

EFFECTIVENESS OF CARDIOPULMONARY RESUSCITATION OVER PROTECTIVE  
ATHLETIC EQUIPMENT AS PERFORMED BY CERTIFIED ATHLETIC TRAINERS

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**Title**

Effectiveness of Cardiopulmonary Resuscitation Over Protective  
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## ABSTRACT

Certified Athletic Trainers (ATCs) are expected to perform cardiopulmonary resuscitation (CPR) on athletes experiencing cardiac arrest, regardless of whether the athlete is wearing protective athletic equipment. The goal of this research was to determine if ATCs were able to deliver high-quality CPR over and under football shoulder pads. Forty-one ATCs completed CPR according to 2015 AHA guidelines over and under shoulder pads fitted on a manikin. CPR quality was measured with the Resusci Anne Wireless SkillReporter. Data were analyzed to compare CPR performed over and under the shoulder pads. Overall CPR score, chest compression depth, and ventilation volume were statistically significant when CPR was performed over the equipment. Equipment removal revealed to cause a delay in compression initiation. Although the data from CPR measures suggest the removal of equipment is indicated, the prolonged delay of compressions due to equipment removal should be taken into consideration before establishing best-practice recommendations.

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## CHAPTER 1: INTRODUCTION

### 1.1. Overview of the Problem

In the United States, it is estimated that sudden cardiac arrest affects over 300,000 individuals each year.<sup>1</sup> One population not often considered when discussing cardiac arrest are those who compete in athletics. The National Collegiate Athletic Association (NCAA) approximates the athlete population at around 450,000 athletes in any given year.<sup>2,3</sup> Although sudden cardiac death is rare in athletics, with incidence for sudden cardiac arrest in NCAA athletes approximated to be 1:43,000 per year, it is still a risk athletes face when participating in contact sports.<sup>2</sup> Athletes are exposed to physical contact or blunt force when participating in sports, such as football and hockey, either by other participating athletes or by the equipment involved with the sport. This physical contact can result in impacts taken to the chest, which can contribute to cardiac events. It has also been noted that sudden cardiac death is the leading cause of death during physical exertion, in which 60% of cases occurring while performing exercise.<sup>3</sup> Studies have indicated that physical activities such as sport participation and training increase the risk of sudden cardiac arrest and death 2.4 times to 4.5 times when compared to non-athletes or recreational athletes.<sup>3,4</sup>

Due to the inherent risk of a cardiac event in contact sports, 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 cardiopulmonary resuscitation (CPR) over athletic equipment such as football and lacrosse padding. Athletic trainers work with football athletes of all ages, and are faced with the responsibility of performing life-saving skills such as CPR to those athletes. Thus, it is critical to conduct research that includes ATCs performing CPR over and under football

shoulder pads to establish evidence-based recommendations to enhance the quality of CPR for equipment-laden football athletes.

## **1.2. Statement of Purpose**

The purpose of this research was to determine if certified athletic trainers were able to provide high-quality chest compressions over sport-specific protective athletic equipment, such as football shoulder pads, or if the equipment should be removed prior to initiating lifesaving maneuvers. The secondary purpose was to determine if covariates such as age, body mass index, gender, level of education or number of years of certification impact performance of CPR.

## **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, and percentage of adequate ventilation volume?

Q2: What was 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 football shoulder pads?

## **1.4. Definitions**

Cardiac Arrest: the sudden cessation of mechanical activity in the heart, identified by lack of signs of circulation.<sup>5</sup>

Cardiopulmonary Resuscitation: an emergency life-saving procedure that is performed on an individual when their breathing or heart rhythm has stopped.<sup>6</sup>

Quality of CPR: Quality of CPR, for this study, will be 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 will be used for this study but will not be the primary focus.

### **1.5. Limitations**

The limitations of this study may affect the strength of the results. The first limitation was that chest compressions and rescue breaths were not performed on a human patient; all CPR was simulated on a Q CPR Resusci Anne manikin. Another limitation was the small population recruited for the study, as the participants were certified athletic trainers in the Midwest region of the United States. Rescue breaths were administered to the manikin; however, the manikin was fitted with a football helmet but with the facemask already removed. The only equipment that was incorporated was the Barnett VISION II (Florida, USA) and Gear 2000 Co. Air-Tech (Texas, USA) football shoulder pads. The use of only the selected sport's protective equipment did not allow for the results of the study to be generalized to other sports and their respective equipment.

### **1.6. Delimitations**

Researchers chose to study certified athletic trainers and their ability to provide high-quality CPR due to the lack in current recommendations provided by the National Athletic Trainers' Association and the American Heart Association regarding the performance of CPR over sport-specific protective athletic equipment. To investigate certified athletic trainers' ability to perform high-quality CPR over football shoulder pads, the researchers chose Barnett VISION II football shoulder pads (Florida, USA) and Gear 2000 Co. Air-Tech (Texas, USA) which are commonly worn by athletes.

### **1.7. Assumptions**

Assumptions have been made that performing chest compressions over sport-specific protective athletic equipment on the Q CPR Resusci Anne manikin will mimic a real-life scenario. The manikin was programmed to the 2015 CPR Guidelines as recommended by

the American Heart Association. It was assumed each certified athletic trainer performed CPR to the best of his or her ability during the skill verification portion and data collection.

### **1.8. Variables**

The dependent variables in the current study were: 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. Covariates of this study were: age, gender, level of education, years of CPR certification, years of ATC certification, weight and height. Independent variables were: under or over the football shoulder pads.

### **1.9. Significance of the Current Study**

The average survival rate of cardiac arrest victims in 2017 was reported to be as low as 10.6%.<sup>7</sup> Athletic trainers are required to provide advanced emergency care to athletes. Because the fatality rate of cardiac arrest victims has been approximated at 90%, it is imperative that athletic trainers provide high-quality CPR. Currently there are no recommendations on how to provide care for sport-specific, protective equipment laden athletes in a cardiac emergency with regard to removal of the protective chest equipment. 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 sport-specific protective equipment laden athletes during a cardiac emergency.

## CHAPTER 2: LITERATURE REVIEW

Approximately 350,000 to 400,000 sudden cardiac events occur in the United States annually.<sup>7-10</sup> Sudden cardiac arrest (SCA) occurs when the heart suddenly stops beating. The most commonly displayed variable in the event of a sudden cardiac arrest is an abrupt disorganization of the heart's rhythm, known as ventricular fibrillation.<sup>8</sup> Many of these events will occur in what is known as an out-of-hospital setting. Because they do not occur in the hospital, the likelihood of an individual surviving a sudden cardiac arrest is unlikely. Researchers have reported the rate of survival after a sudden cardiac arrest to be as low as 10.6%.<sup>7</sup>

Sudden cardiac arrest has been observed in the athletic population and has been recorded as the leading cause of sudden death in athletes.<sup>7</sup> When a sudden cardiac arrest occurs, it is critical to initiate appropriate life saving measures, such as cardiopulmonary resuscitation (CPR). Often times, the first medically trained individual on scene at an athletic event is a certified athletic trainer (ATC). The athletic trainer is responsible for initiating high-quality CPR promptly after recognizing a SCA. At events such as football, hockey, or baseball, the athletic trainer must choose whether to perform CPR over protective athletic equipment or remove the equipment to perform CPR directly to the athlete's chest. Currently, neither the American Heart Association (AHA) nor the National Athletic Trainers' Association (NATA) have provided specific guidelines as to whether or not to remove protective equipment prior to initiating CPR efforts. Equipment removal can be time consuming and may impede immediate initiation of CPR, which in turn could potentially lead to a decreased rate of survival for athletes. However, bulky equipment may impede athletic trainers' ability to perform quality CPR in terms of depth and recoil. The purpose of this literature review is to explain the physiology and history of CPR.

Additionally, background of the current research on CPR performance over protective equipment will be presented.

## **2.1. Physiology of CPR**

CPR is a skill that combines lung inflation and chest compressions to assist in restoring perfusion and oxygenation to the body of individuals experiencing SCA.<sup>7</sup> The science of CPR is relatively new, with the term “CPR” being published approximately 60 years ago.<sup>11</sup> There are two main components of CPR: chest compressions and ventilations. The two components play an important role in performing high-quality CPR, and like many other medical techniques, have changed over time. The physiology of why these two components are critical to restoring perfusion and oxygenation in the body are important to gain an appreciation of CPR.

### **2.1.1. Physiology of Compressions**

When the rescuer applies force on the patient’s chest, the heart is squeezed between the sternum and the spine. The force creates increased intrathoracic pressure, or pressure within the pleural cavity within the chest. The pleural cavity is the fluid-filled space between the lungs. When the intrathoracic pressure is increased, it results in a greater aortic and right atrial pressure.<sup>12</sup> Due to the pressure increase in the chest, blood is forced forward from the heart to the brain, coronary arteries, and remainder of the body as a result of the one-way valves inside of the heart and the resulting pressure differences between the thorax and non-thorax regions of the body.<sup>12</sup>

Once the pressure from the rescuer’s hands is released, the decompression phase begins. In this phase, the heart refills the blood that was previously expelled. The pressure that is created during the decompression phase is known as coronary perfusion pressure (CPP). CPP is largely responsible for myocardial blood flow, which is an important factor for successful resuscitation.<sup>13</sup> CPP is determined by taking the difference of aortic diastolic

pressure and right atrial pressure of the heart. The blood flow that is generated during these cycles of external chest compressions only consist of about one-third of the normal cardiac output.<sup>14</sup> Because there is a minimal amount of blood circulated through the body during external chest compressions, it is important to understand the physiological effects compressions have on successful resuscitation to optimize performance and effectively utilize the blood that is present.

There has been speculation as to which physiological process is responsible for blood flow during CPR. Some researchers believe the thoracic pump theory is responsible while others support the cardiac pump theory. The thoracic pump theory relies on the idea of intrathecal pressure driving blood to and from the body, whereas the cardiac pump theory indicates compression of the heart between the anatomical structures of the body is responsible for this action. Researchers have hypothesized if the heart acts as a pump, then the proximal descending thoracic aorta would be constricted when compressions are performed.<sup>15</sup> The constriction may result in the proximal descending aorta becoming blocked, resulting in a decreased amount of blood flow during compressions. If this occurs, adequate blood circulation would be unable to occur.

To test their hypothesis, researchers analyzed 14 patients experiencing cardiac arrest. CPR was performed in accordance with the 2000 AHA guidelines; 80 compressions per minute, ventilations with 100% oxygen by a self-inflated bag, and 1 milligram of epinephrine injected every three minutes.<sup>15</sup> To examine the heart during CPR, the researchers implemented an imaging technique known as transesophageal echocardiography (TEE). The TEE was performed during CPR after the completion of tracheal intubation and injection of the first dose of epinephrine. Once the TEE was applied, the probe was guided into the heart. Several areas were examined in the heart: the left atrium and left ventricle to inspect mitral and aortic valve closure, four chamber view

to analyze the left ventricle compression, longitudinal view of the descending thoracic aorta to identify the area of maximal compression, a horizontal view to observe for deformation and measurement of the aorta, and the descending thoracic aorta to determine the point of maximal compression.<sup>15</sup> If a morphological abnormality was identified during the TEE, the patient was excluded from analysis in the study.

The researchers discovered at the point of maximal compression, deformation of the descending thoracic aorta was present in all patients. The deformation ratio of the descending thoracic aorta was found to decrease during compressions as compared to the relaxation phase ( $0.58 \pm 0.15$  mm vs  $0.81 \pm 0.11$  mm,  $p=0.001$ ). The findings allowed researchers to determine eccentric compression of the descending thoracic aorta occurs during external chest compressions.<sup>15</sup> The eccentric compression likely occurs due to the heart becoming displaced posteriorly when the sternum is compressed, causing the displaced heart to compress the descending thoracic aorta. At the point proximal to the maximal compression site, the researchers observed an increase of the cross-sectional area of the descending thoracic aorta ( $15 \pm 12\%$  increase) during the compression phase as compared to the relaxation phase in twelve patients.<sup>15</sup> The cross-sectional increase results in the dilation of the proximal descending aorta during compressions, which suggests aortic volume increases as a result of blood flowing from the heart into the aorta during the compression phase. Researchers' analyses support the idea of the cardiac pump theory of forward blood flow is caused by direct compression of the heart between the sternum and the spine. The findings allowed researchers to determine the cardiac pump theory is the dominant mechanism in creating blood flow during compressions as compared to the thoracic pump theory. The cardiac pump theory supported the change to an increased compression rate to improve circulation of blood in the body during CPR.<sup>15</sup>

### 2.1.2. Physiology of Ventilations

To achieve adequate gas exchange during CPR, ventilations must be incorporated. The need for gas exchange increases the longer CPR administration is prolonged. Ventilations work to inflate the lungs, bring oxygen into the lungs, and allows for oxygen to be dispersed throughout the body.<sup>16</sup> One complication that can occur when administering ventilations is hyperventilation. Hyperventilation results in negative effects on return of spontaneous circulation (ROSC) and survival rates. In one study, researchers observed a group of physicians and paramedics performing CPR on out-of-hospital cardiac arrest patients.<sup>16</sup> The goal of the study was to analyze the average ventilation rate and duration performed by trained rescuers performing CPR. Ventilations were recorded using a portable pressure monitor (Propaq) until all resuscitation efforts were discontinued. A total of thirteen patients were observed during this study. The first seven patients in which data were collected revealed that the physicians and paramedics were hyperventilating the patients at an alarming rate ( $34 \pm 4$  breaths per minute). The result of excessive hyperventilation called for a pause in data collection to retrain these individuals and instruct proper ventilations be performed at a rate of twelve breaths per minute. The remaining six patients saw a decrease in breaths being performed per minute ( $22 \pm 3$  breaths per minute), but hyperventilation still occurred.<sup>16</sup> To achieve proper ventilation rates during CPR, it is important to stress proper training and adherence to the guidelines presented by the AHA.

