THE EFFECT OF MEN’S LACROSSE EQUIPMENT ON CHEST COMPRESSION AND VENTILATION DELIVERY

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ABSTRACT

Mikaela Paige Davis: The Effect of Equipment on the Ability of Athletic Trainers to Deliver Cardiopulmonary Resuscitation Men’s Lacrosse Athletes
(Under the direction of Meredith Petschauer)

Background: Current management guidelines for the care of equipped athletes in the case of cardiac emergencies are unclear regarding the decision to remove protective sports equipment prior to the delivery of cardiopulmonary resuscitation (CPR). It has been shown that the presence of football equipment decreases the effectiveness of CPR delivery. Our objective was to determine the effect of men’s lacrosse equipment on performing chest compressions and delivering adequate ventilations on patient simulators. Hypothesis: Conditions with more men’s lacrosse equipment left in place would decrease chest compression and ventilation efficacy for athletic trainers. Methods: Twenty-six certified athletic trainers participated in three different compression conditions and six different ventilation conditions using human patient simulators. Data for chest compressions (mean compression depth, compression rate, percentage of correctly released compressions, and percentage of adequate compressions) and ventilations (total ventilations, mean ventilation volume, and percentage of ventilations delivering adequate volume) were analyzed within subjects across each equipment condition. Results: The fully-equipped athlete was found to have the lowest mean compression depth ($F_{2,50}=26.57$, $p<0.001$) and the fewest number of compressions reaching an adequate depth ($F_{2,50}=21.48$, $p<0.001$) compared to all other conditions. The fully equipped athlete was also found to have the lowest mean ventilation volume ($F_{2,125}=17.79$, $p<0.001$), and a lower percentage of ventilations reaching
adequate volume ($F_{2,125}=43.05$, $p<0.001$), in both one-person pocket mask and two-person bag valve mask scenarios. **Conclusions:** Our results indicate that chest compression and ventilation delivery are compromised in equipment-laden conditions in the sport of men’s lacrosse. As a result, in the case of a men’s lacrosse athlete requiring CPR, the shoulder pads must be lifted or cut away to expose the chest, and the facemask and chinstrap must be removed to access the airway.
<table>
<thead>
<tr>
<th>TABLE OF CONTENTS</th>
</tr>
</thead>
</table>
| ABSTRACT
ABSTRACT .................................................................................................................................. iii |
| CHAPTER 1
Clinical Significance....................................................................................................................3 |
| Research Questions & Hypotheses..............................................................................................3 |
| CHAPTER 2
Introduction..................................................................................................................................5 |
| Epidemiology..................................................................................................................................6 |
| Normal and Pathological Anatomy ............................................................................................6 |
| Pathological Conditions Precipitating Cardiac Emergencies ......................................................9 |
| Hypertrophic Cardiomyopathy ......................................................................................................9 |
| Coronary Artery Anomalies .........................................................................................................10 |
| Commotio Cordis ..........................................................................................................................10 |
| Marfan Syndrome ....................................................................................................................11 |
| Long QT Syndrome ....................................................................................................................11 |
| Sickle Cell Trait ..........................................................................................................................12 |
| Current Management Guidelines ................................................................................................12 |
| Cardiopulmonary Resuscitation Guidelines ..............................................................................12 |
| Airway Opening Techniques ........................................................................................................13 |
| Guidelines for Athletic Trainers ...............................................................................................14 |
| Airway Access Techniques ..........................................................................................................15 |
| Lacrosse Airway Access Guidelines ..........................................................................................15 |
| Lacrosse Facemask Removal .......................................................................................................15 |
Limitations .................................................................................................................................39
Conclusion ...............................................................................................................................40

TABLES AND FIGURES .......................................................................................................... 41

REFERENCES ............................................................................................................................ 44
CHAPTER 1
INTRODUCTION

Men’s lacrosse is a rapidly growing sport in the United States, experiencing a 41% expansion in collegiate teams since 1988 (Dick, 2007). With this increase in participation, there is a growing need for establishing evidence-based guidelines for proper emergency management of catastrophic injuries, particularly cardiac injuries. Sudden cardiac death is the most common athletic related death in young athletes, representing 64 of the 182 deaths of National Collegiate Athletic Association athletes from 2001 to 2011 (B. J. Maron, Haas, Murphy, Ahluwalia, & Rutten-Ramos, 2014). Athletic trainers, as on-site medical providers and first responders to injuries, are often the primary party responsible for initial management of cardiac emergencies. Early cardiopulmonary resuscitation (CPR), defibrillation, and access to advanced medical care greatly improve cardiac emergency outcomes (Drezner, 2007). Thus, it is imperative the responding athletic trainer is able to quickly and successfully access an athlete’s chest and airway to initiate rescue breathing, chest compressions, or both.

Cardiopulmonary Resuscitation outcomes inside and outside the hospital are greatest when the chest compression rate is between 100 and 120 compression rates per minute; any deviations above or below this range decreases survival rates following CPR (Meaney et al., 2013). Additionally, a compression depth of at least 50 mm is known to improve survival outcomes (Meaney et al., 2013). The current American Red Cross (ARC) CPR guidelines recommend 2 breaths for every 30 compressions, resulting in rate of 8 to 10 breaths per minute during CPR administration. The ARC CPR guidelines are in accordance with the 2010 AHA
CPR guidelines, which recommends a ventilation rate of <12 breaths per minute to minimize the impact of positive pressure ventilation on blood flow (Field et al., 2010).

There is currently no definitive evidence-based guideline for how to manage a cardiac episode in equipment-laden athletes such as men’s lacrosse. There are, however, recommendations for equipment removal during other catastrophic injuries, such as cervical spine injury scenarios. The current National Athletic Trainers Association (NATA) position statement on preventing sudden death in sport states that access to the chest and airway must be established in equipment laden cervical spine injured athletes in case CPR or an AED must be administered for vital life support (Douglas J. Casa, 2012). Additionally, the current NATA position statement on acute management of the cervical spine injured athlete recommends that removal of the equipment be deferred with three exceptions, one being that the equipment prevents airway or chest access (Swartz, 2009).

Currently, no evidence is available to address whether or not men’s lacrosse equipment impedes an athletic trainer’s ability to deliver effective CPR, with effective being defined as the current recommended 100-120 compressions per minute, at least 50 mm compression depth, and 8-10 breaths per minute. This study will determine whether or not chest pads will reduce the efficacy of chest compressions due to the padding material covering the chest, making it difficult to achieve the necessary depth and rate, as well as creating a soft surface on which compressions are being performed. Additionally, the study will determine whether or not ventilation rate and depth are affected due to the helmet and chinstrap interfering with the ability to achieve and maintain an open airway. The presence of a helmet over the athlete’s forehead and chinstrap under the chin may interfere with the practitioner’s ability to perform the modified jaw thrust maneuver that opens the airway prior to rescue breath administration. Since there is currently no
definitive recommendation regarding lacrosse equipment removal in cardiac emergency situations, some athletic trainers may choose to remove equipment in order to allow unobstructed chest access, while others may choose to leave equipment in place, in order to save time, potentially resulting in less effective CPR. This study aims to determine the appropriate course of action in these cardiac emergency scenarios by examining CPR effectiveness in different equipment conditions. Therefore, the purpose of this study is to compare the efficacy of cardiopulmonary resuscitation in different men’s lacrosse equipment scenarios, and to use these data to determine whether equipment should be removed or left in place when managing lacrosse cardiac emergencies.

Clinical Significance

One of the major roles of athletic trainers is to act as first responders to emergency situations. Successful athlete outcomes depend on athletic trainers having proper preparedness in emergency protocols and procedures. For this reason, this study aims to determine best practices in the case of cardiac emergencies in lacrosse equipment laden athletes. Both chest compressions and rescue breathing will be assessed. The current investigation will equip athletic trainers with empirical evidence to determine best practices for safely removing, or not removing, equipment in the event of emergency situations in which chest compressions or rescue breathing are necessary.

Research Questions & Hypotheses

Research Question 1: What is the effect of men’s lacrosse equipment conditions (chest pads on, chest pads lifted up, and chest pads removed) on athletic trainers’ ability to deliver quality CPR chest compressions, as measured by compression depth, compression rate, percentage of correctly released compressions, and percentage of compressions that reached an adequate
Hypothesis 1: There will be an effect of equipment condition on compression depth, compression rate, percentage of correctly released compressions, and percentage of compressions that reached an adequate depth such that compressions will be deeper and delivered at a higher rate in conditions without chest pads compared to conditions with the chest pads lifted up. Additionally, compression depth will be greater and delivered at a higher rate in conditions with chest pads lifted up compared to chest pads left on.

