# EFFECTIVENESS OF CARDIOPULMONARY RESUSCITATION VENTILATION DEVICES WITH PROTECTIVE HOCKEY EQUIPMENT AS PERFORMED BY CERTIFIED ATHLETIC TRAINERS

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

By

Lauren Lynn Konkol

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Program:
Advanced Athletic Training

April 2022

Fargo, North Dakota

# North Dakota State University
Graduate School

**Title**

Effectiveness of Cardiopulmonary Resuscitation Ventilation Devices with Protective Hockey Equipment as Performed by Certified Athletic Trainers

**By**

Lauren Lynn Konkol

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

MASTER OF SCIENCE

SUPERVISORY COMMITTEE:

Dr. Katie Lyman
Chair

Dr. Jay Albrecht

Dr. Joe Deutsch

Approved:

04/01/2022
Date

Dr. Yeong Rhee
Department Chair

**ABSTRACT**

Certified Athletic Trainers (ATCs) are expected to perform cardiopulmonary resuscitation (CPR) on athletes experiencing cardiac arrest regardless of the protective equipment worn by the athlete. Additionally, ventilation devices used by ATCs aide in the delivery of ventilations during CPR. The goal of this research was to determine which ventilation device allowed ATCs to deliver adequate ventilations and to establish recommendations for helmet removal method in hockey players requiring CPR. Twenty ATCs completed four scenarios of CPR according to the 2020 AHA guidelines using a PocketMask (PM) or FaceShield (FS) to deliver ventilations and accessing the airway by removing only the facemask or the entire helmet. Overall, the PM resulted in higher quality ventilations compared to the FS and complete removal of the helmet was superior compared to removing the only facemask. For hockey athletes requiring CPR, ATCs should remove the helmet completely and use a PM for ventilation delivery.

## ACKNOWLEDGEMENTS

I would first like to give a huge thank you to my family and friends for their continued support throughout my entire education, I would not be here without them. Additionally, a thank you is necessary for Dr. Katie Lyman and her unwavering commitment to me and my research even when career opportunities created unique challenges. I want to also thank my committee members, Dr. Joe Deutsch, and Dr. Jay Albrecht for their guidance during this process. Lastly, thank you to my support system of supervisors, coworkers, coaches, and athletes at Concordia College for offering advice and motivation through this research.

**TABLE OF CONTENTS**

# LIST OF TABLES

## LIST OF ABBREVIATIONS

| | |
|---|---|
| AED | Automated External Defibrillator |
| AHA | American Heart Association |
| ANOVA | An Analysis of Variance |
| ATC | Certified Athletic Trainer |
| BVM | Bag Valve Mask |
| CPM | Compressions per Minute |
| CPR | Cardiopulmonary Resuscitation |
| EMS | Emergency Medical Services |
| ERC | European Resuscitation Council |
| FS | Faceshield |
| ILCOR | International Liaison Committee on Resuscitation |
| NATA | National Athletic Trainers' Association |
| NCAA | National Collegiate Athletic Association |
| NCCSIR | National Center for Catastrophic Sports Injury Research |
| PM | PocketMask |
| ROSC | Return of Spontaneous Circulation |
| SCA | Sudden Cardiac Arrest |
| SCD | Sudden Cardiac Death |
| USRSDA | United States Registry for Sudden Death in Athletes |

# 1. INTRODUCTION

## 1.1. Overview of the Problem

In the year 2020, the International Ice Hockey Federation reported over 1.7 million registered players worldwide and 561,700 of them residing in the United States.[1] Although sudden cardiac arrest (SCA) is rare in athletics, with incidence rates ranging from 2.3 to 4.4/100,000 per year, it is still a risk athletes face when participating in a contact sport.[2] Ice hockey is an at-risk sport due to the high intensity of effort required to participate as well as the risk of being hit by opponents or the hockey puck. Athletes are also exposed to blunt trauma from pucks or other athletes, which can increase the chance of commotio cordis.[3] Treatment of SCA and commotio cordis include the initiation of cardiopulmonary resuscitation (CPR) intervention as quickly as possible[4] until emergency services arrive.

Due to the inherent risk of a cardiac event in ice hockey, it is of the utmost importance for emergency responders to provide emergency care when necessary. Certified Athletic Trainers (ATCs) are often the first medical providers on scene to provide care for athletes experiencing SCA. After an extensive literature review, limited research has been found on the effectiveness of performing CPR ventilations with hockey equipment. Multiple studies have been conducted to establish a recommendation for football and lacrosse players[5,6], but best practices for airway access for hockey athletes has not been established. ATCs have the responsibility to perform life-saving skills, such as CPR, using algorithms published by the American Heart Association (AHA) and the National Athletic Trainers' Association (NATA). Researchers must study all types of athletic and CPR equipment available to establish clinical-care guidelines for practicing ATCs.

Ventilation devices, specifically PocketMasks (PM), FaceShields (FS), and bag valve masks (BVM), have been implemented to improve the quality of CPR ventilations and prevent disease transmission to the rescuer. The AHA considers BVM the gold standard for ventilation delivery; however, for optimal outcomes, two rescuers are needed to administer ventilations via BVM.[6] ATCs often cover athletic events and practices alone[7,8]; therefore, they are not in an optimal position to utilize a BVM as recommended by the AHA. Current research is inconsistent for which type of ventilation device is best for the single rescuer. ATCs have access to PM and FS to deliver ventilations, but research specific to one-person CPR scenarios without the inclusion of a research assistant[5] has not been published.

### 1.2. Statement of Purpose

The purpose of this research was to investigate the ability of certified athletic trainers to provide CPR ventilations with or without helmets using a PocketMask (PM) and FaceShield (FS). This research study was designed to help establish emergency care algorithms in the event of cardiac arrest in a hockey athlete.

### 1.3. Research Questions

Q1: Without visual or verbal feedback, how do Athletic Trainers score their own ability to perform CPR without athletic equipment?

Q2: What is the relationship between ventilatory devices and the ability to provide high-quality ventilations?

Q3: What is the relationship between the removal of partial or full helmet and the ability to provide high-quality ventilations?

Q4: What is the average time Athletic Trainers took to initiate care?

## 1.4. Definitions

*Cardiac arrest*: Cardiac arrest is the abrupt loss of heart function in a person who may or may not have been diagnosed with heart disease.[9]

*Cardiopulmonary resuscitation*: Cardiopulmonary Resuscitation (CPR) is an emergency life-saving procedure that is performed when a victim's breathing or heart rhythm has ceased to perform adequate perfusion.[9]

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

*Ventilation device*: A device used to assist and protect a rescuer while delivering ventilations during CPR.

*FaceShield*: A foldable ventilation device made of one sheet of plastic and a one-way valve.

*PocketMask*: A rigid ventilation device with a one-way valve shaped to fit over the nose and mouth of a patient to create a seal during ventilation.

## 1.5. Limitations

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 an actual patient; all CPR was simulated on a QCPR Anne manikin. Another limitation was the small population included in the study. The participants were limited to certified athletic trainers (ATC's) within the Midwest region. The only athletic equipment used were the CCM U+ CL shoulder pads (Ontario, Canada) and BAUER RE-AKT 150 helmet facemask combo (New Hampshire, USA). Thus, the results cannot be generalized to other sports and their associated protective equipment. To better understand the environmental factors associated with ice hockey, the trials should have been conducted at an ice arena where treatment may need to be performed. Instead, for this study, trials were completed on a tile floor with a pad. Finally, with multiple trials, there was a risk of participants learning the best way to remove equipment after the first condition.

### 1.6. Delimitations

Researchers chose to study ATCs and their ability to provide high-quality CPR because there is no current recommendation provided by the NATA regarding CPR with hockey equipment. To investigate ATCs' ability to perform high-quality CPR with hockey equipment, the researchers chose CCM U+ CL shoulder pads (Ontario, Canada) and BAUER RE-AKT 150 helmet facemask combination (New Hampshire, USA), which are commonly worn by athletes. The ventilation equipment PM /FS were chosen because they are the used for CPR training.

### 1.7. Assumptions

Assumptions were made that performing CPR and the condition selected to perform on the QCPR Resusci Anne manikin would mimic a real-life rescue scenario. It was assumed each athletic trainer performed CPR to the best of his/her ability during the skill verification portion and data collection.

### 1.8. Variables

The dependent variables for this study were overall CPR score, the rate and volume of ventilations, measure of hand position during compressions, compression rate, compression depth, chest compression fraction, chest recoil, time to first compression, and perception of difficulty. Independent variables were age, gender, level of education, years of CPR certification, years of ATC certification, ventilation device used, and helmet condition.

### 1.9. Significance of the Current Study

The purpose of this research was to determine whether certified athletic trainers were able to deliver quality ventilations for patients wearing protective hockey equipment. Athletic trainers act as emergency responders for hockey athletes and need to be prepared to perform CPR in the event of cardiac arrest. The results of this research are used to enhance existing evidence-based recommendations for CPR protocols. By understanding how hockey helmets and ventilation equipment impact the effectiveness of ventilations during CPR, best-practice guidelines can be adapted to improve survival outcomes in hockey athletes.

# 2. LITERATURE REVIEW

## 2.1. Sudden Cardiac Arrest

Sudden cardiac arrest (SCA) is the leading cause of death in competitive sports.[10,11] SCA is characterized as a cardiac arrest resulting from an underlying cardiac abnormality brought on by intense exercise.[2] Hypertrophic cardiomyopathy and coronary artery anomalies are the leading causes of SCA.[2,10,12,13] Generally, there are no warning signs or symptoms of a heart abnormality before the cardiac emergency.[10] In rare cases, SCA can occur when an impact to the chest is sustained directly over the heart during a specific moment is the cardiac cycle, known as commotio cordis.[14] The first indication of SCA is the sudden collapse of an athlete during high-intensity training or competition.[7] To increase the rate of survival of an athlete who suffered SCA or commotio cordis, it is imperative the treatment, prevention, and risk factors for SCA are understood. Although the etiology of SCA is not well understood, it is known that immediate initiation of cardiopulmonary resuscitation (CPR) is essential as a medical intervention to prevent sudden cardiac death (SCD).[2,7,15]

The exact number of deaths due to SCA in sports is unknown and has a large variation of estimates. The variations between estimates of likelihood probability in research can be seen in Table 1. Likelihood probability for SCA is related to the possibility of an individual suffering from the condition. This probability can be applied to athletes overall as well as for specific demographics within the athletic population. There are multiple reasons for the disparity in numbers of reported SCA events. The inaccuracy within the incidence reporting for SCA stems from the differing terms used to describe the same cardiac event. Alternative language can be observed in terms used to describe the cardiac event such as SCD instead of SCA or inclusion criteria primarily with the definition of “athlete.” Further, the proportion utilized to calculate the likelihood probability is not standardized, and case reporting remains unorganized without a regulated database. Due to the above-mentioned factors, the exact number and probability of SCA rates remains unknown and varies between researchers.

**Table 1.** Incidence of SCA in Sports

| Study | Age group | Sport | Biological Sex | Incidence |
|---|---|---|---|---|
| Asif 2017 | College | All | M/F | 1/3,000 AY |
| | HS | All | M/F | 1/23,000 - 1/917,000 AY |
| | College/HS | All | M | 1/300,000 AY |
| | College/HS | All | F | 1/1,300,000 AY |
| | College (17-24yo) | All | M/F | 1/43,000 – 1/67,000 AY |
| | All | "Athlete" | M/F | 2.3-4.4/100,000 |
| Chandra 2013 | College/HS | All | M | 2.6/100,000 |
| | College/HS | All | F | 1.1/100,000 |
| Drezner 2018 | 11-27yo | All | M | 84% (of 132 over 2 years) |
| | 11-27yo | Basketball | M/F | 30% (of 132 over 2 years) |
| | 11-27yo | Football | M/F | 25% (of 132 over 2 years) |
| | 11-27yo | Track/XC | M/F | 12% (of 132 over 2 years) |
| | 11-27yo | Soccer | M/F | 11% (of 132 over 2 years) |
| | College | All | M/F | 11% (of 132 over 2 years) |
| | HS | All | M/F | 59% (of 132 over 2 years) |
| Maron 2009 | College/HS | All | M/F | <100 per year |
| Maron 2014 | College | All | M/F | 2.3/100,000 |
| | HS | All | M/F | 0.7/100,000 |
| Harmon 2014 | College/HS | All | M/F | 1/50,000 |

Abbreviations: Athlete years, AY; Male, M; Female, F High School, HS; Years old, yo.

Literature reviews of SCA in sports have noted that the lack of a centralized database for reporting SCA leads to misrepresentation of data.[2,11,15,16] Data collected from news media archives, insurance claims, and medical examiner autopsy reports have been used to confirm cases of SCA. Each of these sources had limitations causing a disproportion in SCA cases reported publicly. First, news media covered a larger percent of deaths from DI athletes (87%) compared to DIII (44%) and were inconsistent in reporting all cases of SCA in collegiate athletes to media outlets.[15] News media is more likely to report cases of SCA in DI athletes due to the increased media coverage of athletics at larger institutions. However, not all incidences of SCA are reported by news media outlets at the DI level. Thus, lower division athletics have even less reports potentially resulting in vastly inadequate data from news media alone. Second, insurance claims were able to include incidents occurring in club and intramural athletes but were limited by privacy acts and those without insurance are excluded by default.[15] Finally, autopsy reports were used to determine the underlying cause of the sudden death in an athlete without a pertinent medical history of cardiac complication.[13] These data were further limited by the lack of autopsy in some participants, different medical examiners, and privacy laws or requests from victims' families[13,15] The constraints of inconsistent data reporting leads to differences in SCA likelihood ratios that vary by author based on their data collection methods. News media, insurance claims, and autopsy reports can provide part of the necessary information for SCA incidence research, but privacy laws and varying data documentation methods obstruct crucial statistics from being reported accurately.

An easily accessible database for recording SCA cases and athlete demographics is a limitation for data collection that researches have acknowledged and institutions have recognized.[11,15] The National Collegiate Athletic Association (NCAA) Resolution List, US Registry for Sudden Death in Athletes (USRSDA) by the Minneapolis Heart Institute Foundation, National Center for Catastrophic Sports Injury Research (NCCSIR), and the NCAA Sports Science Institute (via NCCSIR) have formed databases to attempt to document SCA events in sports.[2,12,15,17] The NCAA Resolution List is a compiled list of the athletes who died during the year; however, it does not specify the cause of death. The USRSDA has been collecting data on sudden death in athletes since 1980.[11,17] NCCSIR is a database that collects injury data on high school and collegiate athletes.[2,11] These databases are necessary for the accurate data collection used for future studies on SCA. Unfortunately, institutions are not required to report incidences of SCA. Therefore, should SCA occur in a competitive athletic setting, the institution sponsoring the team does not have a place to list the event, victim, treatment, or results of treatment in a standardized way. However, in 2014 the NCCSIR created an online reporting system for high schools and the NCAA can report instances of SCA.[15] Initiating mandatory incidence reporting from the NCAA and the creation of databases for case reporting is a promising step towards a centralized and standardized data collection method to improve the analysis of SCA.