It can be challenging to determine if CPR is being administered effectively to patients. One way to combat this challenge is to measure end-tidal carbon dioxide (ETCO<sub>2</sub>). Carbon dioxide is created in healthy tissues and is transported to the alveoli where it is then expired.<sup>13</sup> The peak ETCO<sub>2</sub> values often occur just prior to inspiration of air after the alveoli have emptied and partial pressure of carbon dioxide (35-45 mmHg) is achieved.<sup>13</sup> A

group of researchers sought to analyze the effects of ETCO<sub>2</sub> measurement to determine if adequate CPR could be performed. The researchers analyzed thirteen in-hospital cardiac arrest patients.<sup>17</sup> The patients received 60 mechanical compressions per minute as well as 1,200 ml of oxygen administered via a bag-valve-mask every fifth compression. To collect ETCO<sub>2</sub> data, concentration of expired carbon dioxide was recorded continuously with an infrared absorption carbon dioxide analyzer (Model 200).<sup>17</sup> Out of the thirteen observed cardiac arrests, seven were successful resuscitations. The researchers collected and analyzed ETCO<sub>2</sub> data for both the resuscitated and non-resuscitated patients at the onset of the cardiac event and 30 seconds after CPR was initiated. The results from the study are displayed in Table 1 below.

**Table 1.** ETCO<sub>2</sub> During Episodes of Cardiac Arrest

	Before Arrest		During Arrest	During Precordial Compression				At Resuscitation		At ROSC
<b>Number of Minutes</b>	2	1	0	1	2	4	8	--	4	>8
<b>Resuscitated Patients (n = 7)</b>	1.5±1.3	1.4±1.0	0.5±0.2	1.0±0.5	1.2±0.3	--	--	3.7±2.1	2.4±1.8	2.6±2.0
<b>Nonresuscitated Patients (n = 6)</b>	1.3±0.5	1.2±0.6	0.3±0.5	0.7±0.8	0.7±0.5	0.8±0.6	0.7±0.4	--	--	--

The results displayed in the table indicate a decrease in ETCO<sub>2</sub> as measured in L/min result in a greater chance of nonresuscitation. The individuals with a higher ETCO<sub>2</sub> value had a greater chance of resuscitation. The researchers concluded from this study that ETCO<sub>2</sub> can be a reliable method to monitor for CPR effectiveness and ROSC likelihood.<sup>17</sup> The AHA has also approved the use of ETCO<sub>2</sub> as a non-invasive physiological measure of CPR effectiveness.<sup>18</sup>

### 2.1.3. Physiological Advancements

As research continues to advance, different techniques have emerged as potential methods to determine effective, high-quality CPR and ensure that both lay public and



healthcare providers are utilizing the appropriate resuscitation techniques. One of these methods is known as cerebral oximetry. Cerebral oximetry utilizes oxygen saturation levels of the brain tissue to determine if adequate cerebral perfusion is achieved during the performance of CPR.<sup>13</sup> The cerebral oximetry technique employs noninvasive methods, which uses near-infrared light to measure brain tissue perfusion. The change in light intensity and the brain's light absorption characteristics operate to collect regional brain tissue oxygen saturation (rSO<sub>2</sub>).<sup>13</sup> The measurement of rSO<sub>2</sub> results from nonpulsatile blood flow, which consists of venous blood found in the cerebral microvasculature. The normative rSO<sub>2</sub> values are approximately 70%.<sup>13</sup> Researchers have discovered supporting evidence for the implementation of cerebral oximetry to predict if an individual is going to have a positive outcome from CPR performance. In the study, 183 patients experiencing cardiac arrest were observed using cerebral oximetry while CPR was being administered.<sup>19</sup> Out of all 183 patients, 62 (33.9%) achieved a sustained ROSC. Patients were allocated into four categories based on the outcomes after CPR: ROSC, survival with favorable neurological outcomes (CPC 1-2), unfavorable neurological outcomes (CPC 3-5), or no ROSC. The four groups were then analyzed for six variables: mean and median rSO<sub>2</sub> during resuscitation, mean and median rSO<sub>2</sub> in the last five minutes of resuscitation, percentage of time with rSO<sub>2</sub> above 50%, and percentage of time in the last five minutes with rSO<sub>2</sub> above 50%.<sup>19</sup> In all six observed variables, the ROSC group had higher cerebral oximetry values than that of the no ROSC group (p<0.001). When comparing the CPC 1-2 group with the CPC 3-5 group, the CPC 1-2 also showed increased outcomes (p<0.001 or p=0.001) over all six variables.<sup>19</sup> With these results, researchers are able to conclude that cerebral oximetry allows clinicians to monitor cerebral oxygenation effectively during the performance of CPR. It should also be noted that a higher level of cerebral oxygenation is associated with ROSC and neurologically favorable outcomes. Through the use of cerebral oximetry, it may

be possible to assure CPR is being performed accurately in every patient. Cerebral oximetry measurements can also be used to study the performance of CPR and help determine how CPR should be performed to achieve positive resuscitation results. This resource, however, is not readily available to athletic trainers or a lay person performing CPR in the out-of-hospital setting.

While brain oxygenation can be implemented as an effective measurement for CPR, another important measurement is coronary perfusion pressure (CPP). CPP is the pressure gradient found between the aorta and the right atrium and occurs during the relaxation phase of the heart.<sup>20</sup> To examine CPP values in patients experiencing cardiac arrest, researchers collected data from physicians in the hospital setting. A total of 100 patients experiencing cardiac arrest were included in the study. CPR was performed through the use of a mechanical compression device. The researchers placed two catheters to measure CPP in the patients; one in the right atrium and one in the aorta. CPP was calculated by subtracting the right atrium pressure from the aortic pressure for five consecutive relaxation phases and then taking the mean of that value.<sup>20</sup> Of the 100 patients, only 24 had ROSC and only 20 of those experienced ROSC for longer than one hour. The researchers collected data points to compare those who experienced ROSC and those who did not. The results are displayed in Table 2 below.

**Table 2.** CPP Values During CPR

	ROSC (mmHg)	No ROSC (mmHg)	p-value
Initial CPP	13.4 ± 8.5	1.6 ± 8.5	p<0.0001
Max CPP	26.6 ± 7.7	8.4 ± 10.1	p<0.0001
5 min after CPR CPP	16.6 ± 10	2.0 ± 9.6	p=0.0001

The patients who did not reach at least 15 mmHg during their max CPP did not achieve ROSC. The results reveal a significant difference between those that experienced

ROSC and those who did not. After analyzing the data, the researchers determined that maximal CPP was an accurate measure of ROSC during CPR ( $p < 0.0001$ ).<sup>20</sup> The researchers also revealed a strong correlation between the initial CPP and the max CPP ( $r = .74$ ). Therefore the initial CPP can also be considered a strong predictor for ROSC. CPP should be used as a clinical prediction tool to help ensure effective CPR is being performed. It can also be used in the future to assist in determining the ideal application of CPR to improve survival rates after experiencing a cardiac event.

## **2.2. History of CPR Prior to 1995**

The physiology behind CPR is vital to know and understand to administer the emergency intervention effectively and efficiently. When the physiology is understood, it also becomes easier to change best-practice recommendations for CPR performance. CPR is comprised of two key elements, and the first of which is known as ventilations. One of the first research-based approaches to ventilations was performed by a scientist named Andreas Vesalius in 1543.<sup>10</sup> Vesalius reported reviving animals who had suffered cardiac arrest was possible through the act of blowing air through a reed placed in the trachea.<sup>10</sup> While this discovery was an important finding, it was not immediately implemented into the performance of life-saving maneuvers.

The technique of ventilation administration remained seemingly unchanged for many years. The standard maneuver for ventilation administration during the time spanning from the 19<sup>th</sup> century until 1958 was known as artificial ventilations.<sup>21</sup> Artificial ventilations are performed by the rescuer pressing down on the patient's chest and/or back and then lifting the patient's arms, causing an exhalation of air from the lungs followed by an inhalation.<sup>21</sup> While artificial ventilations are less invasive, the rate of success is relatively low. One group of researchers sought to determine if proper ventilations could be performed artificially using the chest-pressure and arm-lift methods, or if it was necessary

to perform mouth-to-mouth or mouth-to-airway ventilations.<sup>22</sup> To determine which method was most effective at delivery proper ventilations, the researchers took recordings of the tidal volumes produced when ventilations were administered in the various positions. Tidal volume represents the normal volume of air displaced between normal inhalation and exhalation when extra effort is not applied. Measurements were obtained by researchers performing the chest-pressure method, the arm-lift method, the mouth-to-mouth method, and the mouth-to-airway method of ventilations. In each position, the patient’s airway was maintained patent by one researcher holding the head in neck extension with the application of an endotracheal tube.<sup>22</sup> Measurements of tidal volume were also recorded when the head was positioned in a neutral, flexed position. The results collected from the study are displayed in Table 3 below.

**Table 3.** Tidal Volumes during CPR Compression Maneuvers

	<b>Back-Pressure Arm-Lift (Ext)</b>	<b>Back-Pressure Arm-Lift (Natural)</b>	<b>Chest-Pressure Arm-Lift (Ext)</b>	<b>Chest-Pressure Arm-Lift (Natural)</b>	<b>Mouth-To Mouth/Mouth-to-Airway</b>
Average Tidal Volume (ml)	8	0	N/A	0	1,500
Tidal Volume Range (ml)	0-60	0-0	N/A	0-0	1000-2000

As displayed, the chest-pressure method had dismal results for overall tidal volume with and without an endotracheal tube in both neck flexion and extension. To achieve proper ventilation, the normal ventilation tidal volume should be approximately 600 mL, which equates to approximately 8 mL/kg for most adults.<sup>12</sup> To achieve a rate of hyperventilation, tidal volumes must be at least 1,000 milliliters.<sup>23</sup> Based on the results displayed in Table 3, the arm-lift maneuver failed to achieve these values. Thus, it was concluded the chest-pressure and arm-lift methods of artificial ventilation should be

discontinued, and the mouth-to-mouth or mouth-to-airway methods should be adopted into the CPR algorithm. The AHA suggested a change for CPR instructors to become comfortable teaching the mouth-to-mouth technique at the 1992 conference, but it was not until the release of the 2000 AHA guidelines that this became a best-practice recommendation.<sup>24,25</sup>

The use of artificial ventilations came to a stand-still when researchers discovered opening the airway was vital to performing quality ventilations<sup>26</sup> In 1959, Safar et al found to open the airway, the rescuer must tilt the head backwards and displace the patient's jaw forward to prevent possible soft tissue obstruction.<sup>22,26</sup> Research was performed to study which method of opening an airway is most effective when administering ventilations during CPR. To observe the opening of the airway, researchers implemented the use of roentgenograms, more commonly known as x-rays.<sup>27</sup> One group of researchers analyzed the airway opening of ten adult patients while utilizing seven different techniques. The first group was considered the control group in the study. The first group remained conscious during the procedure, whereas participants in all other groups were placed under anesthesia. The head and neck of the first group remained in a neutral position with the participant's mouth closed. The second group's head and neck also remained in a neutral position with the participant's mouth closed while the patient was placed under anesthesia. The third position placed the participant's head and neck in maximal extension with the mouth open. The fourth position also placed the participant's head and neck in maximal extension, but the mouth was manually closed. For the fifth position, the researchers wanted to analyze the participant's head and neck in full extension, the mouth manually closed, and the occiput lowered by placing a three-inch pad under the shoulders. The sixth position had the participant's head and neck in maximal extension, the mouth closed, and the occiput elevated using a three-inch pad. The seventh and final position had the

participant's head and neck in a neutral position, while the mandible was displaced forward by an examiner grasping the chin, and the mouth slightly open.<sup>27</sup> Once the participants were placed into each position, an x-ray image was obtained. The following measurements were recorded from the image: clearance space between the tongue and the posterior pharyngeal wall, smallest clearance between the epiglottis and the posterior pharyngeal wall, and smallest clearance between the soft palate and posterior pharyngeal wall.<sup>27</sup> The findings are displayed in Table 4, 5, and 6 below.

**Table 4.** Hypopharynx. Smallest Clearance Between Tongue and Posterior Pharyngeal Wall (Millimeters)

Patient (Pt)	Position 1	Position 2	Position 3	Position 4	Position 5	Position 6	Position 7
Pt 1	8.0	4.5	12.0	17.5	N/A	15.5	10.0
Pt 2	4.5	0	2.0	5.0	8.0	5.5	0
Pt 3	14.0	7.5	14.5	18.0	19.5	19.5	0
Pt 4	9.0	0	13.5	18.5	11.5	17.0	3.5
Pt 5	14.0	17.5	20.5	25.0	22.5	23.0	20.0
Pt 6	8.5	8.0	14.0	20.0	17.5	20.0	19.0
Pt 7	14.0	9.0	11.0	17.0	18.0	15.0	18.0
Pt 8	7.5	0	3.0	11.0	11.0	16.0	9.0
Pt 9	11.5	6.0	10.5	22.0	16.5	21.0	0
Pt 10	14.0	10.5	10.0	21.5	24.5	N/A	18.0
Avg Range	4.5-14.0	0-10.5	2.0-20.5	5.0-25.0	8.0-24.5	5.5-23.0	0-20.0

**Table 5.** Hypopharynx. Smallest Clearance Between Epiglottis and Posterior Pharyngeal Wall (Millimeters)

Patient (Pt)	Position 1	Position 2	Position 3	Position 4	Position 5	Position 6	Position 7
Pt 1	6.0	0	16.0	23.0	N/A	20.5	0
Pt 2	0	0	1.5	9.5	11.5	10.0	0
Pt 3	9.0	5.0	10.5	18.0	18.0	19.5	0
Pt 4	5.0	0	14.0	23.0	10.5	21.0	0
Pt 5	10.0	11.0	14.0	21.0	21.0	21.5	13.0
Pt 6	4.5	5.5	9.5	15.0	13.0	16.0	13.0
Pt 7	6.5	0	7.0	13.0	11.5	13.0	8
Pt 8	5.0	0	5.5	16.0	16.0	24.0	15.5
Pt 9	3.0	2.0	3.5	16.5	13.5	13.0	0
Pt 10	5.5	5.0	7.5	13.5	16.0	N/A	8.0
Avg Range	0-10.0	0-5.5	1.5-16.0	9.5-23.0	10.5-21.0	10.0-24.0	0-15.5

**Table 6.** Nasopharynx. Smallest Clearance Between Soft Palate and Posterior Pharyngeal Wall (Millimeters)

Patient (Pt)	Position 1	Position 2	Position 3	Position 4	Position 5	Position 6	Position 7
Pt 1	0	0	5.0	5.0	N/A	7.0	0
Pt 2	0	0	0	0	0	0	0
Pt 3	7.0	4.5	6.5	6.5	6.0	6.0	0
Pt 4	5.0	0	6.5	8.0	7.0	9.0	8.0
Pt 5	6.0	9.0	N/A	10.0	10.0	N/A	8.0
Pt 6	9.5	9.0	7.0	9.0	9.0	10.0	11.0
Pt 7	9.0	0	3.0	6.0	6.5	7.0	11.5
Pt 8	0	0	0	0	0	0	0
Pt 9	5.0	3.0	N/A	5.0	7.0	7.0	0
Pt 10	10.0	6.0	6.5	8.0	9.5	N/A	9.5
Avg Range	0-10.0	0-9.0	0-7.0	0-10.0	0-10.0	0-10.0	0-11.0

Researchers discovered the head-tilt maneuver always produced a patent airway as compared to the forward displacement of the mandible, also known as the jaw-thrust maneuver.<sup>22</sup> Based on this finding, researchers determined that the head-tilt maneuver outperformed the other positions to opening the patient’s airway. While in certain

circumstances the jaw-thrust maneuver is preferred, the head-tilt maneuver has been shown to be more effective in ensuring a patent airway to administer rescue ventilations. The findings highlighting the effectiveness of the head-tilt chin-lift maneuver to deliver ventilations support the implementation of this technique into the practice of CPR.

