Hoadley (2009)[134]	- Determine if ACLS course participants using high-fidelity simulation were more satisfied with design and learning, and tested higher than those who were in an ACLS course with low-fidelity simulation	- 53 participants who were health care providers who held advance practice or specialty certification	- Participants completed an ACLS pretest and demographic survey and participated in an interactive learning session with ACLS instructors - Participants who were in the low-fidelity group were verbally told all the information required to resuscitate the manikin while participants in the high-fidelity group gathered the assessment data directly from the high-fidelity manikin - The second part of the course included participants actively practicing skills in a station format and were tested in adult CPR skills - The third part of the study included participants completing the mega-code skills test and written ACLS posttest - If they did not past the post-test remediation and further assessment was required	- Pre-test scores showed no significance between groups - Post-test scores for knowledge also were not significant between groups (P =.26) - Findings show a positive correlation between enhanced practice and learning but not a significant correlation between pre- and post-test skills	- Instructor and manikin to manikin ratio was 6:1 which does not provide time to much hands-on practice with high-fidelity equipment - CPR metric quality was not assessed - Nursing students who had advanced practice or specialty certifications were sampled, which may have contributed to lack of significance in findings

Table 28. Research Analyzing Low- and Medium-fidelity Manikins in CPR Education (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Yeung et al. (2014)[85]	- Compare the effect of three CPR feedback devices on quality of chest compression in health care providers	- 101 health care providers who were trained in CPR and able to perform CPR for 2 minutes participated in the study	- Single Blinded randomized control trial - Compared a 1. Pressure sensor/metronome device 2. Accelerometer device and 3. a metronome on the quality of chest compressions by trained rescuers - Main outcome measure was compression depth - Secondary measures were rate, proportion of compressions with inadequate depth, incomplete release, and satisfaction	- The pressure sensor device significantly improved chest compression depth when compared to baseline (P = .02). - Accelerometer use decreased depth significantly when compared to baseline (P =.04) - Feedback devices all led to compression rates closer to 100 compressions per minute when compared to baseline (pressure sensor P = .001, accelerometer P = .072, and metronome P = .009). - Metronome and accelerometer feedback devices were well received by participants	- Manikin training environment - Health care professionals who may perform CPR often: results may not be applicable to laypeople - Only 2 minutes of CPR was measured
Adams et al (2015)[135]	- Examine the ability of novice learners to learn selected aspects of ACLS in training conditions that did not incorporate simulation compared to those that contained low- and high-fidelity simulation	- 39 medical students and physician assistant students	- Randomly assigned to one of four training conditions: control (lecture only), video-based didactic instruction, low fidelity instruction and lastly high-fidelity instruction - Participants were assessed using a baseline pretest of ACLS knowledge - Next they all received a lecture outlining ACLS science and correct algorithm - They then trained according to their assigned group and were assessed via Mega code and a written exam	- All groups performed better on the post-test when compared to their pretest ($p < .001$) - Video-based, low- and high-fidelity simulation groups significantly outperformed the control group (P = .028, _ < .001, and P =.019, respectively) -No groups outperformed any other on written post-test (knowledge)	- No CPR psychomotor skills specific to CPR metrics were completed - Small sample per group - Did not include previous ACLS knowledge prior to training even if participants were considered novice - Did not control self-directed learning

Table 28. Research Analyzing Low- and Medium-fidelity Manikins in CPR Education (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Buleon et al. (2016)[121]	- Determine the impact of a feedback device on chest compression quality	- 60 professional rescuers (physicians, nurses, ambulance personnel)	- Randomized control crossover study - Rescuers were randomized to two groups: feedback and no feedback group - They practice performed 2 sets of 10 minutes of continuous compressions with 4 hours of rest between the sets to reduce fatigue - Feedback was given via the CPR meter, included data on rate, depth recoil and force	- Feedback group performed compressions at a rate and depth greater than the no feedback group ($p < .0001$, $p < .0001$) respectively) - Overall compression quality was greater in the feedback group when compared to the no feedback group ($p < .0001$)	- manikin study - Compression sessions were performed in a low stress environment - Utilized health care professionals for population so CPR training had occurred in the past - Did not discuss previous CPR experience
Girish et al. (2018)[136]	- Measure the adequacy of chest compression depth after training on low-fidelity manikins	- 72 first year post-grad students who had not previously undergone BLS training	- Students took a pre-test for skills and knowledge and then underwent a BLS workshop (AHA) which utilized low-fidelity manikins for training. -Proficiency was assessed with a written test and practice evaluation of 5 cycles of chest compressions (2 minutes) on a high-fidelity manikin which recorded quality aspects of CPR	- Statistical significance in pre- and post-test learning ($p < .0000001$) - No participants performed compressions with adequate depth - Only 40% of participants performed compressions with the optimal rate	- Participants were from the same institution preventing generalization of results - No comparison to a control group or a different experimental group (high-fidelity)

Low- and medium-fidelity manikins are often utilized in BLS education, yet the 2015 AHA CPR guidelines emphasize the use of high-fidelity equipment. When analyzing the success of low- and medium-manikins, it appears that knowledge acquisition is similar when compared to the use of high-fidelity manikins. Adams et al., Hoadley utilized a pre-test/post-test design in health care students who had previous CPR education experiences while Girish et al.'s sample included students who had no previous CPR training. All researchers found that the post-test scores for knowledge in the groups who had low-fidelity simulation were not more nor less significant compared to high-fidelity.[134-136] Contrary when compared to the control, Girish et al. and Adams et al. found that the low-fidelity group had statistical significance in their knowledge tests after training ($p < .0000001$ and $p < .001$, respectively).[135, 136] Limitations from Adams et al. and Hoadley include the use of participants who had previous CPR training. The baseline knowledge scores and skill performances were most likely higher than the standard baseline that would be expected when comparing a control group and an intervention group. Additionally, the lack of significance in findings could contribute to the previous CPR education and medical specialties participants participated.[134, 135]

Regarding skill performance, results indicate positive correlations between low- or medium fidelity manikins but not statistical significance. Adams et al. found that a video-based simulation group, low-fidelity group, and high-fidelity group all outperformed the control group in overall CPR skills ($P = .028$, $< .001$, and $P =.019$, respectively). Unfortunately, studies that evaluated CPR psychomotor skills did not measure all the specific psychomotor skills such as compression rate, depth, chest leaning and recoil or ventilation data, but rather limited skills or group skills to an overall performance score. Buelon et al. and Grist et al. both found that compression depth was performed poorly in both control and intervention groups. Findings from

Buelon et al. indicated that those who received limited feedback during CPR training with low-fidelity equipment performed compression depth significantly better than a baseline group, but still did not meet the guideline recommendation ($p < .0001$).[121, 136] Of course practicing specific CPR psychomotor skills on any manikin regardless of fidelity should assist in acquiring psychomotor skills, but the quality of the skills acquired from training on low- or medium-fidelity manikins may not be as great as what an individual may gain from training on a high-fidelity manikin. When comparing low- and medium-fidelity trainings to a control group, overall CPR skills are generally better, yet findings are not clear on if the quality of the acquired skills are enough regarding the performance of high-quality CPR outside of a structured CPR course.

High Fidelity

Concerning medical education, high-fidelity manikins and simulation are utilized to encourage learners to fully engage in the deliberate practice that is presented. According to the 2015 CPR guidelines education update, high-fidelity manikins demonstrate functions of physical findings such as heart and lung/breath sounds, pulses, chest rise and fall, and vital signs that correlate with physical findings. Additionally, high-fidelity manikins are often paired with computerized feedback devices, which provide individuals with real-time feedback to ensure proper psychomotor skills are acquired. As previously mentioned, high-fidelity manikins have a high cost associated with them. Thus, the 2015 CPR AHA guidelines education section discusses implementing high-fidelity equipment in programs where existing resources are in place, such as medical training programs. Meanwhile, the guidelines recognize that there is limited data suggesting high-fidelity equipment provides long term retention of CPR psychomotor skills. The initial benefit of improved skills after training is apparent, but more research must be completed analyzing long term benefits of high-fidelity manikins in CPR education.[83] Table 29 highlights research that explores the use of high-fidelity equipment in CPR education along with the benefits and disadvantages of utilizing the equipment.

Table 29. Research Analyzing High-fidelity Manikins in CPR Education

Author	Purpose	Participants	Design	Outcomes	Limitations
Hoadley (2009)[134]	- Determine if ACLS course participants using high-fidelity simulation were more satisfied with design and learning, and tested higher than those who were in an ACLS course with low-fidelity simulation	- 53 participants who were health care providers who held advance practice or specialty certification	- Participants completed an ACLS pretest and demographic survey and participated in an interactive learning session with ACLS instructors - Participants who were in the low-fidelity group were verbally told all the information required to resuscitate the manikin while participants in the high-fidelity group gathered the assessment data directly from the high-fidelity manikin - The second part of the course included participants actively practicing skills in a station format and were tested in adult CPR skills - The third part of the study included participants completing the mega-code skills test and written ACLS posttest - If they did not past the post-test remediation and further assessment was required	- Pre-test scores showed no significance between groups - Post-test scores for knowledge also were not significant between groups ($p = .26$) - Findings show a positive correlation between enhanced practice and learning but not a significant correlation between pre- and post-test skills	- Instructor and manikin to manikin ratio was 6:1 which does not provide time to much hands-on practice with high-fidelity equipment - CPR metric quality was not assessed - Nursing students who had advanced practice or specialty certifications were sampled, which may have contributed to lack of significance in findings

Table 29. Research Analyzing High-fidelity Manikins in CPR Education (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Rodgers et al. (2009)[137]	- Examine high-fidelity versus low-fidelity simulation in an AHA ACLS course to determine educational outcomes via rating of a cardiac arrest simulation	- 34 nursing students divided in either a high-fidelity simulated course (n =17) or low fidelity course (n = 20)	- Pre-test was administered to both groups from a written evaluation, with statistical significance indicating the low fidelity group had more knowledge at the beginning of the course (p =0.005) -Both courses were identical with teaching and content (AHA ALCS course), with the independent variable being the use of high-fidelity equipment versus low-fidelity equipment - High fidelity equipment features included palpable pulses, chest excursion on breathing and a generated voice, these features were turned off to create a low-fidelity manikin - High fidelity also gave feedback that was utilized in the debrief after a skills session - 3 experts rated and scored each subject using a ACLS Mega Code Performance Score Sheet	-Both groups improved cognitive knowledge from the pre-test (P =.000), and the high-fidelity cognitive knowledge improved significantly when compared to the low fidelity group (p = .002) - When analyzing initial ECG rhythm there was significance in the high-fidelity group (p=.048), and when the rhythm changed there was significance in the high-fidelity group by recognizing the change (p =.013) - The high-fidelity group demonstrated a statistically significant change in their confidence as well as their apparent knowledge (p= .006 and p = .005 respectively)	- Specific aspects of CPR were not analyzed such as chest compression metrics - Small sample

Table 29. Research Analyzing High-fidelity Manikins in CPR Education (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Davis et al (2013)[138]	- Determine if a high-fidelity simulation technique compared with lecture only would provide greater improvement in ACLS knowledge, confidence and satisfaction	- 149 Pharm D students	- Students were randomized into two groups: teaching and then hands-on high-fidelity sim, or high-fidelity sim first and then teaching -Classroom lecture was a 50-minute, passive lecture on ACLS pharmacotherapy -Simulation was a 30-minute exercise using a high-fidelity simulator for the following: code team leader, medication prep, medication administration, airway management, and circulation - Debriefing with a faculty member who monitored simulations occurred - Written examination consisted of 13 knowledge-based questions was taken and 2 Likert-scale questions regarding confidence was included and was completed before and after the intervention	- Test scores improved significantly from baseline in all groups (p=.114), but was highest when lecture was followed by simulation (p = .003)	- Passing grades were analyzed, not specific skills - No retention of knowledge was tested - Specific CPR psychomotor skills were not analyzed
Langdorf et al. (2014)[139]	- Evaluate the effectiveness of an expanded ACLS course using high-fidelity simulation	- 19 late fourth year medical students participated in the study	- Pre/Post design - ACLS course was held over a 4-day period with pretest scenarios occurring prior to the start of the course and then a re-test at the end of the course - 12 hours of didactics, 8 hours of simulation, 8 hours of self-study, 4 hours of practical and written testing - To assess ACLS skills, participants directed a high-fidelity simulation scenario of a patient with multiple issues (cardiac arrest, advanced airway placement, ROSC, hypotension etc.). Participants were awarded ROSC if they began near-continuous CPR, performed effective BVM ventilations, and administered medications properly - Participants were graded on a 121-point scale and the mean of the assessment was utilized for analysis	- After receiving ACLS instruction there were significant improvements in the following areas • Average time to CPR (P=.004) • Average time to defibrillation (P =.03) • Of the students who achieved CPR and defibrillation withing the first 2 minutes, they also achieved ROSC (P=.001)	- Small sample of highly motivated students - Specific aspects of CPR metrics not measured (Chest compression data) - Pre-post-test design with no control group

