

AN ANALYSIS OF CERTIFIED ATHLETIC TRAINERS' ABILITY TO PROVIDE HIGH-
QUALITY CARDIOPULMONARY RESUSCITATION (CPR) OVER HOCKEY SHOULDER
PADS

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An Analysis of Certified Athletic Trainers' Ability to Provide High-Quality
Cardiopulmonary Resuscitation (CPR) Over Hockey Shoulder Pads

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ABSTRACT

Certified Athletic Trainers (ATCs) are expected to perform CPR for athletes regardless of whether the athlete is wearing protective equipment. The goal of this research was to determine /if ATCs were able to/ deliver high-quality CPR over hockey shoulder pads. Fifty ATCs completed CPR according to 2015 AHA guidelines on a medium-fidelity manikin, which had been fitted with hockey shoulder pads. CPR quality was measured with the Resusci Anne Wireless SkillReporter. CPR data included the following dimensions of compressions: overall score, mean rate, chest compression fraction, mean depth, % chest recoil, and % compressions with appropriate depth. Data were analyzed to compare differences of CPR performance between covariates. Overall score separated by gender was significant with men outperforming women. 56% of ATCs did not compress at the recommended depth. Therefore, the removal of hockey shoulder pads is recommended to ensure high-quality CPR performance as administered by ATCs.

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TABLE OF CONTENTS

| | |
|---|------|
| ABSTRACT..... | iii |
| ACKNOWLEDGEMENTS..... | iv |
| LIST OF TABLES..... | viii |
| 1. INTRODUCTION..... | 1 |
| 1.1. Overview of the Problem..... | 1 |
| 1.2. Statement of Purpose..... | 1 |
| 1.3. Research Questions..... | 2 |
| 1.4. Definitions..... | 2 |
| 1.5. Limitations..... | 3 |
| 1.6. Delimitations..... | 3 |
| 1.7. Assumptions..... | 3 |
| 1.8. Variables..... | 4 |
| 1.9. Significance of the Current Study..... | 4 |
| 2. LITERATURE REVIEW..... | 5 |
| 2.1. Introduction..... | 5 |
| 2.2. Cardiopulmonary Resuscitation (CPR)..... | 5 |
| 2.2.1. CPR Overview..... | 5 |
| 2.2.2. Epidemiology of Sudden Cardiac Arrest..... | 6 |
| 2.2.3. Physiology of CPR..... | 9 |
| 2.2.4. History of CPR..... | 10 |
| 2.2.5. Changes in CPR Protocols..... | 11 |
| 2.2.6. Components of High Quality CPR..... | 16 |
| 2.2.7. Chest Compression Fraction..... | 16 |
| 2.2.8. Compression Rate..... | 18 |

| | |
|--|----|
| 2.2.9. Chest Compression Depth | 20 |
| 2.2.10. Full Chest Recoil | 22 |
| 2.2.11. Adequate Ventilation Rate and Volume | 24 |
| 2.3. Effectiveness of Recent CPR Guidelines | 27 |
| 2.4. CPR with Athletic Equipment | 29 |
| 2.4.1. Football Pads | 29 |
| 2.4.2. Lacrosse Pads | 31 |
| 2.4.3. Hockey Pads | 32 |
| 2.5. Techniques for Monitoring and Improving CPR Performance | 32 |
| 2.5.1. Importance of Monitoring | 32 |
| 2.5.2. Visual Feedback Devices | 33 |
| 2.5.3. Manikins with Real-Time Feedback | 34 |
| 2.6. Conclusion | 35 |
| 3. METHODOLOGY | 36 |
| 3.1. Purpose of the Study | 36 |
| 3.2. Participants | 37 |
| 3.3. Equipment and Instruments | 37 |
| 3.4. Procedures | 38 |
| 3.5. Documentation | 39 |
| 3.6. Statistical Analysis | 40 |
| 3.7. Conclusion | 40 |
| 4. MANUSCRIPT | 41 |
| 4.1. Abstract | 41 |
| 4.2. Introduction | 43 |
| 4.3. Methods | 45 |

| | |
|--|----|
| 4.3.1. Research Questions | 45 |
| 4.3.2. Demographics | 45 |
| 4.3.3. Study Design and Protocol | 46 |
| 4.3.4. Statistical Analysis | 48 |
| 4.3.5. Results | 48 |
| 4.4. Discussion | 54 |
| REFERENCES | 61 |
| APPENDIX. PARTICPANT DEMOGRAPHICS FORM | 67 |

LIST OF TABLES

| <u>Table</u> | <u>Page</u> |
|---|-------------|
| 1. Causes of Sudden Death in 387 Young Athletes | 7 |
| 2. Effects of Manual Compression Rate on Hemodynamics in Dogs with Cardiac Arrest | 19 |
| 3. Compression Depth and Rate Under and Over Equipment | 30 |
| 4. Number of ATCs and % of Full Chest Recoil | 49 |
| 5. Number of ATCs and % of Adequate Ventilations | 49 |
| 6. Correlation Matrix (N=50)..... | 50 |
| 7. Summary of Regression Analysis for Variables Predicting Overall CPR Score..... | 51 |
| 8. Summary of Regression Analysis for Variables Predicting Mean Compression Depth | 52 |
| 9. Summary of Regression Analysis for Variables Predicting Mean Compression Rate..... | 52 |
| 10. Summary of Regression Analysis for Variables Predicting Chest Compression Fraction | 53 |
| 11. Summary of Regression Analysis for Variables Predicting Full Chest Recoil | 53 |
| 12. Summary of Regression Analysis for Variables Predicting Percent of Ventilations that were Adequate | 54 |

1. INTRODUCTION

1.1. Overview of the Problem

In the year 2016, the International Ice Hockey Federation reported 1.7 million registered players worldwide and 543,239 of them residing in the United States (Merk, 2016). Although sudden cardiac death is rare in athletics, with incidence rates ranging from 2.3 to 4.4/100,000 per year, it is still a risk athletes face when participating in a contact sport (Chandra, et al 2014). Ice hockey is an at-risk sport due to the high intensity of effort required to participate as well as the risk of being hit by opponents or the hockey puck. During participation, athletes often exceed current guidelines of maximum heart rate ($\leq 85\%$), which translates to an increased risk for a cardiac event by 2-2.5 fold (Hopkins-Rosseel, 2006). Athletes are also exposed to blunt trauma from pucks or other athletes, which can increase the chance of commotio cordis.

Due to the inherent risk of a cardiac event in ice hockey, it is of the utmost importance for emergency responders to provide emergency care when necessary. After an exhaustive literature review, limited research has been found on performing CPR over athletic equipment. Studies have been completed in regards to performing chest compressions over football and lacrosse equipment. Athletic Trainers have the responsibility to perform life-saving skills, such as cardiopulmonary resuscitation (CPR), using best practices published by the American Heart Association (AHA) and European Resuscitation Council (ERC). Researchers need to study all types of athletic equipment and associated variables so ATCs have a better understanding of how to provide high-quality compressions for an athlete suffering from cardiac arrest.

1.2. Statement of Purpose

The purpose of this research study is to determine if certified athletic trainers are able to provide high-quality chest compressions over hockey shoulder pads. The secondary purpose is to

determine if covariates such as age, body mass index, gender, level of education or number of years of certification lead to greater performance of CPR over hockey shoulder pads.

1.3. Research Questions

Q1: What percentage of participants achieved satisfactory performance on overall CPR score, compression depth, compression rate, chest compression fraction, full chest recoil, in addition to exploring the percent of adequate ventilation volume?

Q2: What is the relationship among participant traits (Body Mass Index [BMI], age, gender, education level, years of CPR certification, and years as an ATC) and performance on dependent variables (overall CPR score, compression depth, compression rate, chest compression fraction, full chest recoil, and ventilations) of CPR when performed over hockey pads?

1.4. Definitions

Cardiac arrest: The cessation of cardiac mechanical activity, as confirmed by the absence of signs of circulation” (Benjamin et al., 2017).

Cardiopulmonary resuscitation: Cardiopulmonary Resuscitation (CPR) is an emergency life-saving procedure that is performed when a victim’s breathing or heart rhythm has ceased to perform adequate perfusion (MedlinePlus, 2017).

Quality of CPR: Quality of CPR, for this study, was defined as proper chest compression depth, proper chest recoil, adequate compression rate, chest compression fraction, compression to ventilation ratio, and correct hand placement. Measurements on ventilation rate and volume were used for this study but were not the primary focus.

1.5. Limitations

Limitations of this study may affect the strength of the results. The first limitation is that chest compressions and rescue breaths were not performed on an actual patient; all CPR was simulated on a QCPR Anne manikin. Another limitation was the small population included in the study. The participants were limited to certified athletic trainers (ATC's) within the Midwest region. Rescue breaths were administered during CPR, but the manikin was not fitted with a hockey helmet. The only athletic equipment used were the CCM U+ CL shoulder pads (Ontario, Canada) and thus, the results cannot be generalized to other sports and their associated protective equipment.

1.6. Delimitations

Researchers chose to study ATC's and their ability to provide high-quality CPR because there is no current recommendation provided by the National Athletic Trainers' Association regarding performing CPR over hockey pads. To investigate Athletic Trainers' ability to perform high-quality CPR over hockey pads, the researchers chose CCM U+ CL shoulder pads (Ontario, Canada), which are commonly worn by athletes.

1.7. Assumptions

Assumptions were made that performing chest compressions over hockey pads on the QCPR Resusci Anne manikin would mimic a real-life rescue scenario. The manikin has been programmed to CPR standards as recommended by the American Heart Association (AHA) (Laerdal, 2017). It was assumed each athletic trainer performed CPR to the best of his/her ability during the skill verification portion and data collection.

1.8. Variables

The dependent variables in the current study are: overall CPR score, compression percentage, ventilation percentage, compression fraction, compression to ventilation ratio, correct hand placement, mean compression depth, full chest recoil, correct depth percentage, correct compression rate percentage, mean rate, adequate ventilations and inadequate ventilations. Independent variables were: age, gender, level of education, years of CPR certification, years of ATC certification, weight and height.

1.9. Significance of the Current Study

The average survival rate of cardiac arrest in 2013 after EMS treatment was 9.7% (Hansen, et al 2015). Athletic trainers are required to provide advanced emergency care techniques for athletes. With the fatality rate of cardiac victims being approximately 90%, it is imperative that athletic trainers provide high-quality CPR. Currently there are no recommendations on how to provide care for hockey athletes in a cardiac emergency with regard to removal of shoulder pads. Therefore, research is needed to determine if athletic trainers should immediately perform chest compressions over the equipment or if the athletic trainer should remove the equipment before administering CPR. This research study was conducted to establish evidence-based guidelines on how to treat hockey athletes during a cardiac emergency.

2. LITERATURE REVIEW

2.1. Introduction

Athletic Trainers have the responsibility to perform life-saving skills, such as cardiopulmonary resuscitation (CPR), using best practices published by the American Heart Association (AHA) and European Resuscitation Council (ERC). From 1980 to 2006, researchers reported an average of 73 deaths per year in young athletes and 56% of these deaths were of a cardiovascular origin (Maron et al., 2009). The National Athletic Trainers' Association (NATA), AHA, and ERC have released updated standards and guidelines for providing high-quality CPR to increase survivability. Few studies have addressed the complexities of providing CPR over protective athletic equipment (e.g. football, lacrosse, or hockey pads). The purpose of this literature review is to provide historical information on CPR and describe current practices and recommendations made by the NATA, AHA, and ERC. To ensure the safety of recreational and competitive participants, it is the responsibility of all allied health care professionals to explore possible changes in emergency care based on the respective needs of athletes.

2.2. Cardiopulmonary Resuscitation (CPR)

2.2.1. CPR Overview

Cardiopulmonary Resuscitation (CPR) is an emergency life-saving procedure that is performed when a victim's breathing or heart rhythm has ceased to perform adequate perfusion (MedlinePlus, 2017). CPR is also performed during cardiac arrest, a condition in which an irregular heartbeat disrupts blood flow throughout the body (AHA, CPR Facts and Stats 2018). When an individual suffers from cardiac arrest, survival depends on the outside-of-hospital chain of survival. The chain of survival consists of immediate recognition of cardiac arrest and activation of the emergency response system, early CPR that emphasizes chest compressions,

rapid defibrillation, effective advanced life support, and the integration of post-cardiac arrest care (Travers et al., 2010). Each link in the chain of survival is crucial, as a weakness in any individual link will lessen the chance of patient survival and will worsen the efforts of an emergency medical system (EMS) response (Cummins et al., 1991). As the bystander is responsible for the initial links in the chain of survival, it is important the rescuer executes each stage as effectively as possible to increase patient survival.