The second aspect of CPR is compressions. The original compression technique was performed in an open chest.<sup>28</sup> In 1874, a German physiologist by name the of Moritz Schiff first discussed a term that came to be known as “cardiac massage” when he noticed a carotid pulse after manually grasping a canine heart using the open-chest method of compressions.<sup>28</sup> The concept of open cardiac massage was the standard for compressions until 1892 when a student named Friedrich Maass performed the first successful closed-chest cardiac massage on a human.<sup>28</sup> The original idea was compressions should be performed at a rate of 30-40 compressions per minute, but better overall outcomes were observed with the cardiac arrest victim when Maass pushed at a faster rate, which was closer to 120 compressions per minute.<sup>28</sup> While these findings proved to be imperative to the modern day application of chest compressions, the discovery did not receive international acceptance. The lack of acceptance delayed the progression of chest compression performance, and the practice went relatively unchanged for many years. It was not until Guy Knickerbocker rediscovered the idea of closed-chest cardiac massage when he applied direct pressure through the electrode paddles against the thorax of dogs during defibrillation and observed a resulting increase in arterial pressure.<sup>29</sup> The rediscovery helped guide more researchers to direct their focus to the potential of utilizing closed-chest cardiac massage as a viable option in resuscitation.

In 1960, William Kouwenhoven and his team performed a study to analyze the idea of closed-chest cardiac massage. In their study, 20 patients experiencing a sudden cardiac arrest were treated using an external cardiac massage while the patient was supine.<sup>29</sup> Once



supine, the researchers placed the heel of one hand placed on the sternum, with the other hand then placed directly on top of the first hand. Downward force was then applied at a rate of 60 times per minute.<sup>29</sup> The researchers were instructed to allow for slight release of pressure between each downward compression to allow chest expansion between each compression. The ideal compression depth was three to four centimeters.<sup>29</sup> After data analysis, the researchers discovered they had achieved a 70% success rate of resuscitation by using this method of external cardiac massage.<sup>29</sup> The findings of Kowenhoven's study revealed manual external compressions can be a valuable tool in the resuscitation of individuals experiencing cardiac arrest. The same year, Safar et al gave one of the first public descriptions of CPR, and the AHA began training medical professionals how to perform CPR.<sup>30</sup>

After the public description from Safar et al and the implementation of proper CPR training to medical professionals, it was imperative to create a device to assist in the instruction of CPR performance. Thus, in 1966, guidelines released on the training of CPR encouraged practice with the use of mannequins.<sup>10</sup> One of the first mannequins used to demonstrate and perform resuscitation techniques was created by Asmund Laerdal. Laerdal owned and operated a plastic-toy company, which manufactured a popular doll named Anne.<sup>10</sup> In his factory, he began making mannequins used for CPR training, which came to be known as "Resusci Anne".<sup>10</sup> Many of the mannequins currently used today still don the name "Resusci Anne" and thus Laerdal's creation has lived on in the CPR industry.

As the years progressed, changes in rate and depth of compressions were also considered. In 1992, the AHA published guidelines indicating closed-chest compressions should be performed at a rate of 60 per minute with a depth of 3.8 to 5 centimeters to achieve optimal results during CPR.<sup>30</sup> The guidelines were published because they were thought to show improvement in circulation, even though the thoracic pump and cardiac

pump theory had been well established. The newly established guidelines provided set standards to continue to improve the quality of CPR being administered to patients in cardiac arrest.

Along with research on compression rate and depth, findings relating to hand position were outlined. Proper positioning of the hands to perform optimal chest compressions had the fingers hyperextended with pressure of the compressions delivered with the heel of both hands.<sup>31</sup> It has also been suggested that the rescuer's shoulders should be positioned directly over the sternum of the patient, with extended elbows, and knees at the level of the patient's mid chest. The results regarding proper rescuer positioning were established on the findings of improper positioning decreasing efficiency and promoting early and excessive rescuer fatigue.<sup>31</sup> The information has helped researchers develop proper rescuer positioning to administer quality CPR, and has also opened the door for continued research on the topic.

In 1992, the researchers for the AHA observed improved survival rates and perfusion results with a compression rate between 80 to 100 compressions per minute.<sup>24</sup> The finding resulted in the creation of new guidelines, which changed the standard of 60 compressions per minute to 80 to 100 compressions per minute. The increase in rate of compression delivery was needed to improve circulation, and the increased compression rate seemed to allow for a pause to administer ventilations without experiencing negative resulting effects.<sup>30</sup>

### **2.2.1. CPR History 2000-2004**

Over time the proper administration of compressions and ventilations as a whole has been taken into consideration. The ratio between compressions and ventilations up to this point was set at 5:1.<sup>7</sup> The ratio means for every five compressions performed, one ventilation was also administered. The release of the 2000 AHA CPR guidelines made a

change from a 5:1 ratio to a 15:2 ratio.<sup>7,25</sup> The guidelines were increased because researchers had observed an increase in positive patient outcomes with a greater number of compressions at a given time. To test the differences between the 5:1 and the 15:2 methods, researchers observed seventeen paramedic students who had just completed a 30-hour certification course.<sup>32</sup> The paramedics each were instructed to act once as rescuer one and then once as rescuer two for both protocols, for a total of four completed CPR scenarios. The pairs were instructed to perform CPR until the completion of intubation, intravenous medication administration, and application of a shock from the defibrillator. CPR was performed on the Ambu Mega Code Trainer and collected data with a computer system.<sup>32</sup> The participants were also recorded on two video cameras in the room to collect additional data during the study. The researchers discovered there were significantly less CPR cycles required when performing the 15:2 method as compared to the 5:1 method (5:1=3.0 cycles, 15:2=1.75 cycles,  $p=0.0000$ ).<sup>32</sup> A decrease in the number of cycles performed also decreases the amount of time spent performing ventilations, which in turn increases the amount of compressions. The researchers noted there were no significant differences in the quality of CPR performed between the two methods. However, the researchers did note a decreased time interval between the start of compressions and the transition to ventricular defibrillation in the 15:2 group (5:1=125 ± 16 seconds, 15:2=90 ± 15 seconds,  $p=0.0001$ ).<sup>32</sup> Through these results, the researchers were able to conclude that the 15:2 method was proven to be an effective, time-saving method to perform CPR without risking dismal outcomes on resuscitation. This is the only human study the AHA cites when discussing the transition to the 15:2 compression-to-ventilation ratio. The AHA also discusses a study that uses pigs as their model. In this study, researchers analyzed 10 pigs that received compression-only CPR and 10 that received the AHA recommended 15:2 compression-to-ventilation ratio.<sup>33</sup> Based on the findings, no significant differences were noted between the

two groups for survival rates. With the limited research supporting the change from 5:1 to 15:2, more research needed to be performed to further the advancement of compression-to-ventilation ratio to maximize survival rates of patients experiencing cardiac arrest.

### **2.2.2. CPR History 2005-2009**

In 2005, the AHA published new guidelines advocating for the change of several aspects of CPR. The application of compressions was to be performed at a rate of at least 100 compressions per minute with very few interruptions for pulse checks or ventilations.<sup>34</sup> The guideline altered the wording from the set of guidelines released in 2000 by changing “approximately” to “at least”.<sup>34</sup> The new wording established a lower rate at which compressions should be performed. Limiting the time between compressions was found to have better perfusion rates, which correlated with improved ROSC rates.<sup>34</sup> Based on the data findings, the AHA made the change to the guidelines to improve overall compression rate quality.

Although advancements in research and guideline changes had occurred, researchers continued to analyze the effect of incomplete chest wall recoil. In 2005, researchers recruited 30 emergency service (EMS) personnel who were retrained in CPR with a focus on allowing for complete chest wall recoil between compressions.<sup>35</sup> The EMS personnel were instructed to perform CPR over a Laerdal Skill Reporter CPR manikin for three minutes. The AHA guidelines for adequate depth, between 38 and 51 millimeters, were used in this study, and any compression that did not return within two millimeters of the baseline measurement were considered an incomplete decompression of the chest wall. Based on the results, the participants only achieved complete chest recoil in 16.3% of compressions.<sup>35</sup> It was also observed that incomplete chest wall decompression occurred during CPR efforts in 6 out of the 13 (46%) cardiac arrest scenarios completed by the EMS personnel.<sup>35</sup> The participants were asked to complete a self-reported survey following

completion of CPR in which the participants significantly over-estimated the percentage of time they had achieved complete chest wall recoil ( $p=0.020$ ). While the researchers had strong findings, their small participant population is a limitation to the study.

The AHA guidelines released in 2005 also provided a change to the performance of ventilations as compared to the guidelines from 2000. The 2005 AHA guidelines on the administration of ventilations state the maneuver for opening the airway should be performed is the head-tilt chin-lift technique, unless trauma is suspected, in which case the jaw-thrust maneuver should be applied to protect the cervical spine.<sup>34</sup> The AHA also recommended two rescue breaths be applied over a time period of one second per breath, for a total of ten to twelve breaths per minute.<sup>34</sup> If an advanced airway is applied, then the recommended breaths to be administered was noted at eight to ten per minute.<sup>34</sup> The changes to the guidelines over the five-year span allowed for improved application of ventilations when performing CPR.

In 2006, the AHA changed the recommended ratio from 15:2 to 30:2 in adult patients.<sup>7</sup> The change, however, was not released as a standard guideline until the new guidelines were released in 2010.<sup>18</sup> The recommendation for this ratio change was supported in a research study in which researchers collected twenty pigs and observed the effects of differing compression-to-ventilations ratios when performing CPR.<sup>36</sup> The hearts of 20 pigs were changed from normal rhythm to ventricular fibrillation. The ventricular fibrillation was left untreated for a total of six minutes followed by the application of CPR. When CPR was initiated, it was administered via a pneumatically driven automatic piston device for six minutes, while randomly implementing either the 15:2 or the 30:2 compression-to-ventilation technique. Researchers discovered when increasing the ratio from 15:2 to 30:2, there was a significant decrease in the time in which no compressions were being performed ( $20.33 \pm 1.44$  to  $9.6 \pm 0.96$  secs/min,  $p<0.0001$ ).<sup>36</sup> The 30:2 ratio also

revealed improvement in diastolic aortic pressure ( $20 \pm 1$  to  $26 \pm 1$  mmHg,  $p < 0.001$ ) and a significant improvement in coronary and cerebral perfusion pressures ( $p < 0.05$ ).<sup>36</sup> Because positive outcomes were viewed using an increased compression rate in the compression:ventilation ratio with little negative effect, the guidelines were changed by the AHA. The limitations to this study include the test subjects being pig models and the use of a piston to administer compressions. It is difficult to generalize the results found in animal subjects to human subjects. By using a piston to administer compressions, the implications of human error and fatigue cannot be observed and directly compared to the human performance of chest compressions. The AHA made the change to a 30:2 compression-to-ventilation ratio without any clear evidence found on humans.

### **2.2.3. CPR History 2010-2014**

In the 2010 AHA guidelines, head positioning and breath duration remained unchanged.<sup>18</sup> The only change made over the five year period was the specification of one breath being administered over six to eight seconds, for a total of eight to ten breaths per minute.<sup>18</sup> The 2005 guidelines stated eight to ten breaths should be administered every minute, while having no specification on duration of the breath.<sup>34</sup> The specification allows for a set amount of time required to administer a ventilation breath, which can decrease the overall pause in compression application.

While there has been an emphasis to decrease the time needed to administer ventilations during CPR, there has not been an abundance of research conducted on the topic. Researchers observed recordings of patients who experienced an out-of-hospital cardiac arrest and compiled a data set of 199 results.<sup>37</sup> The researchers analyzed the data and obtained information regarding the duration of ventilations during the performance of CPR. Information was recorded for the time period when the rescuers were not performing compressions and were presumably performing ventilations.<sup>37</sup> During the analysis of the

collected data, the researchers discovered 81% of the mean compression rate was above the minimum guideline of 100 compressions per minute.<sup>37</sup> The median time for compression interruptions to administer two rescue ventilations was seven seconds (25<sup>th</sup>-75<sup>th</sup> percentile, 6-9 seconds).<sup>37</sup> When combining the two values, the researchers were able to conclude the majority of the rescuers were able to deliver two rescue breaths under ten seconds while also delivering at least 70 compressions per minute.<sup>37</sup> The findings assisted the researchers conclude rescuers performing CPR are able to deliver an adequate number of effective compressions while also delivering two rescue breaths without an adverse outcome.<sup>37</sup> Timing of ventilation administration is an important factor for developing a process to deliver adequate and successful CPR. While the findings from this study help support the implementation of mouth-to-mouth or mouth-to-airway ventilations over the standard time frames, more research needs to be performed to reveal the overall success of CPR when performing these various techniques.