Research Question 2: What is the effect of men’s lacrosse equipment conditions (helmet off, facemask flipped up, facemask removed) on athletic trainers’ ability to deliver quality ventilations individually (pocket mask) or in pairs (2-person bag-valve mask), as measured by ventilation volume, ventilation rate, and percentage of ventilations achieving adequate volume?

Hypothesis 2: There will be an effect of equipment condition on frequency of ventilations attempted, ventilation volume (in milliliters), and percentage of attempted ventilations delivering adequate volume, such that ventilations will be delivered at a higher rate, higher volume, and have a higher percentage achieving adequate volume in conditions without a helmet compared to conditions with just the facemask removed.
CHAPTER 2

LITERATURE REVIEW

Introduction

Sudden cardiac arrest is a risk to athletes and access to immediate and appropriate medical care is essential in the management of this condition. According to the 2013 participation study, there are 319 sanctioned men’s lacrosse teams (11,722 total student athletes) in the National Collegiate Athletic Association (National Collegiate Athletic Association, 2013). Lacrosse is a fast-paced collision sport which increases injury risk, including risk for cardiac emergencies. Athlete care for cardiac emergency situations in nonequipment laden sports is relatively straightforward; however, in men’s lacrosse the added component of equipment worn over the chest and face complicates the treatment of cardiovascularly compromised athletes by potentially limiting access to the airway and chest for administration of cardiopulmonary resuscitation. Currently, there are no explicit guidelines for the management of equipment-laden athletes during a cardiac emergency.

This thesis seeks to compare the effectiveness of cardiopulmonary resuscitation under a variety of equipment-laden conditions for men’s lacrosse. Specifically, we will assess chest compression depth and rate as well as ventilation rate and volume. This purpose is important in order to determine the best practices during a cardiac or respiratory emergency in lacrosse equipment-laden athletes.
Epidemiology

Sudden cardiac death is the most common source of athletic related death in young athletes, representing 64 of the 182 deaths of NCAA athletes from 2001 to 2011 (B. J. Maron et al., 2014). Sudden cardiac death is defined as an unexpected, non-traumatic death from cardiac causes, signaled by an abrupt loss of consciousness within 1 hour of the onset of acute symptoms (Lateef, 2000). The incidence of sudden cardiac death in NCAA student-athletes is rare, with 1 case per every 43,770 athletes annually (Harmon, Asif, Klossner, & Drezner, 2011). The most common cause of cardiac related deaths is hypertrophic cardiomyopathy, but other mechanisms include: coronary artery anomaly, coronary artery disease, aortic rupture, arrhythmogenic right ventricular cardiomyopathy, dilated cardiomyopathy, myocarditis, long QT syndrome, mitral valve prolapse, and acute myocardial infarction (B. J. Maron et al., 2014). Lacrosse is the sport with the third highest risk of SCD, behind basketball and swimming, with an overall incidence rate of 1 in 23,357 athletes (Harmon et al., 2011).

Normal and Pathological Anatomy

The function of the heart is to circulate oxygenated blood throughout the body to supply the body systems with oxygen needed to keep organs functioning and body cells alive. The heart is comprised of four chambers, two atria and two ventricles. Deoxygenated blood enters the heart through the vena cava into the right atrium. It then is pumped through the tricuspid valve into the right ventricle. When the right ventricle contracts, blood exits the heart through the pulmonic valves into the pulmonary arteries where it is taken to the lungs to be oxygenated. Oxygenated blood returns to the heart from the lungs via the pulmonary veins and enters the left atrium. Blood then passes through the mitral valve into the left ventricle, from which it is pumped into systemic circulation via the aorta ("Anatomy and Physiology: Understanding the Importance of
CPR," 2006). The pumping action of the heart is regulated by the heart’s electrical system that is responsible for the timing of the contraction of each chamber (Rhodes, 2008).

Cardiac arrest (CA) is a clinical syndrome defined as the “cessation of cardiac mechanical activity, as confirmed by the absence of signs of circulation (Varvarousis et al., 2015). Cardiac arrest occurs when the heart stops beating normally, due to an interruption of the heart’s electrical system. The American Heart Association reports that 166,000 Americans experience out-of-hospital cardiac arrest each year (Sasson, Rogers, Dahl, & Kellermann, 2010). Other estimates put the number of cardiac arrest cases even higher at over 300,000 within the United States and Canada (Graham Nichol, 2008). Sudden cardiac death can be caused by several different interruptions of electrical activity. Ventricular fibrillation causes a rapid unsynchronized contraction of the ventricles. Atrial fibrillation is a fast irregular contraction of the atria of the heart. Ventricular tachycardia results in an extremely rapid contraction of the ventricles. In some cases, the electrical system of the heart fails entirely causing no contraction of the heart to occur at all, a conditions known as asystole (Rhodes, 2008).

In the event of a cardiac emergency in sport, quick access to CPR and defibrillation is crucial to increasing survival rates (Nolan, Perkins, & Soar, 2015). In their 2015 consensus statement, the European Resuscitation Council state that “expeditious response with initiation of immediate resuscitation at the side of a collapsed player remains crucial for survival, and chest compressions should be continued until the automated external defibrillator (AED) has been fully activated. They recommend the onsite medical team respond to a non-contact collapsed player on the field of play with AED and defibrillation within a maximum of 2 min from collapse” (Kramer, Serratosa, Drezner, & Dvorak, 2015) This recommendation is supported by a subsequent study in which out-of-hospital cardiac arrest cases were examined from 2006-2012 to
determine the relationship between time to recall and survival rates. As time to shock increased, survival rate decreased from 71.1% with shock occurring within 2 minutes, to 63.4% at 4 minutes, and to 20.9% at 12 minutes (Blom et al., 2014). This recommendation of early AED use is supported by another study for the American Heart Association by Larsen that found that for each minute that access to CPR and defibrillation is delayed, a victim’s chance of survival is reduced about 7 to 10% (Larsen, 1993).

When the heart fails to beat normally, oxygen is not being delivered to the systems of the body and body systems begin to die. This lack of oxygenation affects some systems more quickly than others. Specifically, the brain is most quickly affected. Postanoxic coma is the leading cause of death among people who have survived a cardiac arrest. Specifically, the condition hypoxic-ischemic encephalopathy, which is brain injury due to asphyxia and can begin to happen within just a few minutes of cardiac arrest (Taccone, Crippa, Dell'Anna, & Scolletta, 2015). This is highlighted by the fact that there is a significant linear association between a good neurologic outcome in CA patients and emergency system arrival time (p<0.0001) and patients with an EMS response time longer than 10 minutes are prone to more significant declines (Bur et al., 2001).

During chest compressions, the practitioner is attempting to mimic the pumping action of the heart manually. By compressing the heart, the practitioner forces the blood to pump to the body, rather than the now failed electrical system causing the heart muscle to contract ("Anatomy and Physiology: Understanding the Importance of CPR," 2006). It is crucial that compressions be of an adequate depth during CPR. An inadequate compression of the chest will not increase the pressure within the heart to the point that the aortic valve is opened and blood exits the heart and enters systemic circulation. Additionally, correct rate of compressions during
CPR is important to mimic the normal heartbeat and effectively circulate blood. Compression rates that are too low do not allow adequate oxygen to be delivered to the body’s systems; however, when compression rates are too fast, the compressions are often not deep enough or the chest is not being allowed to fully recoil between compressions. Both of these scenarios result in ineffective compressions being performed.

The second element involved in CPR is the delivery of ventilations. During ventilations the practitioner is introducing oxygen into the body that is then circulated by the action of the chest compressions. Without the correct administration of ventilations there can be too little oxygen that is available to be delivered to the body’s systems. However, too much volume or frequency of ventilation can cause vomiting and further injury to the patient. It is crucial that both chest compressions and ventilations be performed correctly, at the appropriate rates and volumes, for the most successful patient outcomes.

**Pathological Conditions Precipitating Cardiac Emergencies**

There are a number of conditions that may predispose an athlete to a cardiac emergency. These predisposing conditions are detailed below.

*Hypertrophic Cardiomyopathy*

Hypertrophic cardiomyopathy (HCM) is the most common cause of sudden cardiac death in young athletes accounting for almost half (21 out of 47) of confirmed cardiac related sudden deaths in NCAA athletes between the years of 2001 and 2011 (B. J. Maron et al., 2014). Hypertrophic cardiomyopathy is defined as abnormal left ventricle thickening without chamber dilation that is usually asymmetrical and develops in the absence of an identifiable cause. HCM predisposes patients to silent myocardial ischemia, ongoing myocardial injury, and fibrosis (Hensley et al., 2015), all of which can precipitate cardiac arrest when cardiac output is increased.
during an aerobically demanding sport, such as lacrosse.

