INVESTIGATING THE RELATIONSHIP BETWEEN SELF-EFFICACY AND CARDIOPULMONARY RESUSCITATION QUALITY IN CERTIFIED ATHLETIC TRAINERS

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Investigating the Relationship Between Self-Efficacy and Cardiopulmonary Resuscitation Quality in Certified Athletic Trainers

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ABSTRACT

Certified athletic trainers (ATCs) are often the first to respond to an athletic sudden cardiac arrest (SCA) and are expected to administer the highest quality of cardiopulmonary resuscitation (CPR) possible. The goal of this study was to investigate the relationship between confidence and CPR quality in ATCs. Fifty ATCs completed confidence questionnaires before and after performing a prolonged CPR assessment on a medium-fidelity manikin. CPR data included measures of chest compression and ventilation quality. Data were analyzed to compare confidence levels pre- and post-CPR assessment, as well as to determine the relationship between CPR performance and self-efficacy. A small, negative correlation was found between confidence and CPR performance but performing a prolonged session of CPR did not affect confidence levels. Overall CPR quality was adequate, but ventilations and compression rates were lacking. The relationship between confidence and CPR quality must be explored further to help revise athletic training educational curricula.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF ABBREVIATIONS

ACC	American Cardiac College
AED	Automated external defibrillator
AHA	American Heart Association
ALS	Advanced life support
ARC	American Red Cross
ATC	Certified athletic trainer
BLS	Basic life support
BMI	Body mass index
BOC	Board of Certification (athletic training)
CAATE	Commission on Accreditation of Athletic Training Education
CAD	Coronary artery disease
CARDIA	Coronary Artery Risk Development in Adults
CDC	Centers for Disease Control and Prevention
CPR	Cardiopulmonary resuscitation
CVR	Compression/ventilation ratio
EAP	Emergency Action Plan
ECG	Electrocardiogram
EMS	Emergency medical service
EMT	Emergency medical technician
HCM	Hypertrophic cardiomyopathy
INL	Inter-nipple line
MBF	Myocardial blood flow
NATA	National Athletic Trainers’ Association

NCAA	National Collegiate Athletic Association
NHLBI	National Heart, Lung, and Blood Institute
OHCA	Out-of-hospital cardiac arrest
PEA	Pulseless electrical activity
ROC	Resuscitation Outcomes Consortium
ROSC	Return of spontaneous circulation
RPE	Rating of perceived exertion
SCA	Sudden cardiac arrest
SCD	Sudden cardiac death
SIDS	Sudden infant death syndrome
VF	Ventricular fibrillation

1. INTRODUCTION

1.1. Overview of the Problem

Sudden cardiac arrest (SCA) is one of the leading causes of death in the United States[1]. Though the American Heart Association (AHA) reports prompt provision of cardiopulmonary resuscitation (CPR) can double or triple the chances of patient survival during a SCA, the mortality rate of individuals who experience an out-of-hospital cardiac arrest (OHCA) remains approximately 90% even after emergency medical service (EMS) treatment[1]. In the athletic population, which has a sudden cardiac death (SCD) incidence ranging from 1 in 40,000 to 1 in 80,000, certified athletic trainers are often the first responders to a SCA[2].

Given that patient survival is already in a perilous position, it is essential that certified athletic trainers attempt to deliver the highest-quality CPR possible. While a substantial amount of research has been conducted on various extrinsic or physical factors that may affect CPR performance in other healthcare professions, athletic trainers are often excluded from studies even though emergency care and CPR are core components of the profession.

The results of previous research studies in other healthcare fields suggest self-efficacy may be a potential factor contributing to CPR quality[3-5]. If lack of confidence while performing CPR could negatively impact CPR performance, current CPR training courses may need to be revised. Research regarding self-efficacy and CPR performance must be completed to determine whether incorporating confidence-building exercises into existing CPR training protocols will help certified athletic trainers to perform higher-quality CPR.

1.2. Statement of Purpose

The primary purpose of this research study was to investigate the relationship between self-efficacy and cardiopulmonary resuscitation (CPR) quality in certified athletic trainers with the use of a self-efficacy survey and CPR simulation manikins. The secondary purpose was to observe how participant CPR self-efficacy changes after performing simulated CPR. The tertiary purpose was to determine whether demographic variables such as number of years as a certified athletic trainer, educational background, age, and gender have an effect on CPR self-efficacy. Finally, the quaternary purpose was to ascertain the percentage of athletic trainers who are able to meet the 2015 AHA CPR guidelines when performing CPR.

1.3. Research Questions

Q1: What is the relationship between athletic trainers' self-efficacy and CPR performance?

Q2: To what degree does self-efficacy predict CPR performance?

Q3: To what degree does educational background, years certified as an athletic trainer, and gender predict CPR self-efficacy?

Q4: What percentage of athletic trainers achieve satisfactory performance (according to the 2015 AHA CPR guidelines) on compression rate, depth, and ventilation quality?

1.4. Definitions

Athletic Trainer (AT): A healthcare professional "who collaborates with physicians to optimize patient physical capacity, health and well-being […through] the prevention, examination and diagnosis, treatment and rehabilitation of emergent, acute, subacute, and chronic neuromusculoskeletal conditions, and certain medical conditions in order to minimize subsequent impairments, functional limitations, disability, and societal limitations"[6(p2)].

Cardiopulmonary resuscitation (CPR): A procedure to support and maintain breathing and circulation for an infant, child, or adult who has stopped breathing (respiratory arrest) and/or whose heart has stopped (cardiac arrest)[1].

Sudden cardiac death (SCD): “Sudden and unexpected death occurring within an hour of the onset of symptoms, or occurring in patients found dead within 24 [hours] of being asymptomatic and presumably due to a cardiac arrhythmia or hemodynamic catastrophe”[7(p280)].

Self-efficacy: An individual’s confidence to effectively perform a certain skill or behavior regardless of the situation[3].

1.5. Limitations

Several limitations were present in this study and may affect the generalizability of findings. Firstly, subjects performed CPR in a controlled environment using a Resusci Anne® QCPR Manikin instead of performing CPR on an actual patient in a clinical setting. Athletic trainers who must perform CPR in a true clinical setting may experience environmental challenges, which could lead to changes in self-efficacy or CPR quality. A second limitation was the small population from which subjects will be recruited. A convenience sample consisting of certified athletic trainers from the Midwest region will be recruited for the study. Athletic trainers in other regions across the country may receive alternative amounts of emergency care education or may have different clinical acumen, which could lead to increased CPR performance or confidence.

1.6. Delimitations

Though research regarding CPR quality and self-efficacy is limited across all healthcare professions, the creators of this study chose to examine this relationship in athletic trainers. Athletic trainers were chosen as the study population because the researchers are ATs and wished to conduct CPR research in their own field. Therefore, the results of this study may not be generalized to other healthcare professions. In addition, the study population was limited to athletic trainers in the Midwest region.

1.7. Assumptions

Since subject self-efficacy was measured by questionnaire, the researchers assumed each subject answered each item truthfully and accurately. In addition, the assumption was made that CPR performance on a Resusci Anne® QCPR Manikin accurately represented CPR performance in a real-life scenario. Finally, the researchers assumed that each subject gave maximal effort while performing CPR and completed the session to the best of his or her ability.

1.8. Variables

For research questions one and two, the independent variable was self-efficacy measured via questionnaire and the dependent variables were overall CPR score, compression score, chest compression fraction, hand placement, mean compression depth, full recoil percentage, full depth percentage, proper compression rate percentage, mean rate, percentage of ventilations that are adequate, and percentage of ventilations that are inadequate. For research question three, the independent variables were educational background, years certified as an athletic trainer, and gender while the dependent variable was CPR self-efficacy measured via questionnaire.

1.9. Significance of Study

Emergency care, including the provision of techniques such as CPR, is one of the six domains of athletic training[8]. Athletic trainers are employed in a wide variety of settings ranging from athletics to industrial businesses to the military, and are often times the first medical professional to respond to a SCA in certain settings[9]. Therefore, it is essential for athletic trainers to provide the high-quality CPR. To do so, factors that affect the CPR performance of athletic trainers must be identified. The results of previous research studies in other healthcare fields suggest self-efficacy may be a potential factor contributing to CPR quality,[3-5] but after an exhaustive literature search, no studies were found in which the relationship between CPR performance and self-efficacy in athletic trainers was assessed. Therefore, research is needed to determine if methods to increase self-efficacy should be incorporated into athletic training emergency care education and CPR practice.

2. LITERATURE REVIEW

2.1. Sudden Cardiac Arrest and Sudden Cardiac Death

2.1.1. Definition

While research is continually being conducted on sudden cardiac arrest (SCA) and sudden cardiac death (SCD) in the realm of emergency medicine, succinct and standardized definitions of either term are difficult to delineate. Definitions of SCA and SCD tend to vary slightly among literature, and both phrases are occasionally used interchangeably[10]. The American Heart Association (AHA) defines SCA as "the sudden cessation of cardiac activity so that the victim becomes unresponsive, with no normal breathing and no signs of circulation," noting the term should be used to describe a reversible event [11(p2540)]. SCD is non-reversible and occurs when attempts to restore normal cardiac function fail[12]. A more specific definition of SCD by the AHA is "sudden and unexpected death occurring within an hour of the onset of symptoms, or occurring in patients found dead within 24 [hours] of being asymptomatic and presumably due to a cardiac arrhythmia or hemodynamic catastrophe"[7(p280)]. The American Cardiac College (ACC)/AHA Task Force's goal was to create definitions and data standards based on the consensus of expert cardiologists. By analyzing existing literature and cardiac registries for definitions and data standards, the Task Force developed definitions, which they considered to be clear and satisfactory[11]. Even with the AHA's efforts in creating concise definitions, there remains no widely accepted standardized definition of either SCA or SCD across current literature[10]. Clear, universally accepted definitions must be established to promote consistency in contemporary SCA/SCD research.

2.1.2. Epidemiology

2.1.2.1. General Population

Research institutes and organizations such as the AHA frequently attempt to draw conclusions about true SCA and SCD incidence in the general population from registry data. In a 2018 update on heart disease and stroke statistics in the United States, the AHA reported the number of annual out-of-hospital cardiac arrests (OHCAs) between 2014 and 2015 as 356,461 persons; 347,322 OHCAs in adults (≥18 years of age) and 7,037 in children (<18 years of age). These statistics were extrapolated from unpublished data collected from seven U.S. sites by investigators in the Resuscitation Outcomes Consortium (ROC) between 2008 and 2015[12]. The ROC is a clinical trial network made up of researchers dedicated to studying OHCAs who are currently working on an epidemiologic registry of the condition; the AHA used this unfinished registry to obtain their OCHA statistics[12]. However, there is no mention of the ROC's research design, inclusion criteria, or exclusion criteria for their acquisition of data leading to difficulties in generalizing and analyzing the AHA's estimates of incidence.

In a 2011 systematic review by Kong et al.,[10] researchers attempted to synthesize data from six different primary sources to obtain a more accurate estimate of SCD and SCA in the general U.S. population. To be included in the final review, studies had to be peer-reviewed articles of primary data collected in the United States. Though the researchers began with 35 potential studies to review, only six met the inclusion criteria[10]. There were several reasons for excluding the other 29 papers; 12 of the other studies were discarded due to estimating incidence of SCD within a subgroup population, 13 more did not extrapolate incidence to the U.S. population, and finally four did not estimate SCD incidence[10]. Interestingly, the estimates of annual SCD prevalence in the general population varied significantly between the final six studies. Estimates ranged from approximately 180,000 to more than 450,000 persons per year[10].

The variance in estimates of annual SCD prevalence in the U.S. from the six studies included in the systematic review by Kong et al.[10] can be partially attributed to aspects of their respective research designs. One key aspect to note about the studies is they are all from different periods of time. The most recent study included in the systematic review was published in 2008[13] and the oldest included study dates back to 1989[14]. The six studies also differ in their estimation method[10]. Three studies used national level registry data to form their estimates,[14-16] though one of them only used data from only 40 states[14]. Another study used registry data from eight U.S. sites,[13] while the remaining two extrapolated their estimates of national SCD/SCA incidence from smaller, community-based studies[17,18]. Definitions of SCD and SCA also varied between studies[10]. Three studies included time-based criteria in their definitions[15,16,18] while two other studies included the stipulation that death must occur within one hour of symptom onset[15,16]. The final study added a criterion of unwitnessed death occurring within 24 hours of the person being observed alive and symptom-free along with the previously mentioned condition[18]. Two studies included cardiac arrest survivors[18] or people who survived their SCA and were subsequently discharged from the hospital[13]. The choice to include survivors in the final estimate could have led to an overestimation of SCD annual incidence in those two studies. Finally, most of the papers included different age cut-offs for their population of study[10]. Two studies used an age cut-off of ≥35 years,[14,16] another used ≥20 years,[17] one more used a cut-off of ≥25 years, and the pair of most recent studies did not delineate age criteria[13,18]. Only two of the studies that included age criteria explained their reasoning; in both papers, the cut-off was established as a result of the relatively low number of SCD/SCA cases in younger populations[16,17]. One of the only aspects of research design shared by six studies was their retrospective nature[10]. To more accurately determine annual incidence of SCD and SCA in the general population, a long-term prospective research design should be utilized, and standardized definitions of SCA/SCD must be developed to promote inter-study consistency.

2.1.2.2. Young Adults

While some researchers choose to exclude young adults when studying SCD and SCA incidence in the general population due to the relative rarity of such events,[16,17] estimates of pediatric SCD/SCA incidence are available. In 2005, the ROC conducted a population-based prospective cohort study over a period of two years in 11 Canadian and U.S. communities consisting of approximately 23.7 million people while choosing an age cut-off of <20 years in order to estimate pediatric SCD prevalence. However, the researchers also utilized data from persons older than 20 years to estimate adult incidence[19]. Ultimately, only 10 sites were utilized, as one of the site's data was incomplete. The researchers calculated incidence rates per 100,000 person-years for each site, weighted each rate by the respective site's population, then averaged all of them together to obtain final estimates[19]. The final estimate resulted in an overall population-based incidence of 8.04 per 100,000 person-years (95% Confidence Interval [CI], 7.27 to 8.81) for pediatric OHCAs; this rate is significantly lower than the incidence of 126.52 per 100,000 person-years (95% CI, 124.63 to 128.4) obtained for adults in the same population[19]. In the pediatric population, cardiac arrest incidence was higher among infants (72.2 per 100,000 person-years, [95% CI, 62.02-83.39]) when compared to adolescents (6.37 per 100,000 person-years [95% CI, 5.30-7.44]) or older children (3.73 per 100,00 person-years [95% CI, 3.02-4.43])[19].

2.1.2.3. Infants

The increased infant prevalence is consistent with one of the studies included in the systematic review by Kong et al.,[10] which found peaks of SCD incidence in infants and geriatrics[18]. The SCD incidence peak found in infants is most likely due to sudden infant death syndrome (SIDS), in which seemingly healthy infants perish unexpectedly during sleep[18,20,21]. In their 2018 update for U.S. heart disease and stroke statistics, the AHA reported an annual pediatric OHCA incidence of 8.3 per 100,000 person-years using more recent data extrapolated from the ROC, which is consistent with the ROC's findings in 2005[12]. The ROC's findings show that while pediatric SCD is a relatively uncommon event, it still occurs frequently enough to warrant the amount of research and time given to studying SCD in general.

2.1.2.4. Athletes

Incidence of SCA and SCD in athletes is sometimes considered by the public to be higher than incidence in the general population, but the notion is a misconception. It is possible the frequency of SCD in athletes is exaggerated by extensive media coverage, leading to misunderstandings in the general public regarding true incidence[21]. In reality, the number of SCD in athletes during competition in the United States is relatively low. The annual number of sudden deaths during sport in young athletes has been estimated by the Centers for Disease Control and Prevention (CDC) to be as low as 100 and 150[21].

Currently only one study has published comparative data supporting the notion of increased SCD incidence in athletes compared to nonathletes[21]. The solitary paper by Corrado et al.[22] details a 21-year-long prospective cohort study in Italy consisting of approximately 1,400,000 young adults (ages 12 to 35). Nearly 113,000 of the subjects were competitive athletes[22]. At the end of the observation period, 259 cases of sudden death resulted from cardiac pathology; 51 cases were in athletes, and 208 in non-athletes[22]. Overall, SCD incidence in the athletic population was calculated to be 2.1 in 100,000 persons per year for athletes and 0.7 in 100,000 persons per year for non-athletes[22].