Along with changes made to ventilations with the new 2010 AHA guidelines, alterations were made regarding the order of priorities for CPR. The order of priorities is a list of steps that should be taken at the scene of a cardiac event. From the year 1960 until 2010, the order of priorities remained the same. The order of priorities was listed as an acronym known as ABC: airway, breathing, and circulation.<sup>21</sup> This meant an airway should be established first and foremost when treating patients in cardiac arrest, followed by administering ventilations, and finally administering compressions. The “Chain of Survival” was changed in 2010 when the AHA and the International Liaison Committee on Resuscitation (ILCOR) changed to CAB: compressions, airway, and breathing.<sup>18,21</sup> The update allowed for the immediate application of chest compressions after establishing a patient is experiencing a cardiac arrest. To provide evidence-based results to support this adjustment, researchers recruited 108 teams, which consisted of either two general practice

doctors and one nurse or two internal medicine doctors or doctors who were in a sub-specialty of internal medicine and one nurse.<sup>38</sup> The participants were instructed to perform cycles of compressions on a Human Patient Simulator manikin following the 30:2 compression to ventilation ratio for at least one complete cycle. The participating teams were split into 53 performing the ABC technique and 55 performing the CAB technique. Each group was provided a flow chart card that described how to perform the technique their group was selected to perform. The researchers analyzed the time to completion of the first cycle and overall accuracy and performance of the techniques. The time for each CPR cycle began when one of the participants touched the patient and ended when the first CPR cycle (30 compressions, two ventilations) was completed. The researchers observed the average time of completion of the first CPR cycle was  $63 \pm 17$  seconds in the group performing the ABC technique, and  $48 \pm 10$  seconds in the CAB group ( $p < 0.0001$ ).<sup>38</sup> A breakdown of the recorded time during the first CPR cycle is displayed in Table 7 below. Based on these findings, the researchers determined that the CAB technique was performed at a more efficient rate than the ABC technique likely due to the delay in start and completion of the first CPR cycle in the ABC group.

**Table 7.** Timing of First CPR Cycle

	ABC (n=53)	CAB (n=55)	p-value
Check airway (sec)	$8 \pm 6$	$7 \pm 8$	0.79
Check pulse (sec)	$16 \pm 13$	$8 \pm 6$	0.0001
Start of rescue breaths (sec)	$37 \pm 15$	$43 \pm 10$	0.005
Start of cardiac massage (sec)	$43 \pm 16$	$25 \pm 9$	0.0001
Start of first 30:2 cycle (sec)	$32 \pm 12$	$25 \pm 10$	0.002
Length of first 30:2 cycle (sec)	$31 \pm 13$	$23 \pm 6$	0.0001
End of first 30:2 cycle (sec)	$63 \pm 17$	$48 \pm 10$	0.0001

Data (means  $\pm$  SD) are time intervals between time 0, defined as first touch of the patient by one of the rescuers and the occurrence of the event specified.



The 2010 guidelines also minimized the importance of pausing to check for a pulse in an effort to reduce compression interruptions. New research was released recommending the rescuer spend no more than a total of 10 seconds palpating for a pulse.<sup>18</sup> Over time, there has been some speculation regarding accurate and timely pulse checks performed by rescuers in the event of a cardiac arrest. Researchers have developed studies to analyze if the guidelines provided by the AHA are realistic and achievable by the rescue. To observe how quickly a carotid pulse could be detected, researchers recruited 449 lay persons.<sup>39</sup> The lay person group consisted of 168 participants who had just finished first aid courses totaling 16 hours, 202 participants directly after completing an eight hour first aid course, and 79 volunteers. The participants were asked to identify the carotid pulse on a young, healthy subject.<sup>39</sup> The participants were recorded via stopwatch from the first contact with the subject's skin until correct detection of the carotid pulse. The average time the participants' needed to detect the subject's carotid pulse was 9.46 seconds (1-70 second range).<sup>39</sup> Based on the results, the researchers also determined that only 47% of the participants detected the pulse within five seconds, 74% detected it within ten seconds, and 2% were unable to detect a pulse at all. The findings of this study raise questions as to the rescuer's ability to determine the presence or absence of a carotid pulse, which can cause a delay in the administration of CPR. The time required to determine if a cardiac arrest victim is pulseless or not is a vital piece in the initiation of CPR, but it is also necessary to consider detection accuracy and rescuer confidence.

Researchers recruited 64 healthcare providers to determine their confidence and ability to detect a carotid pulse on a manikin.<sup>40</sup> The researchers utilized a Laerdal ALS Skillmaster manikin to create seven combinations that altered pulse strength and detection time for a pulse that the participants randomly performed. After each combination was completed, participants were asked to answer if they did or did not detect a carotid pulse,

along with reporting a visual analog scale (VAS) score (0=no conviction, 100=absolute certitude) of how confident they were with their findings.<sup>40</sup> The results from the study are displayed in Table 8 below.

**Table 8.** Results of the Ability and Confidence when Assessing for a Carotid Pulse

<b>Situations</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>
Time Interval (seconds)	10	10	30	10	10	10	30
Pulse Strength n (%)	Pulseless	Pulseless	Pulseless	Weak	Normal	Normal	Normal
<b>Performance</b>							
Wrong Answer n (%)	27 (42)	27 (42)	32 (50)	11 (17)	5 (8)	10 (16)	10 (16)
Right Answer n (%)	37 (58)	37 (58)	32 (50)	53 (83)	59 (92)	54 (84)	54 (84)
<b>Degree of Conviction (from 0=no conviction to 100=absolute conviction)</b>							
Wrong Answer; Median (25-75 percentiles)	65 (58-100)	72 (51-100)	80 (50-100)	100 (100-100)	75 (59-100)	90 (40-100)	65 (33-100)
Right Answer ; Median (25-75 percentiles)	100 (52-100)	66 (50-100)	83 (48-100)	100 (90-100)	100 (100-100)	100 (100-100)	100 (100-100)

Based on the results, the researchers determined that CPR was poorly performed during all seven of the situations. They revealed that if the only determining factor to initiate CPR was an absence of a carotid pulse, nearly 50% of the simulated pulseless patients in the study would not have had CPR initiated because a pulse was wrongly determined to be present by the participants.<sup>40</sup> The researchers also speculated that the lack of conviction present in the participants of this study could contribute to delays in CPR initiation. One noted limitation present in this study was the simulated pulse on a manikin versus a pulse on a human subject.

To help negate the limitation of utilizing a simulated carotid pulse, researchers collected data on detection of the carotid pulse on 16 human patients who were undergoing coronary artery bypass surgery.<sup>41</sup> The 206 participants selected to detect the carotid pulse

consisted of: laypersons with eight hours of first aid training and four hours of basic life support training (EMT-1), EMT students who had completed four weeks of theoretical instruction and six weeks of practical instruction (EMT-2), paramedics in training who had completed one year of theoretical and practical instruction (PM-1), and certified paramedics (PM-2).<sup>41</sup> The participants were provided access to only the left carotid artery on each patient, were instructed to palpate for a carotid pulse for five to ten seconds, and had a maximum of 60 seconds to determine pulse status. The patients were either in a state of spontaneous circulation or nonpulsatile circulation during the study while they were in surgery. The participant's assessment time began when they arrived at the patient's side and was not terminated until the diagnosis of pulse status was measured. The study included 147 assessments in which a pulse was detectable and 59 assessments of which were pulseless.<sup>41</sup> The significant difference in number of testing assessments creates a strong limitation to this study. After analyzing the results, the researchers noted that in 10% (6/59) of the assessments, the absence of a pulse was not recognized within 60 seconds. They also noted that 45% (66/147) did not detect a pulse in a patient when a pulse was present.<sup>41</sup> This inconsistency can be one of the determining factors on the decision to initiate CPR or to continue to monitor the patient. The inaccuracy can create a delay in life saving efforts and can result in lower resuscitation rates in patients experiencing SCA. Based on the results, the researchers also noted a median delay in declaration of pulse status was 24 seconds (range 3-60 seconds). The time to decision was longer (32 seconds; range 12-60 seconds) if there was not a pulse present when compared to cases with a pulse (22 seconds; range 3-55 seconds) ( $p < 0.001$ ). In the event participants concluded they could not detect a pulse, they communicated their findings significantly later (30 seconds; range 13-60 seconds) than when they were confident they had identified a pulse (15 seconds; range 3-48 seconds) ( $p < 0.001$ ). The training level of the participants had an effect on

decreasing the delay to their decision, with the PM-1 group declaring their findings faster than the EMT-1 group ( $p < 0.02$ ). It was also observed that only 16.5% (34/206) of the participants declared pulse status within the ten second recommendation from the AHA, while only 15% (31/206) provided a correct diagnosis of pulse status in the recommended ten seconds.<sup>41</sup> When the delay in reporting of findings is paired with the inaccurate findings by the participants, the impact on resuscitation efforts becomes significant. After analyzing all the results, the researchers observed high levels of inaccuracy and delay in pulse checks performed by first responders. The ability of accurate pulse detection is vital to the initiation of CPR, and inaccuracy or lack of confidence in the finding can lead to unnecessary and negative delays in life saving efforts to patients experiencing cardiac arrest.

#### **2.2.4. CPR History 2015-Present**

The most recent guidelines, which were published by the AHA in 2015, created an upper limit to the recommended number of chest compressions per minute. To gain insight on this statement, researchers recruited 38 CPR-trained individuals to perform five, two-minute cycles of chest compressions.<sup>42</sup> The participants were instructed to perform chest compressions on a manikin with the use of a metronome, which was set at tempos of 100, 120, 140, and 160 beats per minute.<sup>42</sup> The researchers found high-quality compressions (i.e., rate, depth, and chest recoil) were best performed at the rate of 120 beats per minute ( $p = 0.016$ ).<sup>42</sup> The researchers also discovered that as the compression rate increased, an identical increase in an incomplete recoil of the chest followed.<sup>42</sup> The range of optimal chest compressions is now 100 to 120 compressions per minute.<sup>43</sup>

It has been found in recent research the higher the number of compressions, the better the outcome, and the lower the number of compressions, the worse the outcome.<sup>43</sup> The creation of the upper limit of 120 compressions per minute was developed after

researchers discovered the quality of the compression depth decreased when the number of compressions was greater than 120, which resulted in negative results on the performance of CPR.<sup>43</sup> The researchers found that 35% of compressions between 100 to 119 per minute achieved inadequate depth. The depth inadequacy increased to 50% of the compressions when the compressions were delivered at a rate between 120 and 139 per minute, and inadequate depth increased again to 70% of compressions when the rate was greater than 140 per minute.<sup>43</sup> The findings supported the 2015 AHA guidelines, which helped to guide the implementation into clinical practice.

The 2015 guidelines from the AHA also stated the depth of compressions needs to be at least two inches (five centimeters) into the chest towards the spine. Equally important, the guidelines also emphasize the rescuer allowing the patient's chest to fully recoil between each compression.<sup>43</sup> Researchers conducted a study to observe if proper chest recoil and chest release rates were achieved during CPR or if excess leaning by the rescuer was occurring. The researchers analyzed 1,004 separate out-of-hospital cardiac arrests.<sup>44</sup> Data were recorded through the use of Q-CPR sensors attached to defibrillator pads.<sup>44</sup> Over an 11-year period, 1,004 resuscitation attempts that lasted for a minimum of two minutes were observed, and data were extracted from these cases. A total of 1,542,283 compressions with rates between 80 and 140 compressions per minute and depths between 30 and 70 millimeters were included in the data set for analysis.<sup>44</sup> Measurements were recorded through the Q-CPR to determine the minimum force at the end of a compression. Leaning was determined to have occurred if the rescuer's minimum force at the end of a compression exceeded 2.5 kg-f.<sup>44</sup> The researchers discovered only 21% of the 1.5 million compressions analyzed were compliant with the 2015 guidelines.<sup>44</sup> Leaning was observed in 12% of the compressions.<sup>44</sup> Due to a lack of literature on the subject, researchers have thus far agreed proper implementation of current CPR guidelines is lacking.

Due to rescuers displaying inaccurate implementation of current compression guidelines of depth, additional research was collected to determine if the new guidelines were realistic and beneficial to survival. A total of 58 EMS agencies affiliated with seven United States and Canadian Resuscitation Outcomes Consortium (ROC) sites were selected to analyze CPR data.<sup>45</sup> The researchers collected CPR recordings from patients who were at least 18 years old and experienced non-traumatic sudden cardiac arrest in the out-of-hospital setting. The compression depth measures were calculated by proprietary automated external defibrillator analytic software. The researchers collected compression depth data from 1,029 patients. Of these 1,029 patients, 25.7% experienced ROSC, 18.2% survived one day, and 4.9% survived to hospital discharge.<sup>45</sup> The median value for compression depth was observed at 37.3 millimeters (IQR 32-43mm) with 52.8% of cases having a mean value less than 38 millimeters. When the researchers compared the results from the 50 patients who survived to hospital discharge to those who did not, they observed better outcomes when compression depths were greater than 38 millimeters ( $p=0.05$ ).<sup>45</sup> More research on human subjects regarding optimal compression depth is needed to increase these numbers and the positive outcomes for cardiac arrest patients.

The occurrence of leaning during CPR has also been attributed to the body type of the rescuer. To observe how different body types effect the performance of compressions during CPR, researchers recruited 333 participants who had just completed a Basic Life Support (BLS) course.<sup>46</sup> The participants were instructed to perform one minute of compression-only CPR on a Laerdal Resusci Anne Wireless SkillReporter manikin.<sup>46</sup> The researchers discovered participants who were heavier, taller, male, and had an increased Body Mass Index (BMI) were less likely to achieve full chest recoil during the study ( $p<0.001$ ).<sup>46</sup> They also observed a correlation between the participants with a higher body weight and the likelihood of proper compression depth ( $p<0.001$ ).<sup>46</sup> Through these

statistical findings, it can be hypothesized that adaptive CPR instruction and training should be implemented into the current curriculum to focus on an individual's body type strengths and weaknesses to ensure efficient CPR is being performed regardless of body type.