Table 29. Research Analyzing High-fidelity Manikins in CPR Education (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Beal et al. (2017)[140]	- Assess the effectiveness of simulation for teaching medical students critical care medicine, and to assess which simulation methods were most useful	- 22 articles were included	- Randomized control trials were included - outcome measures included: acute coronary syndrome, stroke, asthma, in-hospital CPR, infant CPR as a first responder, prehospital CPR with AED	- 17 studies compared simulation with other teaching modalities and reported that simulation was significantly more effective than other teaching modalities ($P < .001$) - High-fidelity simulation was favored over low-fidelity simulation ($p < .001$)	- Quality of CPR was not analyzed or included - Large range of professions in the medical field were included
McCoy et al. (2019)[118]	- Compare the effectiveness of high-fidelity simulation training vs standard manikin training for medical students	- 70 fourth year medical students	- Prospective Randomized study - Simulation group learned CPR via an hour session that included a lecture with training on a high-fidelity simulator - Standard training included a power point lecture with training on a low-fidelity manikin - Primary outcome measures were based on the AHA guidelines of high-quality CPR: • Compression rate • Compression depth • Recoil • CCF	- Sim group students performed CPR more closely adhered to AHA guidelines of compression depth and compression fraction - Mean depth was 4.57cm for the sim group and 3.89cm for the standard training group ($P = .02$) -CCF in sim group was 0.724 and 0.0679 ($P = .01$) - No significance for rate or recoil	- Medical students may have previously encountered high-fidelity simulation - Retention was not studied - Past experience with CPR education and real-life experience were not included

Table 29. Research Analyzing High-fidelity Manikins in CPR Education (continued)

Author	Purpose	Participants	Design	Outcomes	Limitations
Berger et al (2019)[141]	- Identify if problem-based teaching combined with high-fidelity CPR simulation improves short- and long-term CPR skills when compared to traditional CPR teaching	- 127 fourth year anesthesiology students participated in the study	- Prospective, randomized single blind, intervention study - Paper-based questionnaire for demographic data was taken, as well as a self-perception questionnaire for CPR-skills. - All students received a 30-minute lecture about CPR, and then the control group received traditional CPR training (two hands-on scenarios on a CPR manikin in groups of 6-8 with no other simulated environment with an instructor correcting errors), while the problem-based teaching group received a 45-minute module with a 45-min hands on training on high-fidelity simulators in groups of 6-8, debriefing occurred after the scenarios - Two hours after training participants were randomly divided into pairs and performed CPR with an assessment and video recording - 6 months later there was an additional assessment - Guideline conformance CPR was the primary outcome measure which consisted of evaluation of manikins' condition, call for help and sufficient chest compressions - Sufficient chest compressions consisted of at least 10 compressions with a minimum depth of 45 mm and a rate between 90-120 compressions per minute - Hands off time, and start of scenario to first compression were also recorded	- Guideline conformance CPR was performed significantly more in the problem-based teaching with high-fidelity simulation group when compared to the traditional (Control) (P = .007) - Compression quality was not significant between groups (P= .93) - Problem-based teaching with high-fidelity simulation group had significant lower percentage of interruptions during CPR when compared to the control at initial test and at the 6-month follow up (P = .007, P = .006, respectively)	- Experiences during the 6-month follow up were not recorded - Selection bias with highly motivated students - Could not control communication between students which may have altered the blinding -

The 2015 AHA CPR guidelines emphasize improved CPR psychomotor skills include a section regarding CPR mastery from experiential learning. Experiential learning includes cognitive knowledge, simulation, and feedback combined with debriefing and the use of high-fidelity manikins. While many CPR education programs utilize some of these aspects of experiential learning, often not all the pieces are included. When observing the effect of high-fidelity manikins in CPR education, Beal et al. found that high-fidelity simulation was favored over low-fidelity ($p < .001$).[140] When utilizing overall guideline conformity as an outcome measure, multiple researchers' findings indicated that high-fidelity manikins and simulation were statistically superior when compared to a control or an alternative education form. Berger et al. found that high-fidelity simulation paired with problem-based teaching provided statistically significant guideline conformity at initial testing as well as at a six-month follow up test ($P = .007$, and $P = .006$, respectively).[141] Additionally, McCoy et al. found that the high-fidelity simulation group performed CPR more closely in adherence to the AHA guidelines for compression depth and chest compression fraction when compared to a standard CPR training group ($P=.02$ and $P=.01$, respectively).[118] McCoy et al. and Berger et al. utilized participants who were in the medical field, which may be considered a limitation due to the high likelihood that participants had not only previous CPR knowledge or training but also experience with high-fidelity simulation.

High-fidelity manikins and simulation improved cognitive knowledge significantly when compared to low-fidelity and control groups. Rodgers et al. found that while both low-and high-fidelity simulations improved cognitive scores from baseline testing ($P=.001$), high-fidelity simulation improved significantly compared to the low-fidelity group ($P= .002$).[137] Similarly, Davis et al. found that test scores improved significantly from baseline in all groups ($P=.114$) but was highest when lecture was followed by high- fidelity simulation (P =.003). In this study, simulation was with a high-fidelity manikin for pharmacological intervention in cardiac emergencies.[138] Berger et al. also found increases in cognitive knowledge in the high-fidelity simulation group when compared to a traditional CPR training group (P=.005).[141] It is important to note that when testing cognitive knowledge, participants were all students or professionals in the medical field and retention of knowledge and skills past six months was not analyzed.[79, 137, 138, 141] While findings indicate that high-fidelity manikins and simulation should be included in CPR education, more research should be completed to identify the effects of the use of high-fidelity manikins on specific metrics of CPR skills, as well as the effect of high-fidelity simulation on the retention of CPR psychomotor skills.

Conclusion

Cardiopulmonary education formats have been in question for many of the past AHA CPR updates, and yet the gold standard remains as an instructor-led course with a two-year certification period. The literature supports the use of high-fidelity manikins that provide real-time feedback, deliberate practice, and booster sessions to ensure cognitive knowledge and psychomotor skill retention occurs. However, clarity regarding the best educational program for CPR knowledge and psychomotor skill acquisition and subsequent retention is still widely variable due to the inconclusive findings regarding the best combination of educational practices. Based on literate regarding factors that may affect the quality of CPR, it is vital to note that different professions may have vastly different experiences with CPR performance. Thus, the cookie cutter idea of one educational format fits all does not apply for CPR rescuers and education across the board. Additionally, while CPR cognitive knowledge appears to increase after CPR education when compared to pre-tests, the true examination of CPR quality should pertain to specific aspects of psychomotor skill performance. Essentially, if a person cognitively knows the best compression rate, depth, and chest compression fraction, but cannot perform these metrics adequately, how successfully was their education program? It is imperative that research be conducted for both health care and non-health care providers to ensure acquisition of skills is obtained such that high-quality CPR is conducted no matter the environmental factors.

METHODOLOGY

Purpose of the Study

Specific components of cardiopulmonary resuscitation (CPR) education have been established in recent American Heart Association (AHA) guidelines. Although both medical and educational experts agree CPR is a critical medical intervention to mitigate death associated with sudden cardiac arrest, debate remains as to the optimal training content and timeframe by which providers should receive reinforcement of skill performance. The conventional educational design may not be applicable for educating CPR rescuers in a variety of professions, but there is a lack of data clarifying alternative approaches. Furthermore, psychological barriers and perceived confidence in rescuers' ability to perform high-quality CPR have received attention in recent decades, but the AHA has failed to recognize the available literature devoted to this topic. For example, data suggests that in a population of nurses and physicians, recent education and skills trainings improved self-efficacy scores, and yet the topic has garnered little research for athletic trainers and EMS.[4] There is value in exploring the differences between professionals who are expected to perform CPR in the event of an emergency. Findings from an analysis of CPR self-efficacy between professions could act as a catalyst to promote changes within specific professions.

A variety of external factors can influence the possibility of return of spontaneous circulation (ROSC). First, the amount of time a patient receives emergency care away from a medical facility can compromise success. The national average for an ambulance to arrive at the scene of an emergency in an urban environment is 8 minutes and 59 seconds.[9] However, most research exploring components of CPR has participants performing for a much shorter period of time.[4-6, 76, 86] Second, barriers on the patient, such as athletic equipment, can present as impediments to receiving high-quality compression depth and ventilation. While some research is devoted to the topic, most of it is dedicated to Athletic Trainers and thus neglecting other emergency medical professions.[7, 8, 93, 109]

The details related to the content for certification/recertification lack evidence-based suggestions. Although there is acknowledgment by the AHA that the two-year certification period is too long, the existing literature suggests a decline in skill acquisition after six months or less.[3] In addition, the use of deliberate feedback devices with appropriate manikins has been mentioned in recent AHA updates. However, the evidence associated with high-fidelity manikins versus debriefing is not yet fully understood. While data indicates that any type of feedback benefits learning and overall skill acquisition and subsequent performance, clarity regarding the accessibility of and feelings concerning deliberate practice and feedback within CPR education for the aforementioned professionals is limited.

Based on the gaps in the literature related to components of CPR self-efficacy and education, this research has been divided into two separate topics. The first investigation is devoted to self-efficacy of nurses, athletic trainers, and EMS professionals and their perceived ability to perform CPR in accordance with current CPR guidelines for 8 minutes and 59 seconds. In addition, we wanted to explore professionals' self-efficacy as it pertains to performing CPR over athletic equipment. The second investigation explores the possible differences in recertification experiences, expectations and educational approaches between professions. In addition to educational expectations and approaches, this survey seeks to explore the use of deliberate feedback manikins and debriefing during training sessions compared across professions.

The research was designed to answer the following questions for investigation 1: An analysis of CPR self-efficacy between emergency professionals related to external factors.

Q1: What is the relationship between nurses, athletic trainers, and EMS self-efficacy and their ability to perform CPR for 8:59?

Q2: What is the relationship between nurses, athletic trainers, and EMS self-efficacy and their ability to perform CPR over protective athletic equipment?

This research was designed to answer the following questions for investigation 2: Investigating the differences among professions in components of recertification experiences.

Q1: What are the differences in recertification requirements between medical professionals?

Q2: What are the differences between professions related to training on various deliberate feedback devices?

Q3: What are the difference between professions related to booster sessions?

Participants

This study was approved by the Institutional Review Board (IRB) at North Dakota State University (NDSU). Participants included nurses (n= 36), certified Athletic Trainers (n=36), and EMS personnel (n=27) for a total of N= 99 participants. Inclusion criteria included valid CPR certification as well as earned credentials in nursing, athletic training, or EMS. Participants must have practiced in their profession for at least 3 years to ensure recertification in CPR had occurred at least once. Recruitment of participants occurred via word of mouth and email to area fire departments, local hospitals, and athletic training list serves. Exclusion criteria included expired CPR certification at the time of the study or non-professional/non-certified personnel.

Additionally, professionals who had not been in their professional role for at least 3 years were excluded.

Procedures

A web-based survey via email (Qualtrics) was utilized to answer the research questions associated with both investigations. A pilot study occurred for validation and feedback. Five individuals who identified as professionals in nursing, athletic training, or EMS fields responded to study and gave feedback regarding clarity and format so adjustments to the survey instruments occurred. These individuals' responses were not included in data analysis.

After approval by IRB at NDSU, the research team obtained email addresses of randomly selected nurses from local area hospitals, certified athletic trainers from alumni list serves, and word of mouth. EMS was recruited from local area fire and ambulance departments. Once email addresses were obtained, the researchers sent a recruitment email with the purpose of the research and relevance described within the email. Researcher's contact information was also provided in the recruitment email. Once participants decided to participate in the study, they were asked to visit the Qualtrics website for additional information, informed consent, and the appropriate surveys that were provided. Before participants proceed to the survey, they clicked "Yes" indicating that they had read and agreed to the listed information and subsequent consent.

Once participants proceed to the survey, the questionnaire took approximately 10 minutes to complete. The survey included demographic information, a modified Basic Resuscitation Skills Self-Efficacy Scale (BRE-SES), and additional questions about CPR recertification, booster sessions and overall educational experiences, including the use of deliberate feedback.[16] All participants received a follow-up email one week after initial email was sent. The survey was active for 15 days total to allow ample time for participant completion. Because we allowed participants to encourage their peers to participate, we are unable to calculate a return rate due to more individuals responding than we originally recruited.

Instrumentation

This study used a web based Qualtrics (Qualtrics LLC, Provo, UT) instrument containing a CPR self-efficacy assessment, as well as specific questions relating to initial CPR certification, recertification, and overall educational experiences, including the use of deliberate feedback, and lastly booster sessions.

<u>CPR Self-efficacy Assessment</u>

A 9-item, self-efficacy questionnaire was utilized to assess participants' confidence in their ability to perform CPR for 8:59 in addition to over protective athletic equipment. The questionnaire was constructed from the Basic Resuscitation Skills Self-Efficacy Scale (BRE-SES), which was created and validated by Hernandez-Padilla et al.[16] Participants used a six-point, Likert-type scale to indicate confidence levels in their ability to perform specific aspects of CPR during an emergency in accordance with the most current AHA CPR guidelines. Because our interest in self-efficacy was two-fold, participants were asked to rate their confidence on both attributes. Therefore, participants were prompted with the following: In the likelihood I encountered an emergency in an out-of-hospital setting in an urban environment for 8 minutes and 59 seconds (8:59), I am confident that I can ALWAYS…

The second prompt was as follows: In the event I encounter an emergency in which the patient is wearing protective athletic equipment (e.g., helmet and chest protection), I am confident that I can ALWAYS….

Survey Regarding Components of CPR Recertification

The CPR education and certification questionnaire incorporated information regarding demographics followed by additional sections pertaining to: certification requirements, perceptions of educational format and trainings, the inclusion of deliberate feedback manikins (low-, medium- and high-fidelity), and booster sessions (Appendix A). Prompts included multiple choice format, as well as a six-point, Likert-type scale to answer questions.

Data Analysis

Data were extracted directly from Qualtrics into a spreadsheet for data analysis. Data for both investigations were analyzed using SPSS (Version 2.4, IBM) to calculate means, standard deviations, and frequencies. Descriptive statistics were utilized to summarize demographic information for both investigations.

For investigation one, participants who did not complete the questionnaire in its entirety were excluded from data analysis. Data were analyzed using SPSS (Version 2.4, IBM) to calculate means and standard deviations. A 3X2 ANOVA model was estimated to test for differences between the professional groups and between the conditions. Descriptive statistics were utilized to summarize demographic information. The analysis focused on recognizing differences in responses between professions as well as trends within each.