While the collection of incidence rates for SCA has improved, finding previous cases continues to be difficult due to the lack of established terminology using keyword entry in databases. The main obstruction in data collection by keyword entry includes using the term SCD and SCA. Authors have used the terms SCA and SCD as separate terms, interchangeable, or the same term. In fact, an author's rendition of the term varies between data collection and analysis in the same study. SCD is defined as "a cardiac death resulting from intense physical exercise in the context of an underlying cardiovascular abnormality."[2] It is often used in place of SCA even when describing the same case, creating the potential for error by reporting the same case twice for one study. An example of possible double reporting is comparing results from Chandra et al.[2] and Link et al.[16] Both used the term SCD during analyses with SCD having the same definition as SCA to gather case reports using keyword search in databases.

In a retrospective analysis by Link et al.[16], researchers analyzed the prevalence of SCD in athletes, its etiology, and barriers to prevention.[2] Data for this study were gathered from public resources including media reports, insurance claims, and previous studies using SCD in the reports. Once compiled, the data were either compared (study findings) or analyzed (public data). First, epidemiology and etiology of SCD were evaluated to establish its prevalence in athletes as well as the demographic characteristics associated with increased risk for SCD. The prevalence of SCD for athletes at all ages was found to range from 2.3 to 4.4 deaths/100,000 athletes.[2] Separating by biological sex, 1.1 deaths/100,000 athletes for female athletes in high school and college ages as compared to 2.6/100,000 for male athletes in the high school and college-age range.[2] Athletes at these ages and activity levels are considered to be the epitome of peak performance and health, yet it was reported that the ratio for a SCD is 2.3 times larger in competitive athletes when compared to those in the same age range.[2]

Data from the public resources were analyzed to address the cardiac abnormalities that likely lead to SCD. Eleven abnormalities were discussed in depth and divided into categories based on their causes. The categories included structural, electrical, and acquired. Each abnormality's etiology, diagnosis, treatment, and prevalence of causing SCD were explained. It was found that most of the conditions were asymptomatic until the incident of SCD even when the heart was examined previously using an electrocardiogram.[2] If a condition produced any symptoms pre-diagnosis, it was often syncope. If syncope is the only sign, it can lead to a misdiagnosis of epilepsy when there is no abnormal findings of the electrocardiogram.[2] After discussing abnormalities, prevention techniques for SCD were analyzed in athletes via use of 12-lead EKG cardiac screenings as part of the pre-participation physical. Barriers to implementing these screenings are the small number of structural abnormalities found during the screenings, a high rate of false positives, and the high cost to the athlete for testing.[2,15,16] While the pre-participation screening had reduced rates of SCA/SCD in Europe, the United States has not implemented these programs because the abnormalities may be attributed to differences in the ethnic populations tested and lack of practicality due to cost.[11,16]

While the previous study found that the incidence rate of SCD is higher among competitive athletes, Link et al.[16] determined the rate was actually lower in athletes. With a retrospective approach, researchers complied data to form a literature review to report SCD in competitive athletics, its prevention, and best practices when conducting research on SCD. Although the authors did not provide specific data or statistical analyses, they concluded the number of SCD events to be smaller in the athletic population compared to non- athletic population of the same age range.[16] Noting that this result varies greatly from others, improvements to research protocols were suggested. Recommendations for research include standardizing the definitions of the competitive athlete and sudden death. While some results show significant variances in data findings, agreement between authors on certain practices based on other uncertain data, such as prevention, display the inconsistencies of SCD/SCA research.

The varying number of reported cases and terminology between studies can contribute to discrepancies in definitions for SCA and SCD inclusion criteria.[15] Researchers conducted a clinical review reporting keyword searches in the PubMed database using terms such as, SCA, SCD, incidence, etiology, pathology, registry, athlete, young, children, adolescents, and sudden death to provide an updated likelihood ratio of SCA in sports.[15] One limitation of this review was the inclusion criteria were not specific enough to provide a reliable framework to gain a full appreciation for SCA and its relevancy for specific populations.[15] An example of the lack of detail is failure to report competition level of athletes with obvious differences pertaining to collegiate competition division and specific ages. Therefore, future researchers or health officials should capitalize on these limitations to provide the public with a better understanding of the rates of SCA incidence in athletes.[15]

Ill-defined inclusion criteria are not uncommon in SCA research, and it leads to contradicting statistics pertaining to overall prevalence for specific demographics. In an effort to obtain a better understanding of overall SCD rates, researchers conducted a review using keyword searches in the PubMed database.[11] Keywords/phrases included: SCD, sudden death, SCA, incidence, etiology, pathology, registry, athlete, young, children, and adolescent.[11] The researchers found 28 investigations meeting the goal of analyzing data in athletes or young people up to the age of 40 during physical exertion. Of the 28 articles meeting the aforementioned criteria, 13 determined the rate of SCD in athletes ranging in age from nine to 40. To compare the rate of SCD in athletes to the non-athletic population, the remaining 15 investigations evaluated SCD rates in "varying populations" under the age of 40.[11] While the age ranges are the same between groups, it was not specified what "varying populations" meant for inclusion. It was not until comparing the findings of both groups that the data were categorized into subgroups.

Results led to the conclusion that SCD rate ranges from 1:50,000 athlete years (AY) to 1:80,000 AY in high school and collegiate athletes.[11] Interestingly, based on the results, researchers concluded that the subgroup of male, black basketball players have a higher SCD rate than the comprehensive ratio. While there is not a specific rate mentioned in the article, it was estimated to be higher based on the increased risk in each of the demographics involved; men having a risk of 1:33,000 AY, black athletes having 1:18,000 AY, and basketball players with 1:11,000 AY.[11] When inclusion criteria and definitions are not uniform between research, large variants in results are found between researchers and subsequently do not improve the understanding of prevalence of SCA. Additional research investigating specific athletes and demographics is necessary to have a comprehensive understanding for various groups.[11] In conclusion, when gathering data for analysis, lack of specified inclusion criteria regarding specific demographics leads to conflicting reports between researchers.

Although the previous research suggested male, black basketball players were at an increased risk of SCA, Maron et al.[17] concluded white males were more likely to suffer an incident of SCA. This research analyzed 1,866 deaths during sports from 1980 to 2006.[17] Incidences were gathered using the US National Registry of Sudden Death in Athletes over 27 years to establish a better understanding of the circumstances of death during athletics. Information from reports, like many of the studies and reviews listed above, included varying ratios for separate demographics (Table 2). A noteworthy difference between the inclusion criteria of this study compared with others is the age range. While previously discussed studies included wide age ranges, between nine and 40 years, this study only included individuals under the age of 25.[11] Lack of specific age criteria is just one of many factors contributing to the ongoing misinformation regarding SCA in athletes. Having explicit inclusion criteria for research will create a better understanding of SCA rates for specific demographics while reducing the conflicting results between research groups.

**Table 2.** SCD Ratios

| Demographic | Ratio |
|---|---|
| ≤17 years | 677/1,866 |
| 18-25 years | 300/1,866 |
| Male | 937/1,866 |
| Female | 112/1,866 |
| Black | 377/1,866 |
| White | 581/1,866 |

Having well-defined language for cardiac events is essential for accurate recording and further analysis of data. Lack of clearly defined terms was apparent in a systematic review conducted by Drezner et al.[12] In this review, the researchers used the terms SCA and SCD with separate definitions for each; however, the results of both terms were combined in the reported findings. In this study, the researchers conducted systematic searches of various SCA and SCD reporting systems and found a total of 13 cases that fit the study criteria.[12] Data included athletes at the middle school, high school, collegiate, semiprofessional, and professional levels; mean patient age was 16 years with a range of 11-27 years.[12] An athlete was defined as an individual involved in regular training for a team or individualized sport with an emphasis on competition or performance. The use of both terms increased the number of studies included and allowed more data to be analyzed for survival and death rate analysis versus prevalence. Unlike the previously described studies,[2,9] Drezner et al.[12] used specific case inclusion criteria of ages and competition levels.[11] The use of specific inclusion criteria can improve the accuracy of results; however, varying language between SCA and SCD created an additional barrier to data accuracy. Of the 132 cases included, 64 were reported as SCA ad 68 as SCD.[12] Although this study attempts to provide more accurate information by having well-defined inclusion criteria, combining vocabulary for case identification may offset those benefits.

Reviews of literature have displayed a lack of organization in methods of calculating the ratio of SCA to specific demographic groups or to athletes as a whole.[11,15,17] Once the data were collected, methods for calculating the results varied greatly. Similar to inclusion criteria, the populations included in the equation are not explicit.[11,15,17] Meaning, if a population (the denominator) chosen is unspecified (ill-defined) without an age group, sport, or level, the result will be much different from a specified population. For example, investigating SCA rates in soccer players compared to all athletes versus SCA rates in soccer players compared to the entire human population. Without knowing which population is being used, the results of the equation will vary greatly, as the human population is significantly larger than the population that play soccer. When using the soccer population, the rate will seem much higher in comparison to the world population. This issue has been noted by researchers who indicate determining accurate rates relies on precise case identification in the numerator and a well-defined population in the denominator.[15] Without both of these requirements being met, the final estimate is highly variable.[11]

### 2.1.1. Treatment of SCA

Although the prevalence of SCA is undetermined, there is a better understanding of the treatment required immediately following the collapse of an athlete believed to have suffered from SCA. During SCA, the athlete will be unresponsive following a sudden and insidious collapse.[2,7,16] The athlete may be taking agonal gasps and have muscle twitches mimicking a seizure.[7,10] When an athlete collapses and is unresponsive, it should be assumed that the patient is having a cardiac event even when agonal gasps and seizure-like activity are present.[7,10] After identifying the SCA, emergency medical services (EMS) should be activated by calling 9-1-1. CPR should immediately be initiated beginning with chest compressions followed by airway management and artificial ventilations until EMS arrive.[7,10] Best-practice guidelines suggest early defibrillation is an essential component to preventing death following SCA.[2,7,10] Access to an automated external defibrillator (AED) in public spaces has improved due to the increased survival rates following AED use in SCA events.[2,7] The best sequence of action for an athlete with SCA is established and effective when recognized promptly and treatment is implemented immediately.

The optimal treatment for SCA includes rapid medical intervention. In the athletic setting, this intervention is typically provided by certified athletic trainers (ATCs). During athletic practices and competitions, ATCs are often the only qualified medical professionals on the scene.[7,10] ATC’s are highly qualified, multi-skilled health care professionals who render service or treatment under the direction of or in collaboration with a physician.[7,18] As a part of the health care team, services provided by athletic trainers include primary care, injury and illness prevention, wellness promotion and education, emergent care, examination and clinical diagnosis, therapeutic intervention and rehabilitation of injuries and medical conditions.[7,18] ATC's are required to provide emergency care to athletes until EMS services arrive. Thus, it is imperative that ATC's are prepared to recognize and react to the signs of SCA to provide immediate, high-quality treatment.[10,15]

Reviews have indicated that when ATCs are present, survival following SCA improves compared to when there is no trained provider on scene.[12] In an analysis of the most effective treatment for SCA, researchers reviewed two years of incidence reports and survival rates for cases with an ATC present.[12] Of the 132 cases, 29 cases of SCA occurred when an ATC was present. When an ATC was present and immediately able to provide treatment, 24 of the 29 (83%) survived.[12] Although the statistic is promising, it should be noted that there is not a statistic for instances where an ATC was not present to compare the 83% survival rate. ATCs' knowledge of SCA and the ability to provide prompt medical interventions are crucial to athlete survival following an SCA event. Yet, only half of athletic sites, such as high schools and recreational sport facilities, have access to an ATC.[7] This lack of coverage could be detrimental to athletes experiencing a SCA event. With evidence suggesting that ATC presence and treatment implementation following an SCA improves survival rates, athletic institutions should work to provide ATC coverage for all recreational and competitive athletes.

### 2.1.2. Commotio Cordis

Commotio cordis is the second leading cause of SCD in athletes and is defined as a mechanical stimulation of the heart by a non-penetrating force that does not damage the structure of the heart but causes disturbances in cardiac rhythm.[3,19,20] This "non-penetrating" force in sport can be a piece of equipment, such as a ball or stick, or opposing player during contact. In hockey, this includes the puck, opponents' stick, and body checking from opponents. For an impact to the chest to result in commotio cordis, the contact must be at the precise moment of the cardiac cycle before the peak of the t-wave, which is about 10-30 msec.[3,20,21] Currently, there is no defined prevalence rate of commotio cordis occurrence in literature. However, analyses from 1995-2018 of the commotio cordis case database reveal statistics from reported cases to better understand who is most at risk for commotio cordis. Overall, young men between the ages of 11 to 20, participating in recreational or organized sports are at highest risk. In addition, between 8% and 25% of total reported commotio cordis cases were ice hockey players.[17,19,21,22]

Sudden collapse of an athlete should alert medical staff, such as ATCs, and bystanders that there is quick action needed to prevent SCD. Both SCA and commotio cordis occur in seemingly healthy athletes and symptoms appear suddenly. However, unlike SCA, commotio cordis only occurs after a non-penetrating force to the chest. This force would not cause obvious deformity or trauma to the chest but would cause the athlete to fall unconscious within seconds of the force due to the change in cardiac rhythm.[14] In 20% of cases, athletes have been able to remain active, or even complete a play, before collapsing.[22] Regardless of how long it takes for the athlete to collapse, it is imperative that CPR and AED application begin within three minutes of the collapse.[22] Even with rapid AED application, commotio cordis has a mortality rate of 65 to 85%.[17,21] When an AED is applied within three minutes, the rate of survival rises to 92 to 100%.[21] For the best chance of survival following commotio cordis, the condition must be recognized early and AED intervention applied as quickly as possible.

Early implementation of treatment is supported by a case study in 1999 of a 15-year-old hockey player who died after being hit in the chest with a puck.[23] After a slapshot was taken to the chest, the player collapsed with no pulse and agonal breathing. CPR was administrated immediately by two nurses and a physician from the crowd, and EMS was activated after a nine-minute delay because an emergency phone could not be found promptly. An additional nine minutes was taken for EMS to arrive and apply the AED. Defibrillation, CPR, and medication were unsuccessful. After arriving at the hospital thirty-nine minutes following the collapse, the patient was pronounced dead.[23] During the discussion of recommendations for future treatment, a medical provider on site, access to on-site AEDs, and phones to lessen time between incident and treatment were the strongest suggestions to prevent death.[23]

Recommendations from the previous case study were applied successfully and resulted in survival after commotio cordis in a 14-year-old rugby player in 2010.[24] Like the previous study, this athlete was struck in the chest during a game, collapsed with no pulse or breathing, and was given treatment by spectators. CPR was initiated and AED applied with shocks delivered, and within 11-minutes the patient had regained a pulse.[24] While unconscious, the athlete was given ventilations via bag-valve mask. After transportation to the hospital, he regained normal vital signs and was discharged after one week. The authors attribute the success of this case to the rapid CPR and defibrillation after recognizing the condition.[24]

Researchers of commotio cordis have recognized the faults of SCA research and applied solutions to commotio cordis studies. These solutions are used to better understand the prevalence and treatment of this nearly always fatal event. An example of this change is the creation of the National Commotio Cordis Registry in 1996[17,21] to track cases of commotio cordis and the details of the event. These details include the environment where the event occurred, treatment provided, and the outcome of commotio cordis events. As mentioned previously with regards to SCA, the creation of a database for tracking cases of any athlete death and their circumstances have allowed for a better understanding of how cases are handled and improvements to be made for optimal treatment. Additionally, growing public awareness increased the reported number of cases for research. When the public is aware of the signs of commotio cordis, treatment can be applied rapidly and more effectively. With improvements to case recording and research methodology compared to SCA not only will best practice guidelines be improved, but also survival rates.