2.2.2. Epidemiology of Sudden Cardiac Arrest

Data from the Center for Disease Control and Prevention (CDC) are published each year to report mortality rates within the United States. One of the more common causes of cardiovascular death is cardiac arrest. Cardiac arrest is defined as, “the cessation of cardiac mechanical activity, as confirmed by the absence of signs of circulation” (Benjamin et al., 2017). In 2013, cardiovascular death was the most common underlying cause of death world-wide, accounting for 17.3 million of 54 million deaths (Benjamin et al., 2017). Within the United States during 2014, there were 353,427 mortalities attributed to cardiac arrest (Benjamin et al., 2017). This epidemic leads to millions of deaths worldwide and can affect a wide variety of individuals.

2.2.2.1. Sudden Cardiac Arrest in Athletics

Although rare, sudden cardiac arrest in athletes is often difficult to comprehend because athletes are perceived as some of the healthiest members of society. Sudden cardiac death in athletes can be from a traumatic or non-traumatic cause. Most nontraumatic deaths are attributed to genetic abnormalities (Chandra et al., 2013). A list of the causes of 387 sudden deaths in athletes can be found in Table 1 (Maron, 2002).

Table 1

Causes of Sudden Death in 387 Young Athletes

| Cause | No. of Athletes | Percent |
|--|-----------------|---------|
| Hypertrophic Cardiomyopathy | 102 | 26.4 |
| Commotio cordis | 77 | 19.9 |
| Coronary-artery anomalies | 53 | 13.7 |
| Left ventricular hypertrophy (indeterminate causation) | 29 | 7.5 |
| Myocarditis | 20 | 5.2 |
| Ruptured aortic aneurysm | 12 | 3.1 |
| Arrhythmogenic right ventricular cardiomyopathy | 11 | 2.8 |
| Tunneled (Bridged) coronary artery | 11 | 2.8 |
| Aortic-valve stenosis | 10 | 2.6 |
| Atherosclerotic coronary artery disease | 10 | 2.6 |
| Dilated cardiomyopathy | 9 | 2.3 |
| Myxomatous mitral-valve degeneration | 9 | 2.3 |
| Asthma (or other pulmonary condition) | 8 | 2.1 |
| Heat stroke | 6 | 1.6 |
| Drug Abuse | 4 | 1.0 |
| Other cardiovascular disease | 4 | 1.0 |
| Long-QT syndrome | 3 | .8 |
| Cardiac sarcoidosis | 3 | .8 |
| Trauma involving structural cardiac injury | 3 | .8 |
| Ruptured cerebral artery | 3 | .8 |

Due to the complex nature of the heart and difficulty diagnosing these conditions, a thorough pre-participation screening is supported by multiple sports organizations at the international and national levels (Chandra., et al 2013). One organization that recommends a screening is the National Athletic Trainers' Association (NATA). The recommendations of the NATA include: personal and family history forms, selective use of electrocardiograms, and a stronger knowledge base for health care professionals (Casa et al., 2012).

Researchers analyzed the total athlete participation from 2004 to 2008 within the United States and compared it to the number deaths reported by the NCAA Memorial Resolutions list. There were 1,969,663 athlete participation years throughout this time frame and 272 deaths. The incidence rate for sudden cardiac death was 1:43,770 per year (Harmon et al., 2011). As an international comparison, a prospective, observational study performed in Italy using regional registry data reported an incidence rate of 3.6/100,000 per year in athletes (Chandra et al., 2013). Males were shown to suffer from sudden cardiac death more often than females. The data collected from the National Center for Catastrophic Sports Injury Research reports a five-fold increase of SCD in males compared to female athletes (Chandra et al., 2013). Based on this data, researchers and practitioners alike have focused their efforts on preventing sudden death as well as evidence-based recommendations for providing emergency care.

Although a genetic abnormality is often the underlying cause of SCD, it can also be caused by a forceful impact. Most examples of sudden death in athletes without pre-existing heart disease occur because of a blunt, nonpenetrating blow to the chest that causes ventricular fibrillation also known as commotio cordis (Maron, 2003). Sudden death due to commotio cordis is often caused by being struck by a sports projectile such as baseballs and hockey pucks (Maron, 2003). A blow to the pericardium can trigger commotio cordis, which is not always prevented by the available safety equipment that athletes wear (Maron, 2002). An analysis of 128 confirmed cases of commotio cordis was conducted using data from 1985 until September 1, 2001. Of the 128 cases, 79 of the victims were competing in an organized sport. The data collected were used to evaluate the effectiveness of athletic safety equipment. Of the 79 cases, 28 participants were wearing commercially available chest barriers. Seven of these fatalities resulted from projectiles making direct contact with protective padding (Maron, 2002). These athletes include: three

lacrosse goalies, two baseball catchers, and two hockey goalies, all of whom were equipped with chest barriers of standard design (Maron, 2002). This study highlights the importance of continually improving protective equipment for the safety of athletes. However, more research is needed regarding the emergency care required for athletes who wear such equipment.

2.2.3. Physiology of CPR

To make recommendations for lay public and emergency medical personnel for those suffering from cardiac arrest, it is important to understand the intricacies of CPR techniques to further justify evidence-based recommendations. Sudden cardiac arrest occurs when the heart's electrical system malfunctions and the heart progresses into a non-perfusing heart rhythm (AHA, Out-of-Hospital Cardiac Arrest, 2014). As the heart is unable to properly provide blood throughout the body, the rescuer attempts to mimic the function of the heart by performing external chest compressions (AHA, Out-of-Hospital Cardiac Arrest, 2014). When cardiac arrest occurs, circulation of blood throughout the body decreases as the heart is no longer able to properly perform normal functions. This lack of blood flow causes decreased oxygen supply to the brain. The resulting lack of oxygen supply has been shown to cause a form of brain damage known as hypoxic brain injury (Middelkamp et al., 2007). CPR is important because it assists with blood flow to the brain and heart, and increases the chance defibrillation will restore a normal rhythm to the heart (Drezner et al., 2007).

The delivery of oxygen and substrates to vital tissues is the primary goal of CPR. These substances can only be delivered to tissues throughout the body when blood is flowing throughout the cardiovascular system. Return of spontaneous circulation (ROSC) after CPR has been shown to be dependent on increased myocardial blood flow during CPR (Ralston et al., 1984). Increased blood flow can be achieved by maximizing coronary perfusion pressure (CPP),

which is described as the difference between aortic diastolic and right atrial diastolic pressure during the relaxation phase of chest compressions (Meaney et al., 2013). When the chest decompresses during CPR, the left ventricle relaxes and pressure in the aorta drops. This value is known as the aortic diastolic pressure (Reynolds, 2011). Right atrial pressure is the pressure value within the right atrium during decompression of the chest (Reynolds, 2011). Allowing the chest to decompress in-between compressions allows the CPP to develop. By maximizing CPP, the rescuer is able to increase the amount of blood circulating throughout the body during CPR, which will allow for maximal delivery of the required oxygen and substrates throughout the body.

2.2.4. History of CPR

Although CPR is thought of as a modern technique, attempts to resuscitate cardiac arrest victims dates back hundreds of years. An understanding of the evolution of the sequence of steps is critical for appreciating current guidelines. Dr. Peter Salfar was an anesthesiologist who investigated techniques for airway management. In 1895, he found half of his patients' airways would open when the rescuer manually tilted the victim's head and the other half by manually thrusting the mandible forward or inserting an airway adjunct (Aitchison et al., 2013). Although Dr. Salfar's observations might not have been fully understood at the time, these techniques are still used in modern CPR; they are now known as the head-tilt chin-lift or the jaw-thrust technique, respectively. Another component of CPR, chest compressions, was partially discovered by Moritz Schiff as he noted pulsing of a canine heart after manually squeezing it (Aitchison et al., 2013). Even though these discoveries were only a small part of the CPR process, they were key components that eventually led to modern day CPR.

A panel of healthcare experts have made comprehensive changes to CPR throughout the years as researchers and physicians learn more about human physiology. The first recommendations for closed-chest CPR were published in 1966 (Aitchison et al., 2013). In the late 1960's Dr. Leonard Cobb, a cardiologist, began training 15 Seattle Fire Department personnel to provide pre-hospital care for cardiac patients. In 1970 the Seattle Fire Department paramedics began incorporating components of CPR, and they produced positive results including stabilization of cardiac patients (History of Medic One, 2015). The success of these paramedics increased demand amongst the public for more rescuers in hopes of saving more victims (Aitchison et al., 2013). Though there have been multiple changes in CPR since its conception, it is continually refined on a yearly basis.

2.2.5. Changes in CPR Protocols

It was not until the year 2000 that international consensus statements were created for CPR guidelines. At the 1992 guidelines conference for Emergency Cardiac Care (ECC) and CPR, an international panel of experts first created the goal to establish international guidelines by the year 2000 (Cummins & Hazinski, 2000). This conference was not just an update of previous recommendations given by the AHA or European Resuscitation Council (ERC); rather, it was specifically assembled to produce international resuscitation guidelines and was named “an international consensus on science” (Cummins & Hazinski, 2000). The focus of the conference was to combine the knowledge of many experts who reviewed the same evidence such that the best guidelines could be established for worldwide practice.

Before the international guidelines were released, a compression to ventilation ratio of 5:1 was recommended in two-person advanced cardiac life support (ACLS). In single rescuer ACLS, the recommendation was a ratio of 15:2. Researchers wanted to determine if the 15:2

ratio would be effective with two rescuers. In the study, 36 paramedics were required to provide ACLS in two experiments, with both compression to ventilation ratios (5:1 vs 15:2), on an Ambu Mega Code trainer manikin. The manikin measured: ventilation, chest compression, carotid pulse, ECG simulation, placement of three-lead ECG, defibrillation, intubation and injection (Wik et al., 1996). During ALCS the paramedics were required to defibrillate, intubate, establish intravenous access, as well as administer drugs all while providing compressions and ventilations.

The theory behind the study was that by freeing one rescuer to accomplish all of the other tasks, the other rescuer would solely be able to provide CPR and, in turn, make the whole process more efficient. With the 5:1 ratio, rescuer one performed all of the other tasks between ventilations. There was not a significant difference between the quality and rate of compressions and ventilations between the two groups (Wik et al., 1996). However, it took significantly less time for the 15:2 group to secure an IV and defibrillate with mean values of (86±17 sec and 144±21 sec) as compared to the 5:1 group (105±13 sec and 177±18 sec), respectively (Wik et al., 1996). The other difference between the two groups was that the 5:1 group averaged seven cycles of CPR in which there was no ventilation given, while the 15:2 group averaged zero cycles. With no significant difference between compression and ventilation values, it was determined that performing ALCS with a ratio of 15:2 was less time consuming and may, in turn, improve the outcome of cardiac arrest.

The result of the 2000 international guidelines conference was the creation of the first international guidelines for ECC and CPR. Guidelines for chest compression were: approximately 100 compressions per minute as well as a compression to ventilation ratio of 15:2

for both one and two rescuers (American Heart Association, 2000). Evidence-based guidelines are continually being developed and tested.

The year 2005 brought about several changes in CPR specifically pertaining to compression to ventilation ratios. These changes were made after several case studies indicated that during CPR, healthcare providers were delivering an inadequate number and depth of compressions, interrupted compressions frequently, and provided excessive ventilation (Hazinski et al., 2005). These findings were the result of a study in which researchers analyzed the data of 176 adult patients who suffered out-of-hospital cardiac arrest. Each of these patients were treated with a defibrillator with the ability to analyze chest compression data via an accelerometer. At the conclusion of the study, it was found compressions were not given 48% of the time (95% CI, 45%-51%) and mean compression depth was 34 mm (95% CI, 33-35 mm) (Wik et.al, 2005). Since the research was conducted in 2005, the appropriate range of compression depth was defined as 38-51 mm. When compressions were given, it resulted in a compression rate of 64/min (95% CI, 61-67/min) although the target values were 100-120/min. Rescuers were not meeting the guidelines at the time for compression depth or rate, which helped support the implementation of the 2005 guidelines.