The results from the Italian prospective cohort study conflict with the findings of other large-scale studies conducted in the United States and other countries such as Denmark[21]. Researchers who conducted a retrospective study examining 27 years of registry data in the United States estimated a SCD incidence of approximately 0.6 in 100,000 persons per year;[23] however, there were several key limitations in this study. At the time of the paper's publication, there was no mandatory reporting system for SCD in young athletes in the United States, which could have led to underreporting and a lower estimate of incidence. The researchers note the higher number of reported SCD over the last six years of the study was likely due to improved methods of surveillance and reporting, and higher numbers would have likely been reported if such methods were implemented during the entire 27-year study[23].

A six-year retrospective study in Denmark of SCD in young adults ages 12 to 35 from 2000 to 2006 reported an athlete SCD incidence of 1.2 in 100,000 persons per year compared to 3.76 in 100,000 persons per year in the general population[24]. Corrado et al.[22] acknowledged the fact that other studies of athletic SCD incidence produced lower estimates. The researchers attribute the discrepancy in results to methods of data collection, a higher mean age in their participants, their study's prospective design compared to the retrospective design used in many other papers, and the possibility athletes included in their research may have participated at a higher level of intensity than athletes in other studies[22]. Estimates of annual incidence for SCD in athletes seems to be just as variable as estimates of SCD prevalence in other populations, again delineating the need for more large-scale prospective cohort studies using similar or standardized methods of reporting.

2.1.3. Causes

2.1.3.1. Structural Diseases

Onset of SCA and subsequent SCD in the general population is commonly attributed to structural diseases of the heart, such as coronary artery disease (CAD)[18]. The main cause of CAD is atherosclerosis, an inflammatory disease in which plaque, consisting of white blood cells and lipids, forms in the smooth muscle lining of blood vessels[25]. If the plaque increases in size, it can eventually occlude the blood vessel; alternatively, the plaque can rupture, attracting platelets and causing the formation of potentially vessel-occluding blood clots[25]. Regardless of cause, vessel occlusion can result in acute myocardial infarction. Myocardial infarction, if left untreated, eventually causes SCA or SCD[25]. CAD is the most common structural clinical finding associated with SCD, and approximately 80% of all SCD is attributed to the disease[18,26,27].

Another common structural cause of SCD is hypertrophic cardiomyopathy (HCM), though estimates of annual prevalence vary[28]. HCM is characterized by left ventricular hypertrophy in the absence of abnormal loading such as exercise training or hypertension[28]. As part of the Coronary Artery Risk Development in Adults (CARDIA) study, Maron et al.[29] were able to estimate annual HCM prevalence in young adults. CARDIA was a large-scale prospective cohort study established by the National Heart, Lung, and Blood Institute (NHLBI) to investigate the effects of lifestyle and other factors on risk for coronary disease[29]. Though the original study consisted of 10,143 participants from four different U.S. cities, Maron et al. only included subjects aged 18 to 30 years, leaving the population of interest at 4,232 persons[29]. Examinations consisting of blood pressure measurements, height, weight, and an electrocardiogram (ECG) were conducted in at the start of the study and then repeated five years later[29]. To be formally diagnosed with HCM, a left ventricular wall thickness of ≥15mm had to be identified in the patient via ECG[29]. Approximately 0.2% (95% CI, 0.07% to 0.35%) of all subjects were diagnosed with HCM, leading to an estimated incidence rate of one in 500 persons per year[29]. In contrast, a nine-year prospective study of the entire population of Olmsted County in Minnesota reported an annual HCM incidence of only 0.02%. In comparison to the population screening conducted by Maron et al.,[29] the researchers of the Minnesota study's methodology was more likely to result in an underestimation of true HCM incidence. Instead of surveying as much of the population as possible, the researchers only included subjects who sought medical treatment from a local hospital and were consequently diagnosed with HCM[30]. However, the calculated incidence by Maron et al.[29] could have been an overestimation due to the exclusion of subjects older than 30; incidence may have been lower in the older population. In addition, the strict diagnostic cutoff employed by Maron et al.[29] could have excluded subjects with less clinically significant HCM and led to an underestimation of true HCM prevalence. Regardless, further prospective-cohort research studies must be conducted to form a better idea of true HCM prevalence in the general population.

HCM is of particular note in the young, athletic population; the structural disease is often considered the most common SCD cause in young athletes[23,28]. In a 2009 retrospective study, researchers analyzed 27 years (1980-2006) of data compiled by the US National Registry of Sudden Death in Athletes to determine the absolute number of sudden deaths and their underlying causes[23]. The analyzed registry was formed by the Minneapolis Heart Institute Foundation to retrospectively and prospectively gather data on deaths of young athletes during competitive sport[23]. To be included in the registry, subjects needed to meet two inclusion criteria:

first, the athlete needed to participate in an organized individual or team sport, which required regular competition against others; intramural sports were not considered. Second, the athlete needed to have experienced sudden death at ≤39 years of age[23]. A total of 1,866 athletes met the inclusion criteria, and 1,049 (56%) of those deaths were attributed to cardiac causes[23]. The researchers reported HCM as the most common cause of sudden cardiac death with 251 deaths occurring as a result of the disease[23].

In contrast, a 2015 retrospective analysis of 514 student athlete deaths in the National Collegiate Athletic Association (NCAA) over a period of 12 years (2003-2013) had differing results in its report of common SCD causes[31]. Data in the analysis were compiled from the NCAA Resolutions List, the Parent Heart Watch database, and NCAA insurance claims. The NCAA Resolutions List is created annually to honor athletes in the NCAA who die of any cause, while the Parent Heart Watch database is a national nonprofit organization, which tracks SCD in young individuals through systemic searches of media[31]. The NCAA covers all athletes with a catastrophic injury insurance plan, and all claims related to SCD/SCA during the study period were retrieved by the researchers[31]. Of all the deaths noted during the study period, approximately 15% were attributed to SCD. After reviewing autopsy reports, the researchers found the most common clinical finding in victims of SCD to be a structurally normal heart (AN-SUD)[31]. AN-SUD was found in 25% of all SCD victims, while HCM was only observed in 8%[31].

The discrepancy in results between the 2015 study and the earlier study could be attributed to several factors. Data in the 2009 study was supplied by the USNRSDA, which is located in the HCM Center at the Minneapolis Heart Institute Foundation[31]. As a result, the study could have suffered from ascertainment bias while collecting cases. In addition, both studies utilized different diagnostic criteria for HCM[23,31]. The differing diagnostic definitions of HCM could have led to the exclusion of viable HCM cases in one study while they were included in the other. To promote consistency in contemporary research, future studies in which researchers examine the causes of SCD must include a set of shared, standardized diagnostic criteria for structural diseases of the heart.

2.1.3.2. Electrical Abnormalities

In addition to structural abnormalities and diseases of the heart, SCD can be caused by abnormalities in the heart's electrical pathways. Two of the most common cardiac arrhythmias that cause SCD are ventricular fibrillation (VF) and pulseless electrical activity (PEA)[18]. VF is characterized by disordered electrical activity in the lower chambers of the heart leading to the ventricles quivering instead of contracting. When the heart cannot contract properly, blood is not pumped and SCA may occur[32]. In contrast, a heart undergoing PEA will seem normal if analyzed via 12-lead ECG but will produce no pulse. Thus, the heart will not pump blood and SCA may occur[33].

Estimation of prevalence for these two arrhythmias in SCD victims has evolved over the past several decades. In 1990, researchers conducting a two-year longitudinal study in Seattle, Washington found that 75% of all SCD victims experienced VF during the initial arrest[34]. However, a more recent retrospective analysis of emergency medical service (EMS) records in the Seattle area found that VF prevalence decreased 56% between 1980 and 2000[17]. A similar study in which researchers analyzed 17 years' worth of hospital registry data in Goeteborg, Sweden found a decrease in VF prevalence of 34% over the study period and an increase in PEA prevalence from 6% to 26%[35]. The gradual shift in prevalence for both conditions could be due to several factors. VF is commonly associated with coronary disease, while PEA can be attributed to non-cardiac conditions as well as cardiac pathologies[36]. Researchers speculate that research, improved methods of primary and secondary prevention, and more effective treatments have all led to a decrease in coronary heart disease mortality; consequently, the reduction in CAD may have contributed to the reduction in VF prevalence[18,36]. PEA has not received the same amount of attention, and most of the large-scale studies in which PEA is examined were conducted in the 1940s[36]. It is clear PEA needs to be examined to the same extent as VF to fully understand its recent increase in prevalence and effectively combat it as one of the most common electrical causes of SCD.

2.2. Cardiopulmonary Resuscitation

2.2.1. History

Though cardiopulmonary resuscitation (CPR) is an integral part of modern emergency medicine, the current techniques utilized to provide emergency perfusion and ventilation of patients suffering from SCA were not established until the late 1950's and early 1960's[37,38]. The first formal CPR guidelines were established in 1966 by the American Heart Association, but the development of various aspects of the technique such as artificial ventilations and chest compressions can be traced back as far as the 18th century[39].

2.2.1.1. Origin of Artificial Ventilations

Artificial ventilation, one of the core components of modern CPR, has evolved through many different iterations and techniques over the course of its development. The Old Testament contains one of the earliest references to a possible use of artificial ventilation in resuscitation; II Kings describes the prophet Elisha reviving a child by pressing the boy's mouth to his own[40]. In the 16th century Swiss physician and alchemist Paracelsus used a pair of bellows, a device designed to supply a fire with a strong burst of air, to ventilate drowning victims[41]. A British surgeon named William Tossach successfully used a mouth-to-mouth technique to resuscitate a coal miner in 1763,[42] but mouth-to-mouth's efficacy in resuscitation was brought into question after the discovery of oxygen by German scientist Carl Scheele[41]. Scheele believed air did not retain its revitalizing properties after being expired, and thus advocated the use of pure oxygen in resuscitation instead[39,43]. Mechanical methods of artificial breathing were favored throughout the 19th century, often involving techniques similar to modern chest compressions to produce expiration and recoil inspiration[44]. While tidal volumes produced by such methods were modest, variations on mechanical ventilation via chest pressure were practiced until the mid-1900's[39]. Several research experiments led by James Elam,[45,46] Archer Gordon,[47] and Peter Safar[46,48,49] included evidence proving expired air, or positive-pressure ventilations, provided sufficient oxygen for successful artificial ventilation. In addition, the aforementioned researchers found that putting a patient in a prone position during ventilation, which was a common practice at the time,[39] compromised the airway[46]. Safar et al.[48] advocated manually extending a patient's neck and bringing his or her jaw forward to maintain a patent airway; these techniques are currently referred to as the 'head-tilt, chin-lift' and 'jaw-thrust' maneuvers. The practice of keeping a patient supine during resuscitation became standard in emergency medicine, as did positive-pressure ventilations[39,44].

2.2.1.2. Origin of Chest Compressions

Another key component of modern CPR, chest compression, first emerged in the 18th century but did not reach a form similar to its contemporary technique until the mid-1900's[44]. The goal of contemporary chest compressions is to manually generate blood flow to the heart and brain,[50] but in their earliest form chest compressions were intended to assist breathing[44]. Early methods of chest compression involved draping unresponsive individuals prone over a barrel or horse. While the barrel rolled or while the horse began to trot, the victim's chest was forcefully compressed[39]. The first compressions intended to stimulate blood flow were performed directly on the heart through a surgical opening in the thorax, and were originally discovered in 1874 when German physiologist Moritz Schiff noted carotid pulsations occurring in a dog every time he squeezed its heart[44]. Schiff's technique was labeled open-chest cardiac massage but remained largely unused in clinical practice until the early 1900's[41]. Open-chest cardiac massage became the standard for SCA resuscitation in the 20th century after Kristian Igelsrud, a Norwegian physician, performed the first successful open-chest cardiac massage on a human patient in 1901[39]. Consequently, SCA was only survivable in places where direct cardiac massage was possible such as hospitals or operating rooms until the late 1950's[44]. While researching manual defibrillation on canines in 1958, electrophysiologist William Kouwenhoven noted a rise in arterial pressure each time defibrillation paddles were pushed onto a dog's chest[39]. Kouwenhoven et al.[51] subsequently performed closed-cardiac massage on 20 hospitalized SCA victims and successfully resuscitated 14, suggesting that external compressions were a viable alternative to open-chest cardiac compressions. Due to the relative simplicity and ease of external chest compression, the technique soon became the standard of care in emergency resuscitation[41].

2.2.1.3. Origin of Modern CPR Guidelines

After landmark research in the late 1950's on chest compressions and artificial ventilations by Kouwenhoven et al.[51] and Safar et al.,[49] the foundations for modern CPR were finally established. The first official conference on CPR was convened in 1966 by the AHA and resulted in the development of standards regarding what techniques to use and how to execute them effectively[39]. The members of the conference encouraged the teaching of the guidelines to trained medical professionals but not the general public. The AHA feared untrained laypersons attempting to perform CPR might further harm SCA victims[44,52,53].

In 1970, a group of physicians and researchers in King County, Washington created and carried out an ambitious emergency response project, which included teaching nearly 100,000 citizens proper CPR technique, thus contradicting the current recommendations[54]. For one year, researchers collected the number and details of SCA cases in King County from hospitals and emergency agencies while tracking factors such as time from collapse to initiation of CPR, time from collapse to definitive care, and the victim's outcome[55]. Only non-traumatic OHCA's were considered, all ages were included, and a valid case was defined as "a patient with cardiac arrest with a pulseless condition (confirmed by an EMT or paramedic) for whom CPR was initiated"[55(p31)]. After a year of collecting data, an independent Pearson's Chi-square test was conducted to determine whether any of the tracked variables were significantly related[55]. The researchers found that a short time to initiation of CPR ($P < .01$), bystander initiated CPR ($P < .01$), and short time to definitive care ($P < .01$) were all significantly associated with positive patient outcomes[55]. Of these variables, the researchers considered shortened time to CPR initiation most important[55]. In this study, the term 'bystander' was applied to anyone who was present at the scene of an SCA. As such, if a bystander was the individual who initiated CPR, it is likely the time between SCA and the start of CPR would be lessened. The researchers concluded that while bystander-initiated CPR was significantly associated with positive patient outcomes, it actually reflected the true significance of early CPR initiation[55]. Even so, this prospective cohort study provided convincing evidence for teaching CPR to the general population. As a result of the King county study,[55] the AHA formally approved the teaching of

CPR to laypersons when revising their guidelines in 1973 and began to investigate other aspects of the CPR technique[44].

2.2.2. 2015 AHA CPR Guidelines

Though the AHA has revised and re-released their CPR recommendations numerous times over the past 50 years, there have only been a few changes to the overall CPR technique[37].

Table 1. Changes in CPR parameter recommendations from 1966 to 2015, adapted from Hwang[37] and AHA 2015 CPR/ECC Guidelines[1]

Guidelines	1966	1992	2000	2005	2010	2015
Compression position	Lower half of the sternum	Lower half of the sternum	Lower half of the sternum	Lower half of the sternum	Center of the chest	Lower half of the sternum
Compression depth (cm)	4-5	4-5	4-5	4-5	≥5	≥5 but ≤6
Compression rate (/min)	60	80-100	~100	~100	≥100	100-120
Compression/ventilation ratio	15:2 for one rescuer 5:1 for two rescuers	15:2 for one rescuer 5:1 for two rescuers	15:2 for one or two rescuers	30:2 for one or two rescuers	30:2 for one or two rescuers	30:2 for one or two rescuers
Ventilation rate (breaths/min)	~12	10-12	10-12	8-10	8-10	8-10

As shown in Table 1, substantial changes in the recommendations are rare. Some recommendations such as compression rate and ventilation rate have gone through somewhat frequent changes but the optimal recommendations for CPR are still being investigated[37]. As a result, the AHA continues to convene and update CPR guidelines to stay up to date with contemporary resuscitation research. The AHA's most recent update was released in 2015 and contains a few key differences from past recommendations.

2.2.2.1. Chest compression rate

The AHA currently recommends a compression rate of 100-120 compressions per minute[1]. This recommendation differs from the 2010 recommendation with the inclusion of an upper limit for chest compressions; previously, the AHA recommended a minimum of 100 compressions per minute[1]. The change was based on a pair of prospective studies from the ROC investigating the relationship between chest compressions and patient outcomes during OHCAs[1].