## 2.2. CPR

CPR is an emergency intervention used to continue blood circulation during cardiac arrest.[9] When performed correctly, CPR can increase the chance of survival after a cardiac arrest until advanced medical care can be provided.[9] CPR is comprised of two primary components: chest compressions, which help continue blood circulation and ventilations, which assist with gas exchange.[25] Experts in the area of resuscitation have formed committees dedicated to the improvement of CPR practices.[26] These committees form best- practice guidelines for administration of CPR, including specific recommendations for performing each of the previously stated components for both trained and untrained rescuers. While there are gaps in knowledge for each component, it is known that early intervention with high-quality CPR is a patient's best chance for surviving cardiac arrest. This life-saving intervention requires constant research to improve best-practice recommendations and subsequently patient survival outcomes.

### 2.2.1. Components of CPR

CPR is a life-saving technique used during cardiac and respiratory arrest to provide the patient with artificial pulses and breaths when the body is incapable. To provide the perfusion of oxygen necessary for survival, the heart needs to pump blood through the body and the blood needs to be supplied with oxygen. CPR uses two components to ensure the patient's body is maintaining oxygen when its own systems have failed. The two components of CPR are compressions to pump the heart and ventilations to supply oxygen. Like any medical technique, the understanding of how these components work has been studied and changed over time. Each component has specific recommendations to establish optimal conditions for survival based on human physiology.

Compressions during CPR are completed by pressing a downward force onto the patient's chest and releasing the force, thereby allowing the chest to recoil and the heart to refill with blood. During compressions the heart is pressed between the sternum and the spine, which creates an increase in intrathoracic pressure.[27] Intrathoracic pressure is pressure inside of the chest within the pleural cavity, which is the space between the lungs that is filled with fluid. The increase in pressure of the pleural cavity leads to an increase in aortic and right atrial pressure in the heart.[27] This increase forces blood through the one-way valves of the heart to the brain and rest of the body and allows for gas exchange.[27] As the compression is released, the blood is rushed back into the heart as a result of coronary perfusion pressure and is refilled for the next compression. This pressure not only brings blood back to the heart to be pumped again, but it is important for supplying the myocardium with oxygenated blood.[27] Although chest compressions allow for blood to move through the body, the cardiac output is one-third compared to a heart beating on its own.[28] With only a fraction of the output created, it is imperative that compressions are conducted in the most effective way to provide optimal conditions for survival. As will be discussed later in this section, compressions have recommendations for hand placement, depth, rate, and recoil based on published research. However, ventilations and its recommendations are not as well-defined and researched.

For optimal gas exchange during CPR, additional oxygen needs to enter the body. When this cannot be done by an unconscious patient, artificial ventilations are necessary. Ventilations inflate the lungs with air filling them with oxygen to be distributed in the blood and to the body by compressions. To ensure air is entering the lungs, the airway of the patient needs to be opened before and during delivery of ventilations. Methods of opening the airway varies by injury to the patient, resources available, and training of the rescuer.[4] If the patient is believed to have suffered a spinal injury, the trained rescuer should open the airway using a jaw-thrust maneuver. If no spinal injury is suspected, the trained rescuer should tilt the head backward lifting the chin to open the airway. Current recommendations state that a rescuer not trained in CPR, or lay-rescuer, should not attempt to give ventilations and therefore do not need to open the airway.[4] If a trained rescuer has access to devices to open the airway such as an oropharyngeal (device inserted into the mouth) or nasopharyngeal (devices inserted into the nose), they should insert these airway adjuncts.

Similar to compressions, there are potential negative effects from attempted ventilations that are delivered incorrectly. A common issue with ventilation delivery is hyperventilation, or too many breaths. Ventilations given at too fast of a rate have detrimental effects on the perfusion of blood to the heart and brain.[27] Additionally, too few breaths, or hypoventilation, also has negative impacts on the patient during CPR.[27] If not enough oxygen is provided to the patient, there is not enough for beneficial perfusion to the entire body and damage will occur.[27] To ensure no further harm is inflicted on a patient suffering from a cardiac or respiratory arrest, not only must ventilation rate per minute be appropriate but also the volume over time per breath. Optimal volume for ventilations has been determined to be between 600 ml-700 ml.[29] Breaths given at too great a speed cause air to travel to the stomach instead of the lungs causing gastric distension.[30]

Research conducted in 2018 to identify the optimal time to deliver a ventilation via bag-valve mask (BVM) and mouth-to-mouth determined that breaths given over one-second provided the optimal amount of oxygen with minimal gastric inflation.[30] This study provided ventilations to a physiological model with a mouth, airway, esophagus, and lungs. Gas would flow to the "stomach" simulating gastric inflation when the pressure in the airway rose above the lower esophageal sphincter pressure.[30] Pressure was set to 20, 15, 10, or 5 cm $H_2O$ to replicate the decline in pressure a patient would measure while suffering from hypoxia.[30] Tidal volume for the sessions were .06 or 1.0 L for each breath because this range was practical to demonstrate low and high volumes.[30] Overall, instances of gastric inflation were slightly higher in the BVM group (.21 L) compared to the mouth-to-mouth group (.019 L).[30] For both tidal volumes, the ideal time for a ventilation to be given was about one second.[30] When ventilations were given over less than half a second, the pressure needed to expel the breath was increased and surpassed the lower esophageal sphincter pressures and leak around the mouth resulting in an ineffective ventilation.[30] However, even though the pressure is higher during the quicker breaths, the amount of time the pressure caused gastric inflation was less when compared to ventilations given over one and a half seconds. If the longer inflation times were above the recommended tidal volume, there was more time at an increased pressure for air to be forced into the stomach.[30] Therefore, breaths at any volume should be delivered over one second to minimize the incidence of gastric inflation.

Although ventilations have been excluded from lay person CPR in recent years in place of compression-only CPR,[31] when EMS arrival is delayed, ventilations are necessary to increase the rate of survival in patients.[27,32] The average time it takes EMS to arrive to a scene is seven minutes from call to arrival in a city and raises to fourteen minutes in rural settings.[33] After four minutes of CPR, ventilations should be included to provide adequate oxygen for perfusion.[32] With most cases of CPR requiring longer than four minutes of intervention, it is imperative that ventilations be given at an appropriate rate, volume, and time.

**2.2.2. Ventilation Devices**

Devices that assist with ventilation delivery have been developed to aid rescuers in providing adequate breaths and protection from potential infection. Ventilation devices in out-of-hospital care date back to 1954 and were created by Dr. James Elam.[28,34] He proposed that air that was exhaled provided adequate oxygen levels for resuscitation in patients experiencing respiratory arrest. Though his recommendation began with mouth-to-mask ventilations, mouth-to-mouth became standard because most lay persons did not have a mask available to them when they needed to provide CPR. However, health care providers were expected to use ventilation devices available in hospitals. In the 1970s, the first mass lay person CPR session was launched and provided training on breathing barriers.[28,34] Following the training, ventilation devices were provided for the newly trained individuals to use if needed. Although trained in how to use the ventilation devices, the devices themselves were bulky and difficult to carry in daily life. In attempt to create an easily accessible breathing barrier, the PocketMask (PM) and FaceShield (FS) were created.

All barriers are composed of plastic and contain one-way valves that prevent substances from the patient from entering the rescuer's mouth. Examples of substances are vomit, mucus, blood, foreign bodies, or pathogens.[35] Some barriers include a bag to deliver the breaths while others are used in mouth-to-mouth. Three ventilation devices used in out of hospital care are bag valve mask (BVM), PocketMask (PM), and FaceShield (FS). BVMs are the largest in size and require frequent training to be used effectively. PocketMasks are smaller in size but easier to transport in a bag and do not require frequent training while FSs are small enough to fit as a key chain. Each ventilation device has its own limitations and benefits but overall, these devices have allowed rescuers to feel more comfortable in delivering ventilations to unconscious victims suffering from respiratory arrest.

***2.2.2.1. BVM***

The standard ventilation device in hospitals and most EMS systems is a bag valve mask.[36] Bag valve masks include a mask with an inflated section to create an air-tight seal around the patient's nose and mouth, a reservoir of air, and a patient connector. The patient connector can be attached to the mask around the patient's nose and mouth or advanced airway such as an endotracheal tube to provide ventilations.[36] Air travels to the patient connector from a one-way valve by squeezing a reservoir of air. Squeezing the bag forces the air to enter the patient's airway and lungs with positive pressure through the one-way valve.[36] Following the delivery of a ventilation, the air is then exhaled passively from the patient and air fills the reservoir through a separate valve to be compressed again.[36] Rescuers know all the air is expelled when the chest falls from its inhaled position. This process requires no air to be delivered from the mouth of a rescuer and can be attached to high-flow oxygen for increased saturation.

Although it is used often by medical professionals and is the recommended ventilation method by the AHA, the BVM is the most difficult device to use correctly.[35,36] This method requires two rescuers to deliver optimal ventilations. One rescuer seals the mask to the patient's face around the nose and mouth and opening the airway while the other rescuer delivers the ventilation by squeezing the air reservoir.[35] This process is difficult for a single rescuer because providing an adequate seal of the facemask while tilting the head to open the airway requires two hands, leaving none to squeeze the reservoir. Providing compressions and taking the time to seal the mask, open the airway, and then provide the ventilation takes an extended amount of time and leads to longer interruptions of chest compressions.[35]

Athletic trainers are trained healthcare professionals and are often the first to provide care to athletes who collapse and require CPR.[7,10] As a healthcare professional, the BVM should be the expected ventilation device readily available for use in case of a cardiac or respiratory emergency. However, ATCs are often mobile during coverage and are not able to carry a BVM device while working. Additionally, ATCs frequently cover events and practices alone thus making it difficult to use the BVM as intended.[7,8] Due to the difficulties associated with using BVM in single-rescuer situations, smaller ventilation devices have been created and used by ATCs.

***2.2.2.2. PocketMask***

Compared to the BVM, the PM is a smaller, more portable option that provides protection from contaminants during ventilations. The PM has a similar shape to the mask attached to the BVM air reservoir, creating an air-tight seal over the mouth and nose of the patient. An adequate seal of the PM is necessary to ensure the air is going into the airway. To create an adequate seal, two hands are required. Unlike the BVM, the delivery of air requires the rescuer to exhale to the patient via the PM. The exhaled air of the rescuer flows through a one-way valve and provides the patient with oxygen. Two rescuers are not needed because the seal of the PM around the mask can be maintained by one rescuer while the breath is being delivered.

PocketMasks are used in out-of-hospital care by healthcare professionals such as ATCs because the ability to provide a similar seal during ventilation delivery without the need for two rescuers. However, research comparing BVM, PM, and mouth-to-mouth ventilations and their quality during CPR indicate that mouth-to-mouth resuscitation is superior.

In 2011, a Dutch research team compared the quality of single-rescuer CPR using a BVM, PM, and mouth-to-mouth ventilations in surf lifeguards.[35] A total of 60 participants were randomly allocated into six groups with the sequence of ventilation method predetermined. Each rescuer completed three minutes of CPR for each method separated by five minutes of rest. Variables collected were time to start compressions, compression rate and depth, no-flow time, tidal volume and inspiratory time.[35] Results were recorded by software connected to the manikin used for CPR and video recording of the session. Normality for all variables were determined by D'Agostino-Pearson's test; the proportion of effective breaths compared using McNemar's test mean; standard deviation was used for continuous variables.[35] Overall comparisons of variables were analyzed using ANOVA with a p-value of .05.[35]

Analysis of data indicate that the time to starting compressions, compression depth, and compression rate had no statistical significance between the three different delivery methods.[35]. Mouth-to-mouth had a significant increase in adequate ventilations when compared to the pocket mask ($p<.001$) and BVM ($p<.001$).[35] Effective ventilations from the mouth-to-mouth, mouth-to-pocket mask, and BVM were 91%, 79% and 59% respectively. Tidal volume was significantly lower in the BVM group (0.4±0.2 L) than the PM group (.06±.03 L) and mouth-to-mouth group (.06±.02 L), but no difference between the PM and mouth-to-mouth.[35] The difference in no-flow time between compressions and ventilations was significant in all groups. The mouth-to-mouth group was 8.9±1.6 s, mouth-to-pocket mask: 10.7±3.0 s and BMV: 12.5±3.5 seconds.[35]

Researchers of this randomized trial found that mouth-to-mouth ventilations when compared to BVM and PM had less interruptions to CPR and higher proportions of effective ventilaions.[35]

It should be noted in the demographic information obtained from participants, 70% of lifeguards indicated they preferred PM ventilations to mouth-to-mouth (18%) and BVM (10%).[35] Also, only seven people, or 12%, of the participants were healthcare professionals.[35] If a majority of the participants are not healthcare professionals, it can be assumed they have not been adequately trained in BVM or PM delivery. Currently, there is little to no research comparing the effectiveness of BVM versus PM ventilations in healthcare professionals. To make an accurate determination on the best ventilation device for healthcare providers, such as ATCs, more research is needed.

#### *2.2.2.3. FaceShield*

FaceShields are an adaptation of the PM that allow for more compact storage and can be transported in daily activity. The design of the FS is a thin, flexible, plastic sheet with a one-way barrier that can be folded to a fraction of its size for transportation. FaceSheilds are often stored in a case attached to a keychain. For ATCs, using a FS may save space in their medical kits and is light enough to have on their person at all times in case of emergency. However, to increase mobility of the device, components to create a seal around the airway had to be eliminated.

When using BVM and PM, the rigid mask shaped to fit around the nose and mouth with the air-filled border to seal the airway, but with a FS there is no border to create the seal. The rescuer is required to provide ventilation similar to mouth-to-mouth, pinching the nose, and sealing the patient's mouth with their own during breaths. Delivering breaths in this way can be difficult over the flexible plastic sheet because the flat design needs to be molded to the patients face for each delivery and is easily shifted out of place. While some research has shown that mouth-to-mouth resuscitation has been the best way to deliver quality ventilations,[35] using a FS during mouth-to-mouth did not reach the same standards.[37] When comparing measurements of resistance of air through the one-way valve in three different FS brands on manikins, none of the devices met the AHA requirements for ventilattions.[37] However, the only published information on this study was in an abstract and conducted in 1996.

Further research is needed to establish if FS models and their ability to provide quality respirations have improved. FS is used in emergency situations to provide ventilations for patients and protection for rescuers. This widely used tool has little research regarding its efficacy to apply recommendations for its use. In addition, the research available does not support its use compared to other devices. Without affirmation that the tool is effective, it cannot be known if the FS should continue to be used.