*Coronary Artery Anomalies*

The second most frequent cause of sudden cardiac death in young athletes is congenital coronary artery anomalies, which account for between 12 and 20% of sudden cardiac death cases (B. Maron, 2003). Most patients with coronary artery anomalies are asymptomatic and may die suddenly at the first manifestation of their abnormality. In those individuals who are symptomatic, complaints are rarely of typical angina and are more often of nonspecific symptoms such as syncope, dyspnea on exertion, and palpitations. (Graham et al., 2005) The vast majority of these symptoms are related to exertion.

In the case of coronary artery anomalies, the problem occurs when myocardial ischemia, or blockage of blood flow to the heart muscle, is precipitated by exercise. This ischemia may lead to a disruption of the normal electrical activity of the heart, causing a fatal arrhythmia in athletes with coronary artery abnormalities.

*Commotio Cordis*

Commotio cordis is another cardiac condition that must be considered when discussing management of cardiac conditions in athletes. Commotio cordis is defined as cardiac arrest resulting from non-penetrating, blunt chest blow produced by projectiles or bodily contact, in the absence of underlying cardiac disease. The trauma occurs at a point during the cardiac cycle in which the heart is vulnerable, the electrical signal in the heart is disrupted and virtually instantaneous cardiac arrest occurs without causing any identifiable morphological injuries to the ribs, sternum or heart (Lateef, 2000). In men’s lacrosse, the risk of the cardiac pathology is relatively high due to the chance of being struck by high-speed projectiles such as a lacrosse ball. There have been 9 cases of commotio cordis in the past 13 years in lacrosse (Frederick O.
Marfan Syndrome

Marfan syndrome has an estimated incidence in the population of 1 in 5,000-7,000 (Marsalese, 1989). Marfan syndrome is a genetic condition characterized clinically by a diverse constellation of abnormalities variable in severity and involving primarily the ocular, skeletal, and cardiovascular organ systems (DePaepe, 1996). Cardiovascular manifestations of Marfan Syndrome that can lead to SCD include progressive dilatation of the aortic root or descending aorta which are predisposed to dissection and rupture (Marsalese, 1989) as well as associated risks of mitral valve prolapse with associated mitral regurgitation or possible left ventricular systolic dysfunction (Yetman, 2003). Any of these complications of Marfan syndrome can result in SCD and the need for emergency cardiopulmonary resuscitation.

Long QT Syndrome

The incidence of cases of SCD due to Long QT Syndrome (LQTS) in young athletes is estimated to be anywhere from 0.5% to 8% (Corrado, 2006; Puranik, Chow, Duflou, Kilborn, & McGuire, 2005). The term congenital long QT syndrome (LQTS) includes a constellation of inherited disorders caused by cardiac ion channel mutations, which produce prolonged ventricular repolarization and a tendency to experience ventricular tachycardia (Kapetanopoulos, Kluger, Maron, & Thompson, 2006). Ventricular tachycardia can progress to ventricular fibrillation, which is a fatal arrhythmia. Long QT Syndrome may manifest itself as heart palpitations, presyncope, syncope, seizures, cardiac arrest, or SCD and these manifestations often occur during exercise (Kapetanopoulos et al., 2006). Specific guidelines are in place governing the participation of athletes with LQTS in competitive sports. According to the 36th Bethesda conference, athletes who have suffered a cardiac arrest or syncopal episode due to long QT
syndrome should be excluded from participation in competitive sports, except for sports with low
dynamic component (golf, billiards, bowling, cricket, curling, and riflery) (Mitchell, Haskell,
Snell, & Van Camp, 2005).

Sickle Cell Trait

Sickle cell trait is a condition in which an individual inherits one normal and one mutated
hemoglobin gene, resulting in the sickling of red blood cells during exertion. Sickle cell trait is
present in 8% of the African American population in the United States (Harris, Haas, Eichner, &
Maron, 2012). A study examining the Unites States Sudden Death in Athletes Registry found
that of 2,462 total athlete deaths over a 31 year period, 23 of them occurred in association with
sickle cell trait, meaning 0.9% of all athlete deaths and 3.3% of all African American athlete
deaths were associated with sickle cell trait (Harris et al., 2012). While not yet conclusively
proven, this evidence supports the idea that sickle cell trait may well be linked to sudden cardiac
death, and sickle cell trait should be considered in the conversation and planning of sudden
cardiac death.

These conditions are not the only pathologies that can lead to SCD in athletes, merely the
more common causes. Other possible causes of SCD include: arrhythmogenic right ventricular
dysplasia, myocarditis, conduction abnormalities, aortic stenosis, idiopathic concentric left
ventricular hypertrophy and, possibly, mitral valve prolapse (O'Connor, 1998).

Current Management Guidelines

Cardiopulmonary Resuscitation Guidelines

In the 2010 American Heart Association Guidelines of Cardiopulmonary Resuscitation
and Emergency Cardiovascular Care stresses an increased focus on high-quality CPR, with
“high-quality” being defined as a depth of at least 2 inches and a rate of at least 100
compressions per minute (Field et al., 2010). This represents a change in wording from previous guidelines, in which the recommendations were a depth of 1.5-2 inches and a compression rate of approximately 100 compressions per minute. The AHA continues to recommend a compression to breath ratio of 30 compressions to 2 breaths (Field et al., 2010). When administering rescue breathing, the AHA recommendation is that breaths occur at a rate of 1 breath every 6 to 8 seconds, with each breath taking approximately 1 second to administer. The AHA guidelines do not offer a specific volume recommendation when giving rescue breaths, instead recommending that the practitioner look for a visible chest rise as an indicator of effective ventilation (Hazinski, 2010). The European Resuscitation Council has recommended a tidal volume of 0.5 to 0.6 liters during ventilations (Baskett & Zideman, 2005). This volume has been shown to decrease risk of gastric inflation; however, it is also associated with a lower lung tidal volume (Wenzel, 1998). It is important to attempt to minimize gastric inflation due to the risks of vomiting during CPR. This volume guideline is echoed in The Textbook of Emergency Cardiac Care and CPR which states that “a tidal volume of 500 to 600 mL is recommended during CPR because it is likely that this is the minimal volume required to produce chest rise in a victim with no advanced airway” (John M. Field, 2012).

Airway Opening Techniques

The American Red Cross currently has two accepted methods for opening the airway of a patient in need of CPR or rescue breathing. The head-tilt/chin-lift maneuver can be used for victims in whom no cervical spine injury is suspected. This maneuver involves the practitioner positioned to the side of the victim, placing one hand on the victim’s forehead and the fingers of the other hand under their chin, and tilting their head back into neck extension in order to open the airway. The jaw thrust maneuver is used when a head or neck injury is suspected, and the
practitioner wants to minimize head and neck motion while providing care. This maneuver involves the practitioner positioned above the head of the victim, placing one hand on either side of the their face, hooking their fingers under both sides of the victim’s jaw, and pulling the jaw forward in order to open the airway with no neck motion needed (American Red Cross, 2010).

**Guidelines for Athletic Trainers**

The National Athletic Trainers’ Association (NATA) has published a position statement on preventing sudden death in sport. This statement recommends that, in any athlete who is collapsed and unresponsive, cardiac emergency should be suspected (Douglas J. Casa, 2012). Additionally, if normal pulse and/or breathing are absent, Emergency Medical Services should be activated and CPR should be performed immediately until an automated external defibrillator can be retrieved (Douglas J. Casa, 2012). There is not a specific guideline for the management of equipment in the case of sudden cardiac episode; however, in the management of cervical spine injury, a provision is included in the position statement for the equipment-laden athlete that states that the primary acute treatment goals in equipment-laden athletes are to ensure that the cervical spine is immobilized in neutral and vital life functions are accessible (Douglas J. Casa, 2012). The position statement recommends that removal of helmet and shoulder pads in any equipment intensive sport should be deferred until the athlete has been transported to an emergency medical facility except in three specific circumstances, those being that the helmet is not properly fitted to prevent movement of the head independent of the helmet, the equipment prevents neutral alignment of the cervical spine, or the equipment prevents airway or chest access (Douglas J. Casa, 2012).

The NATA position statement fails, however, to specifically define what airway and chest access entail, and whether the chest pads must be removed, or whether they may stay in
place during the administration of cardiac emergency care, likely because sufficient evidence is not available to make an evidence-based recommendation.

While information surrounding the effect of lacrosse equipment on CPR is unknown, a few studies have been conducted with football equipment. In 2014, Waninger et al. studied whether CPR can be performed over football protective equipment. This study found that chest compressions, when performed over football shoulder pads, had a 15% decrease in compression depth (Waninger et al., 2014). No significant difference was found in chest compression rate or chest recoil (Waninger et al., 2014). This study offers some evidence that athletic protective equipment may prevent the chest access needed to adequately perform CPR; however, this study was limited in scope to compression-only CPR. Further research is needed to determine whether a helmet or facemask interferes with the administration of ventilations.