For investigation two, data were analyzed to calculate means, standard deviations, and frequencies. No inferential statistics were calculated because our interest was in raw data.

AN ANALYSIS OF PERCEIVED CPR SELF-EFFICACY AMONG NURSES, ATHLETIC TRAINERS, & EMS PROFESSIONALS

Introduction

It is widely known that the rapid provision of high-quality cardiopulmonary resuscitation (CPR) is necessary for the potential to survive an out of hospital cardiac arrest (OHCA).[74] However, the factors associated with the quality of CPR performance are widely understudied. Psychological barriers and perceived confidence in rescuers' ability to perform high-quality CPR have received attention in recent decades, but the AHA has failed to recognize the available literature devoted to this topic. For example, data suggests that in a population of nurses and physicians, recent education and skills trainings improved self-efficacy scores, and yet the topic has garnered little research for athletic trainers and EMS.[4] There is value in exploring the differences between professionals who are expected to perform CPR in the event of an emergency. Findings from an analysis of CPR self-efficacy between professions could act as a catalyst to promote changes within specific professions.

The literature focused on intrinsic or psychological factors that affect the quality of CPR performance is limited. According to psychologist Albert Bandura, self-efficacy is defined as a person's sense of confidence in his or her ability to perform a behavior.[12] Regarding resuscitation, Maibach, Schieber and Carroll further define self-efficacy as the perceived ability to organize and execute the processes of care correctly during a CPR attempt.[142] While the perceived confidence in rescuers' ability to perform high-quality CPR has received attention in recent literature, the American Heart Association (AHA) has failed to acknowledge the potential impact this factor has on overall psychomotor performance. Research suggests that after recent training sessions, nurses' self-efficacy improves.[4, 88, 98] Meanwhile, other professions such as athletic trainers and EMS professionals, are vastly understudied.[3, 4] The ability to perform high-quality CPR is a major facet in nurses', athletic trainers' and EMS professionals' skill set, yet the effect of perceived self-efficacy on CPR psychomotor skill performance is unclear.

In an attempt to analyze CPR performance among health care professionals, researchers have incorporated methodologies requiring performance ranging from two to five minutes.[4-6, 39, 40, 42, 57, 59, 76, 104, 110, 111] This performance time is much shorter than the national average time it takes an ambulance to arrive on scene of 8 minutes and 59 seconds in which those trained in CPR would be expected to adequately perform high-quality CPR.[9] There are limited publications exploring professionals' ability to perform high-quality CPR for an extended period of time. With a recognition of the gap in the literature, best teaching practices cannot be implemented for either allied health care professionals or lay public. Thus, further exploratory research analyzing psychomotor scenario time is necessary before providing recommendations to the AHA.

Another factor that may hinder an individual's ability to provide high-quality CPR is equipment worn by the patient at the time of an OHCA. Specifically, protective equipment worn by competitive or recreational athletes may hinder chest compression quality during CPR, yet the amount of time saved by providing compressions prior to equipment removal may be significant in survival for cardiac emergencies. Data appears to be conflicting regarding best practices for CPR over athletic equipment. Boergers et al.[111] found that chest compression depth varied depending on the brand of lacrosse chest protector worn, while Del Rossi et al.[110] and Waninger et al.[8] findings indicated that chest compression depth was correct more often when a football chest protector was in place. In contrast, Skaro et al.[109] found that over chest compression scores were significantly lower with the football pads in place when compared to no pads. Specific to the idea of CPR and athletic equipment, there is limited data regarding the perceived ability of nurses, athletic trainers, and EMS personnel to perform high-quality CPR over protective athletic equipment.[7, 8, 107, 109] There is little data analyzing specific professions' reports of their self-efficacy and their ability to perform high-quality CPR. Clarity in CPR education for those who may be assisting the equipment-laden patient is lacking due to inconsistencies in reported results as well as an overall lack of proven algorithms for providing care. As such, it is critical to the health care industry that we analyze identified barriers (e.g., self-efficacy) for quality improvement processes.

As we recognize self-efficacy to be a predictor of CPR performance, it is critical that we explore self-efficacy with two additional factors that hinder CPR quality: length of care and athletic equipment.[4, 88, 90, 91, 143] This study aims to identity perceived self-efficacy in nurses, athletic trainers, and EMS personnel and their ability to perform high-quality CPR for an extended period of time as well as over protective equipment. Our results contribute to the ongoing body of literature utilized to make informed changes in CPR education and training efforts with the potential of improving patient outcomes

Methodology

Participants included nurses (n= 36), certified Athletic Trainers (n=36), and EMS personnel (27) for a total of N= 99 participants. Those who reported more than one profession, for example athletic trainer and paramedic, were included for data analysis only in their assumed full-time profession. Inclusion criteria included a valid CPR certification as well as earned credentials in nursing, athletic training, or EMS to be included in the study. Exclusion criteria included expired CPR certification at the time of the study or non-professional/non-certified personnel. Additionally, professionals who had not been in their professional role for at least 3 years were excluded to ensure they had received a CPR recertification training while working in their professional career.

Prior to the start of data collection, this research study was approved by the university's institutional review board. A web-based survey (Qualtrics) was utilized to rate perceived confidence levels in CPR. The survey was evaluated via pilot study of five individuals all of whom provided feedback for survey development purposes.

The survey took approximately 10 minutes to complete and included demographic information and a modified Basic Resuscitation Skills Self-Efficacy Scale (BRE-SES).[16] The questionnaire was constructed from the Basic Resuscitation Skills Self-Efficacy Scale (BRE-SES), which was created and previously validated by Hernandez-Padilla et al.[16] Participants were prompted with the following: In the likelihood I encountered an emergency in an out-of-hospital setting in an urban environment for 8 minutes and 59 seconds (8:59), I am confident that I can ALWAYS… A six-point, Likert-type scale was utilized to indicate confidence levels in their ability to perform specific aspects of CPR during an emergency in accordance with the most current AHA CPR guidelines. Nine items specific to CPR compressions and ventilations were included as a part of this analysis.

Next, participants were asked to consider their self-efficacy when an athlete donned athletic equipment. The same six-point, Likert-type scale was used for consistency purposes. The second prompt was as follows: In the event I encounter an emergency in which the patient is wearing protective athletic equipment (e.g., helmet and chest protection), I am confident that I can ALWAYS … Participants were asked to consider the same nine items related to CPR compressions and ventilations.

Statistics

Data were extracted directly from Qualtrics into a spreadsheet for data analysis. Participants who did not complete the questionnaire in its entirety were excluded from data analysis. Data were analyzed using SPSS (Version 2.4, IBM) to calculate means and standard deviations. Descriptive statistics were utilized to summarize demographic information. A 3X2 ANOVA model was estimated to test for differences between the professional groups and between the conditions. Follow-up pairwise tests were conducted using Tukey's HSD method focusing on recognizing differences in responses between professions as well as trends within professions.

Results

Raw data (in the form of percentages) for both prompts and aspects of CPR in which participants strongly agreed and agreed can be found in table 30.

Table 30. Strongly Agree and Agreed (Percentages) for CPR Performance for an Extended Period of Time (9 Minutes) and Over Athletic Equipment

	Extended Amount of Time	Over Athletic Equipment
Perform CPR in accordance with the 2015 American Heart Association (AHA) guidelines	82.20	65.34
Perform chest compressions with an adequate rate (100-120 compressions/minute)	75.80	68.31
Perform chest compressions with an adequate depth (≥5 but ≤6 cm)	73.83	57
Allow the chest to fully recoil while performing compressions	83.33	68.68
Perform CPR with a correct compression to ventilation ratio (30:2)	87.97	85
Deliver ventilations at an adequate rate and volume (8-10 breaths/minute)	80.38	74
Correctly position hands during CPR (Over the lower half of the sternum)	95.38	77.56
Perform CPR with an adequate chest compression fraction (≥ 80%)	75.63	86.13
Provide high-quality CPR consistently during a prolonged (approximately 9-minute) resuscitation attempt	38.89	40.09

Summary statistics for survey responses appear in table 31. The average score was relatively stable across all conditions with the exception of nurses, who reported a lower total score on the second prompt relating to performing CPR over protective athletic equipment.

Table 31. Average Score (Standard Deviation) of Self-efficacy Survey

	Traditional	Over Athletic Equipment
Athletic Trainers	46.6	45.4
	(5.22)	(7.29)
EMS	46.8	44.1
	(7.28)	(7.41)
Nurses	44.9	39.4
	(6.35)	(7.42)

A 3X2 ANOVA model was estimated to test for differences between the professional groups and between the condition with and without protective equipment. The model was statistically significant for both profession ($F[1,192]=10.6$, $p=.001$, $\eta^2=.052$) and condition ($F[2,192]=6.50$, $p=.002$, $\eta^2=.063$), though both effect sizes were in the small to medium range. The interaction effect was not statistically significant ($p=.164$).

Follow-up pairwise tests were conducted using Tukey's HSD method. The comparisons showed that the statistical significance is almost entirely driven by the lower score for nurses in the condition with CPR performance over athletic equipment. Nurses had a lower self-reported self-efficacy score than Athletic Trainers ($p=.003$) and EMS ($p<.001$). The within-subject comparison was also statistically significant, with nurses reporting a lower total score with CPR performance over athletic equipment ($p=.011$). No other differences were statistically significant at a 5% level.

Discussion

To our knowledge this is study is the first to compare CPR self-efficacy for an extended period of time and over protective athletic equipment in the specific population of nurses, athletic trainers, and EMS personnel. Our results support the need for alterations in CPR education. By recognizing that CPR self-efficacy contributes to the overall quality of CPR performance, the focus of CPR education can and should be shifted to ensuring quality performance with a variety of external factors, such as self-efficacy. Also, the shift should refocus on ensuring health care providers are confident in their ability to perform high-quality CPR as a direct result from their education. Similar to results reported by Lammert et al., our results indicate that athletic trainers claim to have high self-efficacy regarding CPR performance over protective athletic equipment as well as CPR performance for an extended period of time. While Lammert et al. compared CPR psychomotor skill performance with the report of self-efficacy in athletic trainers, the current study did not incorporate actual performance for any of the sampled professions.[107] Therefore, comparing published CPR self-efficacy and actual CPR performance is not possible with the current findings.

The opportunity for CPR education to be altered according to specific professions also should be noted. For example, athletic trainers, EMS, and nurses may have the opportunity to perform CPR on an equipment-laden athlete simply based on their potential presence on the sideline at athletic events. However, current CPR education does not include psychomotor practice in scenarios involving equipment. There is limited amount of published data delineating differences between CPR self-efficacy in a population of specific health care professionals. Current findings add to the data that clarifies self-reported differences in confidence surrounding CPR performance for specific scenarios, (ie; nurses are not confident in their ability to perform CPR on an equipment laden athlete). Additionally, the prompt regarding CPR performance over athletic equipment indicated that the sampled nurses were less confident in specific aspects of their CPR performance when compared to their ability to perform CPR for an extended amount of time. Thus, more education must occur so that all medical professionals are prepared to provide a quality medical intervention no matter the external factors.

To date there is limited data clarifying self-efficacy of health care providers' ability to provide high-quality CPR over athletic equipment, as well as clarification of best practices for the equipment-laden athlete who is undergoing a cardiac emergency. The studies that analyze athletic trainers' performance over athletic equipment conclude that CPR is inadequate when CPR is performed over a chest protector.[7, 8, 109, 110] When focusing on CPR being performed over athletic equipment, the population studied seems to focus on athletic trainers, therefore it is unknown how successful other health care providers are at performing CPR on the equipment-laden athlete, as well as how confident they are. Understanding the self-efficacy of other health care providers, such as nurses and EMS personnel, in specific situations is crucial to making appropriate changes in CPR education and practice. Moreover, clarification regarding contributing factors to CPR performance, such as performing over athletic equipment, is an essential component to create the scenarios in CPR educational practice that are deliberate and most beneficial for the students to acquire proper skills and confidence.

Our research builds on findings supporting the need for educational programs to shift their focus on ensuring participants are confident in their ability to perform high-quality CPR for an appropriate amount of time. Results from the current study indicated that 38.89% of surveyed health care providers strongly agreed or agreed that they could perform high-quality CPR consistently for an extended duration of CPR. Conversely that indicates the majority of health care providers are not confident in their ability to perform CPR for a prolonged amount of time (nine-minutes). Currently there is no specified guideline indicating that participants in an education course must be able to perform CPR for an extended amount of time. Nevertheless, with the earned credential gained from an education course, it is expected that they can perform proper CPR for the necessary amount of time during real CPR performance. Therefore, educational experiences need to include realistic and deliberate practice, which may consist of performing CPR for at least nine minutes based on the national average amount time it takes for an ambulance to arrive on scene.[9] Most methodologies in published research have participants providing CPR for two to four minutes, which is simply not a realistic time frame for actual CPR performance.[4-6, 39-42, 57, 59, 104] Estabrooks et al.[7] and Lammert et al.[107] had athletic trainers perform CPR for approximately nine minutes. Methodologies by Cheskes et al.[78] had EMS personnel perform CPR for ten minutes, and Yang et al.[66] had non-allied health care providers perform CPR for eight minutes, which to date, are the most realistic performance times in the literature.

Our survey was not without limitations. Participants did not perform CPR, thus no comparison between reported self-efficacy and actual ability to perform high-quality CPR occurred. The recruited participants in nursing, athletic training, and EMS professions were prompted to answer based on two scenarios (equipment and extended amount of time). Other potential scenarios in which they may perform CPR were not included (e.g., obvious orthopedic injury, blood, etc.), potentially causing a reporting bias. Although there are limitations to this research, we suggest advisory committees consider revising current educational practices to assist specific health care professions for medical encounters respective to their role.