### 2.2.3. AHA CPR Recommendations

The International Liaison Committee on Resuscitation (ILCOR) is a committee comprised of international organizations that work to develop the latest guidelines for CPR. The ILCOR has members around the world, including but not limited to, the American Heart Association (AHA), European Resuscitation Council (ERC), Heart and Stroke Foundation of Canada, Resuscitation Council of Asia, and others who contribute both scientific and anecdotal research for the cause.[25] Using its expansive membership, the ILCOR can access a large number of resources to gather data on a global scale to use towards determining best practices. The ILCOR has been working to advance resuscitation medicine since 1992 through research. Through collaboration with the AHA, the two have established an up-to-date, standardized system of care that provides updated CPR and emergency cardiac care (ECC) guidelines every five years.[25]

*2.2.3.1. 2000 Recommendations*

In 2000, the AHA provided updated recommendations for rescuers to assess and intervene in the event of cardiac arrest.[38] One of the most notable aspects of these recommendations was a difference in assessment and treatment recommendations for the lay person versus the health care provider. Before providing treatment, an assessment must be made to evaluate the patient's condition. For both groups, assessment began with checking for responsiveness and breathing using the "look, listen and feel" technique. This is a cue to look for chest rise and fall, listen for an inhale or exhale of air, and feel for air flow indicative of breathing. If the patient was not breathing, the rescuer would administer CPR in the order of, opening the airway, delivering breaths and circulation via compressions. The process of beginning CPR in this order is called the "ABCs." The ABCs are an acronym for reminding the rescuer to open the airway, then breathing, followed by compressions in that order.[38] To open the airway, both rescuers are told to open the mouth and move the head back.

When opening the airway, it is recommended that the rescuer (both lay person and health care professionals) use the head tilt-chin lift, or the jaw thrust maneuver. The head tilt-chin lift maneuver is for those without suspected cervical spine injury because this lift moves the entire head and neck into extension to access the airway.[38] In contrast, the jaw-thrust maneuver is recommended for those with suspected spinal injuries as it involves movement of the mandible forward to open the airway while cervical spine is in a neutral position.[38] Once the airway is opened with the appropriate method, breathing was the next step in CPR administration. Breathing is accomplished through artificial ventilations provided by the rescuer. Rescuers were instructed to deliver ventilations slowly over two seconds allowing chest rise (inhalation) then allowing the chest to fall (expiration). After delivering two breaths, the rescuer would move to the circulatory step of the ABCs and deliver chest compressions. The guidelines suggested a compression depth of 1.5 to two inches at a rate of approximately 100 compressions per minute (cpm) while allowing full chest recoil between each compression.[38] Additionally, minimizing interruptions during CPR administration was emphasized to improve blood circulation. The process of "look, listen and feel" and the ABC order of interventions was congruent between lay rescuers and health care rescuers, yet there are some differences determined by the AHA in the 2000 guidelines for the lay rescuer.

Differences in treatment between health care rescuers and bystanders began after the "look, listen, and feel" technique. The health care rescuer was instructed to complete a pulse check by placing two fingers on the carotid artery to establish if the patient was in respiratory arrest versus cardiac arrest, while lay rescuers were instructed to move directly to CPR administration. For the health care rescuer who established that the patient was not breathing but had a pulse, they would administer ventilations at the rate of one breath every four to five seconds.[38]

The aforementioned difference in the assessment process between health care providers and lay public was included based on research that established lay rescuers' pulse checks were ineffective.[4,5] Evidence suggested the pulse check delayed initiation of CPR because lay rescuers tended to take longer than ten seconds to find a pulse.[39,40] A randomized, blinded study tested the accuracy of carotid pulse checks in 206 participants with varying levels of medical experience.[39] Participants were separated into the following groups based on their medical education, eight-hour first aid class (EMT-1, n=107), beginner EMT class participants with four weeks of training ( EMT-2, n= 16), paramedics with one year of training (PM-1, n=74), and certified paramedics (PM-2, n=9).[39] Participants were randomly assigned to assess surgical patients for a pulse during normal circulation under anesthesia (pulse present) or during non-pulsatile cardiopulmonary bypass during a surgical cardiac procedure (pulse absent).[39] Participants were asked to identify the presence or absence of a pulse within 5 to 10 seconds but were allowed up to one minute. All monitors indicating any respiratory or cardiac data and the doctors monitoring them were blocked from view and silenced during the assessment.

Statistical analysis included a two-tailed *t*-test for overall accuracy with a p-value $<.05$ indicating significance.[39] All groups were 65% accurate with the lowest group accuracies from both EMT groups. Pulse-check accuracy for the EMT-1 and EMT-2 groups were 53% and 56%, respectively. In contrast, the PM-1 and PM-2 groups had much higher accuracies at 81% and 89%, respectively.[39] There was a statistically significant difference in time required for the pulse-check (med=24 seconds, range=3-60 seconds, $p<.001$). [39] Interestingly, only 31 of the 206 participants accurately found a pulse in the 10-seconds or less recommended by AHA.[39] Although the elimination of the pulse check was implemented for lay rescuers, it should be highlighted that more educated health care providers also struggled to locate a pulse in less than 10 seconds.[39]

In a similar evaluation of pulse check accuracy, researchers observed 79 participants with varying levels of training who conducted a carotid pulse check. In this randomized trial, participants completed 10 trials of carotid pulse assessment on a simulation manikin..[40] The groups were labeled lifesavers (instructor level, n=48), paramedics (current practitioners, n=16) and lay persons (clerks or janitorial, n=15).[40] In this study, the “patient” was a CPR practice mannequin with a balloon acting as the carotid artery to simulate the pulse rate. The condition of the pulse present or absent was randomly determined with a coin toss prior to the assessment.[40] Time taken to reach a result as well as the accuracy of the diagnosis were measured. Accuracy comparisons between the three groups was assessed using a chi-square test with Bonferroni corrections.[40] Accuracy results for lifesavers, paramedics, and lay persons were 93%, 94%, and 63%, respectively.[40] There were significant differences between the lifesaver group and lay person group ($p<.001$) and between the paramedic group and lay person group ($p<.001$).[40] The amount of time taken to assess a pulse for the lifesaver, paramedic, and lay person groups were 6.01±5.23 seconds, 7.04±11.23 seconds, and 20.51±15.04 seconds, respectively.[40] Additionally, a significant difference was noted between the lifesaver and layperson groups as well as the paramedic and layperson groups ($p<.001$ for both).[40] The findings of this research support the notion that lay rescuers struggle with the pulse check component of cardiac arrest management. Thus, these studies validate the removal of the pulse check from the AHA guidelines for lay rescuers.

In addition to removing pulse checks for the lay rescuer, the AHA altered the components of CPR for lay rescuers due to bystanders' hesitation to initiate ventilations. The hesitation stemmed from the concern of disease transmission during mouth-to-mouth ventilations, leading to the delay or complete avoidance of CPR onset.[38] To counteract this fear, the recommendation was for lay rescuers to conduct chest-only CPR if they did not feel comfortable administering ventilations. Chest-only CPR involves delivering compressions with the same rate, depth, and recoil as standard CPR but eliminating the ventilations.[38] The AHA's understanding that lay rescuers are less capable and willing to adhere to the health care professionals' CPR guidelines and providing alternate instructions, provides the most opportunity for successful patient outcomes.

### *2.2.3.2. 2005 Recommendations*

In 2005 the AHA released updated guidelines that reinforced past guidelines while updating protocols for accessing the airway and compression to ventilation ratio. Carrying over from 2000, the "look, listen and feel" technique was to be used while determining responsiveness, then progressing through the ABCs.[41] During compressions, the depth and rate remained consistent at one and a half to two inches and around 100 compressions per minute (cpm), respectively.[41] The emphasis on chest recoil between compressions was maintained in the 2005 guidelines. While there were no changes to the process of CPR initiation, there were significant changes to the components of the ABCs.

For lay rescuers, the ABC's changed from determining which airway maneuver was best, to only using the head-tilt chin lift for all scenarios. The jaw thrust maneuver is no longer recommended for lay rescuers to open the airway due to the more complicated process.[41] Jaw thrust requires direction from medical dispatch and is often confusing to bystanders, resulting in ineffective opening of the airway.[41] Health care professionals are taught and well-practiced in completing this maneuver and are recommended to continue its use when spinal precautions are in place. It should be noted that there is no research supporting this claim, even 16 years later. This decision was reached by a consensus of the experts at the AHA and ILCOR. Lay rescuers who wish to perform ventilations are recommended to use the head-tilt chin lift.[41] While this change is directed toward lay rescuers, there were other changes to the components of CPR that would apply to both rescuer groups.

The most notable difference from the 2000 guidelines to 2005 was the change in compression-to-ventilation ratio from 15:2 for all populations to 30:2 for adults.[42] This revision was a topic discussed in the 2000 Guidelines but needed further research to establish if rescuer fatigue would be too great while using the ratio with 30 compressions. While there was limited research supporting this change before 2005, a 2007 study analyzed the differences in perceived exhaustion, average compression depth and rate, total compressions and correct compressions in groups using both the 30:2 ratio and the 15:2 ratio.[43] A total of 130 nursing and bioengineer students were separated into a 30:2 or 15:2 compression ratio groups. Participants completed five minutes of CPR on a practice manikin with their assigned ratio, rested for 15 minutes, then completed five minutes of CPR with the other ratio. After each bout, participants were asked to rate their fatigue on a visual analog scale with zero being no fatigue and ten being high fatigue.

It was found that perceived exhaustion and average compression rate were significantly higher during the 30:2.[43] While the increase average compression rate was statistically significant, it should be noted that both groups were within the recommended compression rate. Additionally, the visual analog score differences were less than 1.5 points between groups. Although that is statistically significant, it can be perceived as a small change between individuals. There was no significant difference in average depth between the two ratios.[43] Adjusting the compression ratio from 15:2 to 30:2 had statistically higher perceived exhaustion and provided more compressions overall, but had no change in depth.[43] Rescuers are able to provide adequate compressions at a higher ratio and subsequently can give the patient longer periods of chest compressions without interruptions.

#### *2.2.3.3. 2010 Recommendations*

In 2010 the AHA guidelines changed both the sequence of steps lay rescuers use to check for responsiveness of a patient and most significantly, the components of CPR. Similar to pulse checks being deemphasized since 2000, the “look, listen and feel” method to check for breathing was deemphasized in the 2010 recommendations. This method was removed to decrease the amount of time taken by lay rescuers to initiate CPR. Once CPR by a lay person was initiated, instead of being instructed to give breaths if they felt comfortable, they were told to give only compressions. The modification to both the checking of patient response and compression-only CPR were enforced to provide the patient with the quickest initiation of CPR and less interruptions.

Considering the lay rescuer does not have the knowledge and practice to provide a quick and accurate “look, listen and feel” technique, the AHA changed the process to a more efficient approach. By shaking the patient’s shoulders while shouting, “Do you need help?,” was adequate for a lay rescuer to check for responsiveness versus taking time to look, listen and feel.[31] This change will decrease the time from collapse to the initiation of CPR, which theoretically improves survival outcomes.[44] While there is not specific research analyzing the difference in survival rates in patients who were given CPR by bystanders using the “look, listen and feel” technique versus the new recommendation, previous research has shown that the faster CPR is initiated better outcomes are recorded. The claim that the faster the CPR can be implemented on unresponsive patients has been part of the AHA Chain of Survival since 1991.[38]

In 2015, a Swedish research team analyzed out-of- hospital cardiac arrests from 1990-2011 where bystanders were recorded on scene.[44] There were 30,381 cases included for comparison between cases where CPR was performed before EMS arrival and when it was not.[44] Out of the 51.1% (15,512) of cases where CPR was performed before EMS arrival, 10% of patients survived 30 days after incident as compared to only 4% of patients surviving when CPR was not performed.[44] This significant increase in survival supports the assertion that bystander CPR can be a factor in the survival of patients experiencing out-of-hospital cardiac arrest. Further research is needed to determine if changing from pulse check and the “look, listen, feel” to visual inspections will lead to a faster initiation of CPR by bystanders. This can be achieved by expanding on the research design of studies, like the previous, by determining what technique they used to check responsiveness and the time taken to initiate CPR.

In addition to the new streamlined approach to decrease the time taken for lay rescuers to begin CPR, lay rescuers also had instructions for the CPR itself. Once CPR was indicated to the lay rescuer, dispatch would instruct the rescuer to begin and maintain compressions until EMS arrived. The change in the approach of lay rescuer CPR came from the studies showing the detriment of pauses to give ventilations during compressions. A study comparing clinical trials from 1985 to 2017 analyzed the findings of these trials and compared the effectiveness of compression-only CPR to CPR with ventilations.[45] Four randomized studies on both bystander and trained rescuers were included in this review. Three compared the compression-only CPR to standard CPR from bystanders under instruction from medical dispatch by telephone when calling 9-1-1.[45] The bystander research included 3,737 participants, the other included CPR by EMS personnel and had a total of 23,711 participants.[45] It was found that CPR by untrained bystanders, continuous chest compressions CPR led to an increase in patient survival by almost 25 more people per 1,000 compared to CPR with ventilations.[45] With this increase in survival rate, the change to compression-only CPR by untrained lay person is supported.

The idea of compressions being the most influential component of CPR to promote survival is reinforced with the change of CPR sequence from “ABC” to “CAB” in 2010.[31,46] CPR should now begin with compressions (instead of circulation assessment) and move to the airway opening and delivering ventilations after 30 compressions. Previously, it was instructed to begin CPR with opening the airway, followed by two ventilations, then compressions. The AHA believed this change would decrease the delay in chest compressions and would reinforce the change to compression only CPR by bystanders.[47] While this change was theoretical in 2010, research from 2013 supports this adaptation.[47]

From 2007 to 2010, researchers used teams of  one nurse and two physicians to compare the time taken to complete one cycle of CPR using the CAB compared to the ABC method.[47] A total of 108 teams were used and randomly assigned to use the CAB or ABC method to perform CPR on a manikin simulating cardiac arrest. Participants were unaware of the outcomes measured and given the same scenario regardless of group. Prior to the scenario, each team was given a 15-minute instruction on the manikin then given a flow chart of what method they should use during data collection. The scenario was a sporting event where the physicians were volunteering to provide medical care, and the nurse would act as a "policeman" to bring the team to the patient and carry equipment.[47] One participant would provide compressions and the other ventilations via BVM. The "patient' was a middle-aged man watching the event and unresponsive due to a cardiac arrest.[47] The scenario ended with the patient regaining consciousness after the second defibrillation.

Time from the first moment a participant touched the patient to the completion of the first cycle of CPR was recorded and used for data analysis, but five total cycles were completed. To determine this time, two independent observers with experience in delivering CPR and teaching watched the video recordings of the scenario and agreed on a time. Differences in observed time that were less than five seconds were considered in agreement, and the shorter time was used in data analysis.[47] Analysis consisted of Student's *t*-test, chi-square and log-rank tests via SPSS; a $p<.05$ was considered statistically significant. Results indicate that using the CAB method leads to faster initiation of a full cycle of CPR compared to the ABC method.[47] The group using the CAB method completed the first cycle of CPR in 48±10 seconds, which was significantly lower than the 63±17 seconds in the ABC group ($p<0.0001$).[47] The switch from the ABC method to CAB method to decrease the time taken to provide compression to a patient is supported in this research.