**Airway Access Techniques**

**Lacrosse Airway Access Guidelines**

In helmeted sport, during cardiac emergencies it is essential that an unobstructed airway be established in order to effectively administer cardiopulmonary resuscitation. The current guidelines for men’s lacrosse athletes, per US Lacrosse Sport and Safety, is that the facemask of an injured athlete should be removed prior to transportation in emergency vehicle so that the athlete’s face and airway may be accessed without interference from the facemask in order to perform, CPR, administer oxygen, and other life-saving tasks. It is the current guideline that all other equipment, shoulder pads and helmet, should be left in place until taken off upon arrival to hospital (Lacrosse Helmet Facemask/Chinguard Removal Hints for Certified Athletic Trainers).

**Lacrosse Facemask Removal**

Several different tools may be used to remove a men’s lacrosse facemask including: a
cordless screwdriver, facemask extractor, or even pruning shears (Lacrosse Helmet Facemask/Chinguard Removal Hints for Certified Athletic Trainers). In a 2013 study, Bradney and Bowman found that of the available tools, the cordless screwdriver is the fastest and easiest to use for men’s lacrosse facemask removal (Bradney & Bowman, 2013). This study found that not only was the cordless screwdriver the fastest facemask removal tool, but it was also given the lowest rate of perceived exertion by subjects in the study (Bradney & Bowman, 2013). Therefore, the cordless screwdriver is the most beneficial tool for facemask removal purposes and is the tool being utilized in this project.

_Men’s Lacrosse Equipment Removal as Compared to Football_

Football equipment removal and airway access have been far more heavily researched than men’s lacrosse. For this reason, many current men’s lacrosse equipment removal guidelines are highly based off research in football equipment laden athletes. Currently, the guidelines for football airway access, and thus for men’s lacrosse, indicate that equipment should be left in place and only the facemask removed for airway access (Douglas J. Casa, 2012).

This guideline stems from research that has found that complete helmet removal without shoulder pad removal places the c-spine in a disadvantageous position (Decoster et al., 2012). Thus, it is not recommended that the helmet be removed to gain access to the airway in a football equipment-laden athlete. It is problematic to extend this recommendation to cardiorespiratory emergencies in which the positioning of the cervical spine is irrelevant in emergency management. Another problem with this recommendation is that lacrosse helmets differ greatly in design from a football helmet, so results from a study using football helmets may not be generalizable to other equipment laden sports. Shoulder pads differ between football and men’s lacrosse as well, with football shoulder pads tending to be thicker than lacrosse shoulder pads.
This shoulder pad discrepancy is notable due to the lordosis that is subsequently caused in a football helmet removed situation and is the basis for the recommendation that the helmet remain on; this phenomenon has been shown to be not as notable in individuals equipped with lacrosse shoulder pads (Higgins, 2010).

These differences between equipment designs between the three equipment-laden sports warrant further investigation to most optimally manage emergencies in each sport. The disparities present between men’s lacrosse and football mean it may be problematic to generalize findings in football to lacrosse as well. Additionally, all current recommendations are centered on care for a cervical spine injured athlete. As many sudden cardiac emergencies occur without cervical spine injury, there is a need for more research for dealing with lacrosse equipment in the case of an athlete with isolated cardiovascular compromise.

Cardiopulmonary Resuscitation on Patient Simulators

A number of devices have been developed that provide guidance or measurement of CPR performance for use in training, research, or clinical setting. These devices are widely used and generally accepted as an appropriate tool for CPR research, as use of human subjects in this area poses many challenges to researchers. These devices can range from mannequins that provide feedback on CPR metrics, to systems that obtain data during actual resuscitations via defibrillator pads, pressure sensors and accelerometers placed on the patients’ chests (Abella, 2005). A study compared two of these methods of CPR analysis when it compared chest compression metrics as measured by the mannequin-based Laerdal Skill Reporter versus those measured by accelerometer-based Q-CPR technology, incorporated into a defibrillator. It was demonstrated in this study that no significant difference was present in the measurement of the number of chest compressions performed in 2 minutes, the compression rate, total number of compressions of
adequate depth, or the number of compressions exhibiting leaning between the LSR and the Phillips Q-CPR devices (Davey, Whatman, & Dicker, 2015). However, there were significant differences present in the measurement of duty cycle and also the depth of compressions between the 2 devices with the Phillips Q-CPR device measuring lower depth of compression and duty cycle compared with the Laerdal device (Davey et al., 2015).

**Significance of the Study**

As previously stated, proper emergency planning and early access to CPR and defibrillation are crucial to positive outcomes in cardiovascular emergencies. In general, CPR tends to be unsuccessful, with studies showing that the survival to hospital admission is 23.8% of patients and survival to hospital discharge was only 7.6% of patients (Sasson et al., 2010). However, this same study shows that cardiac emergency survival rates increased in instances where a bystander (6.4%-13.5% survival rate) or EMS (4.9%-18.2% survival rate) witnessed the cardiac event, causing earlier access to CPR and emergency services (Sasson et al., 2010). For this reason, it is crucial that athletic trainers perform the most effective CPR in order to give cardiac injured athletes the best possible chance of survival.

There is a limited amount of research currently available that specifically pertains to men’s lacrosse airway and chest access. Current guidelines instruct on-field personnel to remove the facemask as the sole means of gaining airway access, and to leave on both the helmet and chest pads (Swartz, 2009). Additionally, it has been found that athletes frequently are wearing improperly fitted helmets (Petschauer, 2010). Both of these findings warrant complete helmet removal, for obtaining airway access in an emergent situation (Julian E. Bailes, 2007). As the research currently stands, all emergency equipment removal studies and subsequent management recommendations are for c-spine injured athletes, not athletes with cardiac
compromise.

The missing piece of this equation, that this study will aim to address, is the effect that equipment has on the administration of cardiac emergency procedures, both chest compressions and ventilations. The purpose of this study is to determine if chest compression and ventilation efficacy is affected by the equipment condition of the athlete. We hypothesize that both compression and ventilation efficacy will be negatively affected by the presence of equipment in men’s lacrosse. Chest compressions will be adversely affected due to the thickness of the pads over the athlete’s chest causing inadequate compression depth. The pad thickness will cause less depth of compression due to the impedance of a soft surface over the chest not allowing the CPR practitioner to compress as firmly. Even if the pads are flipped up so that the chest is exposed, compressions will be affected due to the pads behind the athlete creating a soft surface on which the CPR is being performed. Rate will likely be affected due to the soft surface causing the practitioner to have to press harder to compress the chest through layers of pads, leading to practitioner fatigue and a decreased rate as the practitioner tires. Additionally, both ventilation volume and rate will be decreased by the obstruction of the helmet and chinstrap making it difficult for practitioners to create and maintain an open airway. The impedance of the helmet and chinstrap will result in practitioners taking longer to open the airway resulting in a decreased rate of ventilation. Removing equipment is a process that takes time and will result in later initiation of CPR if performed; however, this delay in CPR start time may be warranted by an increased effectiveness of the compressions and ventilations being delivered. Therefore, this study aims to justify that equipment removal will improve the quality of CPR to an extent that the time it will take to remove the equipment is warranted. We hypothesize that this study will provide further evidence that full equipment removal is the best practice for the equipped athlete.
CHAPTER 3

METHODOLOGY

Study Design

This cross-sectional cohort study will investigate athletic trainers in chest compression and ventilation scenarios. These procedures will be performed during equipped, semi-equipped, and no equipment conditions. Specifically, the chest compression scenarios will include 4 lacrosse equipment combinations: 1) fully equipped (pads on, helmet on), 2) pads lifted, helmet and facemask on, 3) pads lifted, helmet on, facemask off, and 4) no equipment. Compression depth, compression rate, percent of compressions reaching appropriate depth, and percentage of compressions released fully will be the four primary dependent variables. The ventilation scenarios will include 3 equipment scenarios: 1) facemask removed, helmet and chinstrap on 2) facemask and chinstrap removed, helmet on, and 3) no equipment. Each of these equipment scenarios will be performed in 2 different rescuer scenarios: 1) 1-person giving ventilations via pocketmask and 2) 2-person giving ventilations via bag-valve mask. Frequency of ventilations attempted, ventilation volume (in milliliters), and percentage of attempted ventilations delivering adequate volume will be our primary outcome measures.