The first study, conducted from 2005 to 2007, contained data prospectively collected from all of the ROC's participating sites across the U.S. and Canada[56]. As mentioned previously, the ROC is a network of regional research centers in the U.S. and Canada, which was formed to investigate strategies for the treatment of patients who experience an OHCA[56]. Patients who experienced traumatic or noncardiac OHCAs were excluded from the study. Inclusion criteria for the study required a patient to be at least 20 years old, experience an OHCA, and subsequently be treated by an EMS provider participating in the ROC; cases were only included if they involved electronic recordings of chest compressions[56]. Out of the 26,902 OHCAs reported by the ROC's research center network, only 3,098 cases had analyzable CPR data[56]. The data were analyzed using a logistical regression to determine the odds ratios of the association between chest compression rate and return of spontaneous circulation (ROSC)[56]. Interestingly, the researchers found the odds of a patient having a ROSC peaked at approximately 125 chest compressions per minute but then declined sharply[56]. In addition, compression depth was found to significantly decrease with increasing compression rate ($P = 0.03$)[56]. Several limitations were present in this study. For example, the ROC was only able to use a case if CPR data had been collected during the medical intervention. As a result, approximately 20% of all reported OHCAs were analyzed[56]. If the other 80% of cases had provided useable data, the study could have resulted in significantly different results. Another limitation was only the first five minutes of CPR were analyzed even though some patients underwent resuscitation for much longer[56]. However, the researchers acknowledged this limitation and stated a prior study included data supporting the notion chest compressions during subsequent minutes of CPR were similar to those in the first five[56]. Even with its limitations, this study provided evidence regarding a possible upper limit for effective chest compression rates[56].

The second study which influenced the AHA's 2010 chest compression rate update took place from 2007 to 2009 and could be considered an attempt by the ROC to validate the results of the previous study[57]. Once again, the ROC collected OHCA prospective data from all of their sites across the U.S. and Canada during the two-year investigation period[57]. Despite having nearly identical inclusion and exclusion criteria to the previous study[56] (the exception being a minimum inclusion age of 18 years instead of 20 years), the ROC was able to collect 6,399 analyzable cases; the number of cases[57] was nearly double the case population of the ROC's first study (n=3,098)[56]. One of the main reasons for the increase in available data was more ROC sites had access to proper electronic CPR monitoring equipment[57]. Once the data were collected, the researchers organized each case by mean compression rate. Cases were split into five different compression rate categories (measured in compressions/minute): < 80, 80-99, 100-119, 120-139, and ≥140[57]. Data were analyzed using a logistical regression to determine the association between chest compression rate and odds of patient survival to hospital discharge[57]. After adjusting for covariates such as chest compression depth and chest compression fraction, the researchers reported compression rates of 100-119 compressions/min were associated with significantly greater odds of survival to hospital discharge than higher or lower compression rates ($P = 0.02$)[57]. Compression rates between 100-119 compressions/min resulted in a 10%

survival rate. Survival percentages for other compression rates ranged from 6% (for compression rates ≥140) to 9% (for compression rates <80)[57]. Finally, the researchers found that compression depth significantly decreased with increasing compression rate in a dose-dependent manner ($P < 0.0001$), suggesting a well-defined upper limit for chest compressions may be beneficial for promoting proper compression depth[57].

While the researchers were able to analyze data from nearly double the case population of the ROC's previous study,[56] only 62% of all OHCA cases reported to the ROC during the study period were analyzed[57]. The remaining 38% of OHCA cases had no analyzable CPR data and were consequently excluded from the study. Had data been available, the unanalyzable OHCA cases could have affected the results of the study. Similar to the ROC's previous study,[56] the researchers only analyzed data from the first five minutes of CPR in each OHCA case even if resuscitation continued for a longer period of time[57]. While the researchers reported little difference between mean compression rates after five (111±16 compressions/min) and 10 (113±16 compressions/min) minutes of CPR, they did not report any measure of statistical significance regarding the difference[57]. Consequently, no conclusion can be made about the statistical similarity of the two mean compression rates. The use of only the first five minutes of CPR data can be considered a potential limitation. However, the results of this study served as further evidence to support establishing an upper limit for chest compression rates[1].

The results from the ROC's 2012[56] and 2015[57] studies were the only data used by the AHA to formulate new recommendations for chest compression rate[1]. However, the optimal chest compression rate to induce ROSC has yet to be determined. Before future guideline updates, more prospective cohort studies involving large populations must be conducted to examine the association between chest compression rate, ROSC, and odds of OHCA survival.

2.2.2.2. Chest compression depth

The AHA currently recommends rescuers strive for a compression depth between five and six centimeters[1]. Similar to the AHA's 2015 chest compression rate guideline update, the difference between the current depth recommendation and the previous one is an addition of an upper limit of six centimeters. Previously, the AHA recommended a compression depth of at least five centimeters[37]. The AHA's updated recommendation was based on evidence presented in two studies: one large-scale, prospective cohort study conducted by the ROC, which included data on the relationship between compression depth and OHCA survival, and another small-scale prospective, observational study in which researchers examined the association between compression depth and risk of patient injury[1].

While the AHA references a prospective cohort study by the ROC which took place from 2007 to 2010 to substantiate its updated recommendation for chest compression depth, the conclusions of the study partially refute the current CPR guidelines[58]. Similar to previously discussed ROC studies,[56,57] OHCA data were collected prospectively from nine ROC sites across the U.S. and Canada[58]. The study's inclusion criteria required subjects to be ≥18 years of age, experience a nontraumatic OHCA, and receive CPR from an EMS provider[58]. Cases were excluded if a bystander-initiated CPR or if electronic CPR data was not electronically recorded[58]. Chest compression characteristics were measured via an accelerometer interface built into automated external defibrillators (AEDs) carried by EMS providers[58]. Of the 27,986 OHCA cases reported to the ROC during the three-year study period, only 9,136 met the inclusion criteria[58]. Researchers examined data from the first 10 minutes of a resuscitation attempt, and cases were followed to determine if a patient survived to hospital discharge[58]. The data were analyzed using a multivariate logistic regression to determine the association between compression depth and patient outcome[58]. Across all reported cases, the mean compression depth was approximately 4.2 cm (SD=1.17 cm), which was well below the AHA's compression depth recommendation of at least 5 cm during the study period[58]. In addition, researchers found that probability of survival gradually increased with deeper compression depths but began to decrease after a certain threshold[58]. The researchers reported compressions with depths in the range of 4.03 cm to 5.53 cm resulted in the highest odds of survival, noting survival probability seemed to peak at a depth of approximately 4.56 cm[58]. It is important to note data were only collected from approximately 33% of all OHCA cases reported within the study period. As with the other ROC studies previously detailed,[56,57] the results of this study could have changed drastically if more OHCA cases had involved proper CPR monitoring equipment. There was also no information collected regarding potential confounders such as patient body size or firmness of the surface where CPR was performed, which could have affected results[58]. While the researchers concluded that establishing an upper limit for chest compression depth may help improve OHCA outcomes, they also suggested that the AHA's recommendation of at least 5 cm for compression depth may be too high[58].

In 2009, a group of researchers at the Tampere University Hospital in Finland began collecting data on CPR quality during in-hospital resuscitation attempts to examine the relationship between compression depth and risk of CPR-related injury[59]. All adult patients who underwent resuscitation by medical staff in the hospital were included in the study. Patients were excluded if they received any resuscitation attempt before arriving at the hospital, or if they experienced any type of pre-resuscitation trauma in the abdominal or thoracic area[59]. CPR characteristics such as average compression depth, peak compression depth, and total number of compressions delivered were collected via AEDs equipped with CPR analysis features[59]. At the conclusion of the three-year study period, injuries related to chest compressions were analyzed retrospectively from forensic autopsy records, medical autopsy records, computed tomography (CT) scan, and chest x-rays of included patients[59]. Injuries considered related to CPR included sternal or rib fractures, pneumothorax, hemothorax, laceration/contusion/bruising of the lungs or heart, damage to the great veins, and damage to the spleen, liver, or stomach[59]. All CT scans and x-rays were analyzed by the same radiologist[59]. Of the 370 patients resuscitated by Tampere University Hospital medical staff, only 170 were included in data analysis; 183 patients were missing either CPR or post-resuscitation exam data, and the remaining 17 met exclusion criteria[59]. Comparisons of chest compression depth between patients who had injuries versus those who did not were completed via independent samples t-test[59]. During the three-year study period, the mean compression depth for injured patients was 56 mm, a value significantly different than the 52 mm mean compression depth of those who did not sustain injuries (P = 0.04)[59]. Upon dividing the mean compression depth across all patients into three categories, the researchers found 49% of all CPR-related injuries occurred when compression depth exceeded 60 mm (6 cm)[59]. When the data were divided by gender, a significant increase in injury rate associated with compression depth >60mm was found in males (P = 0.008). Conversely, no significant association between compression depth and injury rate was found in female patients[59]. One of the major limitations of this study is its sample size. Compared to other studies[56-58] used by the AHA to substantiate its CPR recommendations, this study had a smaller sample size of 170 patients;[59] other studies utilized by the AHA included sample sizes ranging from 3,100 patients[56] to 9,136 patients[58]. In addition, the researchers concede the compression depths measured in the study may not be entirely accurate due to the limitations of current technology[59]. Even so, the researchers of this study concluded increasing chest compression depth may result in higher rates of CPR-caused injury, and compression depths exceeding 60 mm may significantly increase risk of injury in males[59].

When comparing the AHA's 2015 compression depth recommendation to the results of the studies[58,59] the organization used to substantiate their claim, the recommendation seems relatively weak. At the conclusion of the ROC's large prospective cohort study[58] examining the relationship between chest compression depth and patient survival, the researchers suggested the AHA's recommendation depth of ≥ 5 cm may be too high. In addition, while researchers at the Tampere University Hospital found higher injury rates in patients when compression depth exceeded 6 cm, a significant association ($P = 0.008$) was only found in male patients[59]. In the future, more research must be conducted on the relationship between chest compression depth, patient survival, and risk of CPR-related injury to further refine recommendations for the optimal chest compression depth.

2.2.2.3. Hand position during chest compressions

In 2015, the AHA updated its guidelines on hand position during CPR by recommending rescuers place their hands on the lower half of a patient's sternum instead of the previous recommendation of placing hands on the center of the chest[1]. However, hand placement during CPR lacks the amount of research conducted in the investigations of other aspects of CPR[1,37]. The AHA uses a pair of human studies using a crossover design to compare physiologic endpoints caused by different hand placements to support their recommendation[1].

The first study incorporated by the AHA to substantiate the new hand position recommendation was conducted by researchers in Oslo, Norway in an attempt to determine whether changing hand placement during CPR would affect the hemodynamics of a patient experiencing SCA[60]. In the city of Oslo, ambulances manned by a paramedic and a physician were dispatched on any call in which a cardiac arrest was suspected[60]. All adults in the Oslo area who suffered from an OHCA and were subsequently treated by the physician-manned ambulance were included in the study[60]. Patient hemodynamics were estimated by measuring end tidal CO_2 ($EtCO_2$) via side-stream capnography[60]. $EtCO_2$, or the partial-pressure of CO_2 detected at the end of exhalation, has been well-supported in contemporary literature as a reliable indicator for the effectiveness of chest compressions on cardiac output and systemic perfusion during CPR[61,62]. An increase in $EtCO_2$ is the first sign of ROSC, and therefore can be utilized by rescuers to monitor the quality of delivered chest compressions[61]. On each OHCA incident, the ambulance crew followed a strictly defined treatment protocol, which began with establishing a patent airway for all patients via endotracheal intubation. The ambulance's crew underwent extensive practical and theoretical training to ensure the treatment protocol was carried out correctly. Intubation tubes were connected to an electronic capnography device, which provided continuous $EtCO_2$ feedback[60]. Following intubation, rescuers performed three minutes of CPR while changing hand position several times. During the first minute, chest compression rate and depth were optimized with the use of $EtCO_2$ feedback while compressions were performed on the inter-nipple line (INL)[60]. Over the course of the next two minutes, $EtCO_2$ was measured in 30-second intervals at four different positions: the INL, two centimeters below the INL, two centimeters to the right of the INL, and two centimeters to the left of the INL[60]. After the two-minute treatment period, chest compressions were continued in the hand position that yielded the highest $EtCO_2$ value[60]. There were 33 adult OHCA cases during the study period, but three were excluded; one patient experienced ROSC during the two-minute treatment period, and the $EtCO_2$ data of two more patients were corrupted[60]. $EtCO_2$ data were analyzed using a non-parametric Friedman's Two-Way Analysis of Variance by Ranks test to determine $EtCO_2$ value differences between hand positions. The researchers found no significant difference between the $EtCO_2$ values produced during chest compressions using the four different hand positions ($P = 0.4$)[60]. Additionally, the hand position that resulted in the highest $EtCO_2$ value was evenly distributed across all patients. All four hand positions produced peak $EtCO_2$ values evenly across all patients[60]. One limitation of this study was its low sample size; the study's results could have been more relevant if more patients experiencing OHCA had been assessed. Perhaps the researchers could have extended the study period to allow more time for additional cases to be encountered by the physician-manned ambulances, thus increasing the amount of potential data. Additionally, compression rate and depth were not formally tracked during resuscitation attempts, resulting in a potential confounder. Finally, the researchers did not attempt to establish a relationship between hand position and patient outcomes, which limits the clinical applicability of their results. The researchers concluded optimal hand placement may vary between patients, encouraged further research into hand position during CPR, and recommended rescuers place their hands near one of the positions described in the study during CPR[60].

The next study cited by the AHA in their 2015 update of hand position was a prospective clinical trial conducted at a university hospital in Korea with the goal of examining the hemodynamic effects of chest compressions at two different positions on a patient's sternum[62]. To be included in the study, subjects had to be at least 18 years of age, suffer a non-traumatic cardiac arrest, and fail to regain spontaneous circulation in the hospital's emergency department after 30 minutes of standard CPR[62]. In this study, standard CPR refers to conducting a resuscitation attempt while adhering to the recommendations outlined in the 2010 AHA CPR Guidelines[62]. Over the course of the study period, only 17 patients met inclusion criteria[62]. Resuscitation attempts were initiated as soon as patients arrived at the hospital, and were conducted by a team of two EMTs, two nurses, and two doctors[62]. Similar to the previously discussed Norwegian study,[60] the hemodynamic effects of chest compressions were estimated via $EtCO_2$ data continuously measured via a capnography unit attached to endotracheal intubation tubes[62]. During the 30 minutes of standard CPR, chest compressions were completed by the EMTs on the medical team; the rescuers were instructed to position their hands on the patient's INL in the center of the chest and perform compressions at a rate of 100 compressions per minute[62]. Compression rates were kept consistent with the assistance of a metronome. If a patient did not experience ROSC after 30 minutes, rescuers switched their hands to an alternate, more caudal position on the infrasternal notch and continued compressions for another two minutes[62]. The data were analyzed using a paired t-test to determine if there were any significant differences in $EtCO_2$ values between the two hand positions[62]. Mean $EtCO_2$ values produced by the alternate hand position were significantly higher than values produced by standard hand placement (11.0 ± 6.7 mmHg vs. 9.6 ± 6.9 mmHg, $P = 0.02$), suggesting positioning one's hands lower on the sternum may result in more effective chest compressions[62]. While the study's results are intriguing, there were several limitations to its design besides the small sample size. While chest compression rate was kept relatively consistent with the use of a metronome, there was no effort to measure compression depth[62]. If there was a difference in compression depth between the two methods, all results would have to be statistically adjusted to control for the lack of consistency between CPR parameters. Resuscitation was not initiated until a patient arrived at the hospital's emergency department and the alternate hand position was not utilized until 30 minutes of CPR had passed, which could have affected the hemodynamics of the patient in some manner. Additionally, the researchers did not examine whether or not the alternative hand position resulted in an increased injury frequency during CPR[62]. Positioning one's hands over the distal end of the sternum could potentially result in an increased risk of xiphoid process fractures, which would be an undesirable effect of the new hand position. The researchers concluded the alternate, more distal hand placement may be more effective than the AHA's recommendation of placing hands on the INL, but the limitations present in the study make the results difficult to use them for clinical practice.

Even after citing the two previously discussed studies[60,62] to substantiate their updated hand placement recommendation, the AHA admits the research does not provide any type of consistent or conclusive evidence regarding the effect of hand placement on resuscitation efficacy[1]. It is clear more research must be conducted on hand placement during CPR. Future research must consist of larger, prospective studies, which include measurements of compression rate and depth in an effort to control for potential confounders. Until further research is completed, the optimal hand position during CPR remains unknown.