Despite an increasing amount of data, the relationship between CPR self-efficacy and the quality of CPR provided by health care professionals is still unclear. Our findings suggest that health care providers are generally confident in their CPR performances for an extended amount of time. Our results they are less confident providing CPR over equipment. Additionally, nurses specifically reported low levels of self-efficacy for CPR performance over athletic equipment for an extended period of time. A concerted effort with the intent of clarifying the relationship of self-efficacy to performance is necessary to further CPR education.

EXPLORING DIFFERENCES IN CPR EDUCATION AMONG NURSES, ATHLETIC TRAINERS, & EMS PROFESSIONALS

Introduction

Specific components of cardiopulmonary resuscitation (CPR) education have been established in recent American Heart Association (AHA) guidelines. Although both medical and educational experts agree CPR is a critical medical intervention to mitigate death associated with sudden cardiac arrest, debate remains as to the optimal training content and timeframe by which providers should receive reinforcement of skill performance. The conventional educational design may not be applicable for educating CPR rescuers in a variety of professions, but there is a lack of data clarifying alternative approaches.

The American Heart Association (AHA) has published cardiopulmonary resuscitation (CPR) updates every five years since the 1990s.[31] These updates commonly include suggestions for altering initial certification and recertification for both allied health care providers and lay public.[2] Medical and educational experts agree that CPR is a critical intervention for cardiac emergencies, yet the optimal training content and time frame to ensure high-quality psychomotor skill performance occurs is still under debate. The AHA clusters health care providers as opposed to lay public for training purposes. However, each health care provider has different expectations in regard to their emergency care. For example, Athletic Trainers are expected to perform medical interventions until emergency medical services personnel arrive, which, on average, takes 8 minutes and 59 seconds in an urban environment.[9] In contrast, those in EMS professions are required to provide medical care during transport to a hospital, and nurses potentially are the care providers in hospital until a code team takes over the patient care.[9]

Because of the differences in patient care demands, it is critical we evaluate the training differences among health care providers.

Current CPR certifications are considered valid for two years, yet data suggests that the quality of skill performance declines around six months after a certification or recertification course.[2, 3, 126, 128, 129] A randomized control trial completed by Au et al. indicated that, in a population of those who had participated in Advanced Cardiac Life Support (ACLS), the most rapid rate of decline in psychomotor skill performance occurred between three and 6 months. Additionally, Au et al.[3] clarified that in the published literature, six months was the most commonly used endpoint as measurement for skill decline. When analyzing psychomotor skill decay at one year, Oermann et al.[126] found that nursing students who had no additional CPR practice other than a testing scenario every three months had a significant loss in compression rate when compared to their initial testing. Health care professionals maintain good standing by ensuring they have a current and valid CPR certification. However, there is limited data delineating if specific professions' recertification courses contain different psychomotor skill practice scenarios based on professional roles and responsibilities.

The use of deliberate feedback devices with appropriate manikins has been mentioned in recent AHA updates.[74] However, the evidence associated with the inclusion of high-fidelity manikins in training paired with any type of debriefing is not yet fully understood. Data indicates that any type of feedback benefits learning, overall skill acquisition, and psychomotor performance.[85, 122, 124, 131, 132, 140] However, clarity regarding the accessibility of and feelings concerning deliberate practice and feedback within CPR education for the aforementioned professionals is limited.[121, 126, 141] High-fidelity simulation provides the most realistic opportunity for rescuers to practice psychomotor skills, but current guidelines indicate that while utilizing high-fidelity equipment is beneficial, it may not be feasible to implement into CPR education.[138-140] The differences between nurses, athletic trainers, and EMS personnel regarding the type of manikin and type of feedback the manikin provides in their education is unclear, which poses a dilemma to ensuring professionals are adequately prepared to perform high-quality CPR.

The current CPR certification period is two years with no requirement for booster sessions within the certification time frame.[2] Booster sessions may improve skill performance due to the increase in psychomotor practice. Currently, there is limited data about the use of booster sessions between recertification time periods within the health care professional population. The data that is available indicates that CPR psychomotor skills in the nursing population are more often performed in accordance with the suggestions when booster sessions are utilized.[3, 126, 128, 129] Data regarding the skills of athletic trainers and EMS professionals' ability to perform CPR in accordance with the guidelines after participating in booster session is vastly understudied. More data specific to the frequency and content provided during the booster sessions are needed to make data-driven inferences and changes in CPR education and psychomotor practice sessions.

This study aims to identity differences between health care professionals and recertification experiences. Additionally, this study aims to identify feelings regarding deliberate practice and booster sessions within health care professionals' experiences in CPR education. To our knowledge, this is one of the first studies to explore differences between specific allied health care professions. Our results can be used to make evidence-based changes to the educational requirements set forth by the AHA.

Methodology

Participants included nurses (n= 43), certified Athletic Trainers (n=47), and EMS personnel (35) for a total of N= 101 data sets. Participants who reported multiple professional credentials were included in all categories that they selected. Therefore, if they reported that they were both a paramedic and an athletic trainer, their data was accounted for in both professional analyses. Participants must have had valid CPR certification as well as earned credentials in nursing, athletic training, or EMS to be included in the study. Exclusion criteria included expired CPR certification at the time of the study or non-professional/non-certified personnel. Additionally, professionals who had not been in their professional role for at least 3 years were excluded to ensure they had received a recertification training while working in their professional career.

Prior to the start of data collection, this research study was approved by the university's institutional review board. A web-based survey (Qualtrics) was utilized to rate perceived confidence levels in CPR. The survey was evaluated via pilot study of five individuals, all of whom provided feedback for survey development purposes.

The survey took approximately 10 minutes to complete and included demographic information as well as a questionnaire regarding CPR education and certification. The education and certification aspect of the survey incorporated information involving certification requirements, perceptions of educational format and trainings, the inclusion of deliberate feedback manikins (low-, medium- and high-fidelity), and debriefing during CPR education. Lastly, a section with questions about booster sessions was included (Appendix __). Prompts included multiple choice format, as well as a six-point, Likert-type scale to answer prompted questions. Data were excluded if participants did not fully complete the survey.

Statistics

Data were extracted directly from Qualtrics into a spreadsheet for data analysis. Data were analyzed using SPSS (Version 2.4, IBM) to calculate means, standard deviations and frequencies. Descriptive statistics were utilized to summarize demographic information.

Results

Because we recorded frequency and descriptive statistics, we chose to allow anyone who identified as dual credentialed to be counted in both categories. Regarding questions associated with recertification, deliberate practice and feedback and booster sessions, findings are illustrated in frequency tables below.

Demographic data including gender, education, profession, good standing in the profession and where participants received their most recent CPR credentials can be found in the tables below (tables 32-36).

<u>Demographics</u>

Table 32. How Do You Identify Your Biological Sex?

	Male	Female	Non-binary	Other	Prefer not to say	Total
Overall	43	58	0	0	0	101
Nurses	8	34	0	0	1	43
Athletic Trainers	21	26	0	0	0	47
EMS	29	6	0	0	0	35

Table 33. What Is Your Highest Level of Education?

	High School Diploma	Certificate program	Associate Degree	Bachelor's Degree	Master's Degree	Doctoral Degree	Total
Overall	1	6	5	37	43	9	101
Nurses	0	1	1	26	12	3	43
Athletic Trainers	0	0	0	4	35	8	47
EMS	3	6	5	11	7	3	35

Table 34. What Is Your Profession? (Select All That Apply)

	LPN	RN	Athletic Trainer	Firefighter	First Responder	EMT Basic	EMT Advanced	Paramedic
Overall	2	35	42	21	5	16	2	4
Nurses	2	41	1	1	0	1	0	0
Athletic Trainers	1	0	47	3	0	5	1	0
EMS	1	1	7	24	6	17	2	4

Table 35. How Long Have You Maintained a Good Standing Credential in Your Profession?

	3-5 Years	5-10 Years	10-15 years	15-20 years	20+ years	Total
Overall	18	30	19	12	22	101
Nurses	10	12	9	3	9	43
Athletic Trainers	6	14	8	6	13	47
EMS	7	9	6	4	9	35

Table 36. From Which Entity Did You Receive Your Most Recent CPR Training?

	American Heart Association	American Red Cross	Other	Total
Overall	83	10	8	101
Nurses	39	2	2	43
Athletic Trainers	32	11	4	47
EMS				

Section 1: Recertification

Participants were asked to recall their most recent recertification course for the survey. Since a part of the inclusion criteria was that participants had been in their profession for at least 3 years, they had participated in a recertification course to maintain good standing in their profession. We sought to identify possible differences in recertification experiences, expectations and approaches between professions. Included in the frequency tables below are questions and findings pertaining to recertification, skill practice within education including pulses, and feelings regarding skill practice, and expectations within CPR education regarding testing (tables 37-47).

Table 37. How Often Do You Participate in a Formal Recertification Process to Maintain Your CPR Credential?

	Every 6 months	Every Year	Every 2 years	Other	Total
Overall	4	21	61	15	101
Nurses	2	1	21	14	38
Athletic Trainers	0	10	30	2	42
EMS	2	12	16	1	31

Table 38. How Long Are Your Recertification Trainings?

	1 hour	2 hours	3 hours	4 + hours	Total
Overall	27	33	23	18	101
Nurses	16	11	5	6	38
Athletic Trainers	12	13	11	6	42
EMS	2	12	9	8	31

Table 39. How Much of the Time Spent During Recertification Is Spent On Skill Practice?

	30 minutes or less	31 minutes-1 hour	1-2 hours	2 or more hours	Total
Overall	35	45	17	4	101
Nurses	20	9	7	2	38
Athletic Trainers	13	23	4	2	42
EMS	5	16	8	2	31

Table 40. How Often Do You Practice Locating a Central or Peripheral Pulse During the Formal Recertification Process?

	Never	1-2 Simulated patients	3-4 simulated patients	5-6 simulated patients	Other	Total
Overall	28	52	12	8	1	101
Nurses	17	13	4	3	1	38
Athletic Trainers	12	24	4	2	0	42
EMS	1	20	6	4	0	31

Table 41. Are You Required to Take and Pass a Written Exam to Maintain a Current CPR Certification?

	Yes	No	Total
Overall	85	16	101
Nurses	28	19	38
Athletic Trainers	37	5	42
EMS	29	2	31

Table 42. If Yes, What Is Considered a Passing Score On The Written Exam?

	70%	75%	80%	85%	90%	Other	Total
Overall	13	7	40	8	8	15	91
Nurses	1	2	10	3	7	8	31
Athletic Trainers	7	2	22	4	2	3	40
EMS	6	3	14	1	1	5	30

Table 43. Are You Required To Pass a Psychomotor Skill Proficiency Exam?

	Yes	No	Total
Overall	66	34	100
Nurses	23	15	38
Athletic Trainers	28	13	41
EMS	23	7	30

Table 44. If Yes, What Is Considered a Passing Score on the Psychomotor Skills Exam?

	70%	75%	80%	85%	90%	Other	Total
Overall	7	5	20	6	8	25	71
Nurses	0	2	5	2	5	10	24
Athletic Trainers	4	1	13	3	3	8	32
EMS	4	3	6	1	2	9	25

Table 45. Enough Time Was Spent on Skill Acquisition During CPR Training

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	Total
Overall	25	45	19	8	2	2	101
Nurses	9	17	9	1	1	1	38
Athletic Trainers	13	17	5	5	1	1	42
EMS	7	16	6	2	0	0	31

Table 46. After The Recertification Process, You Were Confident You Could Properly Perform High-quality CPR

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	Total
Overall	49	37	12	2	0	0	100
Nurses	15	16	6	1	0	0	38
Athletic Trainers	22	14	5	0	0	0	41
EMS	19	10	1	1	0	0	31

Table 47. CPR Training Scenarios Were Similar to Real-life Situations You May Have Encountered In Your Professional Career

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	Total
Overall	17	26	26	7	11	14	101
Nurses	7	12	9	2	3	5	38
Athletic Trainers	7	10	11	3	3	8	42
EMS	5	8	8	3	5	2	31

Section 2: Deliberate Practice and Feedback

Current CPR guidelines suggest deliberate practice and subsequent feedback are essential components of resuscitation education.[83] Included in deliberate practice is the use of high-fidelity equipment to simulate the most realistic scenario for CPR education. For the purposes of this study, low-fidelity equipment was defined as traditional manikin that may or may not provide a clicking noise for proper compression depth. Medium-fidelity equipment was defined as; provides feedback on performance… (for example: simulated pulse ventilations, eye opening/closing, etc.). High-fidelity equipment was defined as; the manikin is realistic by having human properties that an instructor has programmed (for example: simulated pulse in accordance with the condition in which you are treating [SimMan]). Questions and findings pertaining to deliberate practice and feedback can be found in the frequency tables below (tables 48-52).

Table 48. On What Type of Manikins Have You Practiced Your CPR Skills? (Thinking About Your Most Recent Recertification)

	Low Fidelity	Medium Fidelity	High-Fidelity	Total
Overall	59	36	6	101
Nurses	21	14	3	38
Athletic Trainers	23	16	3	42
EMS	20	11	0	31

Table 49. Utilizing Manikins That Provide Feedback Concurrent With Your Performance Enhances Your Ability To Properly Perform High-quality CPR.

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	Total
Overall	34	50	15	1	1	0	101
Nurses	11	21	5	0	1	0	38
Athletic Trainers	17	19	5	1	0	0	42
EMS	8	16	6	1	0	0	31

Table 50. Your Instructor Provided Helpful Feedback During CPR Trainings.