Participants

Our group has completed a similar study (IRB: 13-1617) examining the effects of American football equipment on compressions and ventilations. Accordingly, we used the effect sizes and design parameters from the previous study to estimate a sample size requirement for the current study. Rather than assuming a correlation of observations within subjects, we opted
for a more conservative approach to the sample size estimate. We used G*Power 3.1.9.2 (options: F test, ANOVA: Fixed effects, omnibus, one-way design with alpha = 0.05 and power = 95%). The effect size observed from the previous study was 0.98 in detecting a difference in chest compression depth (a primary outcome of the current study) between 6 equipment conditions. Using this effect size, with one fewer condition, we will need 24 total participants. The effect size for detecting a difference in ventilation volume (a primary outcome of the current study) across six equipment conditions was 1.47 in the previous study. To observe this effect size with 95% power requires 18 subjects. Given these sample size estimates a total of 26 participants will be recruited into this study in order to obtain an adequate effect size with 95% power due to the fact that lacrosse chest pads are significantly thinner than football pads and likely more subjects will be needed to observe the same effect as the previous study. Testing was counterbalanced, with half of the participants completing chest compression scenarios first and the other half completing ventilation scenarios first. The condition order within each scenario will be randomized for each participant. Twenty-six certified athletic trainers (ATs) (female = 18; age = 24.85 ± 6.78y; AT experience = 2.08 ± 1.62y; equipped sport experience = 0.88 ± 1.62y) participated in our study. Participants were excluded if they had any current upper extremity injury, neuromuscular disorder, or general unfitness that may influence their ability to provide proper emergency care. Exclusion was determined by verbally asking subjects whether they have any of these limitations. If they answered “yes” to having an upper extremity injury, neuromuscular disorder, or felt they were not fit enough to complete four 2-minute rounds of compressions and six 2-minute rounds of ventilations, their participation in the study was discontinued. All participants completed and signed an informed consent form approved by the Institutional Review Board of The University of North Carolina at Chapel Hill. The participants
completed a demographic questionnaire (age, height, mass, years of AT experience, years experience working with equipped sports) and were permitted to ask questions regarding their participation in the study. All participants completed all the procedures described during a single data collection session lasting approximately 1 hour.

**Instrumentation**

The lacrosse helmet used in testing scenarios was a Cascade R (Cascade Lacrosse, Liverpool, NY). The helmet facemask is attached via three screws: one on either side of the jaw and one at the forehead. The helmet also features a chinstrap that attaches via four snap fasteners, two on either side of the helmet. The facemask and chinstrap can be removed independently of one another, and in this study the facemask was removed to allow access to the face and airway, but the chinstrap remained in place to keep the helmet attached to the head. The lacrosse chest pads used in testing were STX Cell III Liner shoulder pads (STX, Baltimore, MD). They attach via one Velcro strap on either side of the athlete’s chest attaching the front pad to the back pad. The pads feature shoulder padding and a soft pad covering both the chest and the upper back. These equipment choices are representative of typically worn men’s lacrosse equipment.

Advanced patient simulators—Laerdal® (Wappingers Falls, NY) Resusci Anne® Simulator with SimPad®—were fitted with helmets and shoulder pads per the manufacturer guidelines for testing. The patient simulator’s jaw, head, and lungs are modeled to simulate human anatomy. The Laerdal® simulators are equipped with SkillReporter feedback to measure CPR performance. Simulators were used as a means of capturing information related to the emergency administration of both chest compressions and ventilations in different equipment scenarios. Simulators embedded with Q-CPR measurement can measure all independent variables of this study: compression depth, compression rate, percentage of compressions
reaching an adequate depth, percentage of compressions released completely, number of ventilations, ventilation volume, and ventilations reaching an adequate volume.

**Protocol**

Each study participant was assigned a unique participant ID number after completing consent and confidentiality forms. Participants were asked to provide demographic information related to age, height and mass, years of athletic training experience, and years of athletic training experience working with equipment intensive sports. A member of the research team provided each participant with a familiarization session, to ensure each individual was introduced and comfortable with the patient simulator technology, athletic equipment, and breathing apparatuses that were to be used during data collection. Participants completed a CPR training session in which they were able to view their CPR performance in real time on a tablet wirelessly connected to the simulator to confirm appropriate rates and depths of compressions and ventilations. Participants were instructed to perform 100-120 chest compressions per minute at least 2 inches in depth and perform ventilations at 8-10 breaths per minute with each ventilation lasting 1 second. Participants were instructed to open the airway from the cephalic position using a jaw thrust maneuver. Subjects were allowed to practice until they felt comfortable that they were regularly performing CPR within the correct parameters, as seen on the SkillReporter feedback screen. There was no specific amount of time that subjects were instructed to practice. Once subjects had a chance to become familiar with mannequin and CPR feedback equipment, they were instructed to perform correct rate and depth of compression without any feedback for 30 seconds in order to confirm adequate compression performance. Next, subjects were instructed to perform ventilations for 30 seconds at correct volume and rate without any feedback to confirm adequate ventilation performance before beginning trials. When
the participant demonstrated proficiency and was rated by the Laerdal SkillReporter as an ‘Advanced’ performer in the Basic Life Support skills necessary to complete the data collection scenarios, they were block randomized to one of the following task scenarios: 1) chest compression, or 2) ventilation. If subjects were not graded as an “Advanced Rescuer” by the SkillReporter software on their first testing attempt, they were permitted to practice with feedback again, and then were allowed one more attempt at the 30-second test to achieve “Advanced Rescuer” status.

**Chest compressions**

We evaluated chest compression outcome measures in four different equipment conditions performed in a randomized order: 1) lacrosse pads on, 2) lacrosse pads lifted with helmet on and facemask in place, 3) pads lifted with helmet on and facemask removed, and 4) no equipment. Prior to beginning the trial, the primary researcher read each participant a script highlighting that they have just observed an athlete collapse suddenly with no evident mechanism of injury (i.e. no collision event precipitating collapse). Participants were told that the athlete was unresponsive and had no pulse, and there was no reason to suspect any other traumatic injury (head, neck, etc.). The participant was instructed to begin chest compressions as soon as possible after entering the room. Participants were instructed to perform compressions on the simulator in the equipment condition in which the simulator was found, and perform no equipment removal themselves. Participants were instructed to limit any interruptions in chest compressions for two minutes. Regardless of the equipment condition of the simulator, participants were to continue chest compressions to the best of their ability until a member of the research team ended the trial with a verbal “stop.” The participant left the room and a member of the research team prepared the next equipment scenario on the simulator. The participant

24
completed this process until all three conditions had been completed in counterbalanced order. If the participant was randomly assigned to begin with the compression conditions, they then proceeded to the ventilation portion of the study upon completion.

Ventilations

We evaluated ventilation outcome measures in three lacrosse equipment conditions: facemask removed with chinstrap attached, facemask and chinstrap removed, and helmet removed. For each equipment condition, ventilations were administered using two breathing methods: 1-person pocket mask and 2-person bag valve mask.

Prior to entering the ventilation room, participants were read a standardized script explaining that they had witnessed an athlete suddenly collapse and that the athlete was not breathing, but did have a pulse and did not require chest compressions. The subject then entered the room and began giving ventilations, in the manner to which they were instructed (1-person pocket mask or 2-person bag valve mask). In the 2-person bag valve mask condition the research assistant was responsible for compressing the bag while the subject sealed the mask and completed the jaw thrust. Participants were instructed to give care in the cephalic position and open the airway via jaw thrust maneuver.

Ventilation outcome measures were measured in six different equipment conditions performed in a randomized order: a) Facemask removed, chinstrap attached, 1-person pocketmask; b) Facemask removed chinstrap attached, 2-person bag valve mask; c) Facemask removed, chinstrap removed, 1-person pocketmask d) Facemask removed, chin strap removed, 2-person bag valve mask e) No equipment, 1-person pocket mask; f) No equipment, 2-person bag valve mask. Each condition lasted for two minutes, beginning with the first ventilation delivered above the simulator’s minimum ventilation volume threshold. If the participant was randomly
assigned to begin with the ventilation conditions, they then proceeded to the compression portion of the study upon completion.