2.2.2.4. Chest compression fraction

The AHA's change to their recommendation on chest compression fraction is small but significant. While the organization affirms the importance of minimizing interruptions in chest compressions that was established in their 2010 guidelines, they clarify the recommendation by stating rescuers should strive for a compression fraction of at least 60%[1]. Chest compression fraction is a way of measuring the proportion of time spent performing chest compressions during a cardiac arrest resuscitation attempt. Compression fraction is inversely proportional to the amount of interruptions to chest compressions experienced by a rescuer; in other words, minimizing interruptions results in a higher fraction. While most current evidence supports the AHA's recommendation, there are a few studies that found no relationship between compression interruptions and patient outcome[1].

One of the studies used by the AHA to support the updated chest compression fraction recommendation was conducted by researchers in the city of San Diego, California to examine the effect of minimizing interruptions during chest compressions on odds of ROSC[63]. Any patient who suffered an OHCA and was subsequently treated by an EMS unit equipped with a defibrillator capable of electronically recording CPR data was included in the study; conversely, patients were excluded if defibrillator data were not available for analysis[63]. Over the course of the study period, 35 patients met the inclusion criteria[63]. Interruptions in chest compressions were identified by trained research personnel and divided into two groups: pre-shock pauses (before defibrillation) and post-shock pauses (after defibrillation)[63]. At the end of the study period, the data were analyzed via receiver-operator characteristic curve to identify optimal thresholds for both pre-shock and post-shock pauses[63]. The researchers found an increase in the odds of ROSC associated with a total pre-shock pause of less than three seconds (OR= 6.68, 95% CI 2.00 - 22.30, $P < 0.01$) and a total post-shock pause of less than six seconds (OR=10.71, 95% CI 2.77 - 41.42, $P < 0.01$)[63]. Meeting both criteria resulted in a higher odds ratio of ROSC (OR=13.07, 95% CI 3.42 - 49.94, $P < 0.001$) than meeting one criteria alone[63]. One limitation in the study was the small sample size, which resulted in wide confidence intervals[63]. Additionally, the potential effects of compression depth and compression rate on odds of ROSC were not considered during data analysis, which could have affected results. Another potential limitation of this study, especially considering the AHA uses it to support their updated guidelines, is that the researchers did not directly measure or calculate chest compression fraction. However, the researchers did concede shorter pre- and post-shock intervals may have been a surrogate for higher chest compression fraction[63]. Even so, no concrete conclusions regarding optimal chest compression fraction can be drawn from the study.

Another study used by the AHA to substantiate the chest compression fraction guideline was a large, prospective cohort study conducted by the ROC in which researchers examined the relationship between chest compression fraction and odds of OHCA survival[64]. Between December 2005 and March 2007, the ROC collected prospective chest compression fraction data from seven sites across the U.S. and Canada. For the purposes of this study, chest compression fraction was defined as "the proportion of resuscitation time without spontaneous circulation during which chest compressions were administered"[64(p.1242)]. All subjects included in the study experienced a cardiac arrest before the arrival of EMS and had an initial recorded cardiac rhythm of ventricular fibrillation or tachycardia. Conversely, subjects were excluded if they received defibrillation from a bystander before the arrival of EMS or if the case did not result in at least one minute of electronically recorded CPR data[64]. While a total of 14,090 OHCAs occurred during the study period, only 3,170 patients presented with an initial rhythm of ventricular fibrillation or tachycardia. Of those 3,170 patients, only 506 cases resulted in useable CPR data[64]. Depending on the type of AED carried by the EMS unit that responded to a particular OHCA, the presence of chest compressions during each resuscitation attempt was measured indirectly by changes in thoracic impedance recorded via defibrillator electrode pads or by an accelerometer interface built into the AED[64]. Subsequently, chest compression fraction was automatically calculated by analytical software included in the AED and reviewed by trained research staff[64]. Chest compression fraction data were divided into five different groups: 0-20%, 21-40%, 41-60%, 61-80%, and 81-100%[64]. The data were analyzed via logistic regression to determine the odds ratio of survival for each category relative to the lowest group[64]. Patients who received a chest compression fraction in the range of 61-80% experienced the highest survival rate (29%), followed by the 81-100% chest compression fraction group (25%)[64]. Subsequently, a chest compression fraction of 61-80% was calculated to result in the highest odds ratio of survival out of all five groups (OR=3.01, 95% CI 1.37 - 6.58)[64]. The small reduction in odds of survival from the second-highest chest compression fraction group to the group with the highest chest compression fraction is surprising, but the researchers attribute the finding to the study's relatively small sample size and wide confidence intervals[64]. The researchers also conducted a secondary multivariable linear-regression analysis to determine the effect of a 10% increase in chest compression fraction on odds of survival. For every 10% increase in chest compression fraction, the probability of survival was estimated to increase by 1.08 (95% CI 0.98 – 1.20)[64]. Similar to previously discussed studies[60,62,63], chest compression depth was not measured and therefore could be a considered a confounder[64]. Additionally, data were only collected from approximately 4% of all OHCAs that occurred during the two-year study period[64]. If more compression fraction-monitoring equipment was available during all OHCA cases, the study may have yielded different results. Despite the study's limitations, it makes a strong case to support the AHA's assertion that higher chest compression fractions are associated with higher odds of cardiac arrest survival.

One of the only studies that found no association between minimized compression interruptions and increased odds of survival was a 2005 randomized control study in which researchers examined whether OHCA outcomes were improved by different AED protocols aimed at decreasing pauses in chest compressions[65]. Over an 18-month study period, EMS stations in the city of Paris, France were assigned AEDs, which were programmed with one of two treatment protocols: a control protocol and a test protocol[65]. The control protocol involved starting the resuscitation attempt by delivering shocks in groups of three, with rhythm checks after the first and second shocks. After three shocks, chest compressions were initiated[65]. In contrast, test protocol was designed with the goal of minimizing interruptions in chest compressions. Instead of starting resuscitation attempts with three consecutive shocks, chest compressions were started immediately, and shocks were separated by one-minute intervals of compressions[65]. All AEDs given to the participating EMS stations were equipped with software to monitor aspects of resuscitation attempts such as time spent performing compressions and how many shocks were delivered[65]. Similar to the previous study by the ROC examining chest compression fraction and odds of survival,[64] all OHCA patients who presented with an initial rhythm of ventricular fibrillation and were subsequently treated by participating EMS were enrolled, resulting in a total of 845 eligible cases[65]. The control group contained 424 patients, the test group contained 421 patients, and there were no significant differences in baseline demographic information between groups ($P = 0.19$)[65]. The data were analyzed using a Mann-Whitney *U* test to determine any differences in the association between each AED protocol and OHCA survival[65]. While the researchers found that the test protocol group had a significantly higher mean chest compression fraction compared to the control (61 ± 12% vs. 48 ± 13%, $P < 0.001$), there was no significant difference in survival rate between groups (13.3% vs. 10.6%, $P = 0.19$)[65]. The somewhat neutral results could be attributed to training effects; before the research period, all emergency medical providers who participated in the study underwent an intensive three-month training course focusing on increasing CPR quality[65]. Even with the differences in the two treatment protocols, rescuers could have provided similar levels of CPR quality to patients resulting in the non-significant differences in patient outcome between groups. One limitation of the study was that it was not blinded. Healthcare providers who participated in the study had to know the protocol differences to perform each type correctly, and thus blinding them was impossible. Additionally, this study continues the trend of not measuring chest compression depth noted in previously discussed research[60,62,63,65]. Once again, compression depth could have acted as a confounder for the study's results. The researchers also note their results may not generalize to EMS with shorter response times. If CPR had been initiated sooner after cardiac arrest onset, minimizing interruptions in chest compressions may have had more of an effect[65]. The researchers concluded shortening interruptions during chest compressions had no noticeable effect on patient survival, but admitted their results contrasted with other contemporary evidence[65].

Though a substantial amount of research examining chest compression fraction exists, the optimal chest compression fraction remains unknown[1]. However, most evidence supports the notion higher chest compression fractions or minimizing interruptions in chest compressions results in more favorable patient outcomes[63,64]. The AHA's recommendation of performing CPR with the goal of achieving a chest compression fraction of at least 60% is reasonable, but given the fact there is some evidence[65] which contradicts the recommendation, further research must be conducted in order to determine if an optimal chest compression fraction exists.

2.2.2.5. Chest wall recoil

The main difference between the AHA's 2010 recommendation for chest wall recoil and their updated 2015 guideline is the addition of instructing rescuers to avoid leaning on a patient's chest between compressions[1]. Full chest wall recoil is crucial to quality CPR. Allowing the chest to recoil fully creates negative intrathoracic pressure which in turn promotes cardiopulmonary blood flow and venous return[1]. Unfortunately, research on leaning and chest recoil is lacking. The AHA uses two animal studies to derive the evidence for their updated guideline; no human research is available on the association between chest wall recoil, leaning, and patient outcomes[1].

The first study referenced by the AHA in the chest wall recoil recommendation update was conducted in 2010 by researchers at the University of Arizona[66]. Researchers induced ventricular fibrillation (confirmed by attached ECG) in ten anesthetized piglets via an electrode placed in the animals' right ventricle[66]. After the induction of ventricular fibrillation, CPR was provided by a rescuer while a device secured to the animal's chest simulated three different levels of residual lean during the recoil phase of chest compressions: no force, 10% of the average force required to maintain 80-90 mm Hg peak aortic systolic pressure (1.8 kg), and 20% of the average force required to maintain 80-90 mm Hg peak aortic systolic pressure (3.6 kg)[66]. Each trial consisted of six, three-minute CPR sessions; the first and last sessions were performed without any simulated lean while the other four were randomly assigned 10% or 20% simulated lean[66]. Left ventricular myocardial blood flow (MBF) was measured via a neutron-activated microsphere assay technique to determine the effect of residual leaning on cardiopulmonary blood flow[66]. MBF data were analyzed via Mann-Whitney *U* test to determine statistically significant differences between the three simulated levels of residual leaning[66]. The researchers found MBF decreased significantly in the CPR sessions with simulated leaning compared to the sessions with no lean ($P < .05$) but found no significant difference in MBF between 10% residual lean and 20% residual lean ($P > .05$), suggesting that the decreased hemodynamic effects of the simulated leaning were primarily due to lack of full chest recoil[66].

The second animal study used to support the AHA's recommendation against leaning was conducted to determine the effects of residual leaning on hemodynamics during CPR[67]. Researchers induced ventricular fibrillation in nine adult pigs via an electrode placed in the animals' right ventricles, and subsequently five minutes of CPR were carried out by a mechanical piston[67]. The piston was set to compress the subjects' chests to a depth equal to 25%

of the subjects' anteroposterior diameters at a rate of 100 per minute[67]. During the first three minutes of CPR, the piston was programmed to allow full chest recoil between compressions; in the fourth minute of resuscitation, the piston only recoiled 75% of the way in order to simulate the effects of residual leaning[67]. During the fifth and final minute of CPR, full chest recoil was resumed[67]. Systolic and diastolic blood pressures during CPR were continuously monitored via micromanometer-tipped catheter placed in the chest cavity level with the subject's descending aorta[67]. The resulting data were analyzed with a one-way, repeated-measures ANOVA to determine the effects of simulated lean on subject hemodynamics[67]. As shown in Table 2, the researchers found significant decreases in systolic blood pressure, diastolic blood pressure, mean arterial pressure, and coronary perfusion pressure during CPR with simulated leaning ($P < 0.05$)[67]. Additionally, the previously mentioned hemodynamic values remained low even when full chest recoil was resumed[67]. These results suggest even brief periods of inadequate chest wall recoil can negatively influence patient hemodynamics during an entire resuscitation attempt. A limitation of this study was the researcher's definition of residual lean. Since lean was simulated by decreasing the piston's compression distance to 75% of its original depth, it is possible the noted hemodynamic decreases could be due to the 25% decrease in stroke length rather than a true residual lean[66,67]. Regardless, the researchers concluded incomplete chest wall recoil due to simulated leaning negatively effects subject hemodynamics during CPR[67].

Table 2. Hemodynamic parameters at baseline, 100% chest recoil, and 75% chest recoil, adapted from Yannopoulos et al[67].

Hemodynamic Measure	Baseline (Pre-Arrest)	100% Chest Recoil	75% Chest Recoil (Simulated lean)
Systolic Blood Pressure	94 ± 6 mmHg	74.6 ± 4.3 mmHg	65.3 ± 5 mmHg
Diastolic Blood Pressure	63 ± 4 mmHg	28.1 ± 2.5 mmHg	20.7 ± 1.9 mmHg
Mean Arterial Pressure	73 ± 3 mmHg	52 ± 3 mmHg	43.3 ± 6 mmHg
Coronary Perfusion Pressure	61 ± 3.2 mmHg	23.3 ± 1.9 mmHg	15.1 ± 1.6 mmHg

The two animal studies[66,67] cited by the AHA to substantiate the updated 2015 chest recoil guidelines are not adequate to make a full recommendation. As animal studies, the results are difficult to generalize to humans. In addition, one of the studies[67] may not have simulated residual lean in an effective manner. Before future recommendations on chest recoil and leaning are established, more research involving human subjects must be conducted to fully understand the hemodynamic effects of leaning during CPR.

2.2.3. CPR Quality

2.2.3.1. Definition and Clinical Impact

The definition of high-quality CPR has evolved in tandem with the technique itself. In current clinical practice, providing high-quality CPR requires following all of the AHA's current guidelines in metrics such as chest compression rate, depth, fraction, and chest recoil[1]. While independent relationships between OHCA survival and chest compression fraction,[64] compression rate,[56,57] and compression depth[58] have been supported by contemporary literature, evidence regarding the collective influence of the AHA's proposed metrics of high-quality CPR on OHCA survival is minimal[68].

One of the only studies in which researchers examine the association between compliance with AHA CPR guidelines and OHCA survival rates was a 2017 secondary analysis of CPR data prospectively collected over a four-year period by the ROC[68]. Data were collected electronically from AEDs available during all OHCA calls at 10 ROC sites across the U.S. and Canada. Electronically-collected CPR data included chest compression fraction, compression depth, and compression rate, and the researchers defined high-quality CPR using the 2015 AHA CPR guidelines[68]. However, the researchers chose to use a chest compression fraction of 0.8 instead of the minimum of 0.6 recommended by the AHA[1,68]. All patients older than 18 years of age who experienced a non-traumatic OHCA were included in the study, while patients whose cases did not result in at least three minutes of AED-measured electronic CPR data were excluded[68]. At the end of the study period, 55,568 OHCAs were treated by EMS providers, but only 19,568 cases were included; 14,280 cases did not result in at least 3 minutes of CPR data, 2,364 more OHCAs occurred in pediatric patients under the age of 18, and finally 19,356 cases were missing one or more CPR quality measurements[68]. The data were analyzed via multiple regression (adjusted for potential confounders such as age, sex, initial cardiac rhythm, and time from dispatch to EMS arrival) to examine the association between high-quality CPR and OHCA survival[68]. By the study's definition, high-quality CPR was only provided during 1.7% of all OHCA cases. Overall, unadjusted survival rates did not significantly differ between the AHA guideline-compliant and non-guideline-compliant groups (7.6% vs. 7.7%)[68]. However, when restricting cases to those with late ROSC (≥10 minutes of CPR), the researchers found a significant association between guideline compliance and increased survival (OR=2.17, 95% CI 1.11- 4.27)[68]. The researchers proposed several explanations for their results. First, the researchers suggested patients who were in the guideline-compliant group may have been more likely to experience a poor prognosis. While both cohorts were similar in most demographic characteristics, individuals who received high-quality CPR were less likely to present with a shockable (treatable) rhythm such as ventricular tachycardia or ventricular fibrillation than individuals who did not receive high-quality CPR[68]. Individuals with an initial shockable rhythm may have experienced early defibrillation, which has been associated with higher OHCA survival rates[1]. The significant difference in initial rhythm between both groups is a limitation of the study and could have skewed results. Another explanation given by the researchers is high-quality CPR may only be effective in a select group of individuals, such as those who experienced a late ROSC[68].

However, the researchers concede the clinical importance of their explanation is limited as the timing of ROSC cannot be predicted. Consequently, the researchers concluded that complying with AHA CPR guidelines is not associated with improved OHCA outcomes, but still recommended the further development of strategies to improve collective guideline compliance due to the limitations present in the study[68].