In addition to an updated CPR implementation sequence, the AHA increased the minimum compression depth and added a maximum depth to further improve compression quality. High-quality CPR was defined as minimum of 100 compressions/min at two inches in depth with full chest recoil and limited interruptions to compressions. The recommendation for depth of compressions changed from 1.5 (38 mm) inch minimum to between 2 (50 mm) and 2.4 (60 mm) inches while maintaining the ratio of compressions to ventilations at 30:2.[31] When the recommendation for depth was altered in 2010, there was limited research to support the change. Retrospective cohort studies have been conducted from 2006-2009, and 2019 have displayed that the depth in the recommendation is not entirely accurate but improved.

A study using patient data from the Resuscitation Outcomes Consortium (ROC) network of emergency medicine services analyzed the compression depth during each minute of CPR.[48] Data were collected from patients who were 18 or older, suffered from a non-traumatic cardiac arrest, were treated with defibrillation, and chest compressions from ROC emergency medicine services were provided.[48] Chest compression data such as compression rate, compression fraction, and depth was recorded via accelerometer interface in the pads of the AED applied for fibrillation. The dependent variable recorded was “survival from hospital discharge;” this included patients that were transferred to a “non-acute” facility but excluded if the patient was moved to another in-patient or “acute” facility. Patient information was collected from 1,029 patients from May 2006- June 2009.[48] Results for chest compression depth ranged from 32-43 mm with a median of 37.3 mm. In addition, 59.3% of cases did not meet the 2005 standards and more than 90% did not meet the 2010 requirements.[48] While the results of compression depth were largely unsuccessful, an association between compression depth and improved outcomes was found.[48]

In 2019, another study was conducted using the same research methods to determine the optimal chest compression rate and depth for different ages, sex, and cardiac rhythms. A total of 3,643 patients who received CPR for out of hospital cardiac arrest from emergency medical personnel from the National Institute of Health were included.[49] Like the previous study, this data were collected through the pads with the applied AED during CPR. Compression depth was recorded to the nearest 0.5 cm and only included data from CPR given between 60-160 compressions per minute to eliminate outliers. The optimal range found from this data was concluded to be a rate of 105-109 compressions per minute and a depth range of 4.5-5 cm (45-50 mm).[49] The peak was determined to be 107 compressions per minute at a depth of 4.7 cm (47 mm).[49] If the rate and depth were within 20% of value, the survival probability increased significantly (6% vs 4.3%).[49] These findings support the 2010 recommendation for increased compression depth and support published data indicating a relationship between compression depth and improved outcomes.

***2.2.3.4. 2015 Recommendations***

Recommendations for optimal CPR from the AHA in 2015 did not have significant changes in protocols compared to 2005 and 2010. CAB would continue to be the process of CPR initiation. The ratio of compressions and ventilations stayed at 30:2, and lay rescuer CPR continued to be compression only. Compression depth remained at a minimum two inches while not exceeding 2.4 inches. The rate of compressions did not change but was given further instruction. Previously, compression rate was to be “a minimum of” 100 beats per minute; in 2015 the description was changed to between 100-120 beats per minute.[49,50]

As mentioned in the previous section, compression rate was found to be optimal around 107 compressions per minute.[48] However, with the 2015 recommendations, a higher maximum compression parameter was implemented than the 107 compressions per minute (cpm) found in published research. Subsequently, additional trials of CPR with varying compression rates were needed to support the new regulations. The main concern with the 2015 compression rate limit was that the rate of 120 would be too physically taxing on the rescuer and lead to inadequate compressions. Additionally, previous research focused on the 2010 recommendations, indicated that compression rates above the instructed “at least 100 compressions” significantly increased the rate of return of spontaneous circulation (ROSC).[48] Yet, it was not determined if there was a limit to this finding before fatigue impacted the ability to perform high-quality CPR before creating the 2015 guidelines.

A research team in China recognized the uncertainty of increased compression rates and its impact on ROSC as well as the quality of CPR, and they compared variables of CPR during compression rates of 100, 120, and 140.[51] In this randomized crossover study, 27 participants with a current CPR certification were recruited from emergency department personnel.[51] Participants were instructed to complete three sets of compression-only CPR on a manikin that was able to record CPR data for two minutes.[51] Each round of CPR had compression rate that randomly predetermined and paced with a metronome. Following the two minutes of CPR, a rest period of up to 30 minutes was taken to limit rescuer fatigue. The manikins recorded the total number of chest compressions, average depth, compressions with full release, and correct hand position.[51] Fatigue, determined as the time when five or more consecutive compressions at inadequate depth occurred, was recorded from the manikin data. Data were analyzed using a repeated-measures analysis of variance.

While the total number of compressions in the two-minute trial increased with compression rate, the compressions with adequate depth were highest at the rate of 120.[51] All recorded data was of highest quality at the rate of 120. Data were considered adequate but of lesser quality at both 140 and 100 cpm.[51] Additionally, fatigue was reached at 96 seconds for 100 cpm, 106 seconds for 120 cpm, and 78 seconds for 140 cpm.[51] The difference between 120 cpm and 140 cpm was statistically significant, as well as 100 cpm and 140 cpm ($p<.05$).[52] Overall, this research team concluded that compressions at a rate of 140/min may lead to earlier fatigue and therefore inadequate CPR. Additionally, the rate of 100/min did not maintain adequate CPR for two minutes due to errors in hand placement and insufficient chest recoil. It should be noted that this finding was not expected by the research team and is speculated to be due to the longer pauses taken between compressions. The recommendation of this research is 120 cpm for compression-only CPR because participants were able to reach and maintain the recommendations of CPR for approximately 90% of their trials.[51] More information is needed from a larger population to confirm the recommendations of this study. However, published data supports the change of compression rate from a minimum of 100 per minute to between 100-120 per minute.

#### *2.2.3.5. Conclusion*

CPR is a lifesaving intervention for preventing death from cardiac arrest. Like any treatment, the efficacy of practice needs to be reviewed and tested to ensure procedures are optimal for survival. The AHA guidelines have been a source of centralized recommendations based on panel of experts. Researchers conduct studies to test the efficacy of current guidelines and give the expert panel more information to base the future guidelines. Changes to the compression and ventilation ratio, ventilation administration, compression rate, and lay rescuer protocols are the most notable changes over the past 20 years. These changes have made CPR more effective, but further research will inform the panel of experts if these components can be improved. There is an abundance of research on the effectiveness of compression ratios, depth, and hand placement but minimal research on ventilations. This is in part due to the difficulty of assessing the variables of ventilation including tidal volume, airway opening, time to inflate, and best delivery method. Although regular updates are given to improve CPR quality, specifically compressions, optimal recommendations have yet to be determined for ventilations.

### 2.3. CPR with Protective Athletic Equipment

Recommendations for optimal CPR have been researched extensively for the general public. However, minimal research is available specific to athletes who may be wearing protective athletic equipment at the time of the medical emergency. The NATA has position and consensus statements that emphasize the importance of rapid treatment of SCA with CPR, AED application, and EMS activation. However, these statements do not have a recommendation of action for athletes who wear protective equipment that blocks access to the chest and airway.[10,53,54] Athletes participating in contact sports wear protective equipment to prevent musculoskeletal injury. In high contact risk sports such as football, ice hockey, and lacrosse, these pads can cover the chest making it difficult to gain access to the chest for compressions.[55] As discussed previously, recommendations for SCA treatment include immediate initiation of CPR and an AED once the emergency is recognized by bystanders or healthcare professionals. This rapid initiation can be delayed due to the protective equipment worn by contact athletes blocking access to the patient’s chest to provide compressions or helmets impeding access to the airway. For ATCs, understanding the most effective and rapid way to begin CPR on athletes wearing equipment should improve patient outcomes.

Research has been conducted on the methods of CPR for the equipment-laden athlete to determine if pads should be removed before beginning compressions, but recommendations have yet to be created for ventilations. In recent years, high-quality chest compressions have been emphasized over ventilation during CPR. This emphasis has been reflected in research on equipment laden athletes. Published research for football, lacrosse, and hockey have begun to investigate different levels of equipment removal and its impact on CPR, but no official recommendations have been made by the AHA or NATA. However, existing literature related to helmet removal for ventilations has focused on football and lacrosse, thereby neglecting other sports such as ice hockey.

**2.3.1. Football**

Football has the highest rate of sudden death during sport and the second highest rate of SCA incidences compared to other sports.[12,17] Due to the high risks associated with football, multiple research studies have been conducted to determine what equipment removal, if any, is needed for rescuers to provide adequate CPR. Guidelines for CPR emphasize rapid initiation of chest compressions for best outcomes, insinuating that compressions should begin over athletic equipment. However, little research has been presented on the topic of beginning CPR over athletic equipment. Furthermore, the limited published research has conflicting results between sports.

In an effort to determine if CPR compressions are effective over football pads, a research team conducted a study on the efficacy of CPR on manikins with and without football protective equipment.[56] This study analyzed 30 basic life-support certified and students in an athletic training undergraduate program or licensed graduate students.[56] Prior to testing, participants were given a standardized scenario and then asked to complete three rounds of compression-only CPR. All participants completed their testing in the same order of baseline (no equipment), over pads (compression over the chest pad), and under pads (hands under unlaced shoulder pads.)[56] Outcomes measured were average compression depth, rate (per minute), percentage of time chest wall was recoiled appropriately, and percentage of hands-on contact during compressions.[56] A p-value of .05 determined statistically significant after using Wilcoxon signed rand and Kruskal-Wallis tests. The only variable with significant differences between trials was compression depth with a p-value of .002.[56] The over-pad scenario resulted in an average of 31.50 cm while the under-pad scenario 37 cm.[56] This research team concluded that when chest compressions are to be given to football athletes wearing equipment, it should be done without the padding blocking the chest.

To further analyze the relationship between CPR and athletes wearing football equipment, an additional research team compared the results of both ventilation and compression efficacy in manikins with and without football equipment.[6] This research team recruited 32 ATCs to assess compression variables such as depth, rate, and percentage of compressions correctly released in addition to ventilation variables including volume, number of attempted breaths and breaths at appropriate volume.[6] After data were collected, ANOVA tests were used for each outcome measure and compared for significance with a p-value of .05.

Unlike previous studies, this team compared data from different conditions of equipment removal versus CPR over pads or CPR under pads/pads removed. The conditions used for compressions were a) simulator fully equipped (helmet and shoulder pads); b) anterior shoulder pads lifted superiorly to expose the chest while wearing helmet with facemask in place; c) anterior shoulder pads superiorly lifted to expose the chest after facemask removal (with helmet on); d) anterior shoulder pads splayed open to expose the chest (with helmet and facemask in place); e) traditional shoulder pad removal using a flat torso technique; and f) shoulder pad removal using RipKordTM style shoulder pads.[6] However, while these variables were tested individually, there was not a scenario where both compressions and ventilations were combined. After completing the compression scenarios, the following scenarios were tested to deliver ventilations, a) Facemask removed, 2-person PM; b) Helmet removed, 2- person PM; c) Facemask removed, 2-person BVM; d) Helmet removed, 2-person BVM; e) Facemask removed, 1-person PM; and f) Helmet removed, 1-person PM.[6]

Following data collection and statistical analysis, this research team supported complete removal of both chest and head protective equipment for football athletes who need CPR. The fully equipped manikin had significantly lower compression depth and adequate compressions overall ($p>.001$ for both).[6] For ventilations, there was no significant difference between conditions for attempted breaths ($p=.673$), volume ($p=.448$) and percentage of breaths at adequate volume ($p=.735$).[6] However, between ventilation devices, volumes with BVM conditions were higher than both one- or two-person PM conditions ($p<.001$).[6] Conditions where there was only one-rescuer were lower in both attempted ventilations and percentage at adequate volume ($p=.002$ and $p<.001$, respectively).[6] The higher rates from the BVM scenarios were within the recommended 400-700 mL while the PM conditions were below.[6] It should be noted that while the data showed no significant difference in ventilation quality with helmet and facemask removal, the research team advocated for complete removal of the helmet in emergent conditions.

The previous study concluded that complete removal of the helmet and chest pads was necessary to provide adequate CPR to football players.[6] However, the amount of time taken to remove the equipment was not researched. The AHA and the NATA emphasize the importance of rapid CPR initiation to improve survival in those suffering SCA. While the removal of the equipment is better for CPR quality, if the compressions are not initiated soon enough to be beneficial, it is unknown if it would be detrimental to delay the start of CPR to take equipment off. To further understand the relationship between equipment removal, a study was conducted to compare the overall quality of CPR and the time to start compressions. Time until first breath and first compression, total number of compressions, depth of compressions, accuracy of hand placement, percentage of compressions that achieved full chest recoil, compressions per minute, average compression rate, time from patient collapse until the facemask was removed, and time needed to expose the chest (determined by calculating the time from when the rescuer grasped a pair of scissors to cut the jersey until the bare chest of the manikin was fully exposed) were the variables compared between conditions.[55]

Before data collection, 34 ATC participants were exposed to a familiarization session to become comfortable with equipment removal expectations and the removal process. All participants followed the same patient scenario for data collection. It was expected that each participant would follow the steps of this protocol: (1) you witness the athlete collapse; (2) approach the athlete (manikin) as quickly as possible using a brisk walk or slow run; (3) assess consciousness; (4) activate emergency action plan if necessary; (5) assess breathing; (6) if athlete found not to be breathing, begin removal of equipment using the approved protocol for facemask removal;6 (7) deliver two breaths; (8) perform pulse check; (9a) if no pulse, jersey needs to be cut and chest protector unfastened in order to begin compressions; or (9b) if no pulse, begin chest compressions over chest protector; (10) continue CPR delivery for a total of four minutes.[55]

Following data collection, a multivariable logistic regression model was used to determine statistical significance between variables at a p-value of .05. While hand placement and compression depth increased when delivering compressions over pads ($p<.0001$ for both), chest recoil in the padded group (63.8%±38.1%) was significantly less than on a bare chest (76.1%±34.9%) with a p-value of .0001.[55] There was no difference in compression rate and time to first ventilation between the two conditions.[55] Time to the first chest compression was over two minutes longer in the equipment removal group compared to the over-equipment group. While this finding was not statistically significant ($p=.08$), it is clinically relevant because every minute CPR is delayed the chance of survival is decreases by up to 18%.[55] It should be noted that during this research the preparation done prior to data collection impacts the ability to determine the impact equipment has on survival rates of patients requiring CPR. However, it is still unknown if the amount of time taken to remove pads to provide CPR is better for survival compared to inadequate CPR that starts sooner.

Published research indicates that when football athletes require CPR without a suspected cervical spine injury, their chest pads and helmets should be removed. While results of this research support the removal of chest protection before starting chest compressions, further research is needed to support the claim that helmets should be completely removed for ventilations. The lack of research on CPR ventilations with varying conditions of head protection is present in not only football, but in other sports, such as lacrosse and hockey.

### 2.3.2. Lacrosse

Similar to football, athletes who play lacrosse have an increased risk for injury due to its high contact and fast pace.[5] Contrary to equipment removal recommendations for football equipment, research has indicated that lacrosse chest pads can remain and still allow for a rescuer to provide adequate CPR.[57] Lacrosse pads are made from foam and are only around three cm thick while football pads are made of rigid plastic and can be over five cm.[57] When attempting CPR over football pads, the rigidity of the plastic inhibits adequate depth to produce purposeful chest compressions. The differences between the padding material needs to be analyzed to determine if effective compressions can be delivered over chest pads in lacrosse players.