**Data Analysis**

All data were analyzed using Levene’s test of equal variance and normality was assessed with q-q plots to determine if parametric analysis is appropriate. We used a within-subject analyses of variance (ANOVA) employing equipment condition as our independent variable. Separate ANOVAs were performed for each outcome measure for the compression conditions: compression depth (in millimeters), compression rate (compressions per minute), percentage of correctly released compressions, and percentage of compressions that reached an adequate depth, and the ventilation conditions: frequency of ventilations attempted, ventilation volume (in milliliters), and percentage of attempted ventilations delivering adequate volume. For each test, we used an a priori alpha of 0.05. For non-normal outcome data, we used Friedman’s rank sum test. post hoc t-tests were used to determine which conditions caused any significant finding. Wilcoxon rank sum tests were used for non-normal data. Tukey correction was used to adjust for multiple comparisons. All statistical analyses were performed using R.
CHAPTER IV
MANUSCRIPT

Background: Current management guidelines for the care of equipped athletes in the case of cardiac emergencies are unclear regarding the decision to remove protective sports equipment prior to the delivery of cardiopulmonary resuscitation (CPR). It has been shown that the presence of football equipment decreases the effectiveness of CPR delivery. Our objective was to determine the effect of men’s lacrosse equipment on performing chest compressions and delivering adequate ventilations on patient simulators. Hypothesis: Conditions with more men’s lacrosse equipment left in place would decrease chest compression and ventilation efficacy for athletic trainers. Methods: Twenty-six certified athletic trainers participated in three different compression conditions and six different ventilation conditions using human patient simulators. Data for chest compressions (mean compression depth, compression rate, percentage of correctly released compressions, and percentage of adequate compressions) and ventilations (total ventilations, mean ventilation volume, and percentage of ventilations delivering adequate volume) were analyzed within subjects across each equipment condition. Results: The fully-equipped athlete was found to have the lowest mean compression depth ($F_{2,24}=26.57$, $p<0.001$) and the fewest number of compressions reaching an adequate depth ($X^2_{2}=21.48$, $p<0.001$) compared to all other conditions. The fully equipped athlete was also found to have the lowest mean ventilation volume ($X^2_{5}=17.79$, $p<0.001$), and a lower percentage of ventilations reaching adequate volume ($X^2_{5}=43.05$, $p<0.001$), in both one-person pocket mask and two-person bag valve mask scenarios. Conclusions: Our results indicate that chest compression and ventilation
delivery are compromised in equipment-laden conditions in the sport of men’s lacrosse. As a result, in the case of a men’s lacrosse athlete requiring CPR, the shoulder pads must be lifted or cut away to expose the chest, and the facemask and chinstrap must be removed to access the airway.

INTRODUCTION

Sudden cardiac death is the most common athletics-related death in young athletes, representing 64 of the 182 deaths of National Collegiate Athletic Association athletes from 2001 to 2011 (Maron, Haas, Murphy, Ahluwalia, & Rutten-Ramos, 2014). Athletic trainers are often the primary party responsible for initial management of cardiac emergencies. Early CPR, defibrillation, and access to advanced medical care greatly improve cardiac emergency survival (Drezner, 2007). Thus, NATA guidelines indicate that responders should begin CPR as quickly as possible after identifying a sudden cardiac arrest, and that good quality compressions should be delivered while EMS is summoned and an AED is retrieved (Casa et al., 2012). However, current recommendations do not specifically address the unique situations that exist when performing compressions and ventilations on patients in equipment intensive sports, specifically the sport of men’s lacrosse.

It has been previously found that protective sports equipment may decrease chest compression effectiveness (Waninger et al., 2014). This is of particular note because one measure of compression effectiveness, compression depth, significantly impacts cardiac arrest survival, with survivors of cardiac arrest being more likely to have received deeper compressions during out-of-hospital cardiac care (Vadeboncoeur et al., 2014).

For decades, recommendations for accessing an airway for a potential catastrophic spine injury in equipped sports have suggested that the facemask be removed from the helmet while
keeping the helmet and shoulder pads in place for ensuing emergency transport (Swartz et al., 2009). While removing the facemask does allow for airway exposure with less motion than helmet removal (Swartz, Mihalik, Beltz, Day, & Decoster, 2014), research has not established if the patient can be adequately ventilated during rescue breathing with the helmet and shoulder pads still in place. Additionally, for adequate stabilization of the cervical spine with the helmet left in place, the chinstrap must be kept on, and the presence of a chinstrap provides another potential barrier to delivering ventilations. To this point, all of these studies have focused on airway and chest access in football players. It was necessary to study this in men’s lacrosse athletes due to the differences in lacrosse equipment.

Human patient simulation is a rapidly growing technology used for medical education and training (Al-Rasheed et al., 2013; Villamaria et al., 2008). Patient simulator research can be used to answer clinical questions that are difficult to answer in human studies due the critical nature of resuscitation and cardiac emergency. Simulators can be used to compare various techniques, procedures, or protocols that otherwise would require complex randomization schemes impossible to carry out.

The purpose of this study was to determine the effect of men’s lacrosse equipment on performing quality compressions and ventilations on the Laerdal® (Wappingers Falls, NY) Resusci Anne® Simulator. Using human patient simulators in a controlled setting, we sought to address what should be done with men’s lacrosse protective equipment in cardiac emergency scenarios. We hypothesized that those conditions with more equipment would decrease effectiveness of compressions and ventilations compared to conditions with less equipment. Specifically that compression depth would be significantly affected by the presence of padding
over the chest; and that ventilation volume would be significantly affected by the interference of
the helmet and chinstrap preventing the practitioner from opening the airway.

MATERIALS AND METHODS

Study Design and Participants

Twenty-six certified athletic trainers (ATs) (female = 18; age = 24.85 ± 6.78y; AT experience = 2.08 ± 1.62y; equipped sport experience = 0.88 ± 1.62y) participated in our cross-sectional study. Any AT with a history of upper extremity injury or a neurological condition resulting in tingling or loss of strength in his or her arms was excluded from participating. The University of North Carolina Institutional Review Board approved the use of human participants. All ATs provided written informed consent and completed all the procedures described herein during a single data collection session.

Instrumentation

We used the Laerdal® (Wappingers Falls, NY) Resusci Anne® Simulator with SimPad® with SkillReporter® feedback to collect CPR performance metrics. We fit the simulator with Cascade R® helmets and STX Cell Liner II® shoulder pads per manufacturer guidelines. The patient simulator’s jaw, head, and lungs are modeled to simulate human anatomy. We used the simulators as a means of capturing metrics related to administering chest compressions and ventilations during emergency simulations in different equipment scenarios. Simulators embedded with SkillReporter measurement and feedback tools can reliably measure all of our variables of interest (compression depth and rate, percentage of compressions reaching adequate depth, percentage of compressions correctly released, ventilation volume and rate, and percentage of ventilations of adequate volume) (Beesems & Koster, 2014).
Procedures

Orientation

Participants were asked to provide demographic information related to age, height and mass, years of athletic training experience, and years of athletic training experience working with equipment intensive sports. A member of the research team provided each participant with a familiarization session, to ensure each individual was introduced and comfortable with the patient simulator technology, athletic equipment, and breathing apparatuses that were to be used during data collection. Participants completed a CPR training session in which they were able to view their CPR performance in real time on a tablet wirelessly connected to the simulator to confirm appropriate rates and depths of compressions and ventilations. Participants were instructed to perform 100-120 chest compressions per minute at least 2 inches in depth and perform ventilations at 8-10 breaths per minute with each ventilation lasting 1 second. Participants were instructed to open the airway from the cephalic position using a jaw thrust maneuver. Subjects were allowed to practice until they felt comfortable that they were regularly performing CPR within the correct parameters, as seen on the SkillReporter feedback screen. There was no specific amount of time that subjects were instructed to practice. Once subjects had a chance to become familiar with mannequin and CPR feedback equipment, they were instructed to perform correct rate and depth of compression without any feedback for 30 seconds in order to confirm adequate compression performance. Next, subjects were instructed to perform ventilations for 30 seconds at correct volume and rate without any feedback to confirm adequate ventilation performance before beginning trials. When the participant demonstrated proficiency and was rated by the Laerdal SkillReporter as an ‘Advanced’ performer in the Basic Life Support skills necessary to complete the data collection scenarios, they were block randomized to one of
the following task scenarios: 1) chest compression, or 2) ventilation. If subjects were not graded as an “Advanced Resucuer” by the SkillReporter software on their first testing attempt, they were permitted to practice with feedback again, and then were allowed one more attempt at the 30-second test to achieve “Advanced Rescuer” status.

**Chest compressions**

We evaluated chest compression outcome measures in three different equipment conditions performed in a counterbalanced order: 1) fully equipped with both lacrosse pads and helmet on, 2) lacrosse pads lifted with helmet on and facemask removed and 3) no equipment. Prior to beginning the trial, the primary researcher read each participant a script highlighting that they have just observed an athlete collapse suddenly with no evident mechanism of injury (i.e. no collision event precipitating collapse). Participants were told that the athlete was unresponsive and had no pulse, and there was no reason to suspect any other traumatic injury (head, neck, etc.). The participant was instructed to begin chest compressions as soon as possible after approaching the victim in the equipment condition in which they were found. They were to continue chest compressions to the best of their ability until a member of the research team ended the trial with a verbal “stop” (at 2 minutes). The participant left the area and a member of the research team prepared the next equipment scenario on the simulator. Each participant completed this process until all three compression conditions were completed. If the participant was assigned to begin with the compression conditions, they then proceeded to the ventilation portion of the study.