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	Total
Overall	28	51	14	4	2	2	101
Nurses	11	17	7	0	2	1	38
Athletic Trainers	17	19	5	1	0	0	42
EMS	8	17	4	2	0	0	31

Table 51. You Prefer Feedback Directly From The Manikin Versus Instructor Feedback

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	Total
Overall	13	19	29	25	13	2	101
Nurses	1	9	8	11	8	1	38
Athletic Trainers	9	6	14	9	3	1	42
EMS	3	7	12	6	2	1	31

Table 52. You Prefer Skill Performance Feedback Visually on a Screen From a Manikin Versus Auditory (Clicking) From A Manikin.

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	Total
Overall	20	28	21	21	8	2	101
Nurses	7	12	10	7	2	0	38
Athletic Trainers	8	13	9	8	3	1	42
EMS	8	6	3	6	6	1	31

Section 3: Booster Sessions

Booster sessions for the purpose of this study were defined as CPR skills and education sessions that occur within a certification window. Booster sessions are commonly used to practice and enhance CPR skills but do not result in formal a CPR certification certificate or credential (commonly are directed by place of employment and may be informal). Questions and findings pertaining to booster sessions are illustrated in frequency tables below (tables 53-56).

The total number of participants was reduced for booster sessions since participants were asked to answer these only if they had the opportunity to participate in booster sessions.

Table 53. How Often Do You Participate In Booster Sessions?

	Never	Every 3 months	Every 6 months	Annually	Other	Total
Overall	35	15	13	16	6	85
Nurses	10	12	4	4	2	32
Athletic Trainers	16	2	5	9	4	36
EMS	12	2	5	3	2	24

Table 54. How Often Do You Think Booster Sessions Should Be Provided Within a 2-year Certification Cycle to Maximize Performance?

	Never	Every 3 months	Every 6 months	Annually	Other	Total
Overall	7	17	25	28	4	81
Nurses	1	11	6	10	3	31
Athletic Trainers	4	4	13	12	1	34
EMS	2	2	10	7	2	23

Table 55. Booster Sessions Improve Your Ability to Properly Perform High-quality CPR to Patients Suffering From a Cardiac Arrest

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	Total
Overall	26	35	18	1	0	1	81
Nurses	9	15	7	1	0	0	32
Athletic Trainers	13	12	6	0	0	1	32
EMS	6	11	7	0	0	0	24

Table 56. Booster Sessions Ensure You Are More Confident in Your Ability to Perform High-quality CPR.

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	Total
Overall	32	32	13	3	0	1	101
Nurses	12	15	4	1	0	0	32
Athletic Trainers	12	13	5	1	0	1	32
EMS	10	7	6	1	0	0	24

Discussion

Literature indicates that CPR psychomotor skills decline significantly within six months of a training course, yet the AHA maintains a certification time frame of two years.[3, 114, 126-128]

Medical and education experts associated with the AHA have contemplated the two-year time frame. The 2015 CPR guidelines section states that it is reasonable for additional training to occur within the certification time period, especially for those who are likely to encounter a cardiac arrest scenario, such as health care providers.[2] The current study intended to examine recertification processes for professionals who are likely to perform CPR. Although the attrition of skills around six months is well documented and there is support for additional trainings within the certification window, our findings show that only 3.96% of surveyed health care professionals participate in formal recertification processes every six months and 20.79% recertify annually. Adherence to guideline suggestions to recertify prior to two-year certification expiration does not occur in the majority of surveyed health care professionals.

Within educational design there is a new push for standards-based grading, also called formative assessment, instead of the assignment of a letter grade or a simple pass/failure. The intention of standard-based education is that of developing programs that are purposeful in ensuring a skill or concept is mastered.[144] Regarding CPR education, our results indicate recertification courses are inconsistent and overall unclear with written and psychomotor skill exams and expectations if those exams occur. Eighty-five of the surveyed health care providers reported they had to take a written exam, but when they were asked what the passing score was, the answers were erratic. Some providers claimed they had to achieve a 70% passing rate, and others claimed 90% was the passing requirement. Sixty-six participants reported completing a skills proficiency exam, and again were seemingly unsure on what the passing expectation was. Participants who filled in the "other" option reported that they simply had to perform the criteria on the checklist for skills. The incongruencies with expectations in CPR is detrimental to the ability of health care providers to meet the expectation that they can properly perform high-quality CPR. If intentional practice does not occur, allowing for mastery of all of the components of CPR, how can the expectation of a masterful performance be in place? Based on the findings our of research, expectations in CPR education must be clarified for students in recertifications courses. In addition, a push to maintain congruency with best educational practice, identifying what mastery is for each aspect of CPR performance is encouraged. Thus, if participants do not master one aspect, the lack of proficiency can be identified and remediation can occur until that skill is mastered and CPR performance overall can be high-quality, hopefully improving outcomes from CPR performance.

Regarding booster sessions, 41.18% of health care professionals reported that they never participated in a booster session in their professional career. The lack of booster session participation indicates that health care professionals do not have additional psychomotor training during their certification period. While 37.5% of nurses reported that they participated in booster session every three months, 44.44% of surveyed athletic trainers reported that they never participated in booster sessions. Again, this is concerning due to the significant rate of attrition of CPR psychomotor skills around the six-month mark during the two-year certification. [3, 114, 126-128] The current education guidelines suggest that booster sessions may be beneficial to maintain the ability to provide high-quality skill provision yet booster sessions not mandated.[83] Booster sessions may also contribute to improved performance due to the increase in confidence from the additional practice. Seventy-five percent (75.31%) of health care providers stated that booster sessions improved their ability to perform high-quality CPR, while 79.02% of surveyed providers agreed they were more confident in their CPR skills when they did participate in booster sessions. These findings were similar to findings from Kallestedt et al.[88] who reported that nurses suggested higher levels of confidence immediately after CPR training. Based on our findings that only 20% of health care providers recertified annually and around 40% of surveyed nurses, athletic trainers and EMS providers do not participate in booster sessions, a call to action is encouraged. Shortening the certification guideline and requiring booster sessions within their professional settings to ensure allied health care professionals are prepared to act in an emergency scenario is encouraged.

Current key recommendations include deliberate practice with the use of high-fidelity manikins and subsequent feedback for CPR psychomotor skill acquisition. The guidelines state: “This deliberate practice should be based on clearly defined objectives and not time spent, to promote student development toward mastery.”[83 (p. 563)] When exploring the amount of time that is spent on actual CPR psychomotor skills practice, our findings show that the majority of health care providers practice for an hour or less, and nurses primarily practiced for 30 minutes or less. Approximately 45% of professionals felt there was enough time on skill acquisition during CPR trainings. Results from our study do not distinguish whether the practice that health care providers had in their training course was that of a deliberate nature as opposed to individual practice. Therefore, more in-depth questioning and observations of and about the psychomotor practice within CPR education for specific health care providers should be further studied. And although nearly half of the participants indicated that they felt there was enough time spent on psychomotor skill practice, it is vital to recognize that conversely, over half of the surveyed health care providers did not feel that they had enough time to practice. Therefore, educational design should be considered to recognize the need for additional psychomotor practice to ensure proper skill acquisition occurs.

High-fidelity equipment for education in medical interventions is thought to improve overall knowledge, performance and subsequent outcomes, and yet the use of high-fidelity manikins are not mandated in CPR educational guidelines for health care providers.[83, 145, 146] Guidelines suggest utilizing high-fidelity equipment to encourage active engagement with the scenario that is presented to learners.[83] Although high-fidelity equipment use is encouraged in the guidelines, our findings indicate that 5.94% of surveyed health care providers actually have trained on high-fidelity equipment in their recertification courses. However, even though the majority of health care providers reported that they did not utilize high-fidelity equipment in their education, they were confident in their ability to perform high-quality CPR. In addition, they felt their most recent recertification course spent enough time on skill acquisition with the low- or medium-fidelity manikins that were provided.

A focal point of deliberate practice incorporates the provision of feedback to refine CPR psychomotor skills and correct errors.[122, 124, 126, 129] In the 2015 guidelines education section, a core AHA emergency cardiovascular care concept is practice to mastery. In this section, the guidelines state, “learners should have opportunities for repetitive performance of key skills coupled with rigorous assessment and informative feedback in a controlled setting”.[83 (p. 563)] When asked about CPR training scenarios, approximately 50% of participants reported they agreed or somewhat agreed that the educational training scenario was similar to real-life situations they have encountered. This finding was unexpected based on the previously reported data stating that only 6% of surveyed health care providers practiced on high-fidelity equipment. Approximately 97% of health care providers agreed that manikin feedback enhanced their ability to properly perform CPR, and 80% of health care providers reported that their instructors provided valuable feedback. Findings from Lin et al. suggest that CPR practice with real-time feedback improved CPR quality.[124] Although the current study did not measure specific CPR metrics, it is valuable to note that the surveyed health care providers reported that they felt feedback improved their CPR performances. In the recent past, research was conducted to compare traditional classes with individuals who learned from the comfort of their own homes with a basic manikin. Although the results suggested individuals performed just as well as those in a traditional class, our research concludes that health care providers appreciate the feedback either from the instructor or from manikins with technology.[85, 121-124] Regarding the specific type of feedback, the majority of health care providers indicated that they prefer visual feedback versus auditory feedback for the manikin. The conflicting part of our findings is that while nurses, athletic trainers, and EMS personnel shared they prefer feedback from a manikin, the majority do not have the opportunity to train on high-fidelity equipment that provides the most realistic practice with real-time feedback opportunities.

Current CPR guidelines for the health care provider indicate that rescuers should determine the presence of a pulse or pulselessness. Additionally, in the 2000 guideline update, the pulse check was removed for the lay rescuer.[147] Evidence supports elimination of the pulse check due to the inability of health care professionals to successfully detect the presence or absence of a carotid pulse within 10 seconds.[33-36] However, even though data suggests health care professionals are not proficient at finding pulses, the pulse aspect of the algorithm is still expected to be completed by health care providers.[2] When asked how often participants practice locating a central or peripheral pulse during the formal recertification process, findings were unsurprising based on the published data that supported the pulse removal, which indicated health care providers were unsuccessful at quickly and correctly locating pulse. Approximately 28% of participants reported that they never practiced locating a pulse during CPR education, and 51.49% reported they practiced on one to two simulated patients. Those who identified as EMS personnel reported the highest percentage (96.77%) of health care professionals that practiced locating a pulse when compared to athletic trainers and nurses (71.36% and 52.63%, respectively). In addition, since only about 6% of participants reported that they trained with high-fidelity equipment, practicing finding pulses correctly and efficiently could not occur based on the equipment they utilize in education. It can be reasonably argued that if health care providers are not practicing the skill, their performance is expected to be subpar, which is congruent with the previously mentioned findings that pushed for the removal of the pulse check in the first place.

While the goal of this study was to identify key components of CPR education in a population of nurses, athletic trainers, and EMS professionals, it was not without limitations. There was no measure of the ability of participants to perform high-quality CPR after their recertification courses. Additionally, there was no intervention incorporated in this study. Therefore, our results cannot contribute to the quantitative findings of other studies that analyze specific components of CPR provision such as compression rate, depth, and chest recoil. With the realization of the limitations, our study provides a baseline set of data so that advisory committees can make recommendations for CPR education in accordance with the needs of health care professionals.

Despite an increasing amount of data, the relationship between CPR education and the quality of CPR provided by health care professionals is still unclear. Our findings suggest that health care providers are not adhering to suggestions in the guidelines. While it is apparent that psychomotor skills decline around six months after initial training, health care providers are not participating in formal retraining as often as they should. Additionally, a large portion of health care providers are not participating in booster sessions to ensure they maintain their ability to perform proper CPR. Current guidelines suggest that deliberate practice should be included in

CPR education, which consists of the use of high-fidelity equipment and the provision of feedback. However, health care providers appear to be partaking in education that utilizes low- and medium- fidelity equipment. Overall, based on our findings, educational design committees should have a clearer picture of what is occurring within CPR education for specific health care professions. It is critical for the AHA to consider our findings when updating the next set of guidelines with a renewed focus on individualized curricula.

REFERENCES

1. Hazinski M, Chameides L, Hemphill R, Samson R, Schexnayder S, Sinz E. Highlights of the 2010 American Heart Association Guidelines far CPR and ECC. A*merican Heart Association*. 2011:1-28.

2. Highlights of the 2015 American Heart Association Guidelines Update for CPR and ECC. *Circulation*. 2015:1-33.

3. Au K, Lam D, Garg N, et al. Improving skills retention after advanced structured bresuscitation training: A systematic review of randomized controlled trials. *Resuscitation*. 05 2019;138:284-296. doi:10.1016/j.resuscitation.2019.03.031

4. Gonzi G, Sestigiani F, D'Errico A, et al. Correlation between quality of cardiopulmonary resuscitation and self-efficacy measured during in-hospital cardiac arrest simulation; preliminary results. *Acta Biomed*. Mar 13 2015;86 Suppl 1:40-5.

5. Mayrand KP, Fischer EJ, Ten Eyck RP. A Simulation-based Randomized Controlled Study of Factors Influencing Chest Compression Depth. *West J Emerg Med*. Dec 2015;16(7):1135-40. doi:10.5811/westjem.2015.9.28167

6. Kaminska H, Wieczorek W, Matusik P, et al. Factors influencing high-quality chest compressions during cardiopulmonary resuscitation scenario, according to 2015 American Heart Association Guidelines. *Kardiol Pol*. 2018;76(3):642-647. doi:10.5603/KP.a2018.0003

7. Estabrooks AG, Lyman KJ, German N, Albrecht J. An analysis of certified athletic trainers' ability to provide high-q uality cardiopulmonary resuscitation (cpr) over hockey shoulder pads. *North Dakota State University*; 2018.