2.2.3.2. Factors affecting CPR Quality

Since delivering high-quality CPR is essential to increasing an individual's odds of cardiac arrest survival,[1] a crucial aspect of CPR research is determining the factors that can affect a rescuer's ability to effectively perform it. If researchers can establish associations between certain factors and CPR quality, rescuers can work to modify those factors to increase the effectiveness of their resuscitation attempts. Over the years, researchers have been able to identify both physical and cognitive factors, which have an impact on rescuer CPR performance[3,69].

2.2.3.2.1. Demographic characteristics

Demographic characteristics such as an individual's sex, weight, and body mass index all play a role in CPR performance, though current research varies in the true nature of the characteristics' roles[69-71]. Body mass index (BMI) is a value used to estimate an individual's body density and is calculated by dividing an individual's mass (in kilograms) by their height (in meters) squared. Once an individual's BMI is calculated, he or she is categorized as underweight (BMI < 18.5 kg/m^2), normal weight (BMI 18.5 to 25 kg/m^2), overweight (BMI 25 to 30 kg/m^2), or obese (BMI > 30kg/m^2)[72]. In a 2015 cross-sectional study, Jaafar et al.[70] examined the association between rescuer gender, BMI, and quality of chest compressions. In an attempt to standardize participants, individuals recruited for the study were required to be healthcare providers older than 18 who were deemed healthy (no chronic diseases or physical disabilities). In addition, subjects could not have received CPR training within the past two years[70]. All 74 participants in the study received CPR training from the same instructor in accordance with the 2010 AHA guidelines, and returned to the testing site approximately one week later to complete a CPR assessment[70]. The assessment consisted of five cycles of CPR (30 chest compressions followed by two ventilations) administered to a Resusci Anne® SkillReporter™ manikin; each mannequin was capable of reporting electronic data regarding chest compression depth and location[70]. Three researchers assisted in data collection during each assessment. One researcher ensured each participant was performing chest compressions in the correct position, another researcher gathered and documented data, and the final researcher used a stopwatch to measure the amount of time taken to administer five cycles of CPR[70]. Average chest compression rate was calculated by dividing the total number of chest compressions delivered during the assessment (150 compressions) by the total time taken to complete them. The five cycles of CPR were deemed effective if >80% of all compressions were of the correct depth and if the average compression rate was ≥100/min. On the same day as the CPR assessment, the height and weight of each participant was measured in meters and kilograms, respectively[70]. The BMI was calculated using recorded height and weight data, and each participant was subsequently categorized into one of two groups: BMI < 26 or BMI >26. These categories were chosen because the average BMI among the study population was 26 kg/m^2[70].

After the conclusion of all assessments, the data were analyzed via nonparametric Chi-Square test for independence to examine the relationships between gender, BMI, and CPR quality[70]. A significantly higher proportion of subjects in the below average BMI group achieved >80% chest compressions with adequate depth (82% of subjects vs. 57% of subjects, $P = 0.04$)

as well as an adequate compression rate (91% of subjects vs. 50% of subjects, $P = 0.00$). However, the only significant difference between genders in terms of CPR performance was in chest compression rate; all female subjects maintained an adequate compression rate, whereas only 40% of male subjects met the criteria for an effective compression rate ($P = 0.00$)[70]. There was no significant association found between gender and compression depth, though a higher percentage of female subjects reached an effective depth compared to male subjects (76% vs. 67%, $P = 0.5$)[70]. However, several limitations are present in the study. Subjects all received CPR training a week before the assessment and had an instructor in the room during the testing period coaching them on correct hand placement. In a true OHCA, there is a low chance rescuers will have had recent CPR training, and they will most likely not have someone coaching them through the resuscitation process. Having recent training and feedback for the subjects during the assessment may have led to skewed results. In addition, there is a possibility resuscitation will take longer than five cycles of CPR in a clinical setting. A longer assessment may have simulated a true OHCA and yielded more accurate results.

The findings of Jaafar et al.[70] differ from results found during a 2011 study by Sayee and McCluskey examining the factors that influence CPR performance of entry-level doctors[71]. All first-year doctors at a teaching hospital in Belfast were invited to participate in the study provided the doctor had received formal CPR training within three months of the study period. In this study, the average BMI among all 34 participants was 24 kg/m^2, and subjects were consequently categorized as above average ($BMI > 24\ kg/m^2$) or below average ($BMI < 24 kg/m^2$). All subjects were required to perform three minutes of CPR on the same type of Resusci Anne® SkillReporter™ used by Jaafar et al.,[70] and data on chest compression depth was collected in a similar manner[71]. The researchers defined a CPR session as effective if >80% of compressions reached an adequate depth[71]. By analyzing the data via Mann-Whitney *U* test, Sayee and McCluskey found significant differences in chest compression depth effectiveness between genders and BMI groups. A significantly higher proportion of male doctors than female doctors administered effective chest compressions (83.3% of males vs. 25% of females, $P = 0.005$), and doctors with above average BMIs performed more effectively than those with low BMIs (76% of subjects with BMI > 24 vs. 35% of subjects with BMI < 24, $P = 0.045$)[71]. Sayee and McCluskey's finding regarding the relationship between BMI and chest compression depth is contrary to the results of Jaafar et al.,[70] who found a significant association between low BMI levels and increased chest compression depth. The latter attribute the discrepancy in results to differences in the mean BMI in each study. The subjects in the study by Jaafar et al. had a mean BMI of 26 kg/m^2, which is categorized as overweight. Jaafar et al. claim overweight individuals show a "tendency of having a slightly abnormal body [position]" during CPR, which could affect compression depth[70(p4)]. Also in contrast to the results of Jaafar et al.[70] was Sayee and McCluskey's finding of a significant association between gender and chest compression depth[71]. While Sayee and McCluskey found males were more likely to administer chest compressions at an adequate depth, Jaafar et al. found no significant difference between genders[70,71]. Sayee and McCluskey[71] concede their study's small sample size (n = 34) limits the statistical power of their findings, which may explain the differences in results from Jaafar et al[70]. Though results differ, there does seem to be some association between CPR quality and an individual's demographic qualities. However, more research consisting of larger sample sizes and more realistic assessments must be completed to establish the association's true nature.

2.2.3.2.2. Rescuer Fitness, Strength, and Fatigue

CPR can be physically taxing for rescuers to perform, especially if the resuscitation attempt is prolonged. As a result, aspects of a rescuer's physical fitness may have an impact on how long the individual can sustain high-quality CPR. One study by Ock et al.[73] evaluated the influence of a CPR provider's physical fitness on the quality of chest compressions delivered during the first five minutes of resuscitation. All medical students with basic life support (BLS) training at the Catholic University of Korea were invited to participate in the study, resulting in a sample size of 47 participants. Each participant underwent a salvo of physical fitness assessments to measure maximal aerobic exercise capacity (VO_2max), upper body muscular strength (via hand-grip dynamometer), and upper body endurance (also measured via hand-grip dynamometer)[73]. After the completion of exercise testing, each subject was required to perform five minutes of CPR on a Resusci Anne® manikin, which was capable of electronically recording and reporting CPR data such as compression rate and depth. In this case, the researchers defined a quality chest compression as one that reached a depth of five centimeters[73]. Participants were also monitored for rating of perceived exertion (RPE), heart rate, and volume of oxygen consumption per minute (VO_2) during the assessment. Heart rate and VO_2 were continuously recorded via heart rate monitor and gas analyzer, while RPE was determined on a 15-point scale via interview at the passing of each consecutive minute of CPR[73]. Collected data were analyzed via one-way repeated measures analysis of variances to compare CPR quality during each minute of resuscitation, then analyzed via multiple linear regression to examine the possible relationships between CPR quality and measures of physical fitness.

While a consistent chest compression rate of approximately 110 per minute was maintained across all subjects during all five minutes of CPR, the researchers found a significant reduction in quality chest compressions after each consecutive minute ($P < 0.001$). Across all subjects, the average percentage of quality chest compressions was 78.8% in the first minute and 57.2% in the second, followed by 43.4% in the third, 36.5% in the fourth, and finally 28.0% in the fifth minute[73]. The researchers attributed the decrease in CPR quality to participant fatigue. Average heart rate, VO_2, and RPE across all participants increased significantly during CPR ($P < 0.001$), which supports the researchers' suggestion of rescuer fatigue increasing during resuscitation[73]. In addition, a significant positive correlation was found between upper body muscle strength and CPR quality ($R^2 = .494$, $P < 0.05$). Subsequently, the researchers concluded fitness programs that incorporate strength training may be more beneficial to CPR providers than a program focusing on cardiorespiratory fitness alone. However, Ock et al.[73] concede a limitation of the study was the fact VO_2max was estimated via submaximal cycle ergometer test. If a more accurate VO_2max had been utilized, it is possible a correlation between aerobic capacity and CPR quality could have been observed. Another limitation of the study is the short CPR performance time, which is similar to previously discussed studies regarding the factors that may influence CPR quality[70,71]. A true OHCA resuscitation may last longer than five minutes, which further highlights the importance of rescuer strength and fitness to prevent fatigue and the subsequent drop in CPR quality. Finally, participants were asked to rate their perceived exertion at the end of every minute of CPR, which could have impeded their concentration and led to a reduction in chest compression quality. Even with the present limitations, the results found by Ock et al.[73] provide a compelling argument to support the proposed association between rescuer fitness (specifically upper body strength) and CPR quality.

In 2011, a randomized, crossover trial was conducted by Russo et al.[74] to examine the objective parameters of physical fitness that affect chest compression quality. Subjects were required to be healthy (no chronic illnesses or physical disabilities) as well as certified in both basic and advanced life support (ALS), resulting in a study sample size of 40 volunteers. Due to the relatively strict inclusion criteria of ALS certification, the study population consisted of paramedics, physicians, and intensive care nurses[74]. Two days prior to CPR testing, the physical fitness of each participant was evaluated via two ergometric endurance tests. The first assessment, designed to focus on upper body fitness, consisted of a three-minute ramp protocol on a rowing ergometer. The rowing intensity began at 25 watts and was gradually increased to a minimum of 75 watts by the end of the protocol. For the intensity to be increased, subjects had to maintain a stroke frequency between 30 and 40 strokes per minute. However, the researchers used subject heart rate at 75 watts (HR_{75}) as the objective marker of upper body fitness as it had the highest correlation with ergospirometric parameters during rowing ($r = -0.85$, $P < 0.05$)[74]. The second assessment, focusing on lower body fitness, required subjects to pedal on a cycle ergometer with increasing intensity (measured in watts) until a heart rate of 170 was reached. Personal watt capacity at a heart rate of 170 has been previously validated as a parameter for lower body fitness[74,75]. Heart rate was measured via chest-belt heart rate monitor during each test, and subjects were given two hours to recover between them. Two days after the fitness assessment, subjects performed two, nine-minute sequences of CPR: one sequence using a compression/ventilation ratio (CVR) of 30:2, and another using a ratio of 15:2[74]. Nine minutes was chosen as the test duration because, at the time of the study, it was reported as the average length of resuscitation given by first responders in an OHCA before EMS arrival[76]. The CVR for the first sequence was randomly assigned to each subject via computer-generated list. Following the first CPR sequence, participants were given 90 minutes to recover before performing another bout of CPR using the other CVR[74]. Similar to previous CPR studies,[70,71,73] chest compressions were performed on a Resusci Anne® manikin, which was capable of electronically recording and reporting CPR data such as compression rate and depth. The researchers defined quality chest compressions using the AHA's 2010 guidelines; to be deemed as effective, chest compressions had to be performed at a rate of approximately 100 per minute at a depth of four to five centimeters. No corrective feedback was given to subjects during the duration of either test[74].

Statistical analysis of the data was completed via two-way ANOVA to determine strength of association between physical fitness parameters and chest compression characteristics. The researchers found significant correlations ($P < 0.001$) between PWC_{170}, HR_{75} and mean compression depth during both 15:2 (r = 0.42 and -0.57, respectively) and 30:2 (r = 0.40 and -0.57, respectively) CVR protocols[74]. Higher values of PWC_{170} and lower values of HR_{75} correspond to increasing levels of lower and upper body fitness. Thus, the aforementioned correlations suggest increases in rescuer fitness may lead to more effective chest compressions. Additionally, HR_{75} was significantly correlated ($P < 0.001$) with both the fraction of chest compressions with a correct compression depth (r = -0.55 and r = -0.38 for CVRs of 15:2 and 30:2, respectively) and the fraction of chest compressions with an inadequate depth (r = 0.6 and r = 0.53 for CVRs of 15:2 and 30:2, respectively). Consequently, the researchers designated upper body fitness as the best predictor of chest compression quality in the study[74]. This finding echoes the results of Ock et al.,[73] who determined upper body strength to be an accurate predictor of CPR quality. Furthermore, Russo et al.[74] reported a significant decrease ($P < 0.05$) in compression depth within the first four minutes of CPR across all participants, which aligns with the finding of Ock et al.[73] regarding the effects of rescuer fatigue on CPR quality. Though the study was well-designed, several limitations were present. Since the study cohort consisted of healthcare providers trained in advanced life support, the results of the study may not be applicable to laypersons who may be present at an OHCA, or even first responders trained in BLS. Additionally, rescue breaths were only imitated during the CPR assessments[74]. Providing actual rescue breaths during CPR may have an effect on rescuer fatigue, which could have led to different results in the study. Russo et al.[74] concluded physical fitness is positively correlated with sustained, high-quality CPR, but recommended the use of upper body fitness tests to more accurately predict a rescuer's quality of CPR.

Given the results of contemporary research,[73,74] there seems to be growing evidence to support an association between rescuer physical fitness, fatigue, and CPR quality. The results of the studies by Ock et al.[73] and Russo et al.[74] suggest upper body strength is most important to staving off rescuer fatigue and maintaining quality chest compressions through a resuscitation attempt. Though further research consisting of large and diverse sample sizes, more realistic CPR assessments, and prospective data collection is required to determine the true association between physical fitness and CPR quality, there is enough current evidence to support the promotion of exercise and strength training for CPR providers.

2.2.3.2.3. Self-Efficacy

Perceived self-efficacy, or confidence, may play a role in a rescuer's ability to effectively perform CPR. Self-efficacy is one's confidence to effectively perform a certain skill or behavior regardless of the situation[3]. The theoretical construct of self-efficacy was first developed and described in 1977 by Albert Bandura, a social psychologist[77]. Bandura's theory states that "initiation of a given behavior is likely to occur depending on one's perceived self-efficacy expectation, outcome expectation, and outcome value"[78(p 236)]. In this case, self-efficacy expectation is the belief that one can effectively perform a certain skill, outcome expectation is the desired result of a skill or action, and outcome value is the personal worth one associates with the desired outcome[77]. Self-efficacy has been previously shown to affect the likelihood of laypersons to initiate CPR,[79-81] but research examining the association between self-efficacy and CPR quality is limited to several investigations of various healthcare providers in hospital settings[3-5].

In 2013, Roh et al.[3] conducted a one-group posttest-only study to examine the association of CPR skills with self-efficacy and overall CPR knowledge in nursing students. The sample population consisted of 124 nursing students recruited during their clinical rotation at a Seoul hospital. The researchers did not specify any other inclusion or exclusion criteria for participation in the study[3]. Once recruited, the participants attended a 30-minute lecture covering current CPR guidelines, then an hour-long hands-on CPR training session. Immediately following the training session, the participants filled out a two-item perceived self-efficacy assessment. The items on the assessment were taken from the Resuscitation Self-Efficacy scale for nurses, which is a 17-item scale previously created and tested for validity by Roh et al.[82]. The two chosen items required participants to use a five-point Likert-type scale to rate their confidence in performing adequate chest compressions and artificial ventilations via bag-valve mask. Higher scores indicated higher levels of self-efficiacy[3]. In addition, subjects were given a 10-item multiple choice questionnaire to assess CPR knowledge. The questionnaire consisted of six items on the principles of BLS, followed by two items on both chest compressions and ventilations[3]. After completing the self-efficacy survey, participants performed CPR on a Resusci Anne® manikin capable of electronically measuring quality of artificial ventilations and chest compressions. Upon completion of the CPR session, CPR quality data were printed and discussed with each participant. Using the printed data, the researchers evaluated the participants using a numerical penalty scoring system. If a student performed a skill correctly by adhering to the guidelines outlines in the 2010 AHA CPR recommendations, no points would be given. If a skill was performed incorrectly, a value of 10 or 20 penalty points would be marked down for the skill[3]. Therefore, lower penalty scores indicated a higher quality of CPR.