**Ventilations**

We evaluated ventilation outcome measures in three lacrosse equipment conditions performed in a counterbalanced order: facemask removed with chinstrap attached, facemask and
chinstrap removed, and helmet removed. For each equipment condition, ventilations were administered using two breathing methods: 1-person pocket mask and 2-person bag valve mask.

Prior to beginning data collection, participants were read a standardized script explaining that they had witnessed an athlete suddenly collapse and that the athlete was not breathing, but did have a pulse. The participant then entered the room and began giving ventilations, in the manner to which they were instructed (1-person pocket mask or 2-person bag valve mask). In the 2-person bag valve mask condition the research assistant was responsible for compressing the bag while the participant sealed the mask and completed the jaw thrust in the cephalic position.

Ventilation outcome measures were recorded in six different equipment conditions (Figure 2) performed in a random order. Each condition lasted for two minutes, beginning with the first ventilation delivered above the simulator’s minimum ventilation volume threshold. If the participant was assigned to begin with the ventilation conditions, they then proceeded to the chest compressions portion of the study upon completion.

**Data Analysis**

All data were analyzed using Levene’s test of equal variance and normality was assessed with q-q plots to determine if parametric analysis is appropriate. We used a within-subject analyses of variance (ANOVA) employing equipment condition as our independent variable. Separate ANOVAs were performed for each outcome measure for the compression conditions: compression depth (in millimeters), compression rate (compressions per minute), percentage of correctly released compressions, and percentage of compressions that reached an adequate depth, and the ventilation conditions: frequency of ventilations attempted, ventilation volume (in milliliters), and percentage of attempted ventilations delivering adequate volume. For each test, we used an a priori alpha of 0.05. For non-normal outcome data (Table 1), we used Friedman’s
rank sum test. Post hoc t-tests were used to determine which conditions caused any significant finding. Wilcoxon rank sum tests were used for non-normal data. Tukey correction was used to adjust for multiple comparisons. All statistical analyses were performed using R.

RESULTS

Generally, the subjects exhibited a marginal performance at reaching the American Red Cross (ARC) recommended compression metrics. Even in the control condition, with a completely unequipped mannequin, subjects only had, on average, 62.5 percent of chest compressions reach an adequate depth, and 83 percent of compressions fully released. Subjects did average a chest compression depth (51.0 mm) and rate (110.3 compressions/second) that were contiguous with the ARC recommended depth of at least 50 mm and rate of 100-120 compressions per minute.

In ventilation metrics, subjects exhibited even more difficulty with consistently reaching ARC recommendations for care, with the percentage of adequate ventilations ranging anywhere from 83.5 percent in the unequipped bag valve mask condition, to only 26.3 percent in the fully-equipped pocket mask condition. Subjects did manage, in all conditions other than conditions in which the chinstrap remained in place, to perform ventilations on average at a volume that fell within the acceptable range of 400-700 mL. In all ventilation conditions, the average rate of ventilation fell within the acceptable range of 8 to 12 ventilations per minute.

Chest compression conditions

We found a significant main effect of chest pad condition on depth (F_{2,50}=26.57, p<0.001) and delivery of adequate compressions (F_{2,50}=21.48, p<0.001). The pads on condition had significant lower compression depth and lower percentage of adequate compressions compared to lifted or removed chest pad conditions. There was no difference in chest
compression rate ($F_{2,50}=1.602$, $p=0.212$) or percentage of correctly released compressions ($F_{2,23}=3.179$, $p=0.051$) the equipment conditions. Chest compression results summarized in Table 1.

**Ventilation conditions**

We observed an effect of equipment condition and method of ventilation delivery on ventilation volume ($F_{2,125}=17.79$, $p<0.001$), percentage of adequate ventilations ($F_{2,125}=17.79$, $p<0.001$), and percentage of ventilations with optimal volume ($F_{2,125}=43.05$, $p<0.001$). In both pocket mask and bag valve mask scenarios the presence of the chinstrap resulted in lower mean ventilation volume and lower percentage of adequate ventilations than either the chinstrap removed or helmet removed conditions. For the pocket mask only, the chinstrap on condition also had a lower mean number of ventilations than the other two conditions ($F=7.194$, $p=0.027$). When using the bag-valve mask, the number of ventilations was not statistically significant. For all three variables, the facemask and chinstrap removed condition and the helmet-removed condition were similar.

**Pocket mask vs. bag valve mask**

While not a focus of this study, during data analysis we noted that when comparing 1-person pocket mask to 2-person bag valve conditions, in general bag valve mask conditions resulted in a greater average ventilation volume than a pocket mask in the same equipment conditions. However, this difference was not found to be statistically significant in any conditions.

Additionally, when examining the percentage of ventilations reaching adequate volume, again the 2-person rescuer scenarios consistently provided a higher percentage of quality ventilations than 1-rescuer scenarios. Notably, in the control unequipped condition, the bag valve
mask was able to achieve an average of 83.5 percent of ventilations reaching adequate volume, while the bag valve mask was only able to achieve 61.6 percent of ventilations reaching adequate volume. However, when looking at pairwise comparisons, this difference was only statistically significant in one condition, being the “chinstrap off” condition.

**DISCUSSION**

The findings of this study demonstrate that chest compression and ventilation delivery are compromised in equipment-laden conditions in men’s lacrosse. Compressing the chest over shoulder pads resulted in the lowest compression depth and smallest percentage of adequate compressions when compared to any of the other shoulder pad conditions. Additionally, administering ventilations with the helmet chinstrap still in place resulted in lower ventilation volume and a lower percentage of adequate ventilations in both one and two-rescuer scenarios, as well as a decreased total number of delivered ventilations in one-rescuer scenarios as recorded by the simulator.

*Chest Compressions*

This study finds that chest compression effectiveness is decreased when shoulder pads remain in place. This finding is supported by Del Rossi et al. (Del Rossi, Bodkin, Dhanani, Courson, & Konin, 2011) and Waninger et al. (Waninger et al., 2014) who found decreased efficacy of chest compressions when performed over football shoulder pads. This study is the first to examine chest compression effectiveness in men’s lacrosse equipment situations.

Current NATA guidelines for providing care for sudden cardiac events are not explicit to equipment removal, stating that equipment should be removed only in the condition that it “prevent access to the chest”, but never defining specifically what this chest access means.
(Douglas J. Casa, 2012). Our data provide evidence that performing chest compressions over shoulder pads results in the lowest mean compression depths and the worst percentage of adequate compressions than any other condition studied. For this reason, our study finds that access to the chest is in fact prevented by the presence of lacrosse shoulder pads, and supports removal of lacrosse chest pads off the chest before performing CPR. There was no difference in any CPR metrics between the pads off and pads lifted conditions; therefore, simply lifting or cutting the pads off the front of the chest is sufficient to deliver quality chest compressions. This may be important when needing to get the chest compression started quickly in the case of cardiac arrest.

Notably, the difference between the mean compression depth in pads off and pads lifted conditions (51.0 mm and 51.3 mm respectively) and the mean compression depth in the pads on condition (45.2 mm) marked a distinction between the subjects reaching the ARC recommended depth of compression, in the pads off/lifted conditions, versus subjects not reaching the ARC recommended depth in the pads on condition. Also of note, Vadeboncoeur found in a study of out-of-hospital cardiac arrest patients, that survivors, on average, received chest compressions that were 5mm deeper than non-survivors (Vadeboncoeur et al., 2014), a difference that is nearly identical to the difference found in this study between the fully equipped condition and the other conditions. This is strong evidence that the removal of pads presents a clinically relevant difference in the ability of practitioners to deliver quality chest compressions.