8. Waninger KN, Goodbred A, Vanic K, et al. Adequate performance of cardiopulmonary resuscitation techniques during simulated cardiac arrest over and under protective equipment in football. *Clin J Sport Med*. Jul 2014;24(4):280-3. doi:10.1097/JSM.0000000000000022

9. Hsia RY, Huang D, Mann NC, et al. A US National Study of the Association Between Income and Ambulance Response Time in Cardiac Arrest. *JAMA* Netw Open. Nov 2 2018;1(7):e185202. doi:10.1001/jamanetworkopen.2018.5202

10. Cardiopulmonary Resuscitation (CPR). (n.d.). *Gale Encyclopedia of Medicine* .2008.

11. Bowser M. What is EMS? *DC Health*. 2021. https://dchealth.dc.gov/service/what-ems

12. Bandura A. Self-efficacy: toward a unifying theory of behavioral change. *Psychol Rev*. Mar 1977;84(2):191-215. doi:10.1037//0033-295x.84.2.191

13. Schoenherr JR, Hamstra SJ. Beyond Fidelity: Deconstructing the Seductive Simplicity of Fidelity in Simulator-Based Education in the Health Care Professions. *Simul Healthc*. Apr 2017;12(2):117-123. doi:10.1097/SIH.0000000000000226

14. Macnamara BN, Hambrick DZ, Oswald FL. Deliberate practice and performance in music, games, sports, education, and professions: a meta-analysis. *Psychol Sci*. Aug 2014;25(8):1608-18. doi:10.1177/0956797614535810

15. Ericsson KA, Harwell KW. Deliberate Practice and Proposed Limits on the Effects of Practice on the Acquisition of Expert Performance: Why the Original Definition Matters and Recommendations for Future Research. *Front Psychol*. 2019;10:2396. doi:10.3389/fpsyg.2019.02396

16. Hernández-Padilla J, Suthers F, Fernández-Sola C, Granero-Molina J. Development and psychometric assessment of the Basic Resuscitation Skills Self-Efficacy Scale. *Eur J Cardiovasc Nurs*. Apr 2016;15(3):e10-8. doi:10.1177/1474515114562130

17. History Of CPR. Accessed 1/12/2018, 2018. http://cpr.heart.org/AHAECC/CPRAndECC/AboutCPRFirstAid/HistoryofCPR/UCM_475751_History-of-CPR.jsp

18. Aitchison R, Aitchison P, Wang E, Kharasch M. A review of cardiopulmonary resuscitation and its history. *Dis Mon*. May 2013;59(5):165-7. doi:10.1016/j.disamonth.2013.03.002

19. Cooper JA, Cooper JD, Cooper JM. Cardiopulmonary resuscitation: history, current practice, and future direction. *Circulation*. Dec 2006;114(25):2839-49. doi:10.1161/CIRCULATIONAHA.106.610907

20. Hurt R. Modern cardiopulmonary resuscitation--not so new after all. *J R Soc Med*. Jul 2005;98(7):327-31. doi:10.1258/jrsm.98.7.327

21. Acosta P, Varon J, Sternbach GL, Baskett P. Resuscitation great. Kouwenhoven, Jude and Knickerbocker: The introduction of defibrillation and external chest compressions into modern resuscitation. *Resuscitation*. Feb 2005;64(2):139-43. doi:10.1016/j.resuscitation.2004.12.004

22. Hwang SO. Cardiopulmonary resuscitation—From the past into the future. *Journal of Acute Medicine*. 2013;3(3):67-72.

23. Casa DJ, Almquist J, Anderson SA, et al. The inter-association task force for preventing sudden death in secondary school athletics programs: best-practices recommendations. *J Athl Train*. Jul-Aug 2013;48(4):546-53. doi:10.4085/1062-6050-48.4.12

24. Cummins RO, Chamberlain DA. Advisory statements of the International Liaison Committee on Resuscitation. *Circulation*. Apr 15 1997;95(8):2172-3.

25. Nolan J, Soar J, Eikeland H. The chain of survival. *Resuscitation*. Dec 2006;71(3):270-1. doi:10.1016/j.resuscitation.2006.09.001

26. About ILCOR. http://www.ilcor.org/about-ilcor/about-ilcor/

27. Zed P, Abu-Laban R, Shuster M, Green R, Slavik R, Travers A. Update on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Guidelines. *American Journal of Health-System Pharmacy*. 2008;65(24):2337-2346.

28. Adult advanced cardiac life support: the European Resuscitation Council guidelines 1992 (abridged). European Resuscitation Council Working Party. *BMJ*. Jun 1993;306(6892):1589-93.

29. Christenson JM, Solimano AJ, Williams J, et al. The new American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiac care: presented by the Emergency Cardiac Care Subcommittee of the Heart and Stroke Foundation of Canada. *CMAJ*. Sep 1993;149(5):585-90.

30. Cummins RO, Hazinski MF. The most important changes in the international ECC and CPR guidelines 2000. *Resuscitation.* Aug 2000;46(1-3):431-7.

31. Part 1: Introduction to the International Guidelines 2000 for CPR and ECC : a consensus on science. *Circulation.* Aug 2000;102(8 Suppl):I1-11.

32. Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Part 6: advanced cardiovascular life support: section 1: Introduction to ACLS 2000: overview of recommended changes in ACLS from the guidelines 2000 conference. The American Heart Association in collaboration with the International Liaison Committee on Resuscitation. *Circulation.* Aug 2000;102(8 Suppl):I86-9.

33. Flesche CW, Blewer S, Mandel LP, Brevik H, Tarnow J. The ability of health professional to check the carotid pulse. *Circulation* 1994. p. 288.

34. Flesche CW, Zucker TP, Lorenz C, Nerudo B, Tarnow J. The carotid pulse check as a diagnostic tool to assess pulselessness during adult basic life support. *Euroanaesthesia*. 1995.

35. Mather C, O'Kelly S. The palpation of pulses. *Anaesthesia.* Volume 51(1996). p. 189-191.

36. Ochoa FJ, Ramalle-Gomara E, Carpintero JM, Garcia A, Saralegui I. Competence of health professionals to check the carotid pulse. *Resuscitation*. Jun 1998;37(3):173-5.

37. Eberle B, Dick WF, Schneider T, Wisser G, Doetsch S, Tzanova I. Checking the carotid pulse check: diagnostic accuracy of first responders in patients with and without a pulse. *Resuscitation*. Dec 1996;33(2):107-16.

38. Bahr J, Klingler H, Panzer W, Rode H, Kettler D. Skills of lay people in checking the carotid pulse. *Resuscitation*. Aug 1997;35(1):23-6.

39. Dunkley CJA, Thomas AN, Taylor RJ, Perkins RJ. A comparison of standard and a modified method of two resuscitator adult cardiopulmonary resuscitation: Description of a new system for research into advanced life support skills. *Resuscitation.* 38 (1998) 7–12

40. Kinney SB, Tibballs J. An analysis of the efficacy of bag-valve-mask ventilation and chest compression during different compression-ventilation ratios in manikin-simulated paediatric resuscitation. *Resuscitation*. Jan 2000;43(2):115-20.

41. Greingor JL. Quality of cardiac massage with ratio compression-ventilation 5/1 and 15/2. *Resuscitation.* Dec 2002;55(3):263-7.

42. Dorph E, Wik L, Steen PA. Effectiveness of ventilation-compression ratios 1:5 and 2:15 in simulated single rescuer paediatric resuscitation. *Resuscitation*. Sep 2002;54(3):259-64.

43. Babbs CF, Kern KB. Optimum compression to ventilation ratios in CPR under realistic, practical conditions: a physiological and mathematical analysis. *Resuscitation*. Aug 2002;54(2):147-57.

44. Valenzuela TD, Kern KB, Clark LL, et al. Interruptions of chest compressions during emergency medical systems resuscitation. *Circulation*. Aug 2005;112(9):1259-65. doi:10.1161/CIRCULATIONAHA.105.537282

45. Brennan RT, Braslow A. Skill mastery in cardiopulmonary resuscitation training classes. *Am J Emerg Med*. Sep 1995;13(5):505-8. doi:10.1016/0735-6757(95)90157-4

46. Kaye W, Mancini ME. Teaching adult resuscitation in the United States--time for a rethink. *Resuscitation*. Jun 1998;37(3):177-87.

47. Kaye W, Rallis SF, Mancini ME, et al. The problem of poor retention of cardiopulmonary resuscitation skills may lie with the instructor, not the learner or the curriculum. *Resuscitation*. Feb 1991;21(1):67-87.

48. 2005 American Heart Association (AHA) guidelines for cardiopulmonary resuscitation (CPR) and emergency cardiovascular care (ECC) of pediatric and neonatal patients: pediatric basic life support. *Pediatrics.* May 2006;117(5):e989-1004. doi:10.1542/peds.2006-0219

49. Nagao K, Kikushima K, Sakamoto T, et al. Cardiopulmonary resuscitation by bystanders with chest compression only: an observational study. *The Lancet*. 2007;369:920-926.

50. Iwami T, Kawamura T, Hiraide A, et al. Effectiveness of bystander-initiated cardiac-only resuscitation for patients with out-of-hospital cardiac arrest. *Circulation*. Dec 2007;116(25):2900-7. doi:10.1161/CIRCULATIONAHA.107.723411

51. Bohm K, Rosenqvist M, Herlitz J, Hollenberg J, Svensson L. Survival is similar after standard treatment and chest compression only in out-of-hospital bystander cardiopulmonary resuscitation. *Circulation.* Dec 2007;116(25):2908-12. doi:10.1161/CIRCULATIONAHA.107.710194

52. Part 3: Overview Of CPR. *Circulation*. 2005;112(IV-12):12-18. doi:10.1161/CIRCULATIONAHA.105.166552

53. Ali B, Zafari AM. Narrative review: cardiopulmonary resuscitation and emergency cardiovascular care: review of the current guidelines. *Ann Intern Med.* Aug 7 2007;147(3):171-9.

54. Mellor R, Woollard M. Skill acquisition by health care workers in the Resuscitation Council (UK) 2005 Guidelines for Adult Basic Life Support. I*nt Emerg Nurs*. Apr 2010;18(2):61-6. doi:10.1016/j.ienj.2009.08.003

55. Olasveengen TM, Vik E, Kuzovlev A, Sunde K. Effect of implementation of new resuscitation guidelines on quality of cardiopulmonary resuscitation and survival. *Resuscitation*. Apr 2009;80(4):407-11. doi:10.1016/j.resuscitation.2008.12.005

56. Hinchey PR, Myers JB, Lewis R, et al. Improved out-of-hospital cardiac arrest survival after the sequential implementation of 2005 AHA guidelines for compressions, ventilations, and induced hypothermia: the Wake County experience. *Ann Emerg Med*. Oct 2010;56(4):348-57. doi:10.1016/j.annemergmed.2010.01.036

57. Mellor R, Woollard M. Skill acquisition by health care workers in the Resuscitation Council (UK) 2005 Guidelines for Adult Basic Life Support. *Int Emerg Nurs*. Apr 2009;18(2):61-6. doi:10.1016/j.ienj.2009.08.003

58. Travers AH, Rea TD, Bobrow BJ, et al. Part 4: CPR overview: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. Nov 2 2010;122(18 Suppl 3):S676-84. doi:10.1161/circulationaha.110.970913

59. Lubrano R, Cecchetti C, Bellelli E, et al. Comparison of times of intervention during pediatric CPR maneuvers using ABC and CAB sequences: a randomized trial. *Resuscitation*. Dec 2012;83(12):1473-7. doi:10.1016/j.resuscitation.2012.04.011

60. Sekiguchi H, Kondo Y, Kukita I. Verification of changes in the time taken to initiate chest compressions according to modified basic life support guidelines. *Am J Emerg Med*. Aug 2013;31(8):1248-50. doi:10.1016/j.ajem.2013.02.047

61. Marsch S, Tschan F, Semmer NK, Zobrist R, Hunziker PR, Hunziker S. ABC versus CAB for cardiopulmonary resuscitation: a prospective, randomized simulator-based trial. *Swiss Med Wkly*. 2013;143:w13856. doi:10.4414/smw.2013.13856

62. Wang CH, Huang CH, Chang WT, et al. Outcomes of adults with in-hospital cardiac arrest after implementation of the 2010 resuscitation guidelines. *Int J Cardiol*. Dec 2017;249:214-219. doi:10.1016/j.ijcard.2017.09.008

63. Bobrow BJ, Spaite DW, Berg RA, et al. Chest compression-only CPR by lay rescuers and survival from out-of-hospital cardiac arrest. *JAMA*. Oct 2010;304(13):1447-54. doi:10.1001/jama.2010.1392

64. Cabrini L, Biondi-Zoccai G, Landoni G, et al. Bystander-initiated chest compression-only CPR is better than standard CPR in out-of-hospital cardiac arrest. *HSR Proc Intensive Care Cardiovasc Anesth*. 2010;2(4):279-85.