Additional research has been completed to analyze rescuer characteristics and their ability to perform high-quality CPR. Researchers collected data on 95 emergency medical technicians (EMTs), which consisted of factors such as: sex, age, weight, height, BMI (weight/height<sup>2</sup>), arm length, leg length, exercise habits, and if they had completed a CPR course in the last three months.<sup>47</sup> Next, they analyzed the participant's ability to perform quality CPR and compared their characteristics to determine if there was an association between participant characteristics and ability to perform high-quality CPR. High-quality CPR was defined as 100 compressions per minute at a depth of at least five centimeters.<sup>47</sup> CPR data were collected using a Laerdal Resusci-Anne manikin with QCPR technology. After participant information was recorded, participants were instructed to perform CPR for two minutes on the manikin. Of the 95 EMTs, only 36 were found to have performed high-quality CPR. High-quality CPR was defined by the participant achieving a compression rate of 100 to 120 compressions per minute, a compression depth of at least 5 centimeters, a fully recoiled chest after each compression, and minimization of the frequency and duration of interruptions.<sup>47</sup> The 36 participants who performed high-quality CPR were placed into group one, whereas the remaining 59 were placed into group two to compare characteristics. The researchers discovered the average exercise time per week was associated with high-quality performance of CPR after adjusting for the other variables (p=0.044). They also revealed a BMI between 20 and 22 along with exercise of four to six days per week for at least 60 minutes was a significant predictor to determine whether high-quality CPR could be performed (p<0.001, sensitivity=0.722, specificity=0.678).<sup>47</sup>

To support the findings in a single study, additional research is needed to enhance the results. Another study, which analyzed the effect of gender and BMI on the effectiveness to perform high-quality CPR, revealed results that supported the previous findings.<sup>48</sup> Researchers collected BMI and biological sex data from 72 healthcare providers or healthcare students. The participants were asked to complete a certification class, followed by performing CPR in the study one week post-instruction. CPR was performed on a Laerdal Resusci Anne Basic manikin and SkillGuide software was used to analyze the performance.<sup>48</sup> Participants were instructed to perform five cycles of CPR using the 30:2 compression-to-ventilation ratio, while achieving at least 2.5 centimeters of compression depth. After analyzing the data, the researchers discovered participants with a BMI less than the mean BMI of  $26 \pm 6.8$  were able to perform chest compressions with the correct depth ( $p=0.045$ ) and were able to complete compressions faster compared to those with a BMI greater than the mean ( $p=0.000$ ).<sup>48</sup> The findings allowed researchers to conclude participants have an increased likelihood of performing high-quality compressions if their BMI was less than 26. The required BMI of an individual to perform high-quality CPR was determined by the researchers to be less than 26. Due to the limitation of the target BMI being determined by taking the average from the study's participants, the results should be carefully considered. Nonetheless, it is important to understand a rescuer's BMI and exercise levels have a direct effect of their ability to perform CPR. The findings result in the need for adaptable certification programs to help better suit individuals and their unique characteristics to improve their ability to perform effective CPR.

Proper placement of the hands when performing compressions is a key factor in performing adequate CPR. The AHA states the current hand placement when performing chest compressions during CPR should be just above the xiphoid process of the sternum.<sup>43</sup> Research has been performed regarding which hand, dominant or non-dominant, should be



placed against the chest during a compression set to achieve high-quality CPR. Researchers recruited 225 participants who completed CPR training. The participants were split into two groups; with 157 performing compressions with their non-dominant hand and 68 performing compressions with their dominant hand. The participants were instructed to perform five cycles of CPR. CPR was performed and data were recorded using the SimMan Essential manikin and system.<sup>49</sup> A questionnaire comprised of questions regarding the participants' general characteristics, dominant hand, choice of compressing hand, and a self-assessment of the quality of CPR they had administered.<sup>49</sup> The researchers discovered from the data that the frequency of chest compressions being performed at a rate of 100 compressions per minute ( $p=0.002$ ) and the frequency of compression depth reaching equal to or greater than five centimeters ( $p=0.001$ ) was increased in the group using their dominant hand.<sup>49</sup> In contrast, they discovered an increased occurrence of full chest recoil between compressions in the group using their non-dominant hand ( $p=0.02$ ).<sup>49</sup> The results of this study showed high-quality CPR could be performed more effectively when the rescuer placed their dominant hand on the patient with their non-dominant hand being placed on top of their dominant hand. The findings are valuable to the progression of CPR because it gives us the correct hand placement to perform effective CPR. However, the limitation of unequal comparison groups must be taken into consideration. More research with more participants is needed to establish this idea of hand placement into the current guidelines of CPR discussing proper hand placement.

Ventilation administration during the performance of CPR has been a widely discussed topic. Some researchers have speculated moving to a compression-only form of CPR can provide adequate tidal volumes for ventilation. To observe if this speculation held any value, researchers observed 21 patients experiencing non-traumatic out-of-hospital cardiac arrest.<sup>50</sup> From the 21 patients, 580 ventilations produced from compressions were

recorded and measured.<sup>50</sup> The median compression depth was found to be 2.2 inches (IQR 1.9, 2.5), the median compression rate was 126.1 compressions per minute (IQR 122.1,129.7), and the median passive tidal volume was found to be 7.5 milliliters (IQR 3.5,12.6).<sup>50</sup> As displayed in the study performed by Elam et al<sup>23</sup>, an adequate tidal volume for rescue ventilations is near 1,000 milliliters, and the results of this study were nowhere near this value.<sup>23,50</sup> The researchers concluded from the results that even if compressions achieved the current recommendations, the compressions did not produce an appropriate tidal volume needed for adequate rescue ventilations. The finding of inadequate performance reinforces the use of mouth-to-mouth or mouth-to-airway ventilations when performing CPR to achieve positive results. While these techniques are the standard for allied healthcare providers, the same is not true for laypersons. The AHA recommends untrained laypersons perform compression-only CPR due to the simplicity of performing compressions and the ability for dispatchers to easily explain the process over the phone.<sup>43</sup> However, it has also been speculated that performing compression-only CPR may cause more rescuer fatigue than the traditional CPR recommendations.

Even when mouth-to-mouth or mouth-to-airway ventilations are performed, it is not always guaranteed proper ventilation is being achieved. Researchers conducted a study to observe if proper ventilations can be administered through the use of a bag-valve-mask (BVM) using three separate rates established with a metronome.<sup>51</sup> A total of 30 physicians were recruited to participate in this study. A metronome was used as a timing for compressions and was set at three different rates: 100, 110, and 120 ticks per minute.<sup>51</sup> A researcher would count to thirty to simulate compressions being delivered, and then the physicians were instructed to perform each ventilation over two ticks of the metronome and allow for expiration over two ticks.<sup>51</sup> The physicians held a head-tilt chin-lift position on the mannequin with the E-C clamp technique with their left hand while squeezing the bag to

administer a ventilation with their right hand.<sup>51</sup> The physicians were instructed to perform five sets of two consecutive ventilations for a total of ten ventilations. The values collected and observed during this study were mean tidal volume and peak airway pressure. The data were recorded using a RespiTrainer Advance mannequin.<sup>51</sup> Mean tidal volume decreased significantly during the scenario of 120 compressions per minute (297 mL) when compared to the 110 compressions per minute scenario (358 mL) with a medium effect size ( $p=0.004$ ).<sup>51</sup> It has been noted in the literature there is a ventilation threshold of 20 mmHg when observing peak airway pressure.<sup>51</sup> The researchers observed more than half of the ventilations resulting in a peak airway pressure of greater than this ventilation threshold with both 110 and 120 compressions per minute scenarios.<sup>51</sup> The greatest increase in peak airway pressure was observed during the 100 and 110 compressions per minute scenarios, with 18.7 mmHg and 21.6 mmHg respectively ( $p=0.006$ ). Through these results, the researchers concluded a higher metronome rate may adversely affect the quality of BVM ventilations.<sup>51</sup> Future research is needed to determine the optimal rate for ventilation application via the BVM.

### **2.3. Athletic Trainers and CPR**

The National Athletic Trainers' Association (NATA) defines athletic trainers as, "highly qualified, multi-skilled health care professionals who collaborate with physicians to provide preventative services, emergency care, clinical diagnosis, therapeutic intervention and rehabilitation of injuries and medical conditions."<sup>52</sup> The five categories that define an athletic trainer are known as the Domains of athletic training. The Domains of athletic training are explained in the Role of Delineation Study, which defines the qualifications and skills that athletic trainers perform daily and are required to remain proficient. The Role of Delineation Study is created and released by the Board of Certification (BOC) for athletic trainers. The third Domain is the category of Immediate and Emergency Care.<sup>53</sup>

Within the domain are four task descriptions, which state an athletic trainer must be able to: develop and implement an emergency action plan (EAP), triage illnesses and injuries, implement appropriate immediate and emergency care, and ensure appropriate referrals and quick transfer of care to emergency responders. The BOC requires that athletic trainers remain up-to-date on new and emerging ideas related to the five Domains. Athletic trainers are required to stay current on best practices and latest research by completing continuing education credits on a biannual basis. Athletic trainers are also required to maintain certification in first aid, CPR, and AED training. Athletic trainers are often on the frontline when dealing with sports-related sudden cardiac arrests. They are the first trained medical professionals on scene, which can result in the athletic trainer having to initiate life-saving medical interventions, such as CPR. Athletic trainers are encouraged to abide by the best-practice recommendations, which are established by the NATA. While the NATA has released Position Statements that detail how athletic trainers should respond to specific conditions, the organization has not released a Position Statement that discusses how athletic trainers should alter their performance of CPR when resuscitating sport-specific equipment laden athletes.

While the NATA has released vague recommendations for athletic trainers, other organizations have established recommendations on how to handle SCA in athletes. The Inter-Association Task Force for Preventing Sudden Death in Secondary School Athletics Programs has developed their own set of best-practice recommendations.<sup>54</sup> The recommendations discuss best-practice options pertaining to preventing and attending to SCA and athletic training best practices. The Task Force also supports the need for an established EAP by stating the athletic training services for each school should be responsible for creating and implementing an EAP.<sup>54</sup> The recommendations also encourage the presence of an athletic trainer at every school. Because catastrophic events can occur in

an athletic setting, it is recommended that an athletic trainer is accessible for practices and competitions. The presence of an athletic trainer during athletic events provides a source of immediate medical care. Instead of having to call emergency services and waiting for their arrival, an athletic trainer is readily available and fully equipped with the appropriate medical knowledge and training.

While having an athletic trainer present during athletic events is beneficial, not every athletic location has access to one. Based on the available literature, it has been reported that roughly 70% of high schools in the United States have athletic trainers available to their student-athletes.<sup>55</sup> A group of researchers sought to analyze the sport-related emergency preparedness in Oregon high schools. The researchers emailed a web-based survey to all 292 Oregon high schools in 2014.<sup>55</sup> The survey was used to ask questions to evaluate if each school had a detailed EAP, had access to an AED, had coaches trained in CPR and AED use, and if the school had an athletic trainer present. Out of the 292 schools, only 108 of the schools' athletic directors responded. The athletic directors who responded indicated only half of the schools (54/108 responding schools) had an athletic trainer available. Of these 54 schools, it was reported that only 10 schools had an athletic trainer available for 40 hours per week or more.<sup>55</sup> The researchers also observed a higher likelihood for each school to comply with having an established EAP, access to an AED, and a coach trained in CPR and AED use when an athletic trainer was available to that school ( $p=0.016$ ). Based on the survey, it was reported 52% (95% CI, 38-66%) of schools with an athletic trainer had a venue-specific EAP for every venue, but only 24% (95% CI, 14-38%) of schools without an athletic trainer had established an EAP. Based on these results, researchers were able to determine athletic trainer availability was associated with EAP adoption at their schools ( $p=0.005$ ). Having an EAP allows the school and the athletic trainer to be prepared in the event of an emergency. Athletic trainers should be used as a

resource by the school to encourage the establishment of an EAP to remain prepared in case of an emergency.

While athletic trainers can provide immediate medical care, some are not properly prepared to handle emergency situations. A study conducted in 2007 assessed the level of emergency preparedness in school-based athletics via a questionnaire mailed out to 1,000 NATA members. The questionnaire consisted of 39 questions regarding clinical background, demographic features of their school, preparedness of their school to handle life-threatening athletic emergencies, the presence of preventative measures to avoid potential sport-related emergencies, and the immediate availability of emergency equipment.<sup>56</sup> Of the 1,000 questionnaires, 944 were delivered and 643 were returned to the researchers. The researchers chose to include 521 (81%) of the questionnaires due to the desired focus on athletic trainers who were working exclusively in the middle school or high school setting. Analyzing the responses to the questionnaire, the researchers were surprised to find 20% of the responding athletic trainers were not currently certified in CPR, and 11% had not been formally trained in the use of an AED.<sup>56</sup> Additionally, only 34% of responding athletic trainers were present during all athletic events at their school, however, most schools had an established EAP. While it is important to have an established EAP, it is also important that it is well known and rehearsed. The researchers revealed only 26% of the responding athletic trainers reported having practiced their EAP throughout the year and 36% had never formally practiced their EAP.<sup>56</sup> This study highlights the importance of emergency preparedness among athletic trainers. Even though athletic trainers are required to be trained in emergency care, if they do not regularly apply their knowledge, it can be lost and become ineffective in the event of an emergency. Additional research should be conducted of the present day athletic trainer to observe the evolution of the profession since this study was completed.

Even when every possible step is taken to prepare for an emergency event, positive outcomes are not always achieved. A group of researchers pursued analyzing cases of SCA in young athletes.<sup>57</sup> Researchers worked in conjunction with the National Center for Catastrophic Sports Injury Research (NCCSIR) and the UW Medicine Center for Sports Cardiology. The group analyzed SCA cases from competitive athletes at the middle school, high school, collegiate, semi-professional, and professional levels who experienced exercise-related SCA. A competitive athlete was defined as someone who regularly trained in an organized sport with an emphasis on performance and competition. The SCA cases were collected from the NCCSIR's athlete surveillance database, and the presence of an athletic trainer during the time of SCA was recorded. Of the 132 total cases, an athletic trainer was onsite during the event of the SCA in 29 (22%) of the cases. An athletic trainer was not present in 19 (14%) of the cases, and it was unknown whether an athletic trainer was present in the majority of the cases 84 (64%) of the cases.<sup>57</sup> The researchers observed that in the cases in which an athletic trainer was present and provided immediate assistance in the resuscitation, 83% (24/29 athletes) of the athletes survived SCA.<sup>57</sup> The importance of having a medically trained professional, such as an athletic trainer, present and readily available during an emergency situation is critical. The immediate care provided by an athletic trainer during such event can be a determinant in survival or death in the event of an SCA.