To establish recommendations for lacrosse athletes,  a research team recruited 36 ATCs to perform CPR on manikins equipped with two different brands of pads and varying levels of equipment removal.[58] Outcomes measured were hand-placement accuracy, chest-wall recoil, percentage of compressions not reaching adequate depth, and perceived exertion.[57] The sessions began with a training course where participant groups watched a video and needed to pass a CPR trial on a manikin as both the compressor and ventilator. Each group had to earn an overall score of 80% to move on to the next session; if they did not pass another video was shown followed by a retest.[57] Around seven days after the training session, the first data collection trials were completed. The teams completed six trials, three as the compressor and three as the ventilator. The data collection session began with an informational video describing the manikin and guidelines for two-person CPR. Following the two-minute trial, during a three-minute rest, participants would give a 0-10 rating of perceived exertion. The third trial was after an additional seven days and followed the same procedure.

Data were analyzed using an ANOVA test and Bonferroni adjustment and deemed significant when above .05.[57] A difference in the mean compression depth between brands of padding was significant at p = .03.[57] The Warrior Burn Hitman (WSP; Warrior Inc, Boston, MA) brand had a lesser average of (54.1 mm ± 5.8mm) than the STX Cell II (SSP; STX LLC, Baltimore, MD) brand at (56.8 mm ± 5.7 mm).[57] However, both of these conditions reached the depth recommended by the AHA in 2015. In addition, the rate of compressions was not significantly different between conditions (p =.42).[57] Unlike football participants, lacrosse athletes do not require the removal of chest protection to initiate CPR. This finding differs from the hypothesis that chest protection decreases the effectiveness of CPR many researchers have found with football pads.

After extensive research, only one study could be found comparing the effects of helmet or facemask removal on lacrosse players. This study recruited five ATCs to compare four different airway adjuncts' and ventilation devices' effectiveness on a manikin equipped with a helmet or without lacrosse equipment in addition to compression rate and depth. The devices used in this study were BVM alone, oral pharyngeal, nasal pharyngeal, and King Airway.[5] When the manikin was equipped with padding, it had shoulder pads and a helmet with the facemask removed but the chin strap fastened. It should be noted that in conditions with an airway device, the device was placed by a member of the research team. In addition, each condition had the participant provide ventilations using BVM while the research team provided compressions. Following the ventilation trials, two compression trials were conducted over and under chest pads to collect data on depth and rate.[5]

Data for compressions were analyzed using Mann-Whitney *U* tests and found no significant difference on rate (p=.79) and depth (p=.23) between groups.[5] But both conditions failed to reach the AHA recommended depth of 5 cm in the no equipment group reaching a depth of 4.28 cm and over equipment reaching a depth of 4.18 cm.[5] Data collected for ventilations in this research were ventilation volume and rate. These variables were compared with a 2x4 repeated measures analyses of variance. If a result was significant, a Wilcoxon sign ranked test with Bonferroni correction was calculated.[5] There was a significant effect between the equipment condition ($p = .01$) and airway device ($p = .001$) on ventilation volume, but not for rate (both $p = .27$).[5] The King Airway delivered the greatest volume in both equipment conditions while the BVM, oropharyngeal, and nasopharyngeal did not reach the minimum volume of 400 mL the AHA recommends.[5]

The research team discussed that the removal of the helmet may increase the ability to create an adequate seal of the PM versus only the facemask removed where participants were unable to produce enough volume. Additionally, it was recommended that chest pads could be left to provide compressions because there was no significant difference between groups. However, neither group reached the depth recommended by the AHA. To confirm the recommendations found in this study, further research is needed comparing different ventilation devices and compression conditions with a larger sample size.

Although this research used ATCs, who are often the first responders to athletes requiring CPR, only five subjects were recruited. It is difficult to make recommendations for future practice with such a limited sample size. Additionally, the devices used are not practiced by ATCs regularly like the traditional PM and FS let alone with two rescuers. These limitations were noted by the research team and presented in the discussion. However, the recommendation for complete helmet removal for lacrosse players was emphasized by this research, similar to the recommendations for football players.

### 2.3.3. Hockey

Like football and lacrosse athletes, hockey players have an increased risk of SCA and commotio cordis due to high-velocity projectiles and high-energy contact involved with participation. However, little to no research has been done on best practices for initiating CPR with the protective equipment required like football and lacrosse. The need for this research is critical for the survival of athletes who need CPR while playing hockey. Hockey pads are not as thick as football pads but are still made of rigid plastic as opposed to foam in lacrosse pads. This combination design means that published findings on football and lacrosse athletes may not yield the same effect on hockey players requiring CPR.

After extensive research, only one study could be found comparing CPR results and hockey equipment. This research team used 50 ATCs to perform 8 minutes and 59 seconds of CPR (compressions and ventilations) on manikins equipped with hockey shoulder pads. Data for CPR included: overall score, mean rate of compressions, chest compression fraction, mean depth, percent of chest recoil, percent of compressions with appropriate depth, percent of ventilations that were adequate or inadequate.[59] Variables were collected from the Resusci Anne Wireless SkillReporter and saved to a computer. The overall CPR score was 69.08% ± 21.65, with 44% of participants reaching the correct depth, and 66% at the correct rate and with full recoil.[59] For ventilations, 82% of participants delivered 60% or less of their ventilations at an appropriate volumes with a PM.[59]

This research is important to begin the process of understanding the necessary steps needed to provide the most beneficial CPR to hockey athletes. With results from this study indicating that ATCs struggled to provide adequate CPR in hockey players, more research is needed to determine if this is due to ineffective compressions, ventilations, or both. When comparing the results of compressions and ventilations directly, it is apparent that ventilations are more ineffective than compressions. Albeit compressions were not 100% effective in the population, the majority of ATCs were able to achieve 90-99% full chest recoil during their compressions, see Table 3.[59] While compressions had elements that were effective, the majority of participants delivering adequate ventilations was below 60%, this can be seen in Table 4.[59] It should be noted that both compressions and ventilations provided were still considered as inadequate when compared to the AHA guidelines. What is concerning about these large discrepancies is that there was equipment over the chest for compressions but nothing around the head, neck or face. Without equipment to remove, ventilations should have been near 100% efficacy in this population, as they are trained healthcare professionals.

**Table 3.** Number of ATCs and % Full Chest Recoil

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

**Table 4.** Number of ATCs and % Adequate Ventilations

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

While there is research that has determined hockey pads should be removed for ATCs to deliver adequate compressions, there is no current research on helmet conditions and ventilations. Hockey helmets have the ability for facemasks to be removed easily allowing for immediate access to the patient's airway. It is unknown if facemask removal is enough to provide adequate compressions with ventilation devices commonly used by ATCs in emergency situations.

### 2.4. Conclusion

In summary, ATCs are vital to athlete survival when requiring treatment from an incidence of SCA, but further research is needed on protective athletic equipment and its impact on CPR. Given the fast-paced nature and potential for high-impact hits of sports requiring protective equipment over the chest and head of athletes, best practices should be well-understood by emergency responders. The current emphasis on compressions during CPR is reflected in research, although as health care professionals, ATCs are expected to deliver ventilations. For hockey specifically, there is no research studying the effects of ventilation devices commonly used by ATCs and whether the helmet or facemask should be removed for ventilation delivery. Therefore, to ensure the best survival outcomes for hockey athletes, future studies need to develop updated recommendations for ventilation devices and head equipment removal.

# 3. METHODOLOGY

## 3.1. Purpose of the Study

Sudden cardiac arrest (SCA) is the leading cause of death in sports among many age groups and competition levels.[10,11] Certified Athletic Trainers (ATCs) are frequently the first responders of medical treatment for athletes who suffer an acute, life-threatening condition.[7,10] ATCs are allied health professionals that provide emergency, preventative, and rehabilitative treatment to athletes in various settings.[10,18] The National Athletic Trainers' Association (NATA) position statement on preventing sudden death in sports recommends removing any equipment if it prevents access to the airway or chest for cardiopulmonary resuscitation (CPR).[10] The American Heart Association (AHA), the governing body that makes CPR guidelines and education, does not specify whether rescuers should take the time to remove barriers or provide CPR directly over protective equipment.

Previous research has been conducted to determine the barriers to providing high-quality CPR when athletes don specific athletic equipment. While it has been found that the removal of protective equipment delays the start of CPR, the ability to produce high-quality CPR over protective equipment is reduced.[55,56] Therefore, it has been determined that football shoulder pads[6] should be removed, but lacrosse chest pads can be left in place[5,57] during compressions. For hockey players, limited research has been conducted on the adequacy of chest compressions over chest pads. However, one study found that only 44% of compressions over pads were delivered effectively on manikins with hockey chest pads.[59] This finding indicates that hockey chest pads should be removed before delivering chest compressions.

As ATCs are considered health care providers, it is expected they perform adequate ventilations in addition to compressions. To access the airway for athletes wearing protective helmets, researchers have found that removing the entire helmet in football and lacrosse players provides greater adequate ventilations with a bag valve mask (BVM) compared to leaving the chinstrap or facemask in place.[5,6] When a spinal cord injury is not suspected and a BVM or advanced airway is unavailable, full helmet removal is recommended for optimal airway access.[5,6] Multiple studies have been conducted to establish a recommendation for football and lacrosse players[5,6], but algorithms specific to airway access for hockey athletes has not been created. Therefore, research needs to be conducted to establish best-practice recommendations for ATCs to provide emergency care to hockey players.

Ventilation devices, specifically Pocket Masks (PM), FaceShields (FS), and BVM, have been implemented during CPR administration to improve the quality of ventilations and prevent disease transmission to the rescuer.  Current research is inconsistent for which type of ventilation device is best for the single rescuer. Separate studies have found that mouth-to-mask ventilations were best[58] and alternatively, mouth-to-mouth ventilations.[35] Yet, none of these studies have used a one-person rescue team of ATCs. The AHA considers BVM the gold standard for ventilation delivery; however, for optimal outcomes, two rescuers are needed to administer ventilations via BVM.[6] Furthermore, extensive practice using BVM is required to obtain and maintain proficiency with the skill.[50] ATC's often cover athletic events and practices alone[7,8]; therefore, they are not in the appropriate position to utilize a BVM as recommended by the AHA. ATCs have access to PMs and FSs to deliver ventilations, but research specific to one-person CPR scenarios without the inclusion of a research assistant[5] has not been published.

The purpose of this research was to investigate the ability of certified athletic trainers to provide CPR ventilations with and without helmets using a PM and FS. This research study was designed to help establish emergency care algorithms in the event of cardiac arrest in a hockey athlete. The research was designed to answer the following questions:

Q1: Without visual or verbal feedback, how will Athletic Trainers score their own ability to perform CPR without athletic equipment?

Q2: What was the relationship between ventilatory devices and the ability to provide high-quality ventilations?

Q3: What was the relationship between the removal of partial or full helmet and the ability to provide high-quality ventilations?

Q4: What was the average time Athletic Trainers took to initiate care?

### 3.2. Participants

A convenience sample of 20 ATCs with current CPR certification were recruited through e-mails and word-of-mouth throughout the region. Participants were currently certified through the BOC® (Board of Certification) as an athletic trainer and have current CPR/first-aid certification. Exclusion criteria for this study included any current cardiovascular or musculoskeletal condition, which could have prevented 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 were obtained from each participant before testing with baseline demographic and clinical data from a survey and questionnaire.

### 3.3. Equipment and Instruments

To measure the quality of CPR being performed in the study, the Resusci Anne® QCPR (Stavanger, Norway) manikin was used with the Laerdal SkillReporter software to measure CPR performance. Prior to testing, the Resusci Anne® was fitted with CCM U+ Crazy Light shoulder pads (Ontario, Canada) and with BAUER RE-AKT 150 helmet facemask combination (New Hampshire, USA). Ventilations were administered via a Laerdal Pocket Mask™ (Stavanger, Norway) or WNL Practi-SHIELD® CPR Training FaceShield (China).

The Resusci Anne® QCPR manikin and Laerdal SkillReporter software (Stavanger, Norway) were used to measure the quality of CPR. The software evaluated the rate of volume of ventilations, the measure of hand position during compressions, compression rate, compression depth, chest compression fraction, and chest recoil were also recorded. At the end of the CPR session, the software calculated an overall compression performance score, as well as an overall score for all CPR parameters. Both of these scores ranged from 0% to 100%.[60] For each cycle of CPR (30 compressions and two ventilations), the rate and volume of ventilations were recorded. The overall CPR score was given after each testing condition was completed (five rounds of CPR/two minutes).

### 3.4. Procedures

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

For the first part of the study, subjects participated in a session to determine CPR proficiency and gather baseline data. One Resusci Anne® QCPR manikin, without hockey pads or helmet, was designated as the proficiency manikin. The parameters for this manikin were in accordance with the 2020 AHA guidelines: 30:2 compression to ventilation ratio, at least 2.0 inches compression depth (50 mm), and 100-120 compressions per minute. A timer was set for one minute of CPR for this initial test. The only value recorded for the proficiency testing was the overall CPR score. Participants were not allowed to use the visual feedback provided by the Laerdal SkillReporter software to correct their performance.

Data from the proficiency section were recorded and monitored by the researcher. Participants were not given verbal or visual feedback from the researchers following the completion of their baseline test. In the post survey, the participant was asked how accurate they believe their CPR was between 0%-100%. The perceived percentage was compared to the actual percentage obtained from the Laederal SkillReporter.

After baseline testing and self-scoring from the questionnaire, participants took a break of no less than two minutes but no more than five minutes before proceeding to the second portion of the study. Participants were tested on four different conditions randomly assigned and counterbalanced via online random number generator prior to testing. These conditions included A) ventilation via PocketMask with the facemask of the helmet removed, B) ventilation via FaceShield with the facemask of the helmet removed, C) ventilation via PocketMask with the entire helmet removed, and D) ventilation via FaceShield with the entire helmet removed.

For every condition, the participant used a Resusci Anne® QCPR manikin fitted with CCM U+ Crazy Light shoulder pads and BAUER RE-AKT 150 helmet facemask combination and the subject was provided with the ventilation equipment necessary for the condition. Additionally, the researcher read a script introducing the emergent scenario to the participant. This script informed the participants that the simulated patient did not have indication for cervical spine stabilization. Script instructions also explained that participants were to perform single-person CPR under the current 2020 AHA guidelines to the best of their ability. It should be noted that the NATA Position Statement does not clarify the order of operations pertaining to the removal of equipment. Therefore, we documented the procedures each ATC chose for each condition. Past research has shown that initiation of CPR is prolonged by protective equipment.[55] To investigate the delay of CPR onset due to protective equipment, the amount of time it took to remove equipment and initiate the first compression were recorded.

Following the initiation of the trial and removal of the chest pads, participants performed five cycles of CPR (30:2=one cycle) or up to two minutes for each testing condition. Participants were not given any visual or verbal feedback during their performance nor were they able to see a clock, as performance may change based on objective feedback. Once the cycles were completed or two minutes was obtained, researchers notified the participant. In addition, a timer was started to begin the participant's rest period. A minimum of two minutes rest was required but allow up to five minutes was allowed if the participant did not feel ready. During this rest period, the researcher reapplied equipment to the manikin for the next condition. Once the participant indicated they were able to continue, they were informed of their next condition. This process was repeated until all conditions were completed or if the participant could no longer continue.