65. Panchal AR, Bobrow BJ, Spaite DW, et al. Chest compression-only cardiopulmonary resuscitation performed by lay rescuers for adult out-of-hospital cardiac arrest due to non-cardiac aetiologies. *Resuscitation*. Apr 2013;84(4):435-9. doi:10.1016/j.resuscitation.2012.07.038

66. Yang Z, Li H, Yu T, et al. Quality of chest compressions during compression-only CPR: a comparative analysis following the 2005 and 2010 American Heart Association guidelines. T*he American Journal Of Emergency Medicine*. 2014;32(1):50-54. doi:10.1016/j.ajem.2013.09.043

67. Mieure KD, Vincent WR, Cox MR, Jones MD. A high-fidelity simulation mannequin to introduce pharmacy students to advanced cardiovascular life support. *Am J Pharm Educ.* Mar 2010;74(2):22. doi:10.5688/aj740222

68. Hughes TC, Jiwaji Z, Lally K, et al. Advanced Cardiac Resuscitation Evaluation (ACRE): a randomised single-blind controlled trial of peer-led vs. expert-led advanced resuscitation training. *Scand J Trauma Resusc Emerg Med*. Jan 2010;18:3. doi:10.1186/1757-7241-18-3

69. Meaney PA, Bobrow BJ, Mancini ME, et al. Cardiopulmonary resuscitation quality: [corrected] improving cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association. *Circulation.* Jul 23 2013;128(4):417-35. doi:10.1161/CIR.0b013e31829d8654

70. Kleinman M, Brennan E, Goldberger Z, et al. Part 5: adult basic life support and cardiopulmonary resuscitation quality: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2015;132(2):S414-S435. doi:DOI: 10.1161/CIR.0000000000000259

71. Idris AH, Guffey D, Pepe PE, et al. Chest compression rates and survival following out-of-hospital cardiac arrest. *Crit Care Med*. Apr 2015;43(4):840-8. doi:10.1097/CCM.0000000000000824

72. Kilgannon JH, Kirchhoff M, Pierce L, Aunchman N, Trzeciak S, Roberts BW. Association between chest compression rates and clinical outcomes following in-hospital cardiac arrest at an academic tertiary hospital. *Resuscitation*. 01 2017;110:154-161. doi:10.1016/j.resuscitation.2016.09.015

73. Vadeboncoeur T, Stolz U, Panchal A, et al. Chest compression depth and survival in out-of-hospital cardiac arrest. *Resuscitation*. Feb 2014;85(2):182-8. doi:10.1016/j.resuscitation.2013.10.002

74. Neumer RW, Shuster M, Callaway CW, et al. Part 1: Executive Summary 2015 American heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation;* 2015. p. S315-S367.

75. Yannopoulos D, McKnite S, Aufderheide TP, et al. Effects of incomplete chest wall decompression during cardiopulmonary resuscitation on coronary and cerebral perfusion pressures in a porcine model of cardiac arrest. *Resuscitation.* Mar 2005;64(3):363-72. doi:10.1016/j.resuscitation.2004.10.009

76. Aufderheide TP, Pirrallo RG, Yannopoulos D, et al. Incomplete chest wall decompression: a clinical evaluation of CPR performance by EMS personnel and

assessment of alternative manual chest compression-decompression techniques. *Resuscitation.* Mar 2005;64(3):353-62. doi:10.1016/j.resuscitation.2004.10.007

77. Fried DA, Leary M, Smith DA, et al. The prevalence of chest compression leaning during in-hospital cardiopulmonary resuscitation. *Resuscitation*. Aug 2011;82(8):1019-24. doi:10.1016/j.resuscitation.2011.02.032

78. Cheskes S, Common MR, Byers AP, Zhan C, Silver A, Morrison LJ. The association between chest compression release velocity and outcomes from out-of-hospital cardiac arrest. *Resuscitation*. Jan 2015;86:38-43. doi:10.1016/j.resuscitation.2014.10.020

79. Christenson J, Andrusiek D, Everson-Stewart S, et al. Chest compression fraction determines survival in patients with out-of-hospital ventricular fibrillation. *Circulation.* Sep 2009;120(13):1241-7. doi:10.1161/CIRCULATIONAHA.109.852202

80. Krarup NH, Terkelsen CJ, Johnsen SP, et al. Quality of cardiopulmonary resuscitation in out-of-hospital cardiac arrest is hampered by interruptions in chest compressions--a nationwide prospective feasibility study. *Resuscitation*. Mar 2011;82(3):263-9. doi:10.1016/j.resuscitation.2010.11.003

81. Cheskes S, Schmicker RH, Rea T, et al. The association between AHA CPR quality guideline compliance and clinical outcomes from out-of-hospital cardiac arrest. *Resuscitation.* 07 2017;116:39-45. doi:10.1016/j.resuscitation.2017.05.003

82. Wik L, Olsen JA, Persse D, et al. Why do some studies find that CPR fraction is not a predictor of survival? *Resuscitation.* Jul 2016;104:59-62. doi:10.1016/j.resuscitation.2016.04.013

83. Bhanji F, Donoghue AJ, Wolff MS, et al. Part 14: Education: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. Nov 2015;132(18 Suppl 2):S561-73. doi:10.1161/CIR.0000000000000268

84. Bobrow BJ, Vadeboncoeur TF, Stolz U, et al. The influence of scenario-based training and real-time audiovisual feedback on out-of-hospital cardiopulmonary resuscitation quality and survival from out-of-hospital cardiac arrest. *Ann Emerg Med*. Jul 2013;62(1):47-56.e1. doi:10.1016/j.annemergmed.2012.12.020

85. Yeung J, Davies R, Gao F, Perkins GD. A randomised control trial of prompt and feedback devices and their impact on quality of chest compressions--a simulation study. *Resuscitation.* Apr 2014;85(4):553-9. doi:10.1016/j.resuscitation.2014.01.015

86. Liu Y, Huang Z, Li H, et al. CPR feedback/prompt device improves the quality of hands-only CPR performed in manikin by laypersons following the 2015 AHA guidelines. *Am J Emerg Med*. 11 2018;36(11):1980-1985. doi:10.1016/j.ajem.2018.02.034

87. Bandura A. Social cognitive theory: an agentic perspective. *Annu Rev Psychol*. 2001;52:1-26. doi:10.1146/annurev.psych.52.1.1

88. Källestedt ML, Berglund A, Herlitz J, Leppert J, Enlund M. The impact of CPR and AED training on healthcare professionals' self-perceived attitudes to performing resuscitation. *Scand J Trauma Resusc Emerg Med*. Apr 2012;20:26. doi:10.1186/1757-7241-20-26

89. Roh YS, Issenberg SB, Chung HS, Kim SS. Development and psychometric evaluation of the Resuscitation Self-efficacy Scale for nurses. *J Korean Acad Nurs*. Dec 2012;42(7):1079-86. doi:10.4040/jkan.2012.42.7.1079

90. Ro YS, Shin SD, Song KJ, et al. Public awareness and self-efficacy of cardiopulmonary resuscitation in communities and outcomes of out-of-hospital cardiac arrest: A multi-level analysis. *Resuscitation*. May 2016;102:17-24. doi:10.1016/j.resuscitation.2016.02.004

91. Riggs M, Franklin R, Saylany L. Associations between cardiopulmonary resuscitation (CPR) knowledge, self-efficacy, training history and willingness to perform CPR and CPR psychomotor skills: A systematic review. *Resuscitation*. 05 2019;138:259-272. doi:10.1016/j.resuscitation.2019.03.019

92. Binkhorst M, Draaisma JMT, Benthem Y, van de Pol EMR, Hogeveen M, Tan ECTH. Peer-led pediatric resuscitation training: effects on self-efficacy and skill performance. *BMC Med Educ*. Nov 2020;20(1):427. doi:10.1186/s12909-020-02359-z

93. Lammert LW, Lyman KJ, Kota R, McGeorge C. Investigating the relationship between self-efficacy and cardiopulmonary resuscitation quality in certified athletic trainers. North Dakota State University 2020.

94. Blackhall LJ, Perry PA. Why physicians Avoid Straight Talk about CPR. *Virtual Mentor*. Sep 2006;8(9):602-8. doi:10.1001/virtualmentor.2006.8.9.pfor2-0609

95. Roshana S, Kh B, Rm P, Mw S. Basic life support: knowledge and attitude of medical/paramedical professionals. *World J Emerg Med*. 2012;3(2):141-5. doi:10.5847/wjem.j.issn.1920-8642.2012.02.011

96. Citolino CM, Santos ES, Silva ReC, Nogueira LeS. Factors affecting the quality of cardiopulmonary resuscitation in inpatient units: perception of nurses. *Rev Esc Enferm USP*. Dec 2015;49(6):908-14. doi:10.1590/S0080-623420150000600005

97. Navalpotro-Pascual S, Blanco-Blanco Á, Torre-Puente JC. Experience of emergency healthcare professionals in cardiopulmonary resuscitation and its relationship with self-efficacy: A qualitative approach. *Enferm Clin*. 2019 May - Jun 2019;29(3):155-169. doi:10.1016/j.enfcli.2018.09.008

98. Silverplats J, Södersved Källestedt ML, Wagner P, Ravn-Fischer A, Äng B, Strömsöe A. Theoretical knowledge and self-assessed ability to perform cardiopulmonary resuscitation: a survey among 3044 healthcare professionals in Sweden. *Eur J Emerg Med*. Oct 2020;27(5):368-372. doi:10.1097/MEJ.0000000000000692

99. Sayee N, McCluskey D. Factors influencing performance of cardiopulmonary resuscitation (CPR) by Foundation Year 1 hospital doctors. *Ulster Med J*. Jan 2012;81(1):14-8.

100. Gibson G. Emergency medical services: the research gaps. *Health Serv Res*. 1974;9(1):6-21.

101. Eisenberg M, Bergner L, Hallstrom A. Paramedic programs and out-of-hospital cardiac arrest: I. Factors associated with successful resuscitation. *Am J Public Health*. Jan 1979;69(1):30-8. doi:10.2105/ajph.69.1.30

102. Ko PC, Chen WJ, Lin CH, Ma MH, Lin FY. Evaluating the quality of prehospital cardiopulmonary resuscitation by reviewing automated external defibrillator records and survival for out-of-hospital witnessed arrests. *Resuscitation*. Feb 2005;64(2):163-9. doi:10.1016/j.resuscitation.2004.08.013

103. Brown TB, Dias JA, Saini D, et al. Relationship between knowledge of cardiopulmonary resuscitation guidelines and performance. *Resuscitation*. May 2006;69(2):253-61. doi:10.1016/j.resuscitation.2005.08.019

104. Lin CC, Kuo CW, Ng CJ, Li WC, Weng YM, Chen JC. Rescuer factors predict high-quality CPR--a manikin-based study of health care providers. *Am J Emerg Med*. Jan 2016;34(1):20-4. doi:10.1016/j.ajem.2015.09.001

105. BOC Standards of professional Practice. Omaha, Nebraska2021.

106. Henderson J. The 2015 Athletic Trainer Practice Analysis Study. Omaha, NE: Board of Certification; 2015.

107. Lammert LW, Lyman KJ. Investigating the Relationship Between Self-Efficacy and Cardiopulmonary Resuscitation Quality in Certified Athletic Trainers. North Dakota State University; 2020.

108. Lyman KJ, Landin KD, Guggisberg R. Evaluation of College Students Performing Compression-Only Cardiopulmonary Resuscitation with High-Fidelity Equipment *Journal of Athletic Training* 2017. p. S-62.

109. Skaro KC, Lyman KJ. Effectiveness of cardiopulmonary resuscitation over protective athletic equipment as performed by certified athletic trainers. North Dakota State University; 2020.

110. Del Rossi G, Bodkin D, Dhanani A, Courson RW, Konin JG. Protective athletic equipment slows initiation of CPR in simulated cardiac arrest. *Resuscitation.* Jul 2011;82(7):908-12. doi:10.1016/j.resuscitation.2011.02.022

111. Boergers RJ, Bowman TG, Lininger MR. The Ability to Provide Quality Chest Compressions Over Lacrosse Shoulder Pads. *J Athl Train*. Feb 2018;53(2):122-127. doi:10.4085/1062-6050-346-16

112. Bowman TG, Boergers RJ, Lininger MR, et al. The Effect of Lacrosse Protective Equipment on Cardiopulmonary Resuscitation and Automated External Defibrillator Shock. *J Athl Train.* Nov 2020;doi:10.4085/437-20

113. Einspruch EL, Lynch B, Aufderheide TP, Nichol G, Becker L. Retention of CPR skills learned in a traditional AHA Heartsaver course versus 30-min video self-training: a controlled randomized study. *Resuscitation.* Sep 2007;74(3):476-86. doi:10.1016/j.resuscitation.2007.01.030

114. Nishiyama C, Iwami T, Murakami Y, et al. Effectiveness of simplified 15-min refresher BLS training program: a randomized controlled trial. *Resuscitation.* May 2015;90:56-60. doi:10.1016/j.resuscitation.2015.02.015

115. Nord A, Svensson L, Hult H, Kreitz-Sandberg S, Nilsson L. Effect of mobile application-based versus DVD-based CPR training on students' practical CPR skills and willingness to act: a cluster randomised study. *BMJ Open*. 2016;6(4):e010717. doi:10.1136/bmjopen-2015-010717

116. Benoit JL, Vogele J, Hart KW, Lindsell CJ, McMullan JT. Passive ultra-brief video training improves performance of compression-only cardiopulmonary resuscitation. *Resuscitation.* 06 2017;115:116-119. doi:10.1016/j.resuscitation.2017.04.008

117. Lau Y, Nyoe RSS, Wong SN, Ab Hamid ZB, Leong BS, Lau ST. Effectiveness of digital resuscitation training in improving knowledge and skills: A systematic review and meta-analysis of randomised controlled trials. *Resuscitation.* 10 2018;131:14-23. doi:10.1016/j.resuscitation.2018.07.033

118. McCoy CE, Rahman A, Rendon JC, et al. Randomized Controlled Trial of Simulation vs. Standard Training for Teaching Medical Students High-quality Cardiopulmonary Resuscitation. *West J Emerg Med*. Jan 2019;20(1):15-22. doi:10.5811/westjem.2018.11.39040

119. Chien CY, Fang SY, Tsai LH, et al. Traditional versus blended CPR training program: A randomized controlled non-inferiority study. Sci Rep. 06 2020;10(1):10032. doi:10.1038/s41598-020-67193-1

120. Lynch B, Einspruch EL, Nichol G, Becker LB, Aufderheide TP, Idris A. Effectiveness of a 30-min CPR self-instruction program for lay responders: a controlled randomized study. Resuscitation. Oct 2005;67(1):31-43. doi:10.1016/j.resuscitation.2005.04.017