#### **2.4. CPR over Protective Equipment**

Athletic trainers face a major challenge when the need for resuscitation occurs in a sport-specific equipment laden athlete occurs. Helmets, shoulder pads, and chest protectors are examples of protective equipment preventing direct access to the chest and face, thereby preventing proper administration of compressions and ventilations during CPR. The governing bodies that oversee athletic trainers do not clearly define the best practice

for performing CPR on athletes wearing protective equipment. The NATA and Inter-Association Task Force simply state compressions should be applied directly on the chest.<sup>58,59</sup> The only discussion with regards to equipment removal is the facemask should be removed and the shoulder pads should be opened before transport when a cervical spine injury is present.<sup>58</sup> The lack of clear direction involving protective equipment removal prior to the administration of CPR has created the need for research to determine what should be implemented in this scenario. Limited and largely inconclusive studies have been performed to analyze the effectiveness of CPR performance over and under protective equipment.

An exploratory study recruited 30 basic life support certified undergraduate athletic training students and licensed graduate students to determine the adequacy of performing CPR over and under protective football equipment.<sup>60</sup> Each participant was given a standardized scenario and instructed to complete three, two-minute sessions of compression-only CPR. The chest compressions were completed and analyzed using a Laerdal SimMan 3G interactive manikin simulator. The participants recorded a session of baseline data by performing chest compressions over the manikin without equipment present. Once the baseline data were collected, the manikin was fitted with Riddell Power shoulder pads and helmet. The remaining two sessions were completed under the following conditions: two minutes over the shoulder pads and two minutes under the unlaced shoulder pads. The participants were to adhere to the 2010 AHA guidelines. The results are displayed in Table 9 below.



**Table 9.** Compression Depth and Rate Under and Over Equipment

<b>Group</b>	<b>Median (Interquartile Range)</b>	<b>p-value</b>
<b>CPR compression depth (n=36)</b>		
Under equipment	37 (31-39)	0.002
Over equipment	31.50 (28-35.50)	
<b>CPR compression rate (n=36)</b>		
Under equipment	113 (101.25-125)	0.20
Over equipment	118 (103.25-130.75)	

After analyzing the results, researchers noted a deeper compression depth was achieved when performing chest compressions under the shoulder pads ( $p=0.002$ )<sup>60</sup>, suggesting compressions were administered more effectively as compared to performing them over the equipment. No significant differences were observed relating to compression rate ( $p=0.20$ ) or chest wall recoil (100% in both groups) for either scenario.<sup>60</sup> Based on these results, it was suggested that performing compressions under the equipment may be more effective than performing them over the equipment. More in-depth research needs to be completed to either support or negate the findings of this study.

The findings of the aforementioned study supported removing football equipment prior to the initiation of CPR. The goal of the study was to observe CPR performance in individuals with different levels of training with the use of audiovisual feedback and the presence of football shoulder pads.<sup>61</sup> Researchers recruited 18 total participants, made up of six basic life support certified athletic training students (BLS-ATS), six emergency medical technicians (BLS-EMS), and six advanced emergency medical technicians (ACLS-EMS). All participants were instructed to perform four, two-minute compression-only CPR sessions over a Laerdal Little Anne CPR manikin. The first session was considered a baseline session with the presence of no feedback device or equipment. The remaining three sessions were completed as follows: two minutes of chest compressions with audiovisual feedback

through the Real CPR Help program, two minutes performed over the shoulder pads, and two minutes performing over the shoulder pads with the use of the audiovisual feedback.<sup>61</sup>

Data were collected on compression depth, compression rate, depth accuracy, and rate accuracy. The results are displayed in Table 10 below.

**Table 10.** CPR Comparison Between Three Groups Under Separate Conditions.

	<b>FSP OFF</b>	<b>FSP ON</b>	<b>p Value</b>	<b>Feedback OFF</b>	<b>Feedback ON</b>	<b>p Value</b>
<b>Depth Accuracy (%)</b>						
BLS-ATS	35.2 (16.8-85.3)	37.6 (21.9-57.8)	0.56	22.0 (7.3-36.2)	71.3 (35.4-86.5)	0.002
BLS-EMS	40.6 (1.9-71.2)	26.1 (6.9-56.7)	0.64	9.3 (0.4-53.2)	45.1 (18.6-69.7)	0.06
ACLS-EMS	38.2 (3.2-79.2)	37.5 (18.9-69.7)	0.82	22.0 (4.4-59.9)	58.8 (17.6-78.8)	0.18
<b>Depth (cm)</b>						
BLS-ATS	5.4 (4.9-6.1)	5.1 (4.5-5.2)	0.05	4.9 (4.4-5.2)	5.4 (5.1-5.7)	0.04
BLS-EMS	5.8 (5.1-6.2)	5.1 (4.2-5.8)	0.16	5.4 (4.2-6.0)	5.5 (5.0-5.9)	0.49
ACLS-EMS	6.1 (5.7-6.5)	5.6 (4.7-6.1)	0.06	6.0 (5.1-6.5)	5.8 (5.4-6.3)	0.69
<b>Rate Accuracy (%)</b>						
BLS-ATS	45.1 (14.3-89.8)	61.5 (17.2-84.3)	0.73	38.9 (10.3-92.8)	61.3 (26.4-72.1)	0.86
BLS-EMS	64.9 (14.3-79.3)	57.7 (39.4-85.1)	0.82	70.0 (7.4-87.5)	57.8 (50.5-70.9)	0.60
ACLS-EMS	0.0 (0.0-71.7)	14.3 (0.1-68.2)	0.42	0.2 (0.0-76.7)	30.5 (0.0-64.2)	0.76
<b>Rate (cpm)</b>						
BLS-ATS	110 (100-125)	106 (100-123)	0.69	112 (97-124)	105 (100-125)	0.95
BLS-EMS	104 (100-125)	106 (100-120)	1.00	110 (102-126)	101 (99-115)	0.17
ACLS-EMS	137 (105-141)	130 (104-138)	0.58	136 (112-141)	126 (100-138)	0.29

Median (IQR); FSP (football shoulder pads) ON includes both FSP and FSP+Feedback conditions, and feedback OFF includes both baseline and FSP conditions

After analyzing the results, no significant difference was noted in the four variables when chest compressions were performed over or under shoulder pads.<sup>61</sup> This finding contradicts that of the previous study, indicating that football shoulder pads may not

compromise the compression depth achieved. The inconsistent findings between the two studies indicates a need for more in-depth, population-focused research.

While using athletic training students to gather data on CPR performance over protective equipment can be effective, it is important to include certified athletic trainers in the study population. The certified athletic trainers will be the primary rescuer in the case of cardiac event and are the most likely personnel to administer CPR. Therefore, their inclusion in research studies is imperative to determine the effectiveness of CPR over protective athletic equipment. To further study the certified athletic trainer population, researchers recruited 32 certified athletic trainers to determine if football equipment removal improves chest compression and ventilation efficiency during CPR.<sup>62</sup> The participants were asked to complete six separate chest compression protocols over a Laerdal Rescuci Anne Simulator with SimPad manikin. The six conditions are displayed in Table 11.

**Table 11.** Chest Compression Conditions

<b>Chest Compression Conditions</b>	
Condition A	Simulator fully equipped with a Riddell helmet and shoulder pads
Condition B	Anterior shoulder pads lifted superiorly to expose the chest; helmet left in place
Condition C	Anterior shoulder pads lifted superiorly to expose the chest after facemask removal; helmet left on
Condition D	Anterior shoulder pads splayed open to expose the chest; helmet and facemask left in place
Condition E	Traditional shoulder pad removal using flat torso technique
Condition F	Shoulder pad removal using RipKord style shoulder pads

The researchers noted condition A revealed a significant barrier for the certified athletic trainers to achieve mean compression depth and to deliver adequate chest compressions.<sup>62</sup> The values from the study are displayed in Table 12.

**Table 12.** Chest Compression Variable Results

Compression Condition	A	B	C	D	E	F	p-value	Effect size
Depth (mm)	40.9 (±8.7)	48.0 (±8.3)	46.1 (±8.0)	48.0 (±8.6)	49.1 (±7.2)	47.8 (±7.2)	<0.001	0.98
Adequate depth (%)	15.0 (±25.3)	45.3 (±43.3)	51.2 (±51.8)	51.6 (±43.5)	63.9 (±42.5)	52.5 (±46.8)	<0.001	1.09
Rate (comp/min)	111.2 (±17.6)	112.8 (±17.5)	112.1 (±17.9)	113.7 (±18.6)	114.1 (±16.0)	114.9 (±16.5)	0.224	0.21
Correct release (%)	78.2 (±34.4)	73.9 (±36.8)	71.1 (±36.8)	81.3 (±29.4)	77.7 (±32.1)	73.5 (±34.5)	0.074	0.30

Table 12. Chest Compression Variable Results. Mean (±SD).

The decreased depth observed in this study can result in decreased performance of effective chest compressions. When inadequate chest compressions occur, a decrease in blood flow and survival likelihood occur. In this case, exposing the chest prior to beginning chest compressions appears to provide a better surface for effective CPR performance. The participants were able to achieve the correct release of the chest between each compression, thereby allowing it to recoil adequately. Full chest recoil is necessary to achieve blood flow through the body.

The researchers also studied the effects protective equipment, such as helmets and facemasks, have during the administration of ventilation. To gather data, the participants were instructed to perform seven different ventilation techniques. These techniques consisted of ventilations via one-person pocket mask, two-person pocket mask, and two-person bag-valve-mask. These techniques were applied to six different conditions. The participants administered ventilations for a total of 90 seconds. The conditions tested are listed in Table 13.

**Table 13.** Ventilation Conditions

<b>Ventilation Conditions</b>	
Condition A	Facemask removed; two-person pocket mask
Condition B	Helmet removed; two-person pocket mask
Condition C	Facemask removed; two-person BVM
Condition D	Helmet removed; two-person BVM
Condition E	Facemask removed; one-person pocket mask
Condition F	Helmet removed; one-person pocket mask

No significant ventilation differences were found between removing the helmet completely and only removing the facemask. However, the researchers did highlight some significant results in the other variables. They discovered certified athletic trainers were able to administer significantly higher mean ventilation volumes when using a BVM compared to either the one-person or two-person pocket mask techniques ( $p < 0.001$ ). Additionally, they revealed the participants who were working alone delivered fewer total ventilations and administered ventilations at a lower adequate ventilation percentage when compared to those working with two rescuers.<sup>62</sup> In the study, the helmet used did not have a chinstrap attached. As the study progressed, the idea of the chinstrap potentially causing obstruction when ventilating the patient was discussed. The researchers came to the conclusion mid-study to address the presence of the chinstrap when the helmet was left in place and only the facemask was removed. They added two additional conditions to observe for ventilation efficiency. The conditions are displayed in Table 14.

**Table 14.** Additional Ventilation Conditions

<b>Additional Ventilation Conditions</b>	
Condition G	Facemask removed; chinstrap buckled; two-person BVM
Condition H	Facemask removed; chinstrap unbuckled; two-person BVM

After analyzing the results, researchers noted certified athletic trainers delivered a greater amount of volume per ventilation, as well as a greater percentage of adequate ventilation volume in the initial six conditions, which did not include a chinstrap as compared to either of the added conditions including the chinstrap. This finding supports the removal of the chinstrap before administering ventilations. The results from the ventilations conditions are displayed in Table 15 and 16.

**Table 15.** Ventilation Condition Variable Results

<b>Ventilation Condition</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	<b>F</b>	<b>p-value</b>	<b>Effect size</b>
Total attempts	25.3	24.3	26.4	26.8	24.2	24.0	0.002	0.26
Volume (mL)	421.7	412.7	624.1	639.5	376.7	422.6	<0.001	1.47
Adequate volume (%)	52.0	46.0	59.7	61.2	28.3	37.8	<0.001	0.89

**Table 16.** Additional Ventilation Condition Variable Results

<b>Ventilation Condition</b>	<b>C</b>	<b>D</b>	<b>G</b>	<b>H</b>	<b>p-value</b>	<b>Effect size</b>
Total attempts	26.5	26.4	30.0	29.4	0.399	0.28
Volume (mL)	675.2	703.0	316.1	363.3	<0.001	1.78
Adequate volume (%)	68.3	60.2	24.5	30.5	0.008	1.12

Based on the results of this study, researchers concluded that chest compressions and delivery of ventilations can become compromised in athletes wearing protective equipment. While the researchers revealed strong data supporting the removal of specific protective equipment, more research is required to implement this idea into everyday clinical practice.

The time it takes to begin resuscitation efforts is vital for a chance at survival. When resuscitation efforts are delayed to remove protective equipment, resuscitation efforts can

potentially suffer. It is important to initiate resuscitation efforts to maintain appropriate cerebral and coronary blood flow. To analyze CPR effectiveness as well as time lost to remove the equipment, researchers chose certified athletic trainers as their target focus group because they are often the first allied healthcare providers at an emergency. A total of 34 athletic trainers, with an average of five years of experience, were included.<sup>63</sup> The participants performed two CPR scenarios that each lasted a total of four minutes. The first protocol required the participants to remove the helmet's facemask and unfasten the chest protector to reveal the chest. The second protocol had the participants remove the helmet's facemask and perform chest compressions directly over the chest protector.<sup>63</sup> Resuscitation efforts were performed on a Laerdal Resusci Anne Skill Reporter CPR manikin. Prior to beginning rescue efforts, participants were read a scenario revealing a football athlete who had collapsed 75 feet away. The results from the study were collected and analyzed. After analyzing the data, the researchers noted it took, on average, 24.4 ( $\pm$  7.2) seconds longer to initiate compressions when unfastening the chest protector as compared to performing compressions directly over the chest protector. Interestingly, although researchers revealed that performing compressions over the chest protector reduced the time to initiation of compressions, it also resulted in a higher frequency of compression delivery and an increased accuracy of hand placement.<sup>63</sup> There was, however, one outcome that was negatively impacted by performing compressions over the chest protector. The researchers observed a decrease in the participant's ability to achieve full chest recoil between compressions when the compressions were performed directly over the chest protector. The results from the study are displayed in Table 17.