Each testing session was saved with a deidentified number in the Laerdal SkillReporter system. Multiple values were recorded from each testing session: overall CPR score (%), ventilation score (%), compression:ventilation, mean rate (cpm), mean depth (mm), rate percent, depth percent, recoil percent, hand placement, chest compression fraction, percent of ventilations that were adequate, percent of ventilations that were inadequate, ventilation volume, and total time of testing. Upon completion, the participants received ten dollars for their time and cooperation.

During testing COVID -19 protocols were in place to protect the researchers and the participants. Prior to testing participants were given symptom screening questions and excluded if they were experiencing symptoms. Additionally, all equipment was disinfected between patients. During testing participants were not masked to deliver ventilations. To mitigate potential exposure to researchers, they wore N-95 masks, eye protection, and maintained a minimum of 12 feet from the participant during testing.

### 3.5. Documentation

Prior to data collection, this study was approved by the Institutional Review Board at North Dakota State University. Each participant read and signed an informed consent form. Participants also completed a demographics form asking about various aspects such as years of CPR and ATC certification, age, gender, highest degree of education, job setting and years of hockey experience (as an ATC) before testing. Post testing, participants completed survey asking for opinions on the perceived accuracy, difficulty of each condition (helmet removal),  and ventilation device used in the study.

### 3.6. Statistical Analysis

Based on the research questions associated with this project, we anticipate the following statistical analysis: For research questions 1 & 2, basic descriptive statistics were calculated to determine the percentage of ATCs who achieved the AHA 2020 Guidelines. For research question 3, a series of linear regression models will be used to explore the relationship among the demographic traits and performance on the CPR dependent variables (i.e., overall CPR score, compression percentage, ventilation percentage, compression fraction, compression to ventilation ratio, correct hand placement, mean compression depth, full chest recoil, correct depth percentage, correct compression rate percentage, mean rate, adequate ventilations and inadequate ventilations). When significant predictive results were found additional Post Hoc statistical exploration will be done to further explore the significant relationships (e.g., independent sample *t*-test).

## 3.7. Conclusion

The purpose of this research was to determine whether certified athletic trainers were able to deliver quality ventilations for patients wearing hockey protective equipment. Athletic trainers act as emergency responders for hockey athletes and need to be prepared to perform CPR in the event of cardiac arrest. The results of this research could be added to existing evidence-based recommendations for CPR protocols. By understanding how hockey helmets and ventilation equipment impact the effectiveness of ventilations during CPR, best-practice guidelines may be improved to apply appropriate and effective medical care in the event an athlete suffers a medical emergency.

# 4. MANUSCRIPT

## 4.1. Abstract

[Study Design] Randomized Control Trial

[Background] Sudden cardiac arrest (SCA) is the leading cause of death in sports among many age groups and competition levels.[10,11] Certified Athletic Trainers (ATCs) are frequently the first responders of medical treatment for athletes who suffer an acute, life-threatening condition.[7,10] Previous research has been conducted to determine the barriers to providing high-quality CPR when athletes don specific athletic equipment. Multiple studies have been conducted to establish a recommendation for football and lacrosse players[5,6], but algorithms specific to airway access for hockey athletes has not been created. Ventilation devices, specifically Pocket Masks (PM), FaceShields (FS), and bag-valve mask (BVM), have been implemented during CPR administration to improve the quality of ventilations and prevent disease transmission to the rescuer. Current research is inconsistent for which type of ventilation device is best for the single rescuer. We hypothesized that the removal of the helmet and use of the PM would increase the quality of ventilations given by ATCs to athletes wearing hockey equipment.

[Objectives] The purpose of this research was to investigate the ability of certified athletic trainers to provide CPR ventilations with or without helmets using a PocketMask (PM) and FaceShield (FS). This research study was designed to help establish emergency care algorithms in the event of cardiac arrest in a hockey athlete.

[Methods] This randomized control trial was conducted at a mid-sized university research laboratory. Twenty certified Athletic Trainers (ATCs) were recruited via word-of-mouth and email to participate in this study. Following the completion of the study, data from N=20

participants were included for statistical analysis. Prior to data collection, participants completed an informed consent and demographic form, then a baseline CPR session lasting one-minute on a bare Resusci Anne® QCPR manikin. After a rest period of 2-5 minutes, participants completed four scenarios of CPR in a predetermined random order. These conditions included A) ventilation via PocketMask with the facemask of the helmet removed, B) ventilation via FaceShield with the facemask of the helmet removed, C) ventilation via PocketMask with the entire helmet removed, and D) ventilation via FaceShield with the entire helmet removed.

[Results] Three, 2x2 repeated measures ANOVAs were calculated to assess performance on ventilation volume, percent of adequate ventilations, and overall CPR performance differences based on independent factors of equipment condition (helmet removed vs facemask removed) and ventilation device (PM vs FS). Ventilation volume was significantly greater with the helmet completely removed (m=449.475 mL) compared to with the face mask lifted (m=389.825 mL). Furthermore, use of the pocket mask (463.45 mL) resulted in better ventilation volume compared to the face shield (m=375.85 mL). The repeated measures ANOVA for overall CPR performance revealed a significant effect for ventilation device ($F$[1, 19]=5.266, $p$=.033), but not for equipment condition ($F$[1, 19]=2.160, $p$=.158). The interaction was also not significant ($F$[1, 19]=2.066, $p$=.167). Overall CPR performance was significantly better with the use of a pocket mask (m=73.4%) compared to when the face shield was used (m=68%).

[Conclusions] When delivering ventilations to athletes wearing hockey equipment, ATCs reached a higher average volume by removing the helmet completely to access the airway versus. Furthermore, the use of the PM resulted in more ventilations reaching an adequate volume and should be used over the FS. Due to the significantly higher quality ventilations with the helmet removed and the use of a PM, there is evidence to suggest that when an athlete wearing hockey equipment requires CPR this combination could improve CPR quality.

[Level of Evidence] Quality Improvement, Level 2b

[Key Words] Certified Athletic Trainer, Cardiopulmonary Resuscitation, Hockey, Sudden Cardiac Arrest, Ventilation Device

## 4.2. Introduction

When a person suffers a sudden cardiac arrest (SCA), chances of survival increase drastically when emergency services are activated while cardiopulmonary resuscitation (CPR) and an automated external defibrillator (AED) are applied.[2,7,15] CPR provides live-saving assistance to unresponsive patients by pumping oxygenated blood through the body via intermittent compressions and ventilations.[25] Organizations such as the American Heart Associations (AHA) provide prevalent evidence-based practice guidelines, which traditionally endorse compressions and ventilations in cooperation.[25,61]

Remarkably, the AHA does not provide best-practice guidelines for patients suffering from an SCA while wearing protective athletic equipment. Certified athletic trainers (ATCs) are qualified healthcare professionals responsible for implementing lifesaving protocol, such as CPR, in the event an athlete suffers from SCA during an athletic event.[7,15] Initiating care for an athlete suffering from SCA differs contingent on whether protective equipment is worn, which restricts access to the chest and airway. The National Athletic Trainers' Association (NATA) recommends removal of all equipment if it inhibits access to the chest and airway in patients who have a cervical spine injury.[10,18] However, few researchers have yet to explore the issue of delaying compressions to remove equipment and whether the delay could compromise patient care.[18] Due to current guidelines failing to consider sports-specific protective equipment, medical algorithms inclusive of all athletes have not yet been established.

Various sports that use protective padding and helmets are considered high-risk contact by the NCAA such as football, lacrosse, and ice hockey.[55] Football shoulder pads are made of thick rigid plastic up to five inches in depth, and the facemask is fixed to the helmet with screws. Numerous researchers who have investigated CPR quality over and under football pads concluded the padding should be removed prior to employing compressions or ventilations.[6,55,56] On the other hand, there is less research and conflicting results on CPR over lacrosse pads as compared to football.[5,57] For hockey athletes, there is one published study investigating the effects of protective padding on CPR, which focused only on the presence of a chest pad and omitting the helmet or facemask.[59] While hockey padding is comparable to lacrosse in material and depth, the researchers suggested removing the chest pads prior to CPR, thereby providing conflicting recommendations for equipment-laden athletes.[59] Further, there is no published research investigating the effects hockey helmets have on ventilation delivery.

Ventilation devices, such as a BVM, PM, or FS, are used by ATCs to provide airflow whilst protecting the rescuer from potential infection. The BVM is a bulky ventilation device for out-of-hospital care and is considered the gold standard for rescuers.[35] Correct use of the BVM requires practice and two rescuers; one to apply a seal to the patient's face while opening the airway and another to provide the ventilation by squeezing the air reservoir. However, many ATCs work alone while covering athletic practices or competitions[53] and would not be able to use the BVM accurately.[35] Due to the limitations of the BVM, ATCs often use the smaller and more mobile PM or FS to aid in ventilation delivery during CPR. The PM has a similar shape to the BVM mask, creating an air-tight seal over the mouth and nose of the patient but only requiring one rescuer to deliver the breath. FaceShields, while more compact and malleable compared to the PM, lack a rigid plastic structure to create a seal over the nose and mouth of the patient. These devices are carried by ATCs to aid in life-saving actions; however, their comparative efficacy is under researched, especially the adequacy of the FS. There are limited studies comparing these three devices and none that investigate the ability of the FS to deliver adequate ventilations by healthcare professionals. Based on the limited data for CPR on hockey athletes, the purpose of this study was to investigate two different types of ventilation devices, as well as patient outcomes dependent on the equipment removal methods for gaining airway access.

## 4.3. Methods

To determine the most effective ventilation device and airway access device for ATCs when encountering an athlete with hockey equipment, a randomized crossover study was conducted comparing four scenarios of CPR to a baseline data set. Each scenario used a different combination of ventilation devices with whole helmet or facemask-only equipment removal. It was hypothesized that the removal of the helmet would have a positive impact on ventilations compared to facemask removal. In addition, it was hypothesized that the PM would provide higher quality ventilations compared to the FS in all scenarios.

### 4.3.1. Participants

Participants were ATCs recruited from a convenience sample in the upper Midwest via word-of-mouth and email (N=20; m=6, f=14; Age: 31.47±11.66). Inclusion criteria for this study included: (1) current certification as an athletic trainer through the BOC® (Board of Certification) and (2) current CPR/first-aid certification. Exclusion criteria for this study included any current cardiovascular or musculoskeletal condition, which could have prevented an individual from delivering high-quality CPR at the time of testing. Informed written and verbal consent were obtained from each participant before testing with baseline demographic and clinical data from a survey and questionnaire.

**4.3.2. Test Conditions**

This study included four CPR scenarios comparing equipment removal techniques and ventilation device efficacy. Prior to the four testing scenarios, a baseline test was conducted on a manikin with no hockey equipment to assess participants' ability to deliver high-quality CPR. Their ability was based on a percentage out of 0-100% for the overall CPR score given by the Laerdal SkillReporter software (Laerdal Medical, Stavanger, Norway) in the One Resusci Anne® QCPR manikin.

Following the baseline testing, participants were given a rest period of no less than two minutes but no more than five minutes before beginning the first scenario. All scenarios were in accordance with the 2020 American Heart Association (AHA) Guidelines. The order of scenarios was randomized and counterbalanced by a random number generator. Conditions tested were A) ventilation via PocketMask with the facemask of the helmet removed, B) ventilation via FaceShield with the facemask of the helmet removed, C) ventilation via PocketMask with the entire helmet removed, and D) ventilation via FaceShield with the entire helmet removed. For all conditions, the participant used a Resusci Anne® QCPR manikin fitted with CCM U+ Crazy Light shoulder pads(Ontario, Canada) and BAUER RE-AKT 150 helmet-facemask combination (New Hampshire, USA).

A script was read prior to beginning each set of data collection informing the participant that the simulated patient did not have an indication for cervical spine stabilization. Timing from the start of equipment removal to the first compression on a bare chest was recorded by the researcher. Data collection for the scenario ended when five cycles of CPR (30:2=one cycle) were completed or two minutes had passed. Each trial ended with a minimum two-minute rest that could go up to five-minutes if requested by the participant.

The Laerdal SkillReporter Software tracked the overall CPR score (%), ventilation score (%), compression:ventilation, mean rate (cpm), mean depth (mm), rate percent, depth percent, recoil percent, hand placement, chest compression fraction, percent of adequate ventilations, percent of inadequate ventilations, ventilation volume, and total time of testing. The data was saved in the Laderal SkillReporter Software system with deidentified numbers. Once five cycles, or two minutes, of CPR were completed the researcher would notify the participant to stop CPR and start the timer for rest. No feedback was given to the participants following the completion of their trial. These processes were repeated until all conditions were evaluated.

#### 4.3.3. Statistical Analysis

Three, 2x2 repeated measures ANOVAs for performance on ventilation volume, precent of adequate ventilations, and overall CPR performance differences based on independent factors of equipment condition and ventilation device.

## 4.4. Results

Independent variables for the present study included equipment condition (helmet removed vs facemask removed) and ventilatory device (PocketMask vs FaceShield). Dependent variables included components of CPR performance. Descriptive statistics and frequency data for demographic information are presented in Table 5.

**Table 5**. Demographic Information

| **Continuous Variable** | | |
|---|---|---|
| Age (years) | Mean ± SD<br>Range | 31.47 ± 11.66<br>23-62 |
| Years BOC Certified | Mean ± SD<br>Range | 9.25 ± 11.11<br>1-36 |
| Years CPR Certified | Mean ± SD<br>Range | 14.35 ± 10.43<br>4-40 |
| Proficiency Test Score (%) | Mean ± SD<br>Range | 78.90 ± 21.60<br>21-97 |
| **Categorical Variable** | | |
| Biological Sex | Male<br>Female | 6<br>14 |
| Education | Bachelor's<br>Master's<br>Doctorate | 9<br>9<br>2 |
| Prior work with equipment | Yes<br>No | 19<br>1 |
| Prior work with hockey | Yes<br>No | 13<br>7 |

CPR performance was assessed in four different equipment and ventilatory device conditions: A) helmet removed, PocketMask; B) helmet removed, FaceShield; C) facemask removed, PocketMask; D) facemask removed, FaceShield. Descriptive statistics for all components of CPR performance for each condition are presented in Table 6.