Researchers also attempted to calculate the most effective compression to ventilation ratios using mathematical equations. This research was completed by using equations that described oxygen delivery and blood flow during CPR as functions of the number of compressions and ventilations delivered over time (Babbs & Kern, 2002). These equations led to the theory that compression to ventilation ratio of 30:2 maximized values for oxygen delivery and blood flow.

On average, the guidelines for compression depth and rate were not being met. Following the results of the study, experts agreed that to achieve optimal compressions and reduce interruptions between compressions, a universal compression to ventilation ratio of 30:2 was mandated (Hazinski et al., 2005). This change was implemented to increase the number of compressions, prevent over ventilation, and minimize interruption of compressions.

By increasing the number of compressions from 15 to 30 between ventilations, rescuers would theoretically be able to provide more compressions per minute and improve hemodynamics throughout the body. Researchers designed a study to determine if the increased number of compressions improved myocardial blood flow. In the study 18 pigs were placed into cardiac arrest and randomly assigned to a C:V ratio of 15:2 or 30:2 (Yannopoulos et al., 2006). Each pig was continuously monitored via an electrocardiograph. Compared to 15:2, those pigs who received 30 compressions to two breaths significantly increased diastolic blood pressure (20 ± 1 mm Hg to 26 ± 1 mm Hg; $p < .01$); coronary perfusion pressure (18 ± 1 mm Hg to 25 ± 2 mm Hg; $p = .04$); and common carotid blood flow (48 ± 5 to 82 ± 5 mL/min; $p < .001$) (Yannopoulos et al., 2006). Overall, hemodynamics improved with the increased number of compressions and there was no significant decrease in quality of compressions.

In an attempt to increase the number and rate of compressions delivered during CPR, the AHA CPR guidelines recommended increasing chest compressions from 15 to 30. Researchers conducted a study to compare CPR performance and perceived exertion during compression to ventilation ratios of 15:2 and 30:2 during two-rescuer CPR. On two separate sessions, 18 BLS-certified healthcare providers performed five minutes of chest compressions on a CPR manikin (Laerdal Resusci Anne, Stavanger, Norway) with the two different ratios. The manikin provided real-time feedback via a Philips HeartStart MRx Monitor/Defibrillator (Philips Electronics, New

York, NY) with Q-CPR feedback technology (Laerdal, Stavanger, Norway). The feedback consisted of compression duration, depth, and chest release during compressions (Betz et al., 2008). Prior to, during, and five minutes after completion of CPR, heartrate was recorded via a CardioSport hear rate monitor (Polar Electro Oy, Sweden). The subjects also rated their exertion via a scale of perceived effort (RPE) after completion of CPR and five minutes afterwards.

When performing CPR with the 30:2 ratio, the rescuers were able to perform more compressions within the five-minute testing period. The average number of compressions was 457 ± 43 cpm versus 15:2, which averaged 379 ± 28 cpm. There was also no statistically significant difference between heart rates 102 ± 24 bpm vs. 106 ± 27 bpm and RPE 4.3 ± 1.2 vs. 4.6 ± 1.1 between the two groups (Betz et al., 2008). Compression rate and depth did not differ between the two groups with values of 102 ± 24 cpm vs. 106 ± 27 cpm and 38.8 ± 3.6 mm vs. 38.2 ± 2.9 mm, respectively. When performing CPR at a ratio of 30:2, rescuers were able to deliver more compressions without a decrease in compression rate or depth or a large increase in perceived effort or heart rate.

As the recommendations for CPR have been updated, researchers have studied whether patient outcomes have improved as new protocols are implemented. In a retrospective cohort study, researchers analyzed 3,960 patient outcomes following resuscitation during a ten-year period. The investigation incorporated a control five-year period in which the 2000 guidelines were practiced compared to a subsequent intervention period of five years in which the 2005 guidelines were applied (Kudenchuk et al., 2012). The main difference between the two guidelines was a compression ratio of 30:2 during the 2005 guidelines compared to 15:2 in 2000. The 2005 guidelines also recommended doubling the required period of CPR between rhythm evaluations, which means increasing the amount of CPR cycles performed before analyzing the

heart with an AED. For each measured patient outcome, the patients who received CPR according to the new recommendations had improved patient outcomes (Kudenchuk et al., 2012). The primary outcome, one-year survival, improved from 2.7% (48 of 1774 patients) to 4.9% (106 of 2186 patients) between the control and intervention periods ($P=0.001$). In addition, return of spontaneous circulation at hospital arrival improved from 26.6% to 33.9% of patients ($P=0.001$); survival to hospital discharge improved from 4.6% to 6.8% ($P=0.004$) (Kudenchuk et al., 2012). With the addition of 15 more compressions per cycle, patient outcomes had drastically improved.

2.2.6. Components of High Quality CPR

Although chest compressions and rescue breaths help to restore oxygen and circulation in the body, they are inherently inefficient when compared to a normally functioning heart. Even when delivered by standard guidelines, CPR only provides 10-30% of normal blood volume to the heart and 30-40% of normal values to the brain (Meaney et al., 2013). When performed properly, CPR is inefficient in nature, which means correct technique is of the utmost importance. Cardiopulmonary resuscitation standards have been established to ensure the proper performance of the skills. Five main components of high-quality CPR have been established by the AHA based on their ability to increase CPP. These components are: chest compression fraction, compression rate, chest compression depth, chest recoil, and ventilation rate/volume (Meaney et al., 2013).

2.2.7. Chest Compression Fraction

The first component of high-quality CPR is chest compression fraction (CCF). Meaney et. al (2013) defines CCF as a proportion of time chest compressions are completed during cardiac arrest. A cohort study of 506 cases of either ventricular fibrillation or ventricular

tachycardia with electronically recorded compression rates were analyzed. During each case, CCF was measured by the presence and frequency of chest compressions via an accelerometer placed between the patient and rescuer. It was found that those patients who received compressions 61-80% of the time had a 29% chance of survival to discharge (Christenson et al., 2009). While those who received a CCF of 0-20% had a 12% chance of survival (Christenson et al., 2009). Every rescuer's priority should be to maximize the time spent giving compressions by delivering compressions at a proper rate and transitioning between compressions and rescue breaths quickly.

One method to increase CCF is the reduction of perishock pause, or the pauses in chest compressions before and after a defibrillatory shock (Cheskes et al., 2011). An analysis was performed on 815 resuscitation attempts. After applying electrodes to each patient, data were collected for CCF, duration of preshock and postshock pauses, as well as compression depth. Out of hospital cardiac arrest patients were shown to have an 18% decrease in survival for every five second increase in both preshock and perishock pause interval (Cheskes et al., 2011). Patients who were treated with a perishock pause of less than 20 seconds had a survival rate of 32.6% (Cheskes et al., 2011). Those who were treated with an average perishock pause of greater than 40 seconds had a survival rate of 20.3% (Cheskes et al., 2011). Thus, if a rescuer ends compressions five seconds before the AED begins to analyze, the patient's likelihood of survival likely decreases.

To increase the likelihood of survival, it is important rescuers maximize the time spent delivering compressions. By quickly recognizing the signs and symptoms of cardiac arrest, the rescuer is able to maximize the amount of time spent providing compressions. AEDs require time to analyze, charge, shock, and reanalyze. During this time, chest compressions must be

halted to prevent the AED from analyzing incorrectly (Valenzuela et al., 2005). Although newer AEDs complete this process faster than older models, they do indeed interrupt the delivery of compressions. Other tasks during resuscitation can interrupt the performance of chest compressions. These tasks include reassessing for pulse or rhythm changes, placement of intravenous lines, and intubation of the trachea (Valenzuela et al., 2005). Extrinsic factors that can interrupt chest compressions include: distressed family members, safety concerns at the scene, and miscommunication with 9-1-1 dispatch. All of these combined factors can decrease the time spent delivering chest compressions. Decreasing the interruptions between compressions will increase CFF, which will increase the delivery of blood throughout the body.

2.2.8. Compression Rate

One component of CPR that has garnered the attention of both practitioners and researchers is the issue of the number of compressions per minute. Because the ultimate goal of CPR is to provide circulation throughout the body in hopes of achieving ROSC, the rate of compressions is critical for a positive patient outcome. As rates fall below 100 compressions per minute, the rate of blood flow is inadequate to maintain perfusion. In contrast, rates above 120 have been linked to a reduction in coronary blood flow. This data comes from a study performed on dogs to measure the effects of different compression rates on hemodynamics. Cardiac output and coronary blood flow were measured by electromagnetic flow probes in 25 dogs (Maier et al., 1984). Results from the study can be found in *Table 2*.

Table 2

Effects of Manual Compression Rate on Hemodynamics in Dogs with Cardiac Arrest

| Compression Rate | Cardiac Output (ml/min) | CBF (% control) |
|------------------|----------------------------|--------------------|
| 60/min | 425±92/16 | 64±15 |
| 100/min | 643±130/24 | 76±12 |
| 150/min | 975±220/36 | 75±6 |

Each canine received one of three compression rates: 60/min, 100/min, and 150/min. Both cardiac output (ml/min) and cardiac blood flow (CBF) increased as the compression rate increased. Cardiac outputs for each rate were as follows: 425±92/16 ml/min, 643±130/24 ml/min, and 975±220/36 ml/min, respectively. Cardiac blood flow also increased along with compression; however, this value peaked and plateaued at 100/min. The values for CBF were: 64±15 %, 76±12 %, and 75±6 %. The results indicate an optimal rate for cardiac output and CBF was between 100/min and 150/min. Thus, providing an adequate compression rate is critical to the survival of dogs suffering from cardiac arrest (Meaney et al., 2013). Although the results on canines indicate the key rate for survival was between 100/min and 150/min, research must be conducted on humans in order to generalize the findings of Meaney et al.

To better understand the intricacies of compression rate, researchers conducted an in-hospital study using a handheld recording device to measure compression rates in 97 cases of diagnosed cardiac arrest. The data collected were used to compare the survival rates of patients and the rate of compressions. The mean compression rate for survivors was 90±17 cpm while the rate for non-survivors was 79±18 cpm (Abella et al., 2005). Compression rates were split into quartiles and used to compare the return of spontaneous circulation between each quartile. Quartile one included the range of 95.5-138.7 cpm and had a ROSC rate of 75%. Quartile four

included a range of 40.3-72.0 cpm and had a ROSC of 42% (Abella et al., 2005). Overall, the results of this study suggests a higher compression rate is associated with a higher chance of survival. However, it should be noted the researchers did not consider the possible delirious effects of compressions exceeding 107 cpm.

Recommendations for chest compression rates have changed as they have been shown to increase the likelihood of patient survival. A prospective, observational study was conducted to identify the relationship between compression rate and survival, specifically with higher rates of compressions. Data were collected from 10,371 cardiac arrest patients who had been treated by 150 EMS agencies from 2007-2009 (Idris et al., 2015). An electronically monitored defibrillator, which had the capability to analyze chest compression rate, was used to compare the rate of compressions administered to each patient. The results indicated a compression rate of 100-120 cpm was associated with the greatest chance of survival. This compression rate contrasts the results of the previously mentioned study, which suggested patients receiving 90 ± 17 cpm had the highest rate of survival. Rates of compression and survival rate were as follows: <80/min (9%), 80-100/min (8%), 100-120/min (10%), 120-140/min (8%), >140/min (6%) (Idris, et al 2015).

Overall, 34% of patients had circulation restored and 9% survived to hospital discharge (Idris et al., 2015). These results suggest a higher compression rate is not always better. Patients who received chest compressions in the range of 100-120 cpm were associated with the best outcomes. Rescuers need to accurately deliver compressions at a proper rate, as compressing too slow or too fast is associated with a drop in the rate of patient survival.