**Table 17.** Comparison of Compressions with Equipment On and Off

	<b>Equipment ON</b>	<b>Equipment OFF</b>	<b>Odds Ratio</b>	<b>95% CI</b>	<b>p-value</b>
Adequate compression (%)	35.6 ( $\pm$ 35.7)	29.3 ( $\pm$ 29.3)	1.46	1.37-1.55	p<0.0001
Hand placement accuracy (%)	68.4 ( $\pm$ 34.9)	64.5 ( $\pm$ 36.0)	1.28	1.20-1.37	p<0.0001
Complete chest recoil (%)	63.8 ( $\pm$ 38.1)	76.1 ( $\pm$ 34.9)	0.57	0.53-0.61	p<0.0001

No significant difference was observed between the two groups regarding compression rate. As displayed in the results of the study, there were noted improvements in CPR quality when compressions were performed over the chest protector. These factors, however, are negated due to the decrease in percentage of complete chest wall recoil between each compression. It is important to achieve full chest recoil to perfuse the blood to the rest of the body during chest compressions. Because both positive and negative outcomes resulted, more research is required to determine which method will have the best survival outcomes for individuals experiencing a cardiac event while wearing protective equipment.

To further analyze the effects of protective equipment on the performance of CPR, researchers expanded their efforts from football by turning their research towards the sport of lacrosse. To collect the data, researchers chose certified athletic trainers as their focus group. A total of 26 certified athletic trainers were recruited to perform one, two-hour session that consisted of three compression protocols.<sup>64</sup> The data were collected via a Laerdal Resusci Anne Simulator<sup>63</sup> with SimPad, SkillReporter, and Quality CPR feedback. The simulated manikin was equipped with Cascade R helmets and STX Cell Liner II shoulder pads, which are popular equipment for lacrosse.<sup>64</sup> To test the effectiveness of compressions in the presence of a lacrosse chest protector, participants were exposed to



three conditions in which they were instructed to perform compressions on: manikin fully equipped with facemask removed, shoulder pads lifted with helmet on and facemask removed, and no equipment present. Participants performed compressions during each of the three conditions for a total of two-minutes. The participants were given a three to five-minute break between each condition. The researchers discovered the presence of shoulder pads left in place created a decreased mean depth ( $p < 0.001$ , effect size=0.835) and a decreased percentage of optimal-depth of compressions ( $p < 0.003$ , effect size=0.900) when compared to the other conditions.<sup>64</sup> Similar to the results of the Del Rossi et al<sup>63</sup> study, a decreased percentage of complete chest recoil in fully equipped conditions as compared to no equipment was revealed ( $p = 0.04$ , effect size=0.579).<sup>64</sup> Based on the findings, researchers determined that lacrosse shoulder pads should be removed to expose the chest to deliver adequate and effective chest compressions. Even with these suggestions, without an abundance of research with similar supporting results about performing CPR under or over protective equipment, no official method can be promoted by the governing bodies for athletic trainers.

## **2.5. Conclusion**

To conclude, future research is warranted to determine if certified athletic trainers are able to perform adequate chest compressions over sport-specific protective athletic equipment. It is important to investigate various types of equipment, such as football shoulder pads, to determine the effect each device has on performance of CPR in the event of sudden cardiac arrest. The lack of definitive research on the order in which CPR should be initiated when sport-specific protective athletic equipment is present supports the need for more in-depth research. The proposed study will help facilitate further discussion into this topic area, as well as assist in the development of evidence-based recommendations for CPR specifically for those athletes who wear particular pieces of equipment.

## CHAPTER 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 and under football shoulder pads. Neither the NATA nor the AHA have clear recommendations discussing how certified athletic trainers should alter their emergency care when performing CPR on sport-specific equipment laden athletes. Previous research has been completed to observe the effect of the barrier of football and lacrosse pads<sup>58,60-65</sup> on preventing adequate chest compressions. This study was designed to help further investigate the effectiveness of CPR performed over and under football shoulder pads and to help establish best-care practices in the event of cardiac arrest in football athletes. 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, chest recoil, and percent of adequate ventilation volume during the study?

Q2: What is the relationship among participant traits (self-reported Body Mass Index [BMI], age, gender, education level, years of CPR experience, sport experience, 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 and under football shoulder pads?

### 3.2. Participants

A sample of 30-50 certified athletic trainers in the GLATA and MAATA regions who are currently licensed and practicing were recruited through recruitment email and word-of-mouth. 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 demographics and clinical data was 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 Barnett VISION II football shoulder pads (Florida, USA) or Gear 2000 Co. Air-Tech football shoulder pads (Texas, USA). Ventilations were administered via a Laerdal Pocket Mask™ (Stavanger, Norway).

The Resusci Anne® QCPR manikin and Laerdal SkillReporter software (Stavanger, Norway) was used as the device to measure the quality of CPR. The software was able to evaluate and/or measure hand position, compression rate, compression depth, chest compression fraction, chest recoil, ventilation rate, and ventilation volume. At the end of the CPR session, the software also calculated an overall parameter, called compression score, which takes into account all of the other values and ranges from 0-100%. All other parameters are summarized into a score, which was given as an overall percentage.

### **3.4. Procedures**

Upon arrival each participant completed the necessary paperwork, including the demographics form and informed consent form. As previously stated, participants were excluded from the study if they indicate 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 any protective athletic 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-inch compression depth (50 mm), and 100-120 compressions per minute. The timer was set for one minute of compression-only CPR for the initial test. The three values to be 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 had to achieve a minimum value of at least 80% on their compression score during the initial test. If the participant scored lower than 80%, they were to practice after receiving feedback from the researcher. Participants were allowed to re-test one additional time.

Once deemed proficient, participants rested for two minutes. Each participant was then required to perform two sessions of single-rescuer CPR on the Resusci Anne® QCPR manikin. One session consisted of performing compression over the manikin equipped with the Barnett VISION II football shoulder pads or Gear 2000 Co. Air-Tech football shoulder pads for four total minutes. The other session consisted of removing the football jersey and opening the shoulder pads from the chest to perform compressions over the bare chest for four total minutes. In addition, participants were timed from beginning of equipment removal to first compression delivered. There was a five-minute rest period between the two sessions. The participants were randomized and counterbalanced to mitigate the effects of fatigue. The participants were instructed to perform rescue breaths with a Laerdal Pocket

Mask™ and were instructed to perform CPR according to the 2015 AHA Guidelines. Participants were unable to observe any visual feedback data about their performance and were not able to see a clock, as performance may change based on objective feedback. In addition, researchers did not provide feedback or encouragement to the participants to avoid positively influencing outcomes.

At exactly four minutes, the researcher informed the participant they have completed the session. 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 highest education level, years of CPR/ATC certification, sport experience, age, gender, height, and weight for data analysis purposes.

### **3.6. Statistical Analysis**

Based on the research questions associated with this study, we anticipated the following statistical analysis: For research questions 1 and 2, basic descriptive statistics were calculated to determine the percentage of certified athletic trainers who achieved the

AHA 2015 Guidelines. A multivariable logistic regression was also performed to explore the relationship among the demographic traits and performance on the CPR dependent variables. If significant predictive results are found, additional Post Hoc statistical exploration was performed 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 are able to deliver quality chest compressions over and under football shoulder pads after being proven proficient in their CPR skills. Athletic trainers act as the first responder for the athletes who participate in football and need to be prepared to perform CPR in the event an athlete experiences cardiac arrest. The results of this research will be used to add to existing evidence-based recommendations for CPR protocols. This research is valuable in determining if protective athletic equipment such as football shoulder pads should be removed immediately or if they can remain in place as rescuers begin chest compressions. Through a better understanding of how football shoulder pads impact the effectiveness of chest compressions, best-practice guidelines can be established to move towards providing a high-quality emergency intervention to increase the possibility of return of spontaneous circulation in athletes experiencing cardiac arrest.

## CHAPTER 4: MANUSCRIPT

### 4.1. Abstract

[Study Design] Experimental

[Background] Certified Athletic Trainers (ATCs) are expected to perform high-quality cardiopulmonary resuscitation (CPR) on athletes in the event of a cardiac emergency, regardless of the protective athletic equipment the athlete may be wearing.

Current guidelines and best-practice standards conveyed by the American Heart Association (AHA) and the National Athletic Trainers' Association (NATA) do not include recommendations in regards to the immediate removal of protective athletic equipment prior to administering chest compressions.

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

[Methods] The ATCs performed two sessions of CPR in accordance to the 2015 AHA guidelines. One session consisted of performing compressions directly over the football shoulder pads. The other session consisted of a timed equipment removal followed by compressions performed under the football shoulder pads. Data were analyzed to compare differences of CPR performance between covariates.

[Results] Overall CPR scores with chest compressions performed over and under the shoulder pads were 43.88% and 77.17%, respectively ( $p < .001$ ). On average, the ATCs were able to achieve a mean depth of 39.41 mm over the shoulder pads, and 54.05 mm under the

pads ( $p < .001$ ). This translates to ATCs achieving 50 mm in compression depth only 18.51% of the time when performed over the football shoulder pads, while they achieved 50 mm under the pads an average of 80.73%. The average time for ATCs to remove the football shoulder pads was 13.77 seconds (SD=4.26), with a range of 7.15 seconds to 22.02 seconds. A regression model was performed to analyze demographic characteristics on CPR performance. No significance was found comparing ATCs' abilities to perform CPR based to any demographic characteristics.

[Conclusions] Results indicate that ATCs are unable to provide high-quality CPR over football shoulder pads. Specifically, performance was inadequate regarding chest compression depth, ventilations, and overall CPR percentage. When compressions were performed over the football shoulder pads, the participants achieved the appropriate depth of 50 mm on average less than 25% of the time. The average ventilations performed at the appropriate volume were under 60% for both conditions. Thus, the removal of football shoulder pads and helmets is recommended prior to performing CPR to ensure high-quality CPR is performed.

[Level of Evidence] Therapy, level 3

[Key Words] Cardiopulmonary Resuscitation, protective equipment, football shoulder pads, Resusci Anne QCPR



## 4.2. Introduction

Certified Athletic Trainers (ATC) are the medical professionals responsible for providing emergency care in the event an athlete suffers from a cardiac event.<sup>59</sup> ATCs are often the first responders to an emergency event in athletics, therefore they would be the individuals initiating resuscitation efforts. Although sudden cardiac death in college athletes is rare, with an incidence rate for sudden cardiac arrest in National Collegiate Athletic Association (NCAA) athletes approximated to be 1:43,000 per year, it is a significant risk athletes face when participating in activities.<sup>2</sup> The physical exertion and contact needed for competitive sports, such as football, place athletes at a greater risk for sudden cardiac arrest. Researchers have indicated that those participating in sport and training increase their risk of sudden cardiac arrest and death 2.4 times to 4.5 times compared to their non-athlete or recreational athlete counterparts.<sup>3,4</sup>

Each year, governing bodies such as the American Heart Association (AHA) and the European Resuscitation Council (ERC) provide updates to the standards and guidelines regarding cardiopulmonary resuscitation (CPR) to continue to ensure high-quality resuscitation care is being provided. However, they provide no recommendations in their standards and guidelines discussing how CPR should be approached for equipment-laden athletes. Athletes who receive blunt-force trauma, such as by objects or another athlete, are at risk for commotio cordis.<sup>66,67,68</sup> Commotio cordis is a form of ventricular fibrillation that occurs from a blunt trauma to the chest during ventricular depolarization of the heart.<sup>66,67,68,69</sup> Due to the inherent risk of sudden cardiac arrest in the equipment-laden population, it is imperative that best-practice guidelines be established for those athletes wearing protective athletic equipment.

When evaluating research involving CPR performance, there are several articles analyzing performance by laypersons, emergency medical technicians and physicians, but

there is an insufficient amount of research with ATCs as the target population. The studies that have been completed in regards to ATCs and CPR performance suggest ATCs are unable to provide compressions at the necessary depth in accordance to the AHA guidelines. From a study including 30 participants (athletic training students and ATCs) who performed CPR under football shoulder pads, average compression depth was found to be 37 mm, compared to the AHA guideline of 50 mm.<sup>60</sup> The results from this study suggest ATCs may not be proficient in providing adequate chest compressions to those even without protective athletic equipment.

The current Position Statement released by the NATA on preventing sudden death indicates that protective athletic equipment should be removed if it prevents access to the airway or access to the chest.<sup>54</sup> There is insufficient research that provides indications if the presence of protective athletic equipment creates a barrier in the delivery of effective, high-quality chest compressions. Previous research has been completed to examine the depth of chest compressions over football shoulder pads and lacrosse pads. The researchers found ATCs and athletic training students achieved an average depth of merely 31.5 mm over football shoulder pads<sup>60</sup> and ATCs achieved an average depth of only 41.8 mm over lacrosse pads.<sup>65</sup> It is important to note that the sample size was limited in both studies, thus it becomes difficult to make generalized recommendations for CPR performance over protective athletic equipment with so few studies from which to infer practice guidelines.

While most studies have indicated the presence of equipment leads to low-quality performance, it can also be argued that removing the equipment takes valuable time away from initial resuscitation efforts. After an extensive search of literature, the only study found which evaluated the effect of time in regards to removing protective athletic equipment incorporated an emergency scenario on a football field. In this study, which was performed in 2011, the ATCs were required to respond to an athlete on the field and remove

the equipment prior to administering compressions.<sup>63</sup> From the time the ATCs reached the athlete to full equipment removal resulted in a delay on 24.4 seconds. The study included only 34 participants thus making additional research necessary to understand the complexities and time constraints when needing to perform CPR on an equipment-laden athlete.

Athletic trainers are expected to perform CPR according to the most recent guidelines and protocols produced by their governing bodies. The researchers in this study sought to determine the best way to treat football athletes suffering from sudden cardiac arrest. Furthermore, the delay in first delivery of compression due to the necessity of removing football shoulder pads, was required as part of an additional scenario to compare data to the existing literature.

#### **4.3. Methods**

To determine the role of protective athletic equipment during CPR performance, a randomized crossover study was conducted in which two CPR scenarios were analyzed. It was hypothesized that performing CPR over the football shoulder pads would have a negative impact on compression depth. It was also hypothesized that removing the protective athletic equipment prior to the initiation of CPR would cause a greater delay in providing care.