**Table 6.** Average CPR Performance by Condition

| Variable | Condition A | Condition B | Condition C | Condition D |
|---|---|---|---|---|
| QCPR (%) | 74.15 ± 27.34 | 72.15 ± 28.91 | 72.65 ± 23.77 | 63.80 ± 28.21 |
| Vent Volume (mL) | 487.3 ± 171.38 | 411.65 ± 200.60 | 439.6 ± 205.4 | 340.05 ± 180.51 |
| Adequate Vents (%) | 61.30 ± 32.75 | 32.10 ± 31.93 | 45.25 ± 35.92 | 25.55 ± 32.34 |
| Low Vents (%) | 27.20 ± 32.88 | 58.80 ± 36.38 | 38.10 ± 39.37 | 61.85 ± 39.70 |
| High Vents (%) | 11.55 ± 25.54 | 9.20 ± 23.61 | 11.65 ± 22.72 | 7.65 ± 22.0 |
| CCF(%) | 65.95 ± 4.76 | 64.45 ± 3.71 | 64.60 ± 3.93 | 61.00 ± 7.58 |
| Depth (%) | 73.55 ± 38.31 | 79.75 ± 34.50 | 77.70 ± 34.48 | 80.25 ± 35.28 |
| Depth (mm) | 51.8 ± 10.02 | 53.45 ± 8.11 | 53.6 ± 8.17 | 53.65 ± 8.39 |
| Recoil (%) | 65.0 ±38.95 | 70.40 ± 33.28 | 68.05 ± 32.24 | 67.85 ± 34.19 |
| Rate (%) | 61.30 ± 41.26 | 62.80 ± 42.24 | 60.50 ± 41.48 | 61.05 ± 40.58 |
| Rate (cpm) | 114.6 ± 13.18 | 115.3 ± 11.09 | 114.5 ± 12.28 | 113.75 ± 11.98 |
| Hand Position (%) | 85.35 ± 33.42 | 90.90 ± 22.31 | 92.75 ± 20.95 | 94.2 ± 21.25 |
| Equipment Removal (s) | 26.53 ± 11.57 | 25.32 ± 6.63 | 21.22 ± 5.40 | 26.56 ± 12.30 |

Abbreviations: QCPR, Overall CPR Score; Vent, Ventilation; FS, FaceShield; PM, PocketMask

For the proportion of ventilations that reached an appropriate volume (400-700 mL), results of the ANOVA revealed a significant effect for equipment condition ($F$[1, 19]=8.624, $p$=.008) and ventilatory device ($F$[1, 19]=9.285, $p$=.007), but the interaction effect was not statistically significant ($F$[1, 19]=1.422, $p$=.248). Significantly more ventilations were performed to an adequate volume with a PM compared to the FS (53.3% and 28.8%, respectively). In addition, when participants removed the entire helmet, they were able to complete significantly more ventilations to a sufficient volume compared to the facemask removed condition (46.7% and 35.4%, respectively).

The repeated measures ANOVA for ventilation volume revealed a significant effect for equipment condition ($F$[1, 19]=7.513, $p$=.013) and ventilatory device ($F$[1, 19]=10.768, $p$=.004), with a non-significant interaction ($F$[1, 19]=0.273, $p$=.608). Ventilation volume was significantly greater with the helmet completely removed (m=449.475 mL) compared to with the facemask lifted (m=389.825 mL). Furthermore, use of the PM (463.45 mL) resulted in better ventilation volume compared to the FS (m=375.85 mL).

The repeated measures ANOVA for overall CPR performance revealed a significant effect for ventilation device ($F$[1, 19]=5.266, $p$=.033), but not for equipment condition ($F$[1, 19]=2.160, $p$=.158). The interaction was also not significant ($F$[1, 19]=2.066, $p$=.167). Overall CPR performance was significantly better with the use of a PM (m=73.4%) compared to when the FS was used (m=68%).

For conditions C & D, the helmet was left in place while the facemask was removed. In these conditions, participants elected whether to remove the chin strap or leave it in place. Therefore, independent samples *t*-tests were used to analyze the effect of the chin strap on ventilation performance. For both the PM (C) and FS (D) conditions, there was no significant difference in the percentage of adequate ventilations delivered or mean ventilation volume based on removal of the chin strap (Table 7).

**Table 7.** Effect of Chin-Strap Removal on Ventilation Performance

| **Variable** | **PocketMask** | | **FaceShield** | |
|---|---|---|---|---|
| | **Chin Strap Removed** | **Chin Strap in Place** | **Chin Strap Removed** | **Chin Strap in Place** |
| **Adequate Ventilations (%)** | 34.0 ± 34.7<br>$p$=.317 | 51.3 ± 36.4 | 18.82 ± 30.1<br>$p$=.273 | 35.5 ± 35 |
| **Ventilation Volume (mL)** | 404.3 ± 218.9<br>$p$=.587 | 458.6 ± 204.2 | 355 ± 190.3<br>$p$=.662 | 317.6 ± 174.9 |

### 4.5. Discussion

The overall purpose of this study was to investigate the ability of certified athletic trainers (ATCs) to provide CPR ventilations with and without equipment comparing a PocketMask (PM) to a FaceShield (FS). This research study was designed to help establish emergency care algorithms for cardiac arrest in a hockey athlete. While there is research pertaining to CPR on sports involving equipment[5,55–57], there are currently no published results indicating best-practice guidelines for equipment removal on athletes wearing hockey pads, specifically helmets. Additionally, the efficacy of ventilation devices traditionally used for out-of-hospital CPR by medical professionals, such as ATCs, is under researched. The results of this study support the method of complete helmet removal for ventilation delivery during CPR by ATCs in a hockey setting. Furthermore, the use of a PM provides a higher percentage of adequate ventilations compared to the FS.

Due to the additional risk for musculoskeletal injuries in high-risk sports, such as football, lacrosse, and hockey, protective equipment is worn by athletes during participation. However, this padding restricts access to the athlete's head and chest if sudden cardiac arrest (SCA) occurs and CPR is needed.[6,55,56] Currently the American Heart Association (AHA) and National Athletic Trainers' Association (NATA) do not have recommendations for equipment removal on patients wearing protective athletic equipment suffering from SCA.[4,10] In the case of a traumatic injury involving the cervical spine, the NATA indicates removal of the equipment to access the airway or chest.[10,53] Padding varies in material and thickness contingent on the sport; therefore, specific guidelines for equipment removal respective to the sport are needed. The present published research supports the complete removal of football padding, helmet, and facemask before beginning CPR compressions and ventilations.[55,56] In contrast, if a lacrosse athlete suffers SCA, the chest pads are recommended to be left in place for compressions[57] but the helmet should be removed prior to ventilations.[5] One group of researchers investigated the quality of chest compressions over and under hockey chest pads, concluding the removal of chest protection is needed to provide adequate chest compressions to hockey athletes.[59]

The removal of hockey specific helmet components with respect to CPR ventilations have yet to discussed in published research. With the ability of both the facemask and the chin strap to be removed, hockey helmets have increased potential variables, which may impact the capability of rescuers to deliver quality ventilations. As participants were completing the four conditions, researchers documented the placement of the chin strap. While this study did not focus on the effect of chin strap removal on ventilations, their removal could notably impact the quality of ventilations when the facemask is lifted. When participants removed the entire helmet, significantly more ventilations at a sufficient volume were performed compared to when only the facemask was removed. The difference is attributed to the facemask being lifted but inhibiting the capability of the rescuer to create an adequate seal of the ventilation device.

Out-of-hospital ventilation devices are used by health care providers, such as athletic trainers, to improve CPR ventilations and protect themselves from potential infection. Bag-valve masks are the gold standard for ventilation devices but require two rescuers and frequent practice to be proficient.[6] Current research is inconclusive on which type of ventilation device is best practice for a single-rescuer situation. Various researchers have concluded mouth-to-mask ventilations were best[58] and alternatively, mouth-to-mouth ventilations.[35] Moreover, FSs are a ventilation device used in out-of-hospital emergencies but their efficacy has not been determined. Of the published studies, none have used a one-person rescue team of ATCs to determine the best ventilation device. Due to the lack of data, this research study included ventilation devices used by ATCs.

In addition to trials with different helmet conditions, this study included two ventilation devices commonly carried by ATCs, the PM and FS. The proportion of ventilations that reached an appropriate volume (400-700 mL) revealed a significant effect between ventilation devices (p=.007). Significantly more ventilations were performed to an adequate volume by the PM (53.3%) versus the FS (28.8%). While there is currently no research on the comparison of PM to FS directly, a previous study investigating the efficacy of the PM compared to other ventilation devices had contrasting results.[35] Researchers found the PM had effective ventilations 79% of the time, an average tidal volume of 600 mL ± 300 mL and concluded mouth-to-mouth ventilations were the most advantageous delivery method.[35] Based on the results of this study, it is notable there is a lack of proficiency in PM compared to the previous study.[35] This indicates the need for additional practice to maintain proficiency in its use between CPR certifications.

The average time taken for ATCs to remove the equipment ranged from 21.22 to 26.56 seconds. The AHA emphasizes the rapid initiation of CPR after a person suffers a SCA, but when an athlete wearing equipment requires CPR, the initiation is prolonged due to removal of padding.[55] Results from previous research indicate for football equipment removal the average time taken to deliver the first compression was over two minutes from the simulated collapse with an additional 24.4 s (±7.2 s) if the chest pads were removed completely.[55] Compared to the removal of football padding, the hockey equipment was able to be removed efficiently, implying that in an emergency situation the protective equipment can be removed quicker than athletes wearing football equipment. However, future research is needed to investigate if this amount of time positively or negatively impacts the survival rates of patients.

Previous research regarding the effects of football protective equipment on CPR determined the removal of the helmet had an impact that significantly increased the quality of compressions and ventilations but were not specific to ventilation devices.[6,55] For lacrosse athletes, researchers determined that depending on the type of airway device used, the helmet should be removed to deliver ventilations.[5] Considering the results from past research, an interaction between helmet condition and ventilation delivery was expected in this research. While removal of the entire helmet led to higher quantity and quality ventilations analogous to the use of a PM, there was no evidence to support an interaction exists between ventilation device and equipment condition. The proportion of ventilations which reached an appropriate volume, ventilation volume, and overall CPR performance did not have a significant interactions. A plausible cause of this trend is the helmet condition impacting the quality of the first ventilation. During the second round of ventilations, adjustments were made to improve the seal and subsequently the breath quality.

Other notable results of this study include the overall CPR score of ATCs on the components of compressions, ventilations, and time for equipment removal, which averaged under 75% across all conditions. These findings are concerning and indicate the need for future studies on whether more frequent CPR training on equipment-laden athletes would increase the overall CPR score. As stated previously, recent CPR research has focused on compressions versus ventilations, which is highlighted by the poor ventilation scores in this study. Average compression rate, depth, and hand placement percentages were consistent across all trials, while ventilation data had large variances across conditions. The number of adequate ventilations ranged from 25.55-61.30%.

For the previously discussed variables, it should be acknowledged that while the means were within the guidelines given by the AHA for high-quality CPR, the large standard deviations indicate a concerning variance within the ATC population. QCPR percentage had standard deviations of 27.34%, 28.91%, 23.77%, and 28.21% for Conditions A, B, C, and D respectively. These large differences imply that while some ATCs are able to deliver high-quality CPR, several struggled to meet the guidelines provided by the AHA. As trained health care professionals, it is expected that all ATCs should be able to demonstrate the ability to perform adequate CPR. Specifically, it appears that the differences in CPR scores are impacted greatly by the quality of ventilations. There are large standard deviations with the variables associated with ventilation delivery, the proportion of ventilations that reached an adequate volume, and ventilation volume across all conditions. A novice reader may assume the ranges could be attributed to a fatigue effect given the lower scores in most variables in Condition D; however, this study design included randomized and counter balanced order of trials to prevent this occurrence. Further investigation is needed on the athletic training population and their ability to deliver ventilations and its impact on overall CPR quality, as it appears a large number are currently unable to effectively provide this life-saving maneuver.

While the collected data from this study provides insight related to ventilation devices commonly used by ATCs, there are areas where this research can be expanded. The sample size only included 20 ATCs in a small geographical area; a larger population would allow for a more in depth understanding of the outcomes found. Moreover, providing CPR for longer periods of time to reflect the average time taken for EMS services to arrive on scene would allow for more accurate data on the effects fatigue play on the variables recorded.[33] Another possible limitation is the use of a manikin in a controlled setting on a dry, flat surface versus with a patient on ice, which is more conducive to a realistic hockey scenario.

When the helmet was completely removed the ventilation volume reached the range of tidal volume necessary for an adequate ventilation (400-700mL) at 449.475 mL compared to 375.85 mL with the facemask lifted. Based on these results, the recommendation for equipment removal prior to CPR delivery as given by prior studies is supported.[6,55] In addition, the average time taken to remove equipment prior to CPR initiation was less than 30 seconds for all conditions. The NATA and AHA best-practice guidelines support beginning CPR as quickly as possible. Future studies are needed to determine if this amount of time is rapid enough to warrant the removal of hockey equipment before starting CPR. With the overall CPR score averaging less than 75%, a need for further research on ATCs and CPR, specifically in equipment-laden athletes, is indicated. While the PM was determined to be better than the FS at delivering ventilations, the overall effectiveness of a PM used by ATCs was lower in this study compared to previous outcomes.[35] For ATCs, being prepared to provide CPR to any athlete is essential, being equipped with tools, such as a PM or FS, that are meant to increase the quality of CPR. This research supports the use of PM for ventilations over the FS in ATCs, although the overall quality of CPR was still low (under 75%) with both devices.

Hockey athletes have an additional barrier of protective equipment that restricts access to the chest and airway. Based on this analysis the equipment should be removed before providing CPR. While there are still elements of CPR that require additional research to fully understand the impact these variables have on the survival rates athletes, this study has contributed to the discussion of improving CPR techniques.

## REFERENCES


1. International Ice Hockey Federation. Published 2020. Accessed July 7, 2021. https://www.iihf.com/en/static/5324/survey-of-players

2. Chandra N, Bastiaenen R, Papadakis M, Sharma S. Sudden cardiac death in young athletes: Practical challenges and diagnostic dilemmas. *J Am Coll Cardiol*. 2013;61(10):1027-1040. doi:10.1016/j.jacc.2012.08.1032

3. Menezes R. et. al. Commotio cordis: A review. *Med Sci Law*. 2017;57(3):146-151. doi:10.1002/yd.430

4. Care EC. Circulation Part 1 : Executive Summary Resuscitation and Emergency Cardiovascular Care. Published online 2020:337-357. doi:10.1161/CIR.0000000000000918

5. Boergers RJ, Bowman TG. The Effect of Lacrosse Protective Equipment and Different Airway Management Devices on the Ability to Provide CPR to a Manikin. *Athl Train Sport Heal Care*. 2017;9(3):103-107. doi:10.3928/19425864-20170109-01

6. Mihalik JP, Lynall RC, Fraser MA, et al. Football Equipment Removal Improves Chest Compression and Ventilation Efficacy. *Prehospital Emerg Care*. 2016;20(5):578-585. doi:10.3109/10903127.2016.1149649

7. Casa DJ, Almquist J, Anderson SA, et al. The inter-association task force for preventing sudden death in secondary school athletics programs: Best-practices recommendations. *J Athl Train*. 2013;48(4):546-553. doi:10.4085/1062-6050-48.4.12

8. Huggins RA, Coleman KA, Attanasio SM, et al. Athletic trainer services in the secondary school setting: The athletic training locations and services project. *J Athl Train*. 2019;54(11):1129-1139. doi:10.4085/1062-6050-12-19

9. What is CPR? CPR: Cardiopulmonary Resuscitation. Published 2021. https://cpr.heart.org/en/resources/what-is-cpr

10. Casa DJ, Guskiewicz KM, Anderson SA, et al. National athletic trainers' association position statement: Preventing sudden death in sports. *J Athl Train*. 2012;47(1):96-118. doi:10