Ventilations

In regard to airway access, the current NATA position statement on preventing sudden death in sport is again vague in the case of an equipped athlete, simply stating that removal of helmet in any equipment-intensive sport should be deferred until the athlete has been transported
to an emergency medical facility. The current position statement guidelines recommend equipment removal only in three specific circumstances, those being that: 1) the helmet is not properly fitted to prevent movement of the head independent of the helmet, 2) the equipment prevents neutral alignment of the cervical spine, or 3) the equipment prevents airway or chest access. Previous studies have already found that men’s lacrosse athletes often wear their helmets improperly fitted (Petschauer, 2010) and it has been shown that an equipped men’s lacrosse athlete has more cervical spine motion when spine boarded, than an unequipped men’s lacrosse athlete (Petschauer, 2010). Additionally, this study demonstrates that the presence of a buckled helmet does indeed prevent airway access as we found that ventilation volume and percentage of adequate ventilations were both lowest in the condition in which the helmet was left on and buckled. The average ventilation depth observed was within the acceptable range of 400 to 700 mL in every condition other than the conditions in which the chinstrap remained in place, regardless of method of ventilation delivery. For that reason, this study supports removal of the facemask and unbuckling of the helmet to access the airway of a men’s lacrosse athlete for administration of ventilations. As there was no difference in the efficacy of ventilations between the completely unequipped condition and the condition in which the facemask and chinstrap is removed, it is possible that the helmet can remain on and unbuckled and adequate ventilations will be delivered. This however, raises a dilemma in the case of a cervical spine compromised athlete, as the athlete’s head is now unsecured in the helmet.

Cervical Spine Injury Considerations

The current NATA position statement for management of the cervical spine injured athlete recommends facemask removal without helmet removal. The rationale for this recommendation is that facemask removal would permit access to the athlete’s airway if
necessary, and leaving the helmet in place would facilitate inline stabilization to limit unnecessary cervical spine motion while maintaining neutral alignment during transport (Swartz et al., 2014). However, when attempting to limit cervical spine motion, the helmet’s chinstrap must remain fastened. Otherwise, the head is free to move within the helmet, eliminating any effectiveness the helmet may have had in limiting cervical spine motion (Mihalik, Beard, Petschauer, Prentice, & Guskiewicz, 2008). However, our study shows that a chinstrap being left in place provides a significant impediment to athletic trainers’ ability to administer ventilations during CPR. The reasons being: the chinstrap makes it difficult to maintain a proper seal with the bag-valve mask or pocket mask, and the chinstrap inhibits the opening of the patient’s airway by blocking the jaw’s movement during a jaw-thrust maneuver. Thus, the chinstrap should be removed to allow for adequate administration of ventilations.

Removal of the chinstrap limits the effectiveness the helmet would have on stabilizing the cervical spine. As a result, the helmet should be entirely removed in the case of suspected cervical spine injury to a men’s lacrosse athlete in which airway access must be established.

A final point to consider is that time is of critical importance in cardiac emergency scenarios. Therefore in these situations, complete removal of the helmet may prove to be a better option to quickly access the airway and begin care. Further research is needed to determine whether helmet removal or facemask removal allows for faster initiation of care.

Limitations

While simulation technology has become quite advanced, patient simulators still are unable to perfectly represent the injured human patient, presenting a limitation to this study. Additionally, all of our scenarios were staged and performed in a very controlled environment, and research participants were instructed in what to expect and what the initial primary survey
findings were before initiating care. Data collection was performed in an indoor laboratory environment, not on a playing field and all equipment needed to perform CPR was readily available at the side of the patient with no retrieval necessary. While this study represents a basic level of simulation, more intensive simulation would be open-ended and provide participants with less information prior to initiating a patient care simulation. Additionally, we only included one type of shoulder pad and one helmet/facemask combination. There are several different manufacturers and styles of men’s lacrosse equipment, however the equipment used in this study is fairly standard and representative of commonly used equipment. Similarly, we only investigated CPR efficacy in scenarios involving an injured men’s lacrosse athlete, therefore continued study of other equipment intensive sports (ice hockey, football) is warranted. Additionally, this study did not have the subjects perform any equipment removal themselves, instead having them enter the scenario to find the simulator with equipment already in the condition of interest. Further study is warranted to examine the time that it takes to remove equipment, as it is of critical importance that care begins as quickly as possible in cardiac emergencies.

CONCLUSION

Our results indicate that chest compression and ventilation delivery are compromised in equipment-intense conditions in the sport of men’s lacrosse. As a result, in the case of a men’s lacrosse athlete that requires CPR, the shoulder pads must be lifted or cut away to expose the chest, and the facemask and chinstrap must be removed to access the airway. In the case of a suspected cervical spine injured athlete, this equipment scenario likely does not offer adequate stabilization of the head and neck; therefore all equipment must be removed to ensure proper stabilization while also allowing for administration of quality CPR.
Table 1. List of dependent variables’ data normality. Normal data was assessed using within-subject ANOVAs. Non-normal data was assessed with Freidman’s rank sum test.

<table>
<thead>
<tr>
<th>Normality of Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Compression Depth (mm)</td>
</tr>
<tr>
<td>Normal Compression Rate (comp/min)</td>
</tr>
<tr>
<td>Normal Compression Correct Release %</td>
</tr>
<tr>
<td>Non-normal Compression Adequate Depth %</td>
</tr>
<tr>
<td>Normal Number of Ventilations</td>
</tr>
<tr>
<td>Normal Mean Ventilation Volume (ml)</td>
</tr>
<tr>
<td>Non-normal Ventilation Adequate Volume (%)</td>
</tr>
</tbody>
</table>
Table 2. Mean (standard deviation), F ratios, p values, and effect sizes for all compression condition outcome measures: compression depth, compression rate, percentage of correctly released compressions, and percentage of adequate (correct) compressions. Effect sizes compare the unequipped and pads lifted conditions to the fully equipment condition.

<table>
<thead>
<tr>
<th>Compression Condition</th>
<th>H + SP in place</th>
<th>H + SP lifted</th>
<th>Unequipped</th>
<th>F Ratio</th>
<th>p</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth (mm)</td>
<td>45.2 (7.2)</td>
<td>51.4 (8.1)</td>
<td>51.5 (7.3)</td>
<td>26.70</td>
<td>&lt;0.001</td>
<td>0.835</td>
</tr>
<tr>
<td>Rate (comp/min)</td>
<td>107.1 (15.8)</td>
<td>109.7 (16.6)</td>
<td>110.3 (13.9)</td>
<td>2.506</td>
<td>0.09</td>
<td>-0.189</td>
</tr>
<tr>
<td>Correct Release (%)</td>
<td>67.7 (26.3)</td>
<td>78.1 (26.3)</td>
<td>83.0 (23.3)</td>
<td>3.179</td>
<td>0.051</td>
<td>0.209</td>
</tr>
<tr>
<td>Adequate Depth (%)</td>
<td>35.0 (40.0)</td>
<td>65.5 (37.3)</td>
<td>62.5 (37.0)</td>
<td>19.843</td>
<td>&lt;0.001</td>
<td>-0.490</td>
</tr>
</tbody>
</table>
Table 3. Mean (standard deviation), F ratios, p values, and effect size for all ventilation condition outcome measures: total ventilations attempted, mean ventilation volume, and percentage of ventilations delivering adequate volume (400-700mL). Effect size compares the helmet removed and facemask and chinstrap removed conditions to the chinstrap in place condition, collapsing across ventilation methods.

<table>
<thead>
<tr>
<th>Ventilation Condition</th>
<th>No Equipment</th>
<th>Helmet and Chinstrap Removed</th>
<th>Helmet Removed, Chinstrap On</th>
<th>F-statistic</th>
<th>p</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BVM</td>
<td>PM</td>
<td>BVM</td>
<td>PM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>23.6 (3.8)</td>
<td>22.4 (3.4)</td>
<td>24.5 (5.0)</td>
<td>22.1 (3.9)</td>
<td>23.5 (4.6)</td>
<td>18.7 (7.0)</td>
</tr>
<tr>
<td>Volume (mL)</td>
<td>589.3 (88.1)</td>
<td>547.2 (198.1)</td>
<td>564.7 (91.7)</td>
<td>493.3 (181.9)</td>
<td>397.6 (85.3)</td>
<td>341.9 (100.4)</td>
</tr>
<tr>
<td>Adequate Volume (%)</td>
<td>83.5 (20.2)</td>
<td>61.6 (38.4)</td>
<td>83.0 (16.7)</td>
<td>57.2 (36.3)</td>
<td>48.3 (40.1)</td>
<td>26.3 (25.0)</td>
</tr>
</tbody>
</table>
REFERENCES


Douglas J. Casa, P., ATC, FNATA, FACSM; Kevin M. Guskiewicz, PhD, ATC, FNATA, FACSM; Scott A. Anderson, ATC; Ronald W. Courson, ATC, PT, NREMT-I, CSCS; Jonathan F. Heck, MS, ATC; Carolyn C. Jimenez, PhD, ATC; Brendon P. McDermott, PhD, ATC; Michael G. Miller, PhD, EdD, ATC, CSCS; Rebecca L. Stearns, MA, ATC; Erik E. Swartz, PhD, ATC, FNATA; Katie M. Walsh, EdD, ATC. (2012). National Athletic Trainers’ Association Position Statement- Preventing Sudden Death in Sports. *Journal of Athletic Training, 47*(1), 96-118.