2.2.9. Chest Compression Depth

A third component of high-quality CPR is chest compression depth. The current recommendation for CPR compression depth is at least two inches (five cm) for adults, two

inches (five cm) in children, and one and a half inches (four cm) in infants (Travers et al., 2010). An analysis completed through the Resuscitation Outcomes Consortium (ROC) analyzed 9,136 patients who were treated for cardiac arrest by EMS personnel to determine the correlation between compression depth and ROSC (Stiell et al., 2014). The researchers analyzed compression depth and rate via accelerometers placed on the patient during resuscitation efforts. Characteristics of chest compressions were obtained from EMS and hospital records to compare the data collected during CPR with the rate of patient survival. The researchers found survival of cardiac arrest peaked at an average depth of 4.56 cm (1.8 in), as shown in figure 2.2.9.1. As the depth of compressions got closer to 4.56 cm (1.8 in), the likelihood of survival increases. When compression depths are further away from that value, the likelihood of survival decreases. The data suggests that the closer average compression depth is to 4.56 cm (1.8 in), the higher the likelihood is of surviving cardiac arrest. It is essential that rescuers deliver compressions at the proper depth as values above and below two inches (five cm) decrease the likelihood of survival.

Even though the current recommendation for chest compression depth is five cm, many rescuers are still not compressing at a proper depth. Researchers analyzed 1,029 patients of cardiac arrest in which values for compression depth during CPR were provided by the EMS professional responsible for the patient. This analysis was performed from data collected between 2006 until 2009. During this time the rescuers were delivering compressions according to the 2005 guidelines (3.8 cm-5.0 cm). Data were collected using an accelerometer interface placed between the rescuer's hands and the patient's chest. Compression depth was defined as the measured posterior depression of the anterior chest wall. The average compression depth for these cases were 3.73 cm (1.47 in), with 52.8% of the cases having a depth of less than 3.8 cm (1.50 in) (Stiell et al., 2012). Nearly half of the rescue attempts had an average compression

depth that fell below this value. Although the required depth for compressions has increased, past rescuers were unable to compress the chest even with the shallower recommendations.

Further research has been completed that suggests rescuers continually fail to reach proper compression depth. In a case series of 176 patients who suffered from cardiac arrest, a chest pad that contained a built-in accelerometer and pressure sensor was applied to the sternum of each patient to record data for patients as they were treated by ambulance personnel. Defibrillators recorded chest compressions (depth, rate) and ventilations by changes in thoracic impedance between the defibrillator pads (Wik et al., 2005). The median depth of chest compressions was 3.5 cm (1.38 in) with an average compression rate of 121/minute and an average of 11 ventilations per minute (Wik et al., 2005). Even though the aforementioned study was completed in 2005, the recommendation at that time was a depth of 3.8-5.1 cm (1.5-2.0 in). Even ambulance personnel, who perform CPR more often than lay public or athletic trainers, are not achieving proper depth during chest compressions.

2.2.10. Full Chest Recoil

In contrast to achieving proper chest compression depth, an equally important component is full chest recoil. Full chest recoil is achieved when the rescuer allows the chest to return to normal resting position after delivering a compression. When the rescuer initiates a compression before the chest fully expands, full chest recoil is not achieved. Full chest wall recoil is necessary because it is a key component in increasing hemodynamics, or blood flow, within the body during CPR. When the chest fully recoils, it generates a negative intrathoracic pressure, which helps draw blood back to the heart (Aufderheide et al., 2006). Incomplete chest recoil increases the duration and frequency of positive intrathoracic pressure, which does not allow a negative intrathoracic pressure to develop. Without the presence of both pressures, there is a decrease in

blood flow throughout the body (Aufderheide et al., 2006). When the rescuer does not allow chest wall recoil, a negative intrathoracic pressure is unable to develop and the hemodynamic portion of CPR is decreased. When circulation of blood throughout the body is decreased, the chance of attaining ROSC decreases as well.

Residual leaning is a phenomenon in which a rescuer leans on the patient's chest impeding full chest expansion and prevents full chest recoil (Meaney et al., 2013). A study was conducted on ten pigs to analyze if residual leaning had an adverse effect on left ventricular myocardial blood flow (MBF) during CPR. Each pig had a puck placed on its sternum that contained a force transducer as well as an accelerometer. Each pig also had a rack placed over the sternum that could be adjusted to restrict chest decompression by 10% or 20% (Zuercher et al., 2010). To determine MBF, a bolus of microspheres were injected into the left ventricle at the beginning of CPR and were used to calculate MBF values and were reported as $\text{mL} \cdot \text{min}^{-1} \cdot 100 \text{ g}^{-1}$ (Zuercher et al., 2010). The mean values were recorded at three-minute intervals for 18 minutes. During the first three minutes, with no leaning, the mean left ventricular MBF was $39 \pm 7 \text{ mL} \cdot \text{min}^{-1} \cdot 100 \text{ g}^{-1}$. After 12 minutes of residual leaning, this value decreased to $16 \pm 3 \text{ mL} \cdot \text{min}^{-1} \cdot 100 \text{ g}^{-1}$. At the 12-minute mark, the researchers removed the rack and allowed full recoil for the last three minutes of compressions with resultant values increasing to $25 \pm 9 \text{ mL} \cdot \text{min}^{-1} \cdot 100 \text{ g}^{-1}$ (Zuercher et al., 2010). It was determined residual leaning of 10-20% of compression force is enough to substantially decrease MBF. The authors of this particular study recommend additional studies in humans are needed to evaluate the effects of residual leaning on the effectiveness of CPR.

Incomplete chest wall recoil can be a result of the rescuer leaning over the patient's chest either because of improper technique or rescuer fatigue (Meaney et al., 2013). A total of 108

episodes of cardiac arrest were examined by researchers using data collected from an emergency department. The goal of the study was to identify how often leaning occurred during resuscitation and, specifically, the number of total compressions where leaning occurred. Characteristics of CPR were observed via defibrillators that collect chest compression data and provide real-time feedback. The data revealed 91% of the rescuers exhibited leaning during at least one point while administering chest compressions. The defibrillators also collected data for every compression delivered and recorded how many of those compressions did not allow for full chest recoil. A total of 112,569 chest compressions were delivered. Of the 112,569 compressions delivered 13,270 compressions exhibited leaning (12% of total compressions) (Fried et al., 2011). Emergency rescuers, including athletic trainers, need to be aware of their positioning over the patient as well as consciously considering full chest recoil during CPR.

2.2.11. Adequate Ventilation Rate and Volume

In addition to compressions, administering adequate ventilation is the other physiological component addressed when performing CPR. Adequate ventilation means a proper rate of ventilation and a proper volume of air with each ventilation. As discussed, previous research indicates negative intrathoracic pressure is needed to increase venous blood return to the heart (Aufderheide et al., 2006). Over-ventilation during CPR can limit the development of a negative intrathoracic pressure. Researchers designed a methodology to determine the effect of rescue breathing on blood flow. The study used swine to compare compression-only CPR with chest compressions and rescue breathing. After being placed into ventricular fibrillation, 14 pigs were randomly assigned to receive chest compressions (CC) or CC and rescue breathing (RB). The pigs were treated with 12 minutes of basic life support. The compression-only rescuers performed compressions at 100 cpm with the guidance of a metronome and were given a brief

rest period each minute to take two breaths (Berg et al., 2001). The CC+RB group provided two manual rescue breaths, followed by 15 compressions at the same metronome-guided rate and repeated that process. At the end of the 12-minute CPR period, each animal was treated with advanced cardiac life support, which included defibrillation (Berg et al., 2001).

Fluorescent, colored microspheres were introduced into the left ventricle of each pig and were used to analyze blood flow throughout the study. The results showed that at two to five minutes of CPR, the median left ventricular blood flow by fluorescent microsphere technique was $60 \text{ mL} \cdot 100 \text{ g}^{-1} \cdot \text{min}^{-1}$ with CC+RB versus $96 \text{ mL} \cdot 100 \text{ g}^{-1} \cdot \text{min}^{-1}$ with CC (Berg et al., 2001). This data suggests the average blood flow was higher in the group receiving only chest compressions. The difference between these two values suggests MCB decreased in the group with RB. Thus, rescue breathing, or positive-pressure ventilation, can have harmful effects as it limits the development of a negative intrathoracic pressure thereby decreasing the hemodynamic effects of CPR (Berg et al., 2001). However, this is not to say ventilation during CPR should not be performed. Continuous chest compressions without rescue breathing results in lower arterial oxygen saturation and is, therefore, less effective at delivering oxygen to the myocardium than compressions with ventilation (Berg et al., 2001). Ventilations need to be performed at a rate of six to 12 breaths per minute in order to provide enough oxygen throughout the body without impeding blood flow.

Recommendations for ventilations during CPR are between ten and twelve breaths per minute. Current recommendations are dependent on multiple factors including: an advanced airway (eight to ten breaths per minute) as well as the patient's age and number of rescuers present (15:2 versus 30:2) (Kleinman et al., 2015). Another factor that can influence ventilation rate, especially with a single rescuer, is compression rate. If compressions are given at a rate that

is either higher or lower than recommended, ventilations would then be performed more or less often throughout the process of CPR.

Adverse effects have been documented when ventilation rates are above twelve breaths per minute. Hemodynamics and survival rates were studied in nine pigs converted to cardiac arrest with ventilation rates of 12, 20, and 30 breaths per minute. Mean intrathoracic pressure values (mmHg/min) were $7.1 \pm .7$, $11.6 \pm .7$, and 17.5 ± 1.0 ($P > .0001$), respectively as measured by a micromanometer-tipped catheter (Aufderheide et al., 2004). As ventilation rates increased, so did intrathoracic pressure. As previously discussed, increasing intrathoracic pressure has adverse effects on the hemodynamics of CPR. There needs to be a buildup of negative intrathoracic pressure to bring blood back to the heart. This increase in intrathoracic pressure leads to decreased venous blood flow to the heart, as there is an insufficient timeframe to allow for the development of negative intrathoracic pressure between ventilations (Aufderheide et al., 2004).

In another portion of the same study, 14 pigs were split into two groups and ventilated at a rate of either 12 or 30 breaths per minute. The survival rates were compared between groups. The survival rates were 6:7 and 1:7 with 12 and 30 breaths per minute, respectively ($P = .006$) (Aufderheide et al., 2004). As ventilation rates were increased, so did intrathoracic pressure, which decreased the venous return of blood to the heart and, in turn, survival rate.

Finally, as ventilations are performed, there should be no more than visible minimal chest rise. When rescuers provide ventilations via a pocket mask or bag-valve mask, they are delivering a positive-pressure ventilation. As previous research has indicated, positive-pressure ventilations have been associated with decreased negative intrathoracic pressure, which decreases the flow of blood during CPR (Berg et al., 2001). Ventilations need to be provided at a

volume that provides enough oxygen to the body during CPR but minimizes the positive-pressure.

A study was performed in a hospital with 80 patients during simulated life support ventilation. The study was designed to observe the oxygen saturation values and presence of stomach inflation when patients were ventilated by either a child (500 ml) or adult (1000 ml) self-inflatable bag. Patients were administered anesthesia and were ventilated for three minutes before the insertion of a laryngeal mask. Respiratory rate, minute ventilation, peak airway pressure, exhaled tidal volume, and arterial oxygen were measured with a respiratory monitor (Wenzel et al., 1999). Stomach inflation was determined with a stethoscope positioned on the upper abdomen. The results of the study revealed the difference in oxygen saturation was non-significant ($97\pm 1\%$ versus $98\pm 1\%$) with the 500 ml bag having a slightly decreased saturation level (Wenzel, et al 1999). Delivering a larger volume of air during each ventilation does not drastically effect oxygen saturation during ventilations. Stomach inflation was found in five of 40 patients in the adult (1000 ml) inflatable bag, but in no patients with the child (500 ml) bag (Wenzel et al., 1999). Although the smaller ventilation volumes lead to decreased oxygen saturation, values between the two groups were nearly identical and those treated with the 500 ml bag did not have stomach inflation. Ventilations should be applied with enough volume for minimal chest rise but not excessively to prevent the buildup of positive pressure physiology.

2.3. Effectiveness of Recent CPR Guidelines

CPR is continually being researched and updated with the latest recommendations to influence patient outcomes. A 2010 meta-analysis of out of hospital cardiac arrests (OHCA) was completed. Data were compiled using information from 1984 until 2008 that included 142,000 patients to analyze trends in OHCA survival over time (Sasson et al., 2010). To complete the

study, eight databases were searched for studies reporting OHCA of a cardiac pathology in adults. Seventy-nine studies were included, which included 142,740 patients. Upon analysis of the data, it was determined that over this three-decade span, survival from OHCA has not significantly improved (Sasson et al., 2010). The aggregate survival rate is between 6.7% and 8.4%, with the overall crude survival rate being 7.1% (10,017 survivors of 141,581 cases) (Sasson et al., 2010). These statistics suggest that despite the advances in CPR research and development, there has not been significant improvement in patient outcomes from 1980 until 2010.

In 2010 the American Heart Association recommended deeper chest compressions, raising the accepted range from 38 mm-50 mm to at least 51 mm (2.1 in). Researchers performed a study in 2014 to analyze patient outcomes during OHCA when the rescuers implemented the 2010 guidelines. The data were collected from two EMS agencies and included 593 patients who met inclusion criteria. In this study mean compression depth was 49.8 ± 11.0 mm and compression rate was 113.9 ± 18.1 cpm. Also, mean depth was significantly deeper in survivors (53.6 mm, 95% CI: 50.5–56.7) than non-survivors (48.8 mm, 95% CI: 47.6–50.0). Overall, 136 patients (22.9%) achieved ROSC, while 63 patients (10.6%) survived (Vadeboncoeur, 2014). Compared to the survival rate from 1984 to 2008, there was a 3.5% increase in patient survival of OHCA when rescuers implemented the 2010 guidelines.

Further research has been completed to explore how current guidelines effect the survival rate of out-of-hospital cardiac rest when taught to the public. In 2010 the North Carolina Regional Approach to Cardiovascular Emergencies Cardiac Arrest Resuscitation System (RACE-CARS) implemented an educational intervention to improve bystander-initiated CPR. This project included education for community members, EMS staff, first responders and

hospital administrators. Between 2010 and 2013 data were collected from cardiac arrest patients to determine the effectiveness of the RACE-CARS system. A total of 4,961 patients were included in the study and 86.3% of all patients received CPR before EMS arrival (Hansen et al., 2015). Survival with favorable neurological outcome increased from 7.1% (82 of 1149; 95% CI, 5.8%-8.8%) in 2010 to 9.7% in 2013 (129 of 1334; 95% CI, 8.2%-11.4%) (P = .02), which was associated with bystander CPR (Hansen et al., 2015). This study suggests that if more bystanders were capable of performing high-quality CPR, it may increase patient survival.

Researchers have analyzed the survival rate from cardiac arrest over time throughout the United States. The Cardiac Arrest Registry to Enhance Survival (CARES) is a large registry of patients with out-of-hospital cardiac arrest. This system collects data from 284 EMS systems across 23 states. Researchers used data from the CARES system to analyze 73,790 cases of cardiac arrest from October 5, 2005 until December 31, 2012 to identify trends in survival. Overall, survival increased from 5.7% between 2005-2006 to 8.3% in 2012 (Chan et al., 2014). The researchers believe the modest increase of bystander CPR and AED use are attributed to pre-hospital survival trends. The continual development of CPR guidelines is necessary to continue to improve patient outcomes. Implementation of the 2010 guidelines has shown to increase OHCA survival rates. Future research should be completed on patient outcomes since the release of the 2015 AHA guidelines to support current recommendations.

2.4. CPR with Athletic Equipment

2.4.1. Football Pads

The National Athletic Training Association (NATA) Position Statement on preventing sudden death has indicated protective equipment should be removed if it prevents access to the airway or the chest (Casa et al., 2012). However, limited research has been conducted exploring

the consequences of starting compressions prior to the removal of athletic equipment. A previous study has been performed by researchers to determine if chest compressions could be completed over football chest pads and still be effective. In this study there were 30 participants who were either athletic training students or licensed graduate students who were certified in CPR (Basic Cardiac Life Support). There were also six emergency department technicians who participated in the study. All participants performed CPR with the Laerdal SimMan 3G interactive manikin simulator (Waninger et al., 2014). These manikins analyzed average compression depth (mm), average compression rate (per minute), percent of time with proper chest wall recoil, and percentage of hands-on contact during compressions (Waninger et al., 2014). All subjects performed two-minute cycles of each scenario: no equipment, over shoulder pads, under unlaced shoulder pads (Waninger et al., 2014). Data can be found in Table 3.

Table 3

Compression Depth and Rate Under and Over Equipment

| Group | Median (Interquartile Range) | P-Value |
|------------------------------|------------------------------|---------|
| CPR compression depth (n=36) | | |
| Under equipment | 37 (31-39) | 0.002 |
| Over equipment | 31.5 (28-35.5) | |
| CPR compression rate (n=36) | | |
| Under equipment | 113 (101.25-125) | 0.20 |
| Over equipment | 118 (103.25-130.75) | |

Chest compression depth significantly decreased when the rescuers performed compressions over the shoulder pads. Mean compression depth was measured both under and over the equipment with the results being 37 mm (1.46 inches) and 31.5 mm (1.24 inches), respectively (Waninger et al., 2014). The difference in compression depth between the two groups was 15% or 5.5 mm (0.22 inches). The 2010 American Heart Association Guidelines

recommends a depth of 50 mm for chest compressions (Travers et al., 2010). Neither group was able to reach the depth recommended by the AHA. This research suggests football pads need to be removed to achieve adequate chest compression depth.

2.4.2. Lacrosse Pads

Another high-impact sport that has protective equipment for the torso is lacrosse. As a high collision sport with significant injury risk, there is concern for cardiac emergencies. The difference between lacrosse pads and football pads is that lacrosse pads are made with thinner padding and do not contain a hard-plastic shell like football pads (Boergers et al., 2017). The study included five licensed athletic trainers who performed CPR on a Laerdal SimMan 3G manikin with and without lacrosse pads (Boergers et al., 2017). The participants then performed CPR in eight different scenarios: CPR with pads and four different airway devices and repeated that process without the pads. Each trial started with a simulation manikin that was placed into a condition of no pulse and no breathing and lasted for two minutes, or five to six cycles of CPR (Boergers et al., 2017).

Compressions delivered without pads had an average depth of 4.28 centimeters as compared to the compressions performed over the pads at an average depth of 4.18 centimeters (Boergers et al., 2017). Once again, the issue of not meeting AHA standards arises as neither group performed CPR at a depth of five centimeters. This leads to the belief that the inefficiency of compressions is not only a result of the equipment but of the performance of the rescuers. The results of this singular study suggest compressions can be applied over the protective equipment specific to lacrosse (Boergers et al., 2017). However, there was a small population of rescuers in this study as well as more focus on airways than compressions. To make further

recommendations regarding chest compressions over lacrosse pads, more research should be conducted with an increased sample size of rescuers with an emphasis on chest compressions.

2.4.3. Hockey Pads

Although researchers have previously conducted studies with regards to CPR over football and lacrosse pads, there is no published data about the adequacy of chest compressions over hockey pads. The AHA guidelines recommend compression depth of at least two inches, but no more than two and two-fifths inches (AHA Adult Basic Life Support and Cardiopulmonary Resuscitation Quality, 2015). The rigidity and thickness of the hockey pads are designed with the safety of the athlete in mind. Although the pads may protect from contusions and fractures, there is a concern the pads are too thick to adequately compress the chest during CPR. Hockey pads are made of a hard, rigid plastic that is meant to disperse any forces applied to it. If, upon further investigation, it is determined chest compressions cannot be adequately administered over hockey pads, removal of the equipment must be required prior to initiating compressions during CPR.

2.5. Techniques for Monitoring and Improving CPR Performance

2.5.1. Importance of Monitoring

CPR has many specific components and guidelines that must be adhered to provide the highest quality of care in the hopes of saving a life. Monitoring the performance and quality of CPR by both rescuers in the classroom and at the scene of cardiac arrest has been transformative to resuscitation science and clinical practice (Meaney et al., 2013). As technology has advanced, it is now possible to provide feedback on compression rates, depth, and other components of CPR. This technology has allowed data to be compiled and then compared to patient outcomes to support or change recommendations for CPR. Not only can monitoring CPR parameters support

already established guidelines, it can also identify whether rescuers are performing CPR properly. This feedback can help educators evaluate if CPR training has been effective or if changes need to be considered. Given the insights into rescuer performance and new discoveries in optimal practice, monitoring CPR quality should be incorporated into every professional rescuer program (Meaney et al., 2013). Monitoring of CPR performance can ensure correct technique and can be a key component in developing future guidelines.

2.5.2. Visual Feedback Devices

Perhaps the easiest way to know a rescuer is performing CPR correctly is if they have visual feedback as they perform the skills. A study was conducted to investigate if a simple visual feedback system would help providers perform CPR correctly. The tested device was a prototype designed by Laerdal and is designed to be placed between the rescuer's palm and the victim's chest (Skorning et al., 2010). As the rescuer provides CPR, this device displays whether or not compression depth or rate is correct.

The study consisted of 93 rescuers (EMS-Physicians, EMT's, and Paramedics) who were split into two groups. The first group performed continuous chest compressions (CCC) on a Skill-reporter ResusciAnne manikin without the visual feedback system for two minutes. They then took a 45-minute break and performed CCC with the visual feedback system. The second group performed the same testing but in opposite order. During each trial, the ResusciAnne manikin recorded chest compression depth and rate. Correct compression depth was performed by 45.2% of subjects without the device (95%-CI: 30.5-64.9 mm) compared to 73.1% (95%-CI: 40.3-57.4 mm) when using the device ($p < 0.001$). Comparatively, correct compressive rate was achieved by 62.4% (95%-CI: 78–147.8min⁻¹) of subjects without the device versus 94.6% (95%-CI: 87.3–126.6min⁻¹) with the device ($p < 0.001$) (Skorning et al., 2010). The visual

feedback system was effective at increasing the number of rescuers who performed CCC at a correct rate. There was also an increase in correct compression depth, although not as drastic as the results of compression rate. Visual feedback is a simple monitoring technique that can greatly improve CPR performance.

2.5.3. Manikins with Real-Time Feedback

The benefit of CPR manikins with real-time feedback is they are useful for teaching CPR for those who have never learned or those who learned incorrectly due to the absence of real-time feedback. Traditional CPR courses are often performed on manikins that do not provide feedback; feedback is provided by instructors. The issue with traditional courses is that an instructor cannot always identify correct compression depth, rates, or chest recoil for their students. They may miscount compressions during an evaluation or may misjudge the depth of compressions. A study was performed on secondary school students to compare the effectiveness of standard instructor-based feedback for chest compressions compared to Laerdal Q CPR real-time training software (Cortegiani et al., 2017). After a lesson on basic life support and chest compressions, 144 students were randomized into two groups. One group practiced with a traditional manikin while the other used the Q CPR manikin. Both groups practiced until they acquired the skill to perform two minutes of CPR according to instructor feedback. Seven days later, all students were required to perform another two-minute session of CPR using the ResusciAnne Wireless Skill Reporter without feedback from an instructor or the training device. The measurement of the study was defined as compression score, or the overall measure of compression quality as defined by the ResusciAnne software (Cortegiani et al., 2017). The group of students who initially practiced on the Q CPR manikin had a compression score average of 90% while the instructor feedback group had an average of 67%. The results of the study suggest

a training system based on real-time feedback software is superior to instructor-based feedback. It should be noted this study included participants who were students. Follow-up research should be conducted with allied health care professionals in order to make changes to the instruction guidelines published by the AHA.

The Laerdal QCPR Resusci Anne and associated software is a product that is useful for measuring CPR performance and teaching correct CPR. These products are paired with a software that gives real-time feedback provided by user-friendly graphics (Cortegiani et al., 2017). The software is able to evaluate/measure hand position, compression rate, compression depth and chest release, which are all important components of high-quality CPR (Cortegiani et al., 2017). Not only does the QCPR Anne measure compressions, it can identify whether or not proper ventilations are being delivered. The Resusci Anne QCPR is built with realistic anatomy and is fully compliant with the American Heart Association (AHA) Guidelines for CPR and ECC (Laerdal Medical, 2017). These devices and their associated software are designed to realistically simulate CPR and help increase performance.

2.6. Conclusion

In summary, future research is warranted to determine if athletic trainers are able to perform adequate chest compressions during cardiac arrest over sport-specific equipment, specifically hockey pads as no research has been conducted respective to this sport. The high-intensity nature of hockey places a great deal of stress on the heart, and the risk of commotio cordis due to collision or the direct blow of a hockey puck makes sudden cardiac death a concern. Therefore, it is necessary for future research to develop evidence-based recommendations for cardiopulmonary resuscitation specific to compressions over athletic equipment.

3. METHODOLOGY

3.1. Purpose of the Study

The purpose of this research was to investigate the ability of certified athletic trainers to provide cardiopulmonary resuscitation (CPR) over hockey shoulder pads. The National Athletic Trainers' Association position statement on preventing sudden death in sports recommends removing any equipment if it prevents access to the airway or chest (Casa et al., 2012). However, the American Heart Association does not specify if high-quality CPR can be performed over athletic protective equipment. Previous research has been completed to determine how much of a barrier football and lacrosse pads are in preventing adequate chest compressions. Hockey players also wear shoulder pads that could prevent full chest compression during CPR. This research study was designed to help establish best care practices in the event of cardiac arrest in a hockey athlete. The research was designed to answer the following questions:

Q1: What percentage of participants achieved satisfactory performance on overall CPR score, compression depth, compression rate, chest compression fraction, and chest recoil, in addition to exploring the percent of adequate ventilation volume?

Q2: What is the relationship among participant traits (Body Mass Index [BMI], age, gender, education level, years of CPR certification, and years as an ATC) and performance on dependent variables (overall CPR score, compression depth, compression rate, chest compression fraction, full chest recoil, and ventilations) of CPR when performed over hockey pads?

3.2. Participants

A convenience sample of 50 ATCs between the ages of 18 and 60 were recruited through word-of-mouth at the North Dakota Athletic Trainers' Association Conference, recruitment e-mail, and additional word-of-mouth recruitment throughout the region. Participants had to be currently certified through the BOC® (Board of Certification) as an athletic trainer and current CPR/first-aid certification. Exclusion criteria for the study included any current cardiovascular or musculoskeletal condition, which would prevent an individual from delivering high-quality CPR at the time of testing. Subjects were compensated for their participation with ten dollars following completion of the study. Informed written and verbal consent was obtained from each participant before enrollment and baseline demographic and clinical data were collected by the Participant Demographic Form.

3.3. Equipment and Instruments

To measure the quality of CPR being performed in the study, the Resusci Anne® QCPR(Stavanger, Norway) manikin was used with the Laerdal SkillReporter software to measure CPR performance. Prior to testing, the Resusci Anne® was fitted with CCM U+ Crazy Light shoulder pads (Ontario, Canada). Ventilations were administered via a Laerdal Pocket Mask™ (Stavanger, Norway).

The Resusci Anne® QCPR manikin and Laerdal SkillReporter software (Stavanger, Norway) were used as the device to measure the quality of CPR. The software is able to evaluate and/or measure hand position, compression rate, compression depth, chest compression fraction, and chest recoil. The software also analyzes the rate and volume of ventilations. At the end of the CPR session, the software also calculates an overall parameter, called compression score, which takes into account all of the other values and ranges from 0% to 100% (Cortegiani, et al 2017).

All the other aforementioned parameters are also summarized into a score, which is given as an overall percentage.

3.4. Procedures

Upon arrival each participant completed the necessary paperwork including the demographics form and informed consent. As previously stated, participants were excluded from the study if they indicated any of the following: any current cardiovascular or musculoskeletal condition, which would prevent an individual from delivering high-quality CPR.

For the first part of the study, subjects participated in a session to determine CPR proficiency. One Resusci Anne® QCPR manikin, without hockey pads, was designated as the proficiency manikin. The parameters for this manikin were in accordance with the 2015 American Heart Association (AHA) guidelines: 30:2 compression to ventilation ratio, 2.0 in compression depth (50 mm), and 100-120 compressions per minute. The timer was set for one minute of compression-only CPR for this initial test. The three values that were recorded for the proficiency testing were compression score, chest recoil, and compression depth. Participants were not allowed to use the visual feedback provided by the Laerdal SkillReporter software to correct their performance. To be labeled as “proficient” each participant needed to achieve a minimum value of at least 80% on their compression score during this initial test. If the participant scored lower than 80%, they were allowed to practice after receiving feedback from the researcher. Participants were allowed to re-test one additional time.

Once deemed proficient, participants took a break of no less than one minute but no more than five minutes before proceeding to the second portion of the study. Each participant was then required to perform single-rescuer CPR for 8 minutes and 59 seconds of CPR on the Resusci Anne® QCPR manikin that had been fitted with CCM U+ Crazy Light shoulder pads. Each

participant was instructed to perform rescue breaths with a Laerdal Pocket Mask™ and were, once again, instructed to perform CPR according to 2010 AHA guidelines. Participants were unable to see any visual feedback data about their performance nor were participants able to see a clock, as performance may change based on objective feedback. In addition, researchers did not provide feedback or encouragement as some research in the field of exercise science has indicated such encouragement could positively influence outcomes such as compression depth (Babbs & Kern, 2002).

At exactly 8 minutes and 59 seconds, the researcher informed the participant they had completed the testing. Each testing session was saved with a deidentified number in the system. Multiple values were recorded from each testing session: overall CPR score, compression score, ventilation score, compression fraction, compression:ventilation, hand placement, mean 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. If participants were unable to complete CPR for the full amount of time, it was documented and they were still compensated for their participation. Upon completion, the participants each received ten dollars for their time and cooperation.

3.5. Documentation

Prior to data collection, this study was approved from the Institutional Review Board at North Dakota State University. Each participant was asked to read and sign an informed consent form. Participants then filled out a demographics form asking about various aspects such as highest educational level, years of CPR/ATC certification, age, gender, height and weight for data analysis purposes.

3.6. Statistical Analysis

Based on the research questions associated with this project, we anticipate the following statistical analysis: For research questions 1 & 2, basic descriptive statistics were calculated to determine the percentage of ATCs who achieved the AHA 2010 Guidelines. For research question 3, a series of linear regression models will be used to explore the relationship among the demographic traits and performance on the CPR dependent variables (i.e., overall CPR score, compression percentage, ventilation percentage, compression fraction, compression to ventilation ratio, correct hand placement, mean compression depth, full chest recoil, correct depth percentage, correct compression rate percentage, mean rate, adequate ventilations and inadequate ventilations). When significant predictive results were found additional Post Hoc statistical exploration will be done to further explore the significant relationships (e.g., independent sample *t*-test).

3.7. Conclusion

The purpose of this research was to determine whether certified athletic trainers were able to deliver quality chest compressions over hockey shoulder pads after being proven to be proficient in their CPR skills. Athletic trainers act as first responders for many hockey athletes and need to be prepared to perform CPR if one of those athletes suffers from cardiac arrest. The results of this research will be used to add to existing evidence-based recommendations for CPR protocols. This research will be valuable in determining if hockey pads should be removed immediately or if they can remain in place as rescuers immediately begin chest compressions. By better understanding how hockey shoulder pads impact the effectiveness of chest compressions, best-practice guidelines can be established to further prevent the death of athletes.

4. MANUSCRIPT

4.1. Abstract

[Study Design] Experimental

[Background] Certified Athletic Trainers (ATCs) are expected to perform high-quality CPR for athletes regardless of whether the athlete is wearing protective athletic equipment. Current American Heart Association (AHA) Guidelines do not include recommendations regarding the immediate removal of protective equipment before administering compressions. No previous research has been conducted investigating the effectiveness of chest compressions over hockey shoulder pads as performed by ATCs.

[Objectives] The goal of the research was to determine if ATCs were able to deliver high-quality CPR over hockey shoulder pads.

[Methods] ATCs completed a one-minute compression-only CPR proficiency test on a medium-fidelity manikin (Resusci Anne QCPR). Once proficient, each ATC completed CPR according to 2015 AHA guidelines on the manikin, which had been fitted with hockey shoulder pads. CPR quality was measured with the Resusci Anne Wireless SkillReporter (Laerdal Ver 2.0.0.14). CPR data included the following dimensions of compressions: overall score, mean rate, chest compression fraction, mean depth, % chest recoil, % compressions with appropriate depth, % of ventilations that were adequate or inadequate. Data were analyzed to compare

differences of CPR performance between covariates, which included: age, gender, body mass index, education level, years certified as an athletic trainer.

[Results] Overall CPR score was $69.08\% \pm 21.65$. Forty-four percent of the participants achieved recommended compression depths with mean compression depth being 48.16 ± 8.57 mm. Sixty-six percent of ATCs compressed at a proper rate throughout the study and 90% of ATCs met chest compression fraction guidelines. Thirty-three (66%) of the ATCs achieved full chest recoil on at least 90% of the compressions they performed. Finally, 42 ATCs (82% of the sample) delivered 60% or less of their ventilations at a volume that was considered adequate. Six linear regressions were ran to determine which traits of each ATC were significant predictors of CPR performance amongst six characteristics of high-quality CPR. Two significant regressions were found (chest compression depth and adequate ventilations). Gender was the only significant predictor of mean compression depth. The *t*-test was significant ($t(48) = 2.00, p < .01$). The mean depth compression for men was 51.52 mm (SD = 5.42) and for women was 44.80 mm (SD = 9.84). The other significant regression was adequate ventilations in which, once again, gender was the only significant predictor of adequate ventilations. An independent sample *t*-test was calculated to further explore the relationship between gender and percent of adequate ventilations. The *t*-test was not significant ($t(48) = 1.61, p > .05$). The mean adequate ventilations for men was 29.32 (SD = 29.10) and for women was 41.96 (SD = 26.30).

[Conclusions] Results indicate ATCs are unable to provide quality CPR over hockey pads. Specifically, performance was not adequate regarding chest compression depth and ventilations. Over half of all participants were unable to compress, on average, at the recommended depth of at least 50 mm. On average, men compressed more deeply than women, however, the range and standard deviation between observed compression depth values is large. Thus, the removal of hockey shoulder pads is recommended prior to performing CPR to ensure adequate depth.

[Level of Evidence] Therapy, level 3

[Key Words] Cardiopulmonary Resuscitation, protective equipment, Resusci Anne Q CPR

4.2. Introduction

Certified Athletic Trainers (ATC) are responsible for providing CPR in the event an athlete suffers from a cardiac event (Johnson, 2010). The incidence for sudden cardiac death in athletes has been found to be 1:43,770 per year (Harmon et al., 2011). Although such incidents are rare, ATCs are expected to provide life-saving interventions. Each year the American Heart Association (AHA), and European Resuscitation Council (ERC) release updated standards and guidelines for providing high-quality CPR to increase survivability. Interestingly, there is no recommendation for providing CPR on an athlete who is wearing protective equipment. There is also minimal research regarding whether or not ATCs provide high-quality CPR (Drezner et al., 2019) (Wanninger et al., 2014). Due to the possibility of sudden cardiac death in athletes, it is imperative that best practice guidelines be established for athletes wearing protective equipment.

The limited research conducted specific to the field of Athletic Training has suggested ATCs are unable to provide compressions at an adequate depth. In a study where 30 participants (athletic training students and ATCs) performed CPR beneath football pads, average compression depth under the pads was 37 mm despite the AHA guideline of 50 mm (Wanninger et al., 2014). Furthermore, a study was completed in which five licensed ATCs provided CPR on a manikin and averaged a compression depth of 42.8 mm, which was also short of the AHA guideline of 50 mm. The results of both studies suggest that ATCs may not be proficient in providing compressions even when an athlete is not wearing protective equipment.

The current NATA Position Statement on preventing sudden death has indicated protective equipment should be removed if it prevents access to the airway or the chest (Casa et al., 2012). There is little to no research that indicates if the presence of specific athletic equipment creates a barrier to the delivery of high-quality chest compressions. Previous researchers have examined the effectiveness of chest compressions over lacrosse (Boergers et al., 2017) and football shoulder pads (Waninger et al., 2014); average compression depths were 41.8 and 31.5 mm, respectively. The barrier created by the protective equipment in both studies did not allow ATCs or athletic training students to achieve AHA compression depth recommendations. It should be noted that sample size in both studies was limited. Thus, with a limited number of studies and several limitations within the available methodology, it is difficult to make evidence-based recommendations for CPR over athletic equipment.

Athletic Trainers are expected to perform life-saving interventions with the most recent guidelines established from governing bodies. The literature is lacking on studies evaluating the effect protective athletic equipment has on the performance of CPR. The researchers in this study sought to determine the best way to treat hockey athletes suffering from a cardiac emergency.

We hypothesized that the presence of hockey shoulder pads would decrease CPR performance. Specifically, the depth of compressions would be affected by the presence of hard plastic and padding over the chest. The purpose of this study was to investigate the ability of ATCs to perform high-quality CPR over hockey pads.

4.3. Methods

4.3.1. Research Questions

Q1: What percentage of participants achieved satisfactory performance on overall CPR score, compression depth, compression rate, chest compression fraction, and chest recoil, in addition to exploring the percent of adequate ventilation volume?

Q2: What is the relationship among participant traits (Body Mass Index [BMI], age, gender, education level, years of CPR certification, and years as an ATC) and performance on dependent variables (overall CPR score, compression depth, compression rate, chest compression fraction, full chest recoil, and ventilations) of CPR when performed over hockey pads?

4.3.2. Demographics

A convenience sample of 50 ATCs between the ages of 18 and 60 were recruited through word-of-mouth at an annual Athletic Trainers' state association conference, recruitment e-mail, and additional word-of-mouth recruitment throughout the region. Participants had to be currently certified through the BOC® (Board of Certification) as an athletic trainer and current CPR/first-aid certification. Exclusion criteria for the study included any current cardiovascular or musculoskeletal condition, which would prevent an individual from delivering high-quality CPR at the time of testing.

The sample was comprised of 25 women and 25 men, who ranged in age from 22 to 59 years. Mean ATC age was 34.76 ± 10.88 . Regarding level of education, ten subjects had a Bachelor's degree, 32 had earned a Master's degree and eight had obtained a PhD. Mean years of experience as an ATC was 11.41 ± 9.70 . Average BMI for females was 25.31 ± 4.07 and 26.91 ± 3.38 for males.

This study was approved by the university's Institutional Review Board. Subjects were compensated for their participation with ten dollars following completion of the study. Informed written and verbal consent was obtained from each participant before enrollment and baseline demographic and clinical data were collected.

4.3.3. Study Design and Protocol

For the first part of the study, subjects participated in a session to determine CPR proficiency. One Resusci Anne® QCPR manikin (Stavanger, Norway) without any additional equipment was designated as the proficiency manikin. The parameters for this manikin were in accordance with the 2015 American Heart Association (AHA) guidelines: 30:2 compression to ventilation ratio, 2.0 inches compression depth (5 cm or 50 mm), and 100-120 compressions per minute. The timer was set for one minute of compression-only CPR for this initial test. The three values that were recorded for the proficiency testing were compression score, chest recoil, and compression depth. Participants were not allowed to use the visual feedback provided by the Laerdal SkillReporter (Stavanger, Norway) software to correct their performance. To be labeled as "proficient," each participant needed to achieve a minimum value of at least 80% on the overall compression score during this initial test. If the participant scored lower than 80%, they were allowed to practice after receiving feedback from the researcher. Participants were allowed to re-test one additional time.

Once deemed proficient, participants took a break of no less than one minute but no more than five minutes before proceeding to the second portion of the study. Each participant was then required to perform single-rescuer CPR for 8 minutes and 59 seconds of CPR on the Resusci Anne® QCPR manikin that had been fitted with CCM U+ Crazy Light (Ontario, Canada) shoulder pads. Each ATC was instructed to perform rescue breaths with a Laerdal Pocket Mask™ and were, once again, instructed to perform CPR according to 2015 AHA guidelines. Participants were unable to see any visual feedback data about their performance nor were participants able to see a clock. In addition, researchers did not provide feedback or encouragement as some research in the field of exercise science has indicated such encouragement could positively influence outcomes such as compression depth (Babbs & Kern, 2002).

At exactly 8 minutes and 59 seconds, the researcher informed the participant they had completed the testing. The researchers chose 8:59 as it is the national average for an ambulance to arrive at the scene of an emergency (Yang et al., 2014). Each testing session was saved with a deidentified number in the system. Multiple values were recorded from each testing session: overall CPR score, compression score, ventilation score, compression fraction, compression:ventilation, hand placement, mean 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. It should be noted that one individual was unable to complete all 8:59 of CPR. However, the participant was able to complete enough of the time (7:41); therefore, data for all 50 participants were analyzed.

4.3.4. Statistical Analysis

Statistical analysis for the approved research was computed using SPSS software Version 24.0 (Armonk, NY). Data were analyzed using descriptive statistics and multiple linear regressions. Post hoc t-tests were completed when statistically significant results were found.

4.3.5. Results

The analysis for the first research question involved calculating the percentage of participants who achieved satisfactory performance on compression depth, rate, chest compression fraction, and ventilation volume. In order to determine if satisfactory performance was achieved, ATCs were expected to perform in accordance to 2015 AHA guidelines (≥ 51 mm, 100-120 cpm, 60-80% CCF, full chest recoil). Before discussing the five components of satisfactory CPR performance, it is important to note that the average overall CPR score for all the participants was $69.08\% \pm 21.65$. To begin to examine the components of the overall CPR score, mean compression depth was 48.16 ± 8.57 mm. Overall, 44% of ATCs achieved the satisfactory depth of 51 mm. In terms of compression rate, satisfactory performance is between 100 and 120 compressions per minute. Sixty-six percent of the ATCs in this study met recommend compression rates. The third component of satisfactory CPR performance is chest compression fraction, which is suggested to be between 60% and 80% to achieve ROSC. Ninety percent of the ATCs in this study achieved the recommended chest compression fraction. The fourth component, chest recoil, was explored via the percent of compressions in which the chest could fully decompress in between each compression. Thirty-three (66%) of the ATCs achieved full chest recoil on at least 90% of the compressions that they performed in the study. Further details regarding chest recoil can be found in Table 4.

Table 4

Number of ATCs and % of Full Chest Recoil

| % of Adequate Ventilations (range) | Number of ATCs | Percent of Sample |
|---------------------------------------|----------------|-------------------|
| 0-10% | 1 | 2% |
| 30-40% | 1 | 2% |
| 40-50% | 5 | 10% |
| 50-60% | 2 | 4% |
| 60-70% | 2 | 4% |
| 70-80% | 3 | 6% |
| 80-90% | 3 | 6% |
| 90-95% | 3 | 6% |
| 96-99% | 17 | 34% |
| 100% | 13 | 26% |

The final component, ventilation volume, was explored in terms of the percentage of adequate ventilation volume. Seven of the ATCs did not provide a single ventilation at an adequate volume, which represents 14% of the sample. 42 ATCs (82% of the sample) delivered 60% or less of their ventilations at a volume that was considered adequate. Further details regarding ventilations can be found in Table 5.

Table 5

Number of ATCs and % of Adequate Ventilations

| % of Adequate Ventilations (range) | Number of ATCs | Percent of Sample |
|---------------------------------------|----------------|-------------------|
| 0-1% | 7 | 14% |
| 2-20% | 12 | 24% |
| 21-40% | 9 | 18% |
| 41-60% | 13 | 26% |
| 61-80% | 6 | 12% |
| 81-98% | 3 | 6% |

The second research question explored the relationship between participant demographics (i.e., BMI, gender, education level, and years as an ATC) and performance on CPR as measured by the five components outlined above. Thus, the dependent variables were overall CPR score, compression rate, compression depth, chest compression fraction, ventilation volume, and full chest recoil while the independent variables were the participant traits. A separate linear regression was used to explore the relationship between the independent variables and each of the dependent variables. The same independent variables were used for each regression. BMI and years as an ATC are all continuous variables, while gender (Men = 0; Women = 1) and education (Bachelor's = 0; Graduate Degree = 1) were dummy coded. Prior to running the regressions, we calculated the correlations between all of the independent and dependent variables (See Table 6).

Table 6

Correlation Matrix (N=50)

| Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-------------------------------|----|-------|------|-------|-------|-------|--------|-------|-------|-------|
| 1. Gender | -- | -.007 | .200 | -.214 | -.314 | -.183 | -.396* | .230 | .140 | .227 |
| 2. Years an ATC | | -- | .060 | .327 | .006 | -.051 | -.116 | .074 | .076 | .209 |
| 3. Level of Education | | | -- | .080 | -.192 | -.141 | -.109 | -.052 | .217 | -.166 |
| 4. BMI | | | | -- | .292 | .117 | .202 | .083 | -.085 | .193 |
| 5. Overall CPR Score | | | | | -- | .450 | .710 | .369 | -.326 | .271 |
| 6. Compression Fraction | | | | | | -- | .413 | .210 | -.248 | .158 |
| 7. Mean Depth (mm) | | | | | | | -- | .046 | -.153 | .051 |
| 8. Full Chest Recoil | | | | | | | | -- | -.029 | .313 |
| 9. Mean Rate | | | | | | | | | -- | -.105 |
| 10. Adequate Ventilations (%) | | | | | | | | | | -- |

** Correlation is significant at the $p < 0.01$ level

* Correlation is significant at the $p < 0.05$ level

The dependent variable for the first regression was Overall CPR Score. The regression was not significant ($F(4, 44) = 2.32, p > .05$) with R^2 as .17. The ATC traits were not significant predictors of their overall CPR performance (see Table 7 for B , $SE B$, and β).

Table 7

Summary of Regression Analysis for Variables Predicting Overall CPR Score

| <i>Variable</i> | <i>B</i> | <i>SE B</i> | <i>β</i> |
|-----------------|----------|-------------|---------------------------|
| Constant | 39.81 | 22.40 | |
| Gender | -8.69 | 6.14 | -.204 |
| Years as an ATC | -0.19 | 0.32 | -0.08 |
| BMI | 1.65 | 0.85 | 0.29 |
| Education Level | -8.52 | 7.45 | -0.16 |

Note: $R^2 = .17$ * $p < .05$ ** $p < .001$

For the second regression, the dependent variable was mean compression depth. A significant regression was found ($F(4, 44) = 2.61, p < .05$) with an R^2 value of .19. Gender was the only statistically significant predictor (see Table 8 for B , $SE B$, and β). An independent sample t -test was calculated to further explore the relationship between gender and mean depth compression. The t -test was significant ($t(48) = 2.00, p < .01$). The mean depth compression for men was 51.52 ($SD = 5.42$) and for women was 44.80 ($SD = 9.84$). A Cohen's d was calculated to assess the effect size of this statistical difference and was 0.85, which represents a large effect size.

Table 8

Summary of Regression Analysis for Variables Predicting Mean Compression Depth

| <i>Variable</i> | <i>B</i> | <i>SE B</i> | β |
|-----------------|----------|-------------|---------|
| Constant | 42.14 | 8.71 | |
| Gender | -5.54* | 2.39 | -.330 |
| Years as an ATC | -0.16 | 0.12 | -0.19 |
| BMI | 0.44 | 0.33 | 0.20 |
| Education Level | -0.76 | 2.90 | -0.04 |

Note: $R^2 = .17$ * $p < .05$ ** $p < .001$

For the third regression, the dependent variable was compression rate. The regression was not significant ($F(4, 44) = 0.82$ with an R^2 of .07. None of the participant traits were significant predictors of compression rate (see Table 9 for B, SE B, and β).

Table 9

Summary of Regression Analysis for Variables Predicting Mean Compression Rate

| <i>Variable</i> | <i>B</i> | <i>SE B</i> | β |
|-----------------|----------|-------------|---------|
| Constant | 110.67 | 12.59 | |
| Gender | 1.33 | 3.45 | .06 |
| Years as an ATC | 0.13 | 0.18 | 0.11 |
| BMI | -0.36 | 0.48 | -0.12 |
| Education Level | 5.66 | 4.19 | 0.20 |

Note: $R^2 = .17$ * $p < .05$ ** $p < .001$

For the fourth regression, the dependent variable was chest compression fraction. The regression was not significant ($F(4, 44) = 0.78$ with an R^2 of .07. None of the participant traits were significant predictors of chest compression fraction (see Table 10 for B, SE B, and β).

Table 10

Summary of Regression Analysis for Variables Predicting Chest Compression Fraction

| <i>Variable</i> | <i>B</i> | <i>SE B</i> | β |
|-----------------|----------|-------------|---------|
| Constant | 61.82 | 9.35 | |
| Gender | -2.48 | 2.56 | -.15 |
| Years as an ATC | -0.07 | .133 | -0.08 |
| BMI | 0.27 | 0.36 | 0.12 |
| Education Level | -2.57 | 3.11 | -0.12 |

Note: $R^2 = .16$ * $p < .05$ ** $p < .001$

For the fifth regression, the dependent variable was full chest recoil. The regression was not significant ($F(4, 44) = 0.99$ with an R^2 of .08. None of the participant traits were significant predictors of compression rate (see Table 11 for B, SE B, and β).

Table 11

Summary of Regression Analysis for Variables Predicting Full Chest Recoil

| <i>Variable</i> | <i>B</i> | <i>SE B</i> | β |
|-----------------|----------|-------------|---------|
| Constant | 60.63 | 25.15 | |
| Gender | 12.53 | 6.90 | 0.28 |
| Years as an ATC | 0.095 | 0.36 | 0.04 |
| BMI | 0.84 | 0.96 | 0.14 |
| Education Level | -6.99 | 8.36 | -0.12 |

Note: $R^2 = .16$ * $p < .05$ ** $p < .001$

For the sixth and final regression, the dependent variable was adequate ventilations. A significant regression was found ($F(4, 44) = 2.87$, $p < .05$) with an R^2 value of .21. Gender was the only statistically significant predictor (see Table 12 for B, SE B, and β).

Table 12

Summary of Regression Analysis for Variables Predicting Percent of Ventilations that were Adequate

| <i>Variable</i> | <i>B</i> | <i>SE B</i> | <i>β</i> |
|-----------------|----------|-------------|----------|
| Constant | -11.18 | 28.67 | |
| Gender | 19.79 | 7.85 | 0.36 |
| Years as an ATC | 0.42 | 0.41 | 0.14 |
| BMI | 1.80 | 1.10 | 0.24 |
| Education Level | -17.53 | 9.53 | -0.25 |

Note: $R^2 = .16$ * $p < .05$ ** $p < .001$

An independent sample *t*-test was calculated to further explore the relationship between gender and percent of adequate ventilations. The *t*-test was not significant ($t(48) = 1.61, p > .05$). The mean adequate ventilations for men was 29.32 (SD = 29.10) and for women was 41.96 (SD = 26.30).

4.4. Discussion

Domain 3 of the Role Delineation Study/Practice Analysis published by the Board of Certification highlights the necessity for certified Athletic Trainers to perform necessary life-saving procedures (Johnson, 2010). Thus, ATCs are expected to perform high-quality CPR during a cardiac emergency for all athletes. Position statements regarding cardiac arrest in athletes make no mention of performing compressions for athletes participating in equipment-laden sports. The Inter-Association Task Force created best practice recommendations for preventing sudden death in athletics. The authors suggest Athletic Trainers should provide “early CPR beginning with chest compressions for a witnessed collapse” (Casa et al., 2013). Although the recommendations within the document reaffirm the AHA guidelines on how initiate CPR, there is no mention of athletic equipment. This is the first study to quantify the effect hockey

shoulder pads have on the performance of CPR. The results of this research will give practitioners a better understanding of how to provide emergency care for athletes participating in equipment-laden sports.

Only 44% of the participants in the present study were able to compress at the recommended depth of a minimum of 50 mm. According to medical and research experts, patient survival increases when average compression depth is 50 mm or more (Stiell et al., 2014). Because limited research exists with an ATC-specific population, we compared our results to research that analyzed performance by emergency medical professionals. Data collected from 2006 to 2009 revealed that EMS professionals were delivering compressions at an average depth of only 37.3 mm (Stiell et al., 2012). Although the minimum recommended depth in that timeframe was 38 mm, the average was still below the AHA recommendation. Additional data from EMS agencies concluded that among 593 cases of cardiac arrest, 52.7% these cases had a mean compression depth that was below AHA guidelines (Vadeboncoeur et al., 2014). Unlike the current study, these rescuers performed chest compressions without any obstructions over the chest. It should be acknowledged that the guidelines published by the AHA mandating an increase in compression depth combined with the barrier created by the shoulder pads makes performing high-quality CPR more difficult.

The results of our study indicated men compressed an average of 51.52 ± 5.42 mm while women compressed 44.8 ± 9.84 mm. In this study, multiple CPR performance variables were compared to self-reported BMI values to find a potential correlation. A trend in data within the current study suggests that rescuers with a higher BMI compress deeper than those with a lower BMI. This data is synonymous with previous research that suggests BMI and gender have an influence on CPR performance. In previous research, a positive correlation was found between

chest compression depth to height, weight, and BMI (Reddy et al, 2018). In addition, other researchers found that physicians with a BMI greater than 24 were more capable of providing effective CPR than those with a lower BMI (Sayee & McCluskey, 2012). Finally, another study was completed to compare the chest compression depths of lighter females with those of females who weighed more. Female rescuers weighing 124 pounds or less were 6.29 times more likely to perform compressions that were inefficient than females weighing between 124-138.2 pounds (Krikscionaitiene et al., 2012). The results of previous research coincide with our findings that male ATCs with a higher BMI are more likely to provide high-quality CPR over hockey shoulder pads. Although we recognize the limitation of self-reported BMI, the data are still critical for comparison purposes to previous literature. By reporting such data, governing bodies can start to consider factors, such as BMI, when educating future rescuers.

Although the number of studies specifically targeting the performance of ATCs and how it is affected by equipment is limited, two previous studies have been performed to analyze the quality of CPR over equipment. For example, in one study 30 participants (athletic training students and ATCs) were instructed to perform CPR directly over football pads as compared to their ability to implement compressions directly to the chest. Results of data suggested participants were unable to complete proper depth (31.5 mm) according to AHA standards, however, compression rate (113 cpm) was acceptable. Data from compressions applied directly to the chest suggested participants were, once again, unable to complete proper depth 37 mm according to AHA guidelines. However, compression rate 118 cpm was acceptable (Wanninger et al., 2014). Average compression depth in the football pad study was more shallow both with (31.5 mm) and without (37 mm) pads as compared to the current study (48.16).

Likewise, a study in which five ATCs performed CPR with and without lacrosse pads using a variety of airway devices also found compressions did not meet AHA standards (Boergers et al., 2017). Compressions delivered without pads had an average depth of 42.8 mm as compared to the compressions performed over the pads at an average depth of 41.8 mm. Each study found compression depth decreased when performed over equipment and was, in turn, inadequate. It should once again be noted that average compression depth in the current study (48.16 mm) was greater than the average depth in the lacrosse pads study (41.8 mm). The researchers studying CPR performance with lacrosse pads made a case that the equipment did not inhibit compression depth or rate and that the equipment “may be left in place to initiate CPR” (Boergers et al., 2017, p. 107). The researchers suggested that because the participants did not reach AHA recommendations for compression depth even without the lacrosse pads, performance could be increased with practice. However, this conclusion should be viewed with caution since their theory has not been tested or validated. Consequently, all data has suggested that the barrier created by the athletic equipment leads to a decrease in CPR performance, especially in relation to compression depth.

It should be noted that a strength of the current study was the amount of time spent performing CPR. In a previous study where participants were asked to perform CPR over football pads, subjects were required to perform CPR for two minutes (Wanninger et al., 2014). Likewise, the participants in the lacrosse pad study were also required to perform CPR in each trial for two minutes (Boergers et al., 2017). In the current study, the researchers chose a timeframe of 8:59, as it is the national average for an ambulance to arrive at the scene of an emergency in an urban area (Yang et al., 2014). A common complaint amongst participants was fatigue and physical strain throughout the trial. ATCs in a rural area may have to perform CPR

for a much longer amount of time. Future CPR research should be conducted with extended time periods to understand the complexities involved with prolonged CPR administration.

In the current study, seven of the ATCs did not provide a single ventilation at an adequate volume, which represents 14% of the sample. Forty-two ATCs (82% of the sample) delivered 60% or less of their ventilations at a volume that was considered adequate, whether they were administered with too much or too little volume. A linear regression showed a trend with women performing adequate ventilations more than men, but the trend was not statistically significant. Previous research has indicated that over-ventilation has adverse effects on hemodynamics, as it is associated with an increased intrathoracic pressure (Aufderheide et al., 2006). However, compression-only CPR leads to lower arterial oxygen saturation and does not allow for optimal oxygen levels throughout the body (Berg et al., 2001). In the present study, participants were required to perform ventilations via Laerdal Pocket Mask™ (Stavanger, Norway) since ATCs are required to utilize a resuscitation mask as a certified healthcare provider. In contrast to the lacrosse pads study, their participants performed rescue breaths with a bag valve mask. The results of the previous study indicate that when providing rescue breaths with a lacrosse helmet still in place, average ventilation volume did not meet AHA standards of 400-700 ml (Boergers et al., 2017). It should be noted that the present study did not fit the manikin with a hockey helmet. Future studies should consider CPR performance with a multitude of different athletic helmets fitted onto the manikin.

The previous literature, as well as the results of the current study, make a case that all protective equipment should be removed before chest compressions are delivered. The AHA and ERC need to adopt this concept and train all individuals, including coaches and emergency responders, to remove equipment before providing care. Despite a few studies attempting to

determine the effect athletic equipment has on CPR performance, more research is required on all types of equipment. Researchers need to study all types of athletic equipment and associated variables so ATCs have a better understanding of how to provide high-quality compressions for an athlete suffering from cardiac arrest.

It should be noted that, on average, participants performed especially well in two characteristics of CPR. The first being full chest recoil. Of the 50 participants, 33 (66%) of them were able to achieve full chest recoil on 90% or more of their chest compressions. The other highlight was that 90% of participants were able to reach the AHA recommendation for chest compression fraction (60-80%). Patients who receive CPR with a CCF in the range of 60-80 % have the highest chance of survival from a cardiac event (Christenson et al., 2009).

This research study is not without limitations due to the numerous variables present. First, this study was limited to participants who were currently certified as an athletic trainer; therefore, the results cannot be generalized to other emergency responders including EMTs and paramedics. Additionally, participants performed simulated CPR on a manikin, which does not perfectly represent an injured hockey player. Another limitation is that the manikin was not fitted with a hockey helmet, and as a result, ventilations were not delivered with a helmet in-place. Finally, the model of hockey pads used were the CCM U+ Crazy Light shoulder pads (Ontario, Canada) and results cannot be generalized to other protective athletic equipment.

Future research on this topic should investigate multiple other facets of ATCs and their CPR performance. One potential study should involve performing CPR over hockey shoulder pads while on a hockey rink to simulate the environmental conditions. Further research should be completed on ATCs performing CPR over all athletic equipment after the participants have been deemed proficient.

CPR guidelines and standards are released as new research is published in the hopes that it will increase patient survival rates, yet no guidelines have been created on how to treat athletes wearing protective equipment. There are still too many unanswered questions with regards to CPR performance even as it is performed by members of one allied healthcare profession. Specific, detailed guidelines must be established such that ATCs can perform a potentially life-saving intervention with confidence no matter the equipment the athlete may be wearing.

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APPENDIX. PARTICIPANT DEMOGRAPHICS FORM

NDSU North Dakota State University

Health, Nutrition, and Exercise Sciences
Department # 2620, PO Box 6050
Fargo, ND 58108-6050
218-443-644

Participant Demographics Form

Name: _____

Preferred email address: _____

Preferred phone number _____

Gender: _____ Female _____ Male **Age:** _____

How many years have you been certified as an athletic trainer?

How many years have you been certified in CPR/first-aid?

Which organization do you acquire your CPR certification from? (AHA, ARC, etc)

Have you ever performed CPR on a patient? If yes, how many times?

What is the highest level of education you have achieved?