The data were analyzed via multiple linear regression to examine the association between perceived self-efficacy and CPR performance. The researchers found a significant negative correlation between compression skills penalty score and self-efficacy ($r = -0.238$, $P = 0.008$), meaning students who reported higher perceived self-efficacy for chest compressions were likely to perform them correctly. However, ventilation skill was not significantly correlated with ventilation self-efficacy ($r = -0.031$, $P = 0.730$). Both compression and ventilation skills were not correlated with knowledge of compressions ($r = -0.060$, $P = 0.510$) or knowledge of ventilations ($r = -0.103$, $P = .257$)[3]. These findings suggest rescuer confidence, possibly gained through hands-on practice, may be a better predictor of CPR skill performance than written exams. A rescuer who is knowledgeable about CPR still may not be able to perform it effectively. Finally, the researchers found a significant positive correlation between total self-efficacy and total CPR knowledge ($r = 0.313$, $P < 0.001$), meaning subjects with higher confidence levels were knowledgeable about CPR as well[3]. One limitation of this study pertains to the methods used to measure student knowledge and self-efficacy. Though both assessments were adapted from previously validated tools,[3,82] they each contained a small number of items. It is possible the limited number of survey items was not sufficient to accurately measure subject knowledge and self-efficacy, which could have led to skewed results. In addition, the researchers did not report the duration of the CPR skills test, nor did they assess any demographic characteristics besides age and gender[3]. Consequently, confounding variables such as rescuer BMI and fatigue were not considered or controlled for in the study. The researchers concluded that, if the correlation between self-efficacy and chest compression is valid, BLS courses should incorporate more hands-on mastery experiences to maximize student self-efficacy[3].

Another similar study by Gonzi et al.[5] examined the correlation between CPR quality and self-efficacy in hospital staff using in-hospital cardiac arrest simulations. The 320 participants, consisting of mainly nurses (approximately 45% of subjects) and doctors (approximately 43% of subjects), were recruited from current staff in an Italian hospital. No other exclusion or inclusion criteria were delineated by the research team[5]. All participants had attended a five-hour BLS class consisting of instructional videos, lectures, and CPR skill practice in the year before the study was conducted. To measure CPR quality, the subjects were paired and asked to complete a five-minute cardiac arrest simulation. A Resusci Anne® manikin was placed in a hospital bed and used as the simulated cardiac arrest patient. During the assessment, CPR compression rate and depth were measured electronically via the mannequin, and two independent observers measured chest compression fraction[5]. Before and after testing, each participant was asked to rate their perceived self-efficacy in effectively performing resuscitation on a 10-point Likert-type scale. Higher scores were indicative of higher confidence levels[5].

After the conclusion of testing, bivariate analysis was conducted to determine the presence of any correlation between CPR quality and self-efficacy. Upon data analysis, the researchers found no significant correlation between pre-test self-efficacy and CPR performance for overall chest compression quality ($r = 0.059$), chest compression rate ($r = -0.032$), or chest compression fraction ($r = 0.123$)[5]. This finding could potentially be attributed to subjects overestimating their CPR skills. Conversely, all three measures of CPR quality were significantly correlated with post-test self-efficacy ratings, as seen in table 3. Therefore, subjects seemed to provide a more accurate estimation of CPR skills and the confidence associated with performing them after completing the simulation. Similar to the results of Roh et al.,[3] these findings suggest a rescuer's CPR knowledge may not predict CPR performance. One strength of this study compared to other examinations of CPR quality[3,71,74] is the effort made to simulate a cardiac arrest. Subjects had to perform CPR skills on a mannequin positioned in a hospital bed and had to work together to retrieve emergency supplies such as AEDs[5]. However, the simulation was still far from realistic and CPR quality in a real in-hospital cardiac arrest may differ. In addition, there was only one item used to assess self-efficacy[5]. A more-developed tool consisting of multiple items assessing self-efficacy for a variety of CPR skill rather than overall CPR performance may have resulted in more accurate results. The researchers conclude by stating perceived self-efficacy does not necessarily affect CPR performance[5]. However, the significant correlations found between CPR quality and post-test self-efficacy ratings suggest individuals who undergo simulated CPR training may be able to use self-efficacy to predict CPR performance.

Table 3. Correlation between CPR metrics and self-efficacy before and after CPR simulation, adapted from Gonzi et al[5].

CPR Metric	Pre-Test	Post-Test
Chest compression fraction	$r = 0.123, P > 0.05$	$r = 0.240, P < 0.01$
Compression quality	$r = 0.059, P > 0.05$	$r = 0.166, P < 0.05$
Correct compression rate	$r = -0.032, P > 0.05$	$r = 0.212, P < 0.01$

It is difficult to make definitive conclusions regarding self-efficacy's effect on CPR quality from the results of contemporary literature due to study limitations and a lack of research[3,5]. Further research focusing specifically on the relationship between rescuer confidence and CPR performance utilizing larger sample sizes, more realistic scenarios, and more detailed self-efficacy assessments is required. In addition, future research should expand sample populations to include both more types of healthcare providers as well as laypersons. Even so, these studies seem to support an association between hands-on simulation training, self-efficacy, and CPR performance[3,5].

2.3. Athletic Training

2.3.1. Definition and Scope of Practice

Certified athletic trainers are healthcare professionals who work under the direction of and in conjunction with physicians to optimize patient physical activity, activities of daily life, and participation in work[9]. In general, athletic trainers practice the examination, diagnosis, treatment, rehabilitation and prevention of acute, subacute, and chronic musculoskeletal and medical conditions. These practices are performed to minimize a patient's functional limitations or disabilities after injury, as well as prevent subsequent ailments[9]. The athletic training scope of practice is defined within a few different sources: the *Role Delineation Study* published by the athletic training Board of Certification (BOC®),[83] the *Athletic Training Education Competencies* established by the National Athletic Trainers' Association (NATA),[84] and state regulation such as practice acts[6,9]. While athletic trainers may be associated with high school, collegiate, and professional sports teams, many athletic trainers are employed in hospitals, physician's offices, industrial or corporate settings, performing arts, or in the military[6,9]. Athletic trainers are expected to practice according to their education and state regulation, as well as participate in continuing medical education to achieve further qualifications and improved skill sets[9].

2.3.2. Role Delineation Study/Practice Analysis

The Role Delineation Study[83] or Practice Analysis[8] (created, conducted, and published by the BOC®) defines the minimum skills, tasks statements and knowledge required for the practice of athletic training[9]. The most recent Practice Analysis,[8] published in 2015, is the seventh edition of the study. Every five years, the BOC® selects a group of qualified athletic trainers to convene in Omaha, Nebraska to define and update the tasks, knowledge, and skills, which best reflect current athletic training practice. Once the group met a consensus on the skills and knowledge that could be expected of entry-level athletic trainers, all the information was organized into five distinct domains[8]. To test the validity and reliability of the newly defined domains, the BOC® organizes and conducts a large-scale validation study. Newly certified athletic trainers, starting with those certified in 2013 and working backwards chronologically to those certified in 2009, were invited to participate in the study. Approximately 5,000 athletic trainers agreed to participate[8]. Athletic trainers were asked to complete three assessments regarding performance expectations (how soon new athletic trainers are expected to perform a domain or task), consequence (the extent of a new athletic trainer's lack of proficiency in a domain in terms of causing harm to patients), and frequency (how often a new athletic trainer performs a certain task or domain)[8]. By incorporating results from the study into a new certification exam, the BOC® ensures the current assessment contains content that accurately reflects the skills newly certified athletic trainers will be required to perform. In addition, the final published practice analysis allows the Commission on Accreditation of Athletic Training Education (CAATE) to update the educational standards for athletic training educational programs. Finally, the new practice analysis helps define the scope of practice for current athletic trainers through the five defined domains of athletic training[6].

Immediate and emergency care comprise one of the domains of athletic training[8]. Athletic trainers must be prepared to react appropriately in any type of emergency situation. Emergency preparedness is an important aspect of this domain. To prepare for emergencies, athletic trainers must develop an emergency action plan (EAP) for specific venues and situations. Typically EAPs consist of a chain of command for emergent situations, a list of all available emergency equipment and their locations, specific directions to a venue, how to direct emergency personnel to arrive correctly, and how to correctly document an emergency situation[85]. Athletic trainers should be able to recognize the signs and symptoms of life-threatening conditions such as SCA, heat illness, or respiratory failure and then manage them effectively using appropriate emergency equipment and procedures[8,9].

Emergency care also plays a role in another domain of athletic training: professional responsibility and healthcare administration[8]. As part of professional responsibility, athletic trainers are required to maintain emergency cardiac care certification to ensure adequate CPR performance in the event of a SCA. Additionally, athletic trainers maintain close communication and collaboration with other healthcare professionals. By establishing relationships with other professionals, athletic trainers create a healthcare team to provide the best possible care for patients[9]. For example, athletic trainers who work in high school or collegiate settings often maintain close communication with local EMS to coordinate and prepare for possible emergent situations. Another aspect of professional responsibility is practicing according to federal regulations, recommendations, and professional standards. For example, the NATA frequently publishes position statements outlining practice recommendations for athletic trainers. These position statements tend to align with current evidence-based practice trends, so it is the professional responsibility of athletic trainers to stay abreast on such recommendations and incorporate them into practice[8].

2.3.3. Athletic Training and Emergency Care Research

As previously mentioned, the current *Practice Analysis Study*[8] designates emergency care as one of the five practice domains of athletic training. Consequence rating data from the study suggests emergency care has the largest risk of all five domains for patient harm through improper practice, which highlights the importance of emergency care education and practice for athletic trainers[8]. While emergency care is a major aspect of the profession, there is a very small amount of research examining the relationship between athletic trainers and various aspects of emergency care. Furthermore, research examining CPR performance in athletic trainers is almost nonexistent. Emergency care research involving certified athletic trainers is limited to studies investigating the effect of various types of protective sports equipment on athletic trainers' ability to perform quality CPR[86-88].

In 2014, Waninger et al.[88] recruited athletic trainers, athletic training students, and emergency medical technicians (EMTs) to evaluate CPR effectiveness during simulated SCA of a fully-equipped football player. A combined group of 30 athletic training students and certified athletic trainers were recruited, in addition to six EMTs. However, no inclusion or exclusion criteria were specified by the researchers, nor did they specify the demographics of the combined student and athletic trainer group[88]. Thus, it cannot be determined how many individuals in the group were certified athletic trainers as opposed to a non-certified student. Each subject was asked to perform three, two-minute bouts of CPR on a SimMan 3G manikin, which was capable of electronically measuring chest compression rate and depth[88]. The three-session sequence began with baseline data collection in which the manikin was not equipped with football pads. Then, football pads were placed on the manikin, and two consecutive CPR sessions were performed: one in which the subject performed CPR over the pads, and another in which the subject performed CPR underneath the pads[88]. All subjects were instructed to perform CPR in accordance with the 2010 AHA guidelines (compression rate of 100/min and compression depth of ≥ 5 cm)[1,88]. The researchers reported baseline data between athletic trainers and EMTs were not statistically significant, so both groups were combined for the final data analysis. However, the researchers did not report the actual baseline values, nor did they report the p-value for significance between the two groups[88]. The data were analyzed via Wilcoxon signed rank and Kruskal-Wallis tests to compare CPR compression adequacy over and under shoulder pads. Table 4 summarizes the results from the study. The researchers found compressions performed under pads were significantly deeper than those performed over pads ($P = 0.002$), but adequate depth was not reached in either situation[88]. No statistically significant difference in compression rate was found between scenarios ($P = 0.20$), but rate was adequate for compressions performed both under and over pads[88]. Numerous limitations were present in this study. First, baseline data was not reported by the researchers, which makes it difficult to draw any conclusions about the rest of the data. For example, while chest compression depth was inadequate in both pad scenarios, there is no way of knowing if depth was inadequate at baseline as well. Furthermore, there was no comparison made between baseline values and either pad scenario[88]. This is important because athletic trainers must make a quick decision on whether or not to remove pads when an equipment-laden athlete experiences a SCA. If CPR performed over pads is of lower quality than CPR performed after pads have been removed, that finding could influence the practice standards of athletic trainers. Another limitation is that no factors that could potentially influence CPR performance (i.e. rescuer BMI, strength, cardiorespiratory fitness) were measured, resulting in a number of potential confounders[88]. While this study may have resulted in data supporting the practice of performing CPR under football pads instead of over them, the large number of limitations prevent it from being an indicator of correct practice or CPR quality in athletic trainers. Even with its limitations, the fact that correct compression depth was not attained by the athletic trainers participating in the study regardless of equipment condition highlights the need for further research regarding CPR quality in the profession.

Table 4. Compression depth and rate under and over equipment. Adapted from Waninger et al.[88]

Group	Median (Interquartile Range)	*P* value
CPR Compression Depth		
Under equipment	3.7 cm (3.1-3.9 cm)	0.002
Over equipment	3.15 cm (2.8-3.55 cm)	
CPR compression rate		
Under equipment	113/min (101.25-125/min)	0.20
Over equipment	118/min (103.25-130.75/min)	

Instead of focusing on athletic trainers' ability to perform CPR over football pads, a 2018 cross-sectional study by Clark et al.[87] examined athletic trainers' CPR performance on a simulated patient with and without lacrosse pads. The participants of the study were 26 certified athletic trainers; subjects were excluded if they had any history of upper body injury or systemic issues resulting in loss of arm strength[87]. All participants were allowed to familiarize themselves with the equipment before beginning data collection, and CPR was performed on a Resusci Anne® SkillReporter manikin. Additionally, each subject was required to perform CPR until they achieved 30 seconds of proficient resuscitation in accordance with the 2015 CPR guidelines before beginning data collection[87]. Following the 30-second proficiency demonstration, subjects were randomly assigned to one of two assessment groups: chest compressions or ventilations. During the chest compression assessment, subjects performed two-minute CPR sequences for each of three manikin equipment conditions: full lacrosse pads, pads lifted, and no pads. For the ventilation assessment, participants performed three, two-minute bouts of ventilations while another rescuer performed chest compressions. Similar to the compression assessment, each of the three ventilation trials were performed under different equipment conditions: helmet on, helmet on with chinstrap removed, and no helmet. However, the ventilation assessment was completed twice: once using a bag-valve mask and once using a pocket mask. Between each two-minute bout, participants were allowed to rest for three to five minutes[87]. All subjects completed both the ventilation and compression assessments over the course of a single, two-hour session[87].

During each session, CPR data including chest compression rate, depth, percentage of compressions with adequate recoil, percentage of compressions reaching adequate depth, mean ventilation volume, and percentage of ventilations reaching adequate depth were measured electronically by the manikin. The data were analyzed via separate within-subjects tests of variance using equipment condition as the independent variable to determine the effect of equipment on CPR performance[87]. As displayed in Table 5, the researchers found CPR over lacrosse pads resulted in lower mean compression depth and lower percentage of compressions with optimal depth compared to other conditions. Additionally, the percentage of compressions with adequate chest recoil was lower in the full-pad condition when compared to the no-equipment condition[87]. Mean data across all subjects showed similar, adequate compression depths and compression rates during the pads-lifted and no-equipment conditions[87]. This finding suggests lifting lacrosse pads or removing pads completely may lead to similar CPR compression quality.

Table 5. Chest compression outcome measures. Adapted from Clark et al[87].

	Compression Condition (Mean ± SD)			**Comparison**	
	Full Pads	Pads Lifted	No Pads	Effect Size	*P* value
Mean depth (cm)	4.52 ± .72	5.14 ± .81	5.15 ± .73	0.835	< 0.001
Rate (/min)	107.1 ± 15.8	109.7 ± 16.6	110.3 ± 13.9	-0.189	.09
Adequate recoil (%)	67.7 ± 29.5	78.1 ± 26.3	83.0 ± 23.3	0.579	.02
Adequate depth (%)	32.1 ± 37.8	65.5 ± 37.3	65.4 ± 37.8	0.900	< 0.001

Table 6. Ventilation outcome measures. Adapted from Clark et al[87].

Ventilation condition (Mean ± SD)							**Comparison**			
	Helmet fully on		Chinstrap removed		No helmet		Equipment condition		Ventilation method	
	BVM	Pocket mask	BVM	Pocket mask	BVM	Pocket mask	Effect size	*P* value	Effect size	*P* value
Volume (mL)	397.6 ± 85.3	341.9 ± 100.4	564.7 ± 91.7	493.4 ± 182.0	589.4 ± 88.2	547.2 ± 198.1	1.323	< 0.001	0.216	0.002
Optimal volume (%)	48.3 ± 40.6	26.3 ± 25.0	83.0 ± 17.0	57.2 ± 36.3	83.5 ± 20.2	61.6 ± 38.4	1.038	< 0.001	0.671	< 0.001

Table 6 summarizes the results for ventilation conditions. The researchers found equipment condition had a significant effect on mean volume of ventilations as well as percentage of ventilations with optimal volume[87]. The fully strapped helmet condition resulted in lower mean ventilation rate and lower percentage of optimal ventilations when compared to other conditions regardless of ventilation method. Finally, ventilations delivered via bag-valve mask had a higher mean ventilation volume and overall higher percentage of optimal ventilations[87]. These findings suggest higher-quality ventilations may be achieved using a bag-valve mask instead of a pocket-mask and with helmet removal. Similar to the study by Waninger et al.,[88] the present study did not control for potential confounders such as subject BMI, fitness, fatigue, or years of experience[87]. Additionally, since the assessment was performed in a controlled environment, CPR quality may differ in an actual SCA. The researchers concluded chest compression and ventilation quality may be compromised if CPR is performed over lacrosse equipment, but no conclusions were drawn regarding CPR performance in the athletic training population[87].

While some athletic trainers have to consider managing a patient’s sports-related protective equipment before administering CPR or other emergency procedures, athletic trainers do not work within an exclusively athletic population. As previously mentioned, athletic trainers are employed in a wide variety of settings such as corporate offices, the military, and hospitals, where equipment may vary[8,9]. Athletic trainers stationed in the military may have to perform CPR on a soldier in full combat attire, or those working in an industrial setting may have to perform emergency care on a patient wearing heavy industrial equipment. However, there is no research on the ability of athletic trainers to perform quality CPR under such conditions. Consequently, future research regarding athletic trainers and emergency care procedures such as CPR must expand to include scenarios other than sports related SCAs. Large-scale, prospective studies which involve evaluating the emergency skills of athletic trainers may help entities such as the CAATE or the BOC® determine if current emergency care education in athletic training curriculum is adequate. In all of the previously discussed studies examining CPR quality amongst healthcare professionals[3,5,68,70,71,73,89], athletic trainers were not included in participant populations. With emergency care and CPR being such significant aspects of their profession,[8] athletic trainers must be incorporated into future emergency care research. In addition, further research covering the factors that may influence an athletic trainer's ability to perform emergency care must be conducted. The results of research conducted on other healthcare professionals such as nurses has identified self-efficacy as one of the many factors which may contribute to CPR performance[3,5]. Therefore, research must be conducted on athletic trainers to determine whether a relationship between CPR self-efficacy and CPR performance exists in the profession.

3. METHODOLOGY

3.1. Purpose of the Study

The primary purpose of this research study was to investigate the relationship between self-efficacy and cardiopulmonary resuscitation (CPR) quality in certified athletic trainers with the use of a self-efficacy survey and CPR simulation manikins. Emergency care is one of the six domains of athletic training, and certified athletic trainers are expected to be proficient in emergency skills such as CPR[8,9]. Since CPR is a core skill for athletic trainers, they must be aware of factors that influence CPR quality. Based on prior research on other healthcare providers such as doctors and nurses, self-efficacy may be one of those factors[3-5]. However, there is no literature regarding CPR self-efficacy in athletic trainers. This research study was designed to identify whether there is a relationship between self-efficacy and performance on CPR skills as determined by a medium-fidelity manikin. The study was completed to answer the following questions:

Q1: What is the relationship between athletic trainers' self-efficacy and CPR performance?

Q2: To what degree does self-efficacy predict CPR performance?

Q3: To what degree does education background, years certified as an athletic trainer, and gender predict CPR self-efficacy?

Q4: What percentage of athletic trainers achieved satisfactory performance (according to the 2015 AHA CPR Guidelines) on compression rate, depth, and ventilation quality?

3.2. Participants

A convenience sample of 50 certified athletic trainers currently active as a clinician and/or educator were recruited through word-of-mouth throughout the region and recruitment e-mail. To be included in the study, participants had to be certified as an athletic trainer by the Board of Certification (BOC®) as well as currently certified in CPR/basic life support (BLS). Exclusion criteria consisted of any current systemic or musculoskeletal conditions, which may have impeded a participant's ability to perform high-quality CPR at the time of testing. Participants were compensated with ten dollars after completion of the study. Informed verbal and written consent were obtained from each subject before enrollment. Clinical and baseline demographic data were collected by a participant demographic form.

3.3. Equipment and Instruments

3.3.1. Resusci Anne® QCPR Manikin

A Resusci Anne® QCPR Manikin (Laerdal Medical, Stavanger, Norway) was used to measure CPR performance in the study. Subjects used a Laerdal Pocket Mask™ (Stavanger, Norway) to administer ventilations. The manikin was equipped with the Laerdal SkillReporter software (Stavanger, Norway), which was capable of evaluating and reporting a subject's hand position, chest compression rate, chest compression depth, chest compression fraction, and chest recoil during CPR. In addition, the software was able to assess and report a subject's rate and volume of ventilations delivered to the manikin. After the conclusion of a CPR session, the software calculated an overall QCPR score ranging from 0% to 100% to give a measure of collective CPR performance[90].

3.3.2. CPR Self-Efficacy Assessment

A self-efficacy questionnaire developed by the creators of this study was used to assess subjects' confidence in performing CPR. The 14-item questionnaire was constructed with the use of the Basic Resuscitation Skills Self-Efficacy Scale (BRS-SES) created by Hernandez-Padilla et al[91]. Using a six-point Likert-type scale, participants indicated how confident they were in their ability to perform specific aspects of CPR during an emergency situation in accordance to the 2015 American Heart Association (AHA) CPR guidelines. All items were phrased positively.

3.4. Procedures

Prior to the start of data collection, the study was approved by the North Dakota State University Institutional Review Board. Participants for this study were recruited through word-of-mouth throughout the region and recruitment e-mail. Upon their arrival at the site of data collection, participants were given an informed consent form to read and sign. The researcher or a research assistant was available to answer any questions subjects may have had regarding the study. After giving informed consent, participants were asked to fill out a demographic questionnaire to collect information such as age, gender, years of athletic training experience, and years of CPR certification. The demographic information provided by the participants were used during data analysis. Finally, the participants were asked to fill out the CPR self-efficacy questionnaire. A research assistant or the researcher explained the Likert-type scale utilized on the questionnaire and clarified information as needed.

Once the paperwork was completed, participants were required to demonstrate CPR proficiency. CPR proficiency was evaluated through a one-minute bout of CPR using a Resusci Anne® QCPR manikin. participants were instructed to perform CPR in accordance with the 2015 AHA guidelines: a compression to ventilation ratio of 30:2, a compression rate of 100-120 per minute, and a compression depth of ≥ 5 cm but ≤ 6 cm[1]. No visual or auditory feedback regarding a subject's performance from the Laerdal SkillReporter software or research assistant were given during the proficiency evaluation. A participant was deemed "proficient" if he or she achieved an overall QCPR score of at least 80%. If a participant did not earn a score of 80% or higher, the researcher provided feedback and allowed the participant to practice before attempting the proficiency evaluation once more.

After demonstrating proficiency, participants were allowed to take a break of up to five minutes before continuing to the next stage of the study. When five minutes had passed or the participants indicated they were ready, the study proceeded. Each participant was instructed to perform eight minutes and 59 seconds of single-rescuer CPR on the Resusci Anne® QCPR manikin in accordance with the 2015 AHA guidelines. Once again, no visual or auditory feedback regarding CPR performance was given during the assessment. All clocks, including wrist watches, were removed from the testing area or hidden so that the time left in the assessment remained unknown.

At the conclusion of the assessment, the researcher or research assistant instructed the participant to cease CPR. The data from each session was saved with a deidentified number in the system. For each session, the following values were recorded: overall QCPR score, compression score, ventilation score, chest compression fraction, hand placement, mean compression depth, full recoil percentage, full depth percentage, proper compression rate percentage, mean rate, percent of ventilations that were adequate, percent of ventilations that were inadequate, and total time of testing. Immediately after testing, participants were asked to fill out the CPR self-efficacy questionnaire once more. After filling out the questionnaire, participants were allowed to view the results of their CPR performance. Finally, participants received ten dollars as compensation for their cooperation in the study. If participants were not able to perform CPR for the full test period, their failure was documented, and they were still compensated for their participation.

3.5. Statistical Analysis

All statistical analyses were completed via IBM® SPSS statistics software version 25.0 (IBM®, Armony, New York). First, Cronbach's alpha was calculated to test the CPR self-efficacy questionnaire for internal reliability. Next, a paired samples T-test was conducted to compare CPR self-efficacy values before and after the CPR assessment. Pearson product-moment correlations coefficients were calculated to examine the relationship between the self-efficacy of athletic trainers and measures of CPR performance. Linear regressions were also performed to determine if (and to what degree) self-efficacy predicted CPR performance and to what degree educational background, years certified as an athletic trainer, and gender are related to CPR self-efficacy. Finally, basic descriptive statistics were used to determine the percentage of certified athletic trainers who achieved satisfactory performance (according to the 2015 AHA CPR Guidelines) on compression rate, depth, chest compression fraction and ventilation depth. Statistical significance for all statistical analyses was set at a P value of < 0.05.

3.6. Conclusion

The purpose of this study was to determine whether an athletic trainer's CPR performance is related to his or her CPR self-efficacy. As previously mentioned, there has been minimal research on athletic trainers and their ability to perform CPR. Furthermore, there is no published literature in which researchers examine the relationship between self-efficacy and CPR performance in athletic trainers. Since performing high-quality CPR is a critical skill for athletic trainers, every effort must be made to increase CPR skill and proficiency. By determining the effect of confidence on CPR performance, recommendations may be made to incorporate activities into CPR training which are designed to increase self-efficacy.

4. MANUSCRIPT

4.1. Abstract

[Study Design] Mixed-methods

[Background] For certified Athletic Trainers (ATC's) to provide high-quality CPR, factors that impact CPR performance must be identified to improve patient outcomes attributed to sudden cardiac arrest. Though self-efficacy is one factor that has been shown to impact the performance of CPR in doctors and nurses, there have been no studies involving ATCs.

[Objectives] The primary purpose of this study was to investigate the relationship between self-efficacy and CPR quality in ATCs.

[Methods] Fifty ATCs (M = 31.5 ± 10.5 years; females = 29, males = 21) with experience ranging from 1 to 34 years volunteered. After completing a one-minute proficiency test, participants completed a 14-item self-efficacy questionnaire before and after performing single-rescuer CPR in accordance with the 2015 American Heart Association CPR guidelines for 8 minutes and 59 seconds. CPR was performed on a Resusci Anne® QCPR Manikin, and objective measures of CPR quality were measured via Laerdal SkillReporter software. Pearson product-moment correlations were computed between self-efficacy and 11 dependent variables consisting of CPR parameters and demographic characteristics to identify any possible associations. Linear regressions were also performed to determine if (and to what degree) self-efficacy predicted CPR performance and to what degree educational background, years certified as an athletic trainer, and gender are related to CPR self-efficacy. Additionally, a paired samples t-test was conducted to compare CPR self-efficacy values before and after the CPR assessment.

[Results] Overall there was a prevalence of small, negative correlations between CPR metrics and self-efficacy. However, CPR confidence was high across all participants, and did not change significantly after performing CPR (Mean difference = 0.04, $t[49] = 0.264$, $p = .792$). Hand position had the most statistically significant negative correlation with self-efficacy ($r = -.26$, $p = .070$). No association was found between demographic characteristics, CPR confidence, and CPR performance. Overall, CPR quality was high ($M = 79.74 \pm 17.47\%$), and 72% of ATCs reached an adequate depth of 5 cm during ≥90% of chest compressions ($M = 5.24 \pm .57$ cm). However, 54% of ATCs did not maintain a chest compression rate between 100-120 per minute and only 20% delivered adequate ventilations.

[Conclusions] Overall, ATCs are very confident in their ability to perform high-quality CPR. However, this high CPR self-efficacy is not always reflected in CPR performance. Further research involving larger sample sizes must be conducted to determine whether the relationship between CPR self-efficacy and CPR performance in ATCs is clinically significant to warrant discussions focused on updating CPR education to include activities addressing the psychological aspects of CPR administration.

[Level of Evidence] Level 6

[Key Words] Cardiopulmonary resuscitation, confidence, education

4.2. Introduction

The estimated incidence of sudden cardiac death (SCD) amongst athletes ranges from 1 in 40,000 to 1 in 80,000,[2] and sudden cardiac arrest (SCA) is the most common cause of SCD in young athletes[23,92]. During an SCA, the quick provision of CPR by a trained medical professional, such as a certified athletic trainer (ATC), is essential to a patient's odds of survival[1]. Since most collegiate and professional teams employ or use the services of an ATC, as do nearly 67% of high schools in the United States,[93] they are often the first responders to an athletic SCA[2]. Furthermore, the provision of CPR is a critical component of one of the five practice domains of athletic training: Immediate and emergency care[8]. Therefore, ATCs are expected to be able to provide the highest-quality CPR possible to ensure the greatest chance of patient survival.

The prompt provision of high-quality CPR can double or triple the odds of a patient's survival, but even with emergency care, mortality during out-of-hospital cardiac arrest (OHCA) remains at approximately 90%[1]. CPR itself is relatively inefficient, providing a mere 30-40% of normal blood flow to the brain and only 10-30% of normal blood flow to the heart even when adhering to current guidelines[94]. Additionally, the American Heart Association (AHA) has found CPR quality varies widely between healthcare providers, significantly affecting patient outcomes[94]. The observed variation in CPR quality has been partially attributed to extrinsic factors such as demographic characteristics[70,71] and rescuer fitness[73,74]. By researching the factors that may affect CPR quality, the AHA and several other organizations continually strive to revise current guidelines so healthcare providers, such as ATCs, can improve their administration of CPR[1,94].

While a substantial amount of research has been conducted on healthcare providers to identify extrinsic or physical factors that may impact CPR performance,[69-71,73,74] there is a lack of literature surrounding intrinsic or psychological factors. One intrinsic factor that has been identified as a possible contributor to CPR quality is self-efficacy, or one's confidence to perform effective skills or actions[3]. However, research examining the association between self-efficacy and CPR quality is limited to a few studies investigating the relationship of the psychological consideration in doctors as well as nurses[3-5]. Overall, the researchers found positive relationships between healthcare provider self-efficacy and several metrics of CPR performance[3-5].

Given that self-efficacy has been identified as a possible contributor to CPR quality[3-5] and the complete absence of research on the topic utilizing ATCs, the researchers in this study sought to investigate the relationship between CPR self-efficacy and CPR performance in ATCs. If lack of confidence while performing CPR negatively impacts CPR performance, current emergency care courses in both athletic training and AHA Basic Life Support (BLS) education curricula may need to be revised to address psychological considerations that may impact the physical administration of CPR.

4.3. Methods

4.3.1. Participants

A convenience sample of 50 ATCs (Mean age = 31.50 ± 10.49) currently active as a clinician and/or educator were recruited through word-of-mouth and recruitment e-mail throughout the Midwest region. To be included in the study, participants had to be certified as an athletic trainer by the Board of Certification (BOC®) as well as currently certified in CPR/basic life support (BLS). Exclusion criteria consisted of any current systemic or musculoskeletal conditions which may have impeded a participant's ability to perform high-quality CPR at the time of testing. Informed verbal and written consent were obtained from each subject before enrollment.

4.3.2. Procedures

Prior to the start of data collection, this research study was approved by the university's institutional review board. Upon subject arrival at the site of data collection, clinical and baseline demographic data were collected by a participant demographic form. Next, participants were asked to complete a 14-item CPR self-efficacy questionnaire that was constructed with the use of the Basic Resuscitation Skills Self-Efficacy Scale (BRS-SES) originally published by

Hernandez-Padilla et al[91]. The first five items on the questionnaire asked participants to report their confidence to effectively carry out the five practice domains of athletic training, while the remaining nine items asked participants to evaluate their confidence in performing specific aspects of CPR during an emergency situation in accordance with the 2015 AHA CPR guidelines. Participants responded to each positively phrased prompt using a provided six-point Likert-type scale ranging from "Strongly Disagree" to "Strongly Agree".

To ensure validity of data and to avoid skewing the results, a CPR proficiency test was included after the completion of paperwork. Each participant was asked to demonstrate CPR proficiency by completing a one-minute CPR session in accordance with the 2015 AHA guidelines on a Resusci Anne® QCPR manikin (Laerdal Medical, Stavanger, Norway). "Proficiency" was defined as achieving an overall QCPR score of at least 80%. If a participant did not earn a score of 80% or higher, the researcher provided feedback and allowed the participant to practice before attempting the proficiency evaluation once more.

After demonstrating proficiency and taking a short break of up to five minutes, each participant was instructed to perform eight minutes and 59 seconds of single-rescuer CPR, which the national standard for emergency medical service (EMS) response time[95]. Results from several contemporary studies suggest that audio and visual feedback may impact CPR performance,[96-98] therefore no feedback regarding performance or time remaining was given to participants during the assessment. For each session, the following values were recorded: overall QCPR score, compression score, ventilation score, chest compression fraction, hand placement, mean compression depth, full recoil percentage, full depth percentage, proper compression rate percentage, mean rate, percent of ventilations that were adequate, percent of ventilations that were inadequate, and total time of testing. Immediately after testing, participants were asked to fill out the CPR self-efficacy questionnaire once more.

4.3.3. Statistical Analysis

All statistical analyses were completed via IBM® SPSS statistics software version 25.0 (IBM®, Armony, New York) with the assistance of Dr. Thomas Hanson at Butler University. First, Cronbach's alpha was calculated to test the CPR self-efficacy questionnaire for internal reliability. Next, a paired samples t-test was conducted to compare CPR self-efficacy values before and after the CPR assessment. Pearson product-moment correlation coefficients were calculated to examine the relationship between the self-efficacy of athletic trainers and measures of CPR performance. Linear regressions were also performed to determine if (and to what degree) self-efficacy predicted CPR performance and to what degree educational background, years certified as an athletic trainer, and gender are related to CPR self-efficacy. Finally, basic descriptive statistics were used to determine the percentage of certified athletic trainers who achieved satisfactory performance (according to the 2015 AHA CPR Guidelines) on compression rate, depth, chest compression fraction and ventilation depth. Statistical significance for all statistical analyses was set at a P value of < 0.05.

4.3.4. Results

Fifty respondents completed all parts of the survey; demographic data are summarized in Table 7. The sample was approximately equal in terms of biological sex and certifying organization: American Heart Association (AHA) and American Red Cross (ARC). Participants ranged widely in terms of age, years of certification, and education level. Only six of the respondents had performed CPR on a patient experiencing cardiac distress.

Table 7. Demographic data summary

Categorical variables			Continuous variables		
Biological sex	Female	29	Age	Mean (SD)	31.5 (10.5)
	Male	21		Min	22
Organization	AHA	28		Max	60
	ARC	22	Years ATC	Mean (SD)	8.3 (9.2)
Live CPR	Yes	6		Min	1
	No	44		Max	34
Education	B	17	Years CPR	Mean (SD)	11.69 (9.0)
	M	29		Min	3
	D	4		Max	38

The participants reported high self-confidence in their abilities to perform in each of the five domains of athletic training practice (Table 8). The response format was a six-point Likert-type scale, from “strongly disagree” to “strongly agree,” but no respondents selected “strongly disagree” or “disagree” to any item.

Table 8. Self-reported confidence in the five domains of athletic training

	Somewhat disagree	Somewhat agree	Agree	Strongly agree
In my daily clinical practice, I am confident that I can always perform all attributes associated with the following domains:				
Injury/Illness Prevention and Wellness Promotion	1	3	24	22
Clinical Examination, Assessment, and Diagnosis	0	2	28	20
Immediate and Emergency Care	0	9	31	10
Therapeutic Intervention	0	8	23	19
Healthcare Administration and Professional Responsibility	1	9	19	21

The nine items of the CPR self-efficacy scale as well as the five items of the athletic training domains of practice scale were tested for internal reliability. In both administrations (pre- and post-CPR task), adequate reliability was observed (Table 9). Therefore, the scales were summed, and a paired t-test compared the results of the two administrations. There was no statistically significant difference in the CPR scale, with a mean difference of 0.48 (t[49] = 0.862, p = .393), nor was there any statistically significant change in the mean confidence score (Mean difference = 0.04, t[49] = 0.264, p = .792). Thus, self-perceptions of abilities were not affected by participation in the study.

Table 9. Reliability statistics

Scale	Cronbach's alpha	Lower bound	Upper bound
CONF (pre)	0.75	0.65	0.86
CONF (post)	0.82	0.74	0.90
CPR (pre)	0.87	0.82	0.93
CPR (post)	0.93	0.90	0.96

The Laerdal SkillReporter software provided assessment data in the form of percent of adequate performance on six variables: overall performance, depth, recoil, ventilation, position, and rate. Tables 10 and 11 present correlations computed between the preliminary scores of reported self-efficacy values for the Immediate and Emergency care domain of athletic training, reported values for CPR self-efficacy, and the six performance measures. Two of the correlations are statistically significant at the 5% level (**), and two others are statistically significant at the 10% level (*). In all cases, the statistically significant correlations are negative, and the remainder of the coefficients are quite small in magnitude. The results suggest that greater confidence and self-efficacy scores are related to slightly worse performance in the CPR task.

Table 10. Correlations with Immediate and Emergency Care self-efficacy

Variable	Correlation	t	p
Overall	-0.25	-1.86	*.069
Depth	-0.19	-1.33	.191
Recoil	-0.29	-2.13	**.039
Ventilation	-0.12	-0.87	.388
Position	-0.30	-2.14	**.037
Rate	0.09	0.62	.538

Table 11. Correlations with CPR self-efficacy

Variable	Correlation	t	p
Overall	-0.12	-0.83	.412
Depth	0.00	-0.01	.996
Recoil	0.04	0.28	.781
Ventilation	-0.08	-0.58	.563
Position	-0.26	-1.85	*.070
Rate	0.04	0.25	.805

More granular analysis emphasized the self-confidence question related to the topic of immediate and emergency care. Descriptive statistics were calculated for the six performance variables for three sub-samples of participants, based on their self-reported confidence prior to the CPR task (Table 12). None of the differences are statistically significant, but the general trend is that greater self-confidence is again associated with worse performance.

Table 12. Descriptive statistics of performance

	Somewhat agree (4)	Agree (5)	Strongly agree (6)
Overall	84.3	79.9	75.0
	(14.8)	(17.9)	(17.7)
Depth	79.4	70.8	66.9
	(37.2)	(32.8)	(34.8)
Recoil	93.2	72	82.1
	(9.0)	(30.9)	(25.3)
Ventilation	79.7	86.1	78.3
	(20.4)	(11.7)	(30.5)
Position	95.7	93.6	79.9
	(13.0)	(20.8)	(23.8)
Rate	75.9	52.3	80.8
	(29.9)	(35.9)	(26.8)

Regression analysis was also employed to explore two aspects of the data. First, a model was estimated to determine if scores on the emergency scale are related to demographic variables (Table 13). The model was not statistically significant (F[7, 42] = 0.88, p = .532). Second, hierarchical linear regression models were fit to determine if the additional data of scores from the emergency scale were statistically significant in predicting performance, while controlling for demographic variables. For the overall CPR performance score, the additional variable was not statistically significant (F[1, 41] = 0.24, p = .626). The other five dependent variables were also not statistically significant: depth (p = .625), recoil (p = .626), ventilation (p = .557), position (p = .123), and rate (p = .988).

Table 13. Regression analysis of demographic characteristics

Demographic characteristic	Beta	t	p
Gender	0.986	0.7	0.488
Years ATC	-0.076	-0.934	0.356
Organization	0.692	0.502	0.619
Live CPR	-0.727	-0.567	0.573
Education (Doctoral)	4.384	1.491	0.143
Education (Masters)	0.988	0.699	0.488
BMI	-0.216	-1.452	0.154

Considered as a whole, these results suggest a small, negative relationship between self-confidence and quality of CPR task performance. Respondents rated their own abilities highly across the domains of athletic training and in their CPR skills specifically. Furthermore, despite the negative correlation between confidence and performance, completing the CPR task for eight minutes and 59 seconds did not cause participants to alter their self-assessments.

4.4. Discussion

The primary purpose of our study was to determine whether an athletic trainer's self-efficacy regarding CPR is related to his or her psychomotor performance. While our study is the first to examine the relationship between self-efficacy and CPR performance in certified athletic trainers, our results differ from the limited research examining the relationship in other healthcare professions[3,5]. In a pair of studies utilizing doctors and nurses as participants, Roh et al.[3] and Gonzi et al.[5] found positive relationships between participant self-efficacy and several measures of CPR performance. Conversely, we found a small, negative relationship between metrics of CPR performance and CPR self-efficacy, which suggests the more confident an athletic trainer is in their ability to perform CPR, the worse their CPR performance. Alternatively, the observed relationship could be indicative of a general sense of overconfidence in CPR performance in ATCs.

Among the measured CPR metrics, we found hand position had the most statistically significant negative correlation with self-efficacy (r = -.26, p = .070). Incorrect hand position during CPR could potentially lead to diminished peak arterial pressure, a measure which is positively correlated with both systemic blood flow and cerebral perfusion pressure[62]. Decreases in systemic blood flow and cerebral perfusion pressure during CPR are associated with a decreased chance of SCA survival, making correct hand position a crucial component of CPR[1,60,62]. Our findings suggest ATCs are overconfident in their ability to perform CPR with correct hand position, highlighting a possible need for the integration of more CPR practice into athletic training pre-professional education. While athletic trainers are required to maintain CPR certification once certified and liscensed,[8] there is no requirement for practicing CPR skills between recertification periods. More frequent practice between and during CPR recertification courses could lead to an increase in CPR performance and help instill more accurate levels of CPR self-efficacy in ATCs.

During required CPR recertification classes, psychomotor skill assessment is typically limited to five cycles (or approximately two minutes) of CPR. When designing this study, we hypothesized the prolonged length of our CPR assessment as compared to recertification assessments would affect participant confidence. However, we found no statistically significant difference in mean CPR self-efficacy score from pre- to post-CPR assessment, suggesting that participant confidence was not affected by the time requirement. While the CPR assessment methodology by Gonzi et al.[5] was shorter than ours (five minutes compared to our eight minutes and 59 seconds), their assessment was created as a fully-simulated cardiac arrest scenario. It is possible that the realism achieved by the simulation helped participants obtain a better understanding of their CPR skills and consequently change their perceived self-efficacy. Future research examining CPR self-efficacy in athletic trainers could focus on providing more realistic clinical scenarios (equipment removal, on-field emergencies, etc.) as possible interventions to determine how ATC confidence is affected by distracting extrinsic factors.

Regardless of actual CPR performance, we found that all ATCs included in our study were very confident in both their ability to correctly perform all aspects of CPR as well as their ability to effectively carry out all five practice domains of athletic training. Despite a wide age range (range 22-60) and years of athletic training experience (range 1-34), reported self-efficacy values were high across all participants. While the high self-efficacy values may represent a general sense of overconfidence when combined with certain aspects of the participants' CPR performances, our findings suggest current athletic training education is effective to instill a reasonable amount of confidence in clinical skills. Future research should focus on more in-depth evaluations of ATC self-efficacy in each of the other athletic training practice domains to determine if the high confidence we found in respect to CPR performance is prevalent in other aspects of the profession.

Though it was not a primary goal of our research, we ran a secondary regression analysis to determine if demographic factors (age, gender, BMI, etc.) had any relationship with CPR self-efficacy or CPR performance. In regards to self-efficacy, we found no correlation between demographic characteristics, confidence levels, and CPR performance. In contrast to our findings, Gonzi et al.[5] reported lower self-efficacy values in female nurses compared to their male counterparts. Additionally, the self-efficacy values reported by female participants had a statistically stronger correlation with CPR performance, suggesting female nurses had more realistic expectations for their own CPR skills[5]. Gonzi et al.[5] had a sample size nearly six times the size of ours, so it is possible that we may have found similar results with more ATCs.

Also in contrast to our results, both Sayee et al.[71] and Jaafar et al.[70] found associations between gender, BMI, and CPR performance. However, the two groups of researchers reported conflicting relationships. Whereas Jaafar et al.[99] found an association between lower BMI values and more effective chest compression rate and depth, Sayee et al.[71] reported that participants with greater BMI values had higher chest compression quality. Furthermore, the two groups of researchers found incongruous results regarding gender, with each study reporting either female[70] or male[71] participants as more likely to administer higher-quality chest compressions. Given the contradictory nature of these findings and our own, it is challenging to draw a meaningful conclusion regarding the association between demographic characteristics, CPR self-efficacy and CPR performance. The topic must be explored further to define and understand this potential association.

To date, research involving CPR quality and athletic trainers has primarily focused on the ability of ATCs to provide quality CPR over equipment such as football, lacrosse, and hockey pads[87,88,100]. While the creators of these studies have unanimously concluded CPR by athletic trainers is inadequate when performed over equipment, these results are less impactful without studies examining the CPR quality of ATCs in the absence of environmental conditions[87,88,100]. Of the 50 athletic trainers included in our study, 35 (70%) achieved a satisfactory overall CPR rating. Similarly, 36/50 (72%) reached an adequate depth of 5 cm during at least 90% of chest compressions. However, both chest compression rate and ventilation quality were found to be lacking. Only 23 ATCs (46%) maintained an average chest compression rate of 100-120 compressions/min during the CPR assessment, and only 10 participants (20%) consistently delivered quality ventilations. Since chest compression rates between 100-120 compressions/min have been shown to increase the chance of patient survival during a SCA by nearly 10%,[56,57] maintaining a proper rate is crucial for rescuers. Furthermore, delivering a greater proportion of quality ventilations during CPR has been associated with higher chance of return of spontaneous circulation (ROSC) and higher survival rates in SCA patients[101].

Rescuer fatigue has been previously shown to impact CPR performance,[73,74] and many participants mentioned feeling tired near the end of our CPR assessment. Consequently, low performance by our participants in both of these aspects of CPR could potentially be attributed to fatigue due to the prolonged length of our CPR assessment. However, we did not track CPR performance on a minute-to-minute basis. Instead, our CPR monitoring software only reported average data, so we cannot determine if participant CPR quality changed due to fatigue over the course of our assessment. While the majority of our participants were able to achieve a satisfactory overall CPR score, future researchers examining CPR quality in athletic trainers should try to include prolonged CPR assessments to determine the effect of fatigue on performance. Additionally, it may be beneficial for athletic trainers to spend more time practicing maintaining a steady chest compression rate and delivering adequate rescue breaths.

Our study was not without limitations. Participants performed CPR in a controlled environment on a Resusci Anne® QCPR Manikin rather than on an actual patient in a clinical setting. Consequently, the lack of environmental factors or stressors could have resulted in an increase in perceived confidence or even CPR quality among participants. Furthermore, recruited athletic trainers were primarily employed in the high school and collegiate settings. SCA incidence in other populations tends to be higher than athletic populations,[2,21] therefore athletic trainers in other clinical settings (military, performing arts, industrial work, etc.) may have more exposure to SCA and actual CPR scenarios. Thus, they may have different levels of CPR self-efficacy. Only six (12%) of our recruited participants had actually performed CPR on a patient, so further research should include athletic trainers from more diverse clinical settings in order to determine if employment setting and varied clinical acumen has an effect on confidence.

Despite an increasing amount of research, the relationship between CPR self-efficacy and CPR quality in healthcare providers, such as ATCs, is still unclear. While our results suggest ATCs are confident in their ability to perform high-quality CPR on a patient suffering from a SCA and can perform the technique in a controlled environment, more research must be conducted incorporating realistic CPR assessments to understand the relationship between confidence and CPR quality. Once the relationship is better understood, educational standards can be revised to better address the psychological considerations that may increase the overall quality of CPR provided by certified athletic trainers.

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APPENDIX. CPR SELF-EFFICACY QUESTIONNAIRE

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 my daily clinical practice, I am always confident in my ability to effectively carry out...

1. Injury/Illness Prevention and Wellness Promotion ___
2. Clinical Examination, Assessment and Diagnosis ___
3. Immediate and Emergency Care ___
4. Therapeutic Intervention ___
5. Healthcare Administration and Professional Responsibility ___

In an emergency situation, I am confident that I can always…

1. Perform CPR in accordance with the 2015 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 (≥ 60%) ___
9. Provide high-quality CPR consistently during a prolonged (approximately 9-minute) resuscitation attempt ___