121. Buléon C, Delaunay J, Parienti JJ, et al. Impact of a feedback device on chest compression quality during extended manikin CPR: a randomized crossover study. Am J Emerg Med. Sep 2016;34(9):1754-60. doi:10.1016/j.ajem.2016.05.077

122. Martin P, Theobald P, Kemp A, Maguire S, Maconochie I, Jones M. Real-time feedback can improve infant manikin cardiopulmonary resuscitation by up to 79%--a randomised controlled trial. Resuscitation. Aug 2013;84(8):1125-30. doi:10.1016/j.resuscitation.2013.03.029

123. Spence AD, Derbyshire S, Walsh IK, Murray JM. Does video feedback analysis improve CPR performance in phase 5 medical students? BMC Med Educ. Aug 12 2016;16(1):203. doi:10.1186/s12909-016-0726-x

124. Lin Y, Cheng A, Grant VJ, Currie GR, Hecker KG. Improving CPR quality with distributed practice and real-time feedback in pediatric healthcare providers - A randomized controlled trial. Resuscitation. 09 2018;130:6-12. doi:10.1016/j.resuscitation.2018.06.025

125. Akizuki K, Yamamoto R, Yamaguchi K, Yabuki J, Ohashi Y. The effects of feedback timing and frequency on the acquisition of cardiopulmonary resuscitation skills of health sciences undergraduate students: A 2 x 2 factorial quasi randomized study. PLoS One. 2019;14(7):e0220004. doi:10.1371/journal.pone.0220004

126. Oermann MH, Kardong-Edgren S, Odom-Maryon T, et al. Deliberate practice of motor skills in nursing education: CPR as exemplar. Nurs Educ Perspect. 2011 Sep-Oct 2011;32(5):311-5. doi:10.5480/1536-5026-32.5.311

127. Mpotos N, De Wever B, Cleymans N, et al. Repetitive sessions of formative self-testing to refresh CPR skills: a randomised non-inferiority trial. Resuscitation. Sep 2014;85(9):1282-6. doi:10.1016/j.resuscitation.2014.06.011

128. Anderson R, Sebaldt A, Lin Y, Cheng A. Optimal training frequency for acquisition and retention of high-quality CPR skills: A randomized trial. Resuscitation. 02 2019;135:153-161. doi:10.1016/j.resuscitation.2018.10.033

129. Oermann MH, Krusmark MA, Kardong-Edgren S, Jastrzembski TS, Gluck KA. Training interval in cardiopulmonary resuscitation. PLoS One. 2020;15(1):e0226786. doi:10.1371/journal.pone.0226786

130. Sawyer T, Sierocka-Castaneda A, Chan D, Berg B, Lustik M, Thompson M. Deliberate practice using simulation improves neonatal resuscitation performance. Simul Healthc. Dec 2011;6(6):327-36. doi:10.1097/SIH.0b013e31822b1307

131. Bhalala U, Velasquez S, Thangavelu M, et al. Rapid-cycle deliberate practice for training of hands-on cpr skills: a randomized controlled trial. Critical Care Medicine2019. p. 745.

132. Diederich E, Lineberry M, Blomquist M, et al. Balancing Deliberate Practice and Reflection: A Randomized Comparison Trial of Instructional Designs for Simulation-Based Training in Cardiopulmonary Resuscitation Skills. Simul Healthc. Jun 2019;14(3):175-181. doi:10.1097/SIH.0000000000000375

133. Meaney PA, Bobrow BJ, Mancini ME, et al. Cardiopulmonary resuscitation quality: [corrected] improving cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association. Circulation. Jul 2013;128(4):417-35. doi:10.1161/CIR.0b013e31829d8654

134. Hoadley TA. Learning advanced cardiac life support: a comparison study of the effects of low- and high-fidelity simulation. Nurs Educ Perspect. 2009 Mar-Apr 2009;30(2):91-5.

135. Adams AJ, Wasson EA, Admire JR, et al. A Comparison of Teaching Modalities and Fidelity of Simulation Levels in Teaching Resuscitation Scenarios. J Surg Educ. 2015 Sep-Oct 2015;72(5):778-85. doi:10.1016/j.jsurg.2015.04.011

136. Girish M, Rawekar A, Jose S, Chaudhari U, Nanoti G. Utility of Low Fidelity Manikins for Learning High Quality Chest Compressions. Indian J Pediatr. 03 2018;85(3):184-188. doi:10.1007/s12098-017-2473-3

137. Rodgers DL, Securro S, Pauley RD. The effect of high-fidelity simulation on educational outcomes in an advanced cardiovascular life support course. Simul Healthc. 2009;4(4):200-6. doi:10.1097/SIH.0b013e3181b1b877

138. Davis LE, Storjohann TD, Spiegel JJ, Beiber KM, Barletta JF. High-fidelity simulation for advanced cardiac life support training. Am J Pharm Educ. Apr 2013;77(3):59. doi:10.5688/ajpe77359

139. Langdorf MI, Strom SL, Yang L, et al. High-fidelity simulation enhances ACLS training. Teach Learn Med. 2014;26(3):266-73. doi:10.1080/10401334.2014.910466

140. Beal MD, Kinnear J, Anderson CR, Martin TD, Wamboldt R, Hooper L. The Effectiveness of Medical Simulation in Teaching Medical Students Critical Care Medicine: A Systematic Review and Meta-Analysis. Simul Healthc. Apr 2017;12(2):104-116. doi:10.1097/SIH.0000000000000189

141. Berger C, Brinkrolf P, Ertmer C, et al. Combination of problem-based learning with high-fidelity simulation in CPR training improves short and long-term CPR skills: a randomised single blinded trial. BMC Med Educ. May 2019;19(1):180. doi:10.1186/s12909-019-1626-7

142. Maibach EW, Schieber RA, Carroll MF. Self-efficacy in pediatric resuscitation: implications for education and performance. Pediatrics. Jan 1996;97(1):94-9.

143. Hsieh TC, Wolfe H, Sutton R, Myers S, Nadkarni V, Donoghue A. A comparison of video review and feedback device measurement of chest compressions quality during pediatric cardiopulmonary resuscitation. Resuscitation. Aug 2015;93:35-9. doi:10.1016/j.resuscitation.2015.05.022

144. Iamarino DL. The Benefits of Standards-Based Grading: A Critical Evaluation of ModernGrading Practices. Current Issues in Education. 2014;17(2):1-10.

145. Cheng A, Lockey A, Bhanji F, Lin Y, Hunt EA, Lang E. The use of high-fidelity manikins for advanced life support training--A systematic review and meta-analysis. Resuscitation. Aug 2015;93:142-9. doi:10.1016/j.resuscitation.2015.04.004

146. Everett-Thomas R, Turnbull-Horton V, Valdes B, Valdes GR, Rosen LF, Birnbach DJ. The influence of high fidelity simulation on first responders retention of CPR knowledge. Appl Nurs Res. May 2016;30:94-7. doi:10.1016/j.apnr.2015.11.005

147. Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Part 12: from science to survival: strengthening the chain of survival in every community. The American Heart Association in collaboration with the International Liaison Committee on Resuscitation. Circulation. Aug 2000;102(8 Suppl):I358-70.

APPENDIX. SURVEY

Section 1: Demographics

1. How do you identify?
    a. Male
    b. Female
    c. Non-Binary
    d. Other _____
    e. Prefer not to answer

2. What is your highest level of education?
    a. High school diploma
    b. Certificate program (no college degree)
    c. Associate Degree
    d. Bachelor's Degree
    e. Master's Degree
    f. Doctoral Degree

3. What is your profession? (Please select all that apply)
    a. Nurse
    b. LPN
    c. RN
    d. Athletic Trainer
    e. Firefighter
    f. First Responder
    g. EMT Basic
    h. EMT Advanced
    i. Paramedic

4. From which entity did you receive your most recent CPR training?
    a. American Heart Association (AHA)
    b. American Red Cross (ARC)
    c. Other ________

Section 2: Self- Efficacy

Please respond to each prompt using the six-point scale listed below.

1: Strongly Disagree
2: Disagree
3: Somewhat Disagree
4: Somewhat Agree
5: Agree
6: Strongly Agree

In the likelihood I encountered an emergency in an out-of-hospital setting in an urban environment for 8 minutes and 59 seconds (8:59), I am confident that I can ALWAYS…

1. Perform CPR in accordance with the 2020 American Heart Association (AHA) guidelines ___
2. Perform chest compressions with an adequate rate (100-120 compressions/minute) ___
3. Perform chest compressions with an adequate depth (≥5 but ≤6 cm) ___
4. Allow the chest to fully recoil while performing compressions ___
5. Perform CPR with a correct compression to ventilation ratio (30:2) ___
6. Deliver ventilations at an adequate rate and volume (8-10 breaths/minute) ___
7. Correctly position hands during CPR (Over the lower half of the sternum) ___
8. Perform CPR with an adequate chest compression fraction (≥ 80%) ___
9. Provide high-quality CPR consistently during a prolonged (approximately 9-minute) resuscitation attempt ___

In the event I encounter an emergency in which the patient was wearing protective athletic equipment (e.g., helmet and chest protection), I am confident that I can ALWAYS….

1. Perform CPR in accordance with the 2020 American Heart Association (AHA) guidelines ___
2. Perform chest compressions with an adequate rate (100-120 compressions/minute) ___
3. Perform chest compressions with an adequate depth (≥5 but ≤6 cm) ___
4. Allow the chest to fully recoil while performing compressions ___
5. Perform CPR with a correct compression to ventilation ratio (30:2) ___
6. Deliver ventilations at an adequate rate and volume (8-10 breaths/minute) ___
7. Correctly position hands during CPR (Over the lower half of the sternum) ___
8. Perform CPR with an adequate chest compression fraction (≥ 80%) ___
9. Provide high-quality CPR consistently during a prolonged (approximately 9-minute) resuscitation attempt ___

Section 3: Recertification

Thinking about your most recent recertification, please answer the following:

1. How often do you participate in the formal recertification process to maintain your CPR credential?
    a. Every 6 months
    b. Every year
    c. Every 2 years
    d. Other ______

2. How long are your recertification trainings?
    a. 1 hour
    b. 2 hours
    c. 3 hours
    d. 4+ hours

3. How much of the time spent during recertification is spent on skill practice?
    a. 30 minutes or less
    b. 31 minutes -1 hour
    c. 1-2 hours
    d. 2 + hours

4. How often do you practice locating a central or peripheral pulse during the formal recertification process?
    a. Never
    b. 1-2 simulated patients
    c. 3-4 simulated patients
    d. 5-6 simulated patients
    e. Other ____

5. Are you required to take and pass a written exam to maintain a current CPR certification?
    a. Yes
    b. No

6. If yes, what is considered a passing score on the written exam?
    a. 70%
    b. 75%
    c. 80%
    d. 85%
    e. 90%
    f. Other ___

7. Are you required to pass a psychomotor skill proficiency exam?
    a. Yes
    b. No

8. If Yes, what is considered a passing score on the psychomotor skills exam?
    a. 70%
    b. 75%
    c. 80%
    d. 85%
    e. 90%
    f. Other ____

Please respond to each prompt using the six-point scale listed below.

1: Strongly Disagree
2: Disagree
3: Somewhat Disagree
4: Somewhat Agree
5: Agree
6: Strongly Agree

5. Enough time was spent on skill acquisition during CPR training__

6. After your initial CPR training you were confident you could properly perform high quality CPR _____

7. CPR training scenarios were similar to real-life situations you may have encountered in your professional career. _____
    a. (If you have never performed CPR in your profession please indicate so here) ___

Section 4: Deliberate practice and feedback

Thinking about your most recent recertification, please consider the type of manikin used for training purposes:

Definitions of fidelity for the purposes of this study:

Low Fidelity: traditional manikin that may or may not provide a clicking noise for proper compression depth

Medium Fidelity: provides feedback on performance… (for example: simulated pulse, ventilations, eye opening/closing, etc.)

High Fidelity: the manikin is realistic by having human properties that an instructor has programmed (for example: simulated pulse in accordance with the condition in which you are treating…)

8. What type of manikins have you trained on?
    a. Low fidelity
    b. Medium fidelity
    c. High-fidelity

Please respond to each prompt using the six-point scale listed below.

1: Strongly Disagree
2: Disagree
3: Somewhat Disagree
4: Somewhat Agree
5: Agree
6: Strongly Agree

9. Utilizing manikins that provide feedback concurrent with your performance enhances your ability to properly perform high quality CPR____

10. Your instructor provided helpful feedback during CPR trainings ____

11. You prefer feedback directly from the manikin versus instructor feedback_____

12. You prefer skill performance feedback visually on a screen from a manikin versus auditory (clicking) from a manikin _____

Section 5: Booster Sessions

Booster sessions are CPR skills and education sessions that occur inside of your certification window, commonly used to practice and enhance CPR skills, but do not result in formal a CPR certification certificate or credential (commonly are directed by place of employment and may be informal)

If you have participated in booster sessions, please answer the following:

13. How often do you participate in booster sessions?
    a. Never
    b. 3 months
    c. 6 months
    d. Annually
    e. Other ___

14. How often do you think booster sessions should be provided within a 2-year certification cycle to maximize performance?
    a. Never
    b. 3 months
    c. 6 months
    d. Annually
    e. Other ____

Please respond to each prompt using the six-point scale listed below.

1: Strongly Disagree
2: Disagree
3: Somewhat Disagree
4: Somewhat Agree
5: Agree
6: Strongly Agree

15. Booster sessions improve your ability to properly perform high-quality CPR to patients suffering from a cardiac arrest ___

16. Booster sessions ensure you are more confident in your ability to perform high-quality CPR. ___