##### **4.3.1. Participants**

Participants included Certified Athletic Trainers because they are often considered the first responders at athletic events and would therefore be the individuals responsible for evaluating the athlete and commencing CPR. Participants were recruited as a convenience sample (N=41; m=18, f=23; Age: 31.9±10.6) via email and word-of-mouth. Inclusion criteria for the study included: (1) current certification as an athletic trainer through the BOC® (Board of Certification); (2) current CPR/first-aid certification; (3)

currently licensed and practicing as a certified athletic trainer. Exclusion criteria for the study included any current cardiovascular or musculoskeletal condition that would prevent an individual from delivering high-quality CPR at the time of testing. This research study was reviewed and approved by the university's Institutional Review Board (IRB) and participants in the study were required to read and sign an Informed Consent document and a Participant Demographic Form.

#### **4.3.2. Test Conditions**

Athletes participating in American football are required to wear a helmet equipped with a facemask, shoulder pads, and a jersey. This study included two CPR scenarios involving performance both over and under American football protective shoulder pads. Prior to attempting the two CPR protocols, participants were asked to complete a one-minute, compression-only CPR proficiency test. The proficiency test was performed to ensure participants could perform high-quality CPR on the standard manikin without protective athletic equipment. Participants were deemed "proficient" if they achieved at least an 80% on their overall compression score, as determined by the Laerdal SkillReporter Software (Laerdal Medical, Stavanger, Norway) during the proficiency test. If participants failed to achieve 80%, they were given the opportunity to practice after receiving feedback from the researcher and allowed to re-test one additional time.

Once deemed proficient, participants were allowed rest for up to two minutes before continuing to the two CPR scenarios. For each of the CPR situations, the facemask had been removed from the helmet and participants were asked to perform single-rescuer CPR in accordance with the 2015 American Heart Association (AHA) Guidelines. The protocol for scenario one involved the participant performing CPR directly over the Barnett VISION II or Gear 2000 Co. Air-Tech football shoulder pads. The protocol for scenario two required the participant to remove the jersey from the manikin, followed by opening the football

shoulder pads by cutting the laces connecting the front of the pads to reveal the manikin's chest. The participants were timed by the researcher from the start of equipment removal to the first compression on the bare chest. Participants were then instructed to perform compressions directly on the manikin's chest. Each session was performed for a total of four minutes with a five-minute rest period between protocols. The participants were randomized and counterbalanced to mitigate the effects of fatigue.

#### **4.3.3. Equipment**

All testing protocols were performed on a Resusci Anne® QCPR (Laerdal Medical, Stavanger, Norway) manikin due to the software's ability to collect real-time data during performance of CPR using the Laerdal SkillReporter Software. The software was programmed in accordance to the 2015 American Heart Association (AHA) Guidelines of: 30:2 compression-to-ventilation ratio (using a Laerdal Pocket Mask™), 2.0-inch compression depth (50 mm), and 100-120 compressions per minute. The facemask was removed from the helmet prior to testing as the primary purpose of this research was to measure compressions and not full equipment removal. The football shoulder pads that were selected for this study were quarterback/wide receiver style due to the physical size of the manikin. The shoulder pads had a traditional practice football jersey over them, which had a Velcro front attached for repeated use during the study.

#### **4.3.4. Procedures**

Following a brief familiarization period during which participants could view the manikins and equipment, participants were read the pre-approved scenarios. The protocol scripts described the patient as a 20-year old male football player who was found unconscious, not breathing, with no spinal precautions. The protocols then instructed the participants to either perform CPR directly over the football shoulder pads or to remove the jersey and football shoulder pads before beginning CPR. Time and data collection for

scenario one began at the start of compressions. During the protocol for scenario two, participants were timed from beginning equipment removal to their first compression, followed by data collection via the Laerdal SkillReporter Software once compressions began.

The values recorded from the Laerdal SkillReporter Software to be analyzed included: 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.

#### **4.3.5. Statistical Analysis**

Based on the research questions associated with this study, basic descriptive statistics were calculated to determine the percentage of certified athletic trainers who achieved the AHA 2015 Guidelines. A paired *t*-test was performed to compare the results from the protocol performed over the football shoulder pads to the protocol performed under the pads. A regression model was also performed to analyze the significance of the demographic variables.

#### **4.4. Results**

The demographic information from the participants can be found in Table 18. Out of the 41 total participants, 27 were CPR certified through the AHA, and 13 through the American Red Cross (ARC). There was a relatively even number of males and females in the group of participants, at 18 and 23, respectively.

Performance with and without pads was tested using paired *t*-tests with participants serving as their own controls. Seven performance variables were measured in percent terms: overall performance, recoil, depth, compressions, adequate ventilation, chest compression fractures, and rate. Table 19 presents the results of these tests.

For three variables, participants performed better to a statistically significant degree under the football shoulders pads. The most important result is that overall performance increased from an average of 43.88% to 77.17% with a large effect size. Substantial increases in performance are also reported for depth and compression. One variable, recoil, actually showed a slight decrease in performance. None of the other percent variables altered significantly. For the physical variables, neither mean rate nor volume differed significantly, but mean depth increased at a statistically significant level with a large effect size.

**Table 18.** Participant Demographics.

Participant Characteristics (n=41; m=18, f=23)	Minimum	Maximum	Mean	Standard Deviation
Age (years)	22	61	31.9	10.7
BMI	19.5	38.3	26.8	4.6
Years of CPR Certification	3	39	12.5	9.7
Years of ATC Certification	1	34	8.6	9.3

n=number of participants, m=male, f=female

**Table 19.** Mean Results from Several CPR Variables Performed Over and Under Football Shoulder Pads.

Variable	Change	Mean over	SD over	Mean under	SD under	t[40]	p	CI Lower	CI Upper	Hedges g
Overall	33.29	43.88	27.56	77.17	20.25	7.97	<.001	24.85	41.74	1.24
Recoil	-11.51	94.8	15.27	83.29	26.19	3.17	0.003	4.17	18.86	0.49
Depth	62.22	18.51	30.93	80.73	29.76	11.37	<.001	51.16	73.28	1.78
Comp	45.8	41.54	34.51	87.34	22.68	7.93	<.001	34.13	57.48	1.24
Vent	1.32	57.34	33.33	58.66	33.43	0.34	0.738	-6.58	9.22	0.05
CF	0.37	66.34	5.56	66.71	7.44	0.24	0.807	-2.65	3.38	0.04
Rate	3.39	77.41	25.52	80.8	29.64	0.69	0.492	-6.49	13.27	0.108
Mean rate (comp/min)	-0.19	112.49	7.56	112.29	7.4	0.177	0.861	-2.43	2.04	0.03
Mean depth (mm)	14.63	39.41	9.72	54.05	6.29	11.43	<.001	12.05	17.22	1.79
Mean volume (mL)	19.63	387.39	161.11	407.02	168.39	1.19	0.241	-13.71	52.97	0.19

\*For change column, positive number indicates NP condition is the larger number



A regression model was estimated with Overall CPR performance as the dependent variable and gender, age, years of CPR certification, Organization, and BMI as independent predictors. The overall model was not statistically significant ( $F[5, 33]=.454, p=.808$ ), nor were any of the individual variables statistically significant. None of these factors play a substantial role in predicting CPR performance. This finding reinforces the importance of the two testing conditions in Table 1.

#### **4.5. Discussion**

The 2015 AHA Guidelines recommends that chest compression depth should reach at least 50 mm in order to be considered effective.<sup>43</sup> The compression depth results during this study revealed that participants averaged just  $39.41\pm 9.72$  millimeters (mm) during performance over the shoulder pads. The participants were however, able to achieve an average mean depth of  $54.05\pm 6.29$  mm under the shoulder pads, which met the 2015 AHA Guidelines ( $p<.001$ ). Due to the limited research with ATCs as the target population, we compared our results to research using other medical professionals. Data collected from emergency medical service (EMS) professionals between the years 2006 to 2009 revealed that inadequate compressions were being delivered with the average depth being only 37.3 mm.<sup>45</sup> During this time period however, the recommended depth was a minimum of 38 mm. The average depth achieved during this study remained insufficient in regards to reaching the lower recommendation. Additional data compiled from 1,004 in-hospital cardiac events revealed that only 21% of the 1.5 million recorded compressions achieved the depth in accordance with the 2015 AHA Guidelines.<sup>44</sup> Several studies have been performed to evaluate ATCs' and athletic training students' ability to achieve the appropriate depth of chest compressions performed over protective athletic equipment, such as football shoulder pads and lacrosse pads. Nearly all studies involving compressions performed over football shoulder pads revealed that depth was inadequate, with the exception of one study stating

proper depth could be achieved in the presence of audiovisual feedback.<sup>60-63</sup> Based on the results from the current study along with others involving compressions over equipment, it can be suggested that football shoulder pads should be removed prior to the initiation of chest compressions in order to achieve the recommended compression depth.

To add to the existing literature about the time commitment of removing equipment, we included a mechanism for timing the process. There are insufficient research studies that have evaluated the amount of time needed to complete removal of athletic equipment prior to initiating CPR. Similar to the present study, one study was conducted with ATCs to evaluate the time needed to remove the football shoulder pads prior to the initiation of chest compressions. This study used similar methodology to our present study in regards to utilizing football shoulder pads, performing CPR under and over the pads, and recording the time for equipment removal. In the study performed by Del Rossi et al, 2005 AHA guidelines were followed and a protocol was implemented to make the scenario similar to real life. This protocol required the participants to witness a collapse, respond to the patient, and perform an initial evaluation prior to initiating equipment removal or resuscitative efforts. Del Rossi et al found the participants needed, on average, an additional  $24.4 \pm 7.2$  seconds to unfasten the chest protector and begin compressions when comparing to resuscitation efforts directly over the chest protector.<sup>63</sup> In our study, the average time from the start of equipment removal to the first chest compression was  $13.77 \pm 4.26$  seconds. The fastest time recorded was 7.15 seconds and the slowest time was 22.02 seconds. The variance in the times from the two studies could be attributed to the methods in which each study used as a start and stop marker. In our study, participants were timed from the moment they touched the equipment until the initiation of the first compression, whereas participants in the Del Rossi et al study were timed from the moment they picked up the scissors to the moment the bare chest was exposed. The range in time

needed in our study should be noted, as some of the participants did not remove all the laces or straps on the shoulder pads prior to beginning chest compressions. Due to the two studies average time for equipment removal having near a ten second difference, further research should be conducted to provide normative data and quantitative suggestions for Athletic Trainers who work directly with football athletes.

While monitoring ventilations was not the primary goal of this research, we found the average ventilation percentage for CPR performance over and under the football shoulder pads were found to be  $57.34 \pm 33.33\%$  and  $58.66 \pm 33.43\%$ , respectively. Although there is no statistical significance between the two conditions, these results indicate that ventilations are only adequate approximately half of the time. The mean ventilatory volume was found to be  $387.39 \pm 161.11$  milliliters (mL) when performed on the fully equipment manikin and  $407.02 \pm 168.39$  mL on the manikin with the equipment removed, which are both drastically below the recommended 500 mL to 700 mL even though the variables were found to be statistically significant between the values.<sup>43</sup> It is vital to achieve the appropriate ventilation volume during CPR to achieve adequate gas exchange in the body, and to avoid hyperventilation and the build-up of carbon dioxide.<sup>7,12,70</sup> The lack of ventilation volume delivery may be attributed to a variety of factors. The first factor was the helmet, which made it difficult for participants to properly perform the head-tilt chin-lift maneuver prior to ventilation delivery. The second factor was the presence of the shoulder pads under the manikin. The shoulder pads also limited the ability of the participants to perform the head-tilt chin-lift maneuver due to the sliding of the pads during chest compressions. In the current guidelines, there are no recommendations for full equipment removal during a cardiac arrest. Because there are no recommendations in place, it is unknown if all equipment, such as the shoulders pads and the helmet, should be removed to deliver effective ventilations.

Contrary to our hypothesis, when CPR was performed over the equipment, mean recoil percentage was better at a statistically significant rate ( $p=0.003$ ). Conversely, in a study with similar methodology, researchers reported a decreased performance (63.8% with equipment on, 76.1% with the equipment off) regarding chest recoil when the compressions were performed directly over the protective equipment.<sup>63</sup> In our study, the increased recoil percentage may have been caused by the participants not achieving the recommended compression depth and releasing the chest in excess to what they normally would in a compensatory manner. Because of their unknowing compensation, they were achieving the appropriate recoil percentage. Participant compensation was not considered in our hypotheses. It should, however, become a consideration in future research studies, not only in regards to complete chest recoil, but also as a factor to be considered in rescuer fatigue in both patients with and without protective athletic equipment.

The results of our study indicated that demographic factors, such as gender, body mass index (BMI), age, years of certification, and years of education, all had no significant effect on CPR performance for either scenario. This data contradicts previous research that has been completed that has concluded demographics have an impact on whether high-quality CPR can be performed.<sup>46,47,48</sup> Although we recognize the limitation of self-reported BMI, the data collected are still crucial for comparing our results to previous literature. This supports that all ATCs can be equally skilled and qualified to provide athletic training coverage to the sport of American football, with no implications on gender, age, BMI, years of certification, or level of education.

This research study was not performed without limitations. The participants performed simulated CPR on a manikin, which does not represent an actual football player. Another limitation is that the facemask was previously removed from the helmet prior to testing. This does not give the true amount of time equipment removal would take in the

event CPR was needed to be performed on a football athlete. Furthermore, the models of football shoulder pads used were the Barnett VISION II and Gear 2000 Co Air-Tech shoulder pads and results cannot be generalized to other protective athletic equipment.

#### **4.6. Conclusion**

CPR guidelines are continuously updated in an effort to improve sudden cardiac arrest survival rates; however, no guidelines currently exist in regards to how to perform CPR on athletes who are wearing protective athletic equipment. There are still unanswered questions in regards to CPR performance both with and without pads. Specific evidence-based recommendations are needed to provide not only ATCs but other emergency responders with the knowledge of the appropriate standard of care for equipment-laden athletes suffering from a cardiac event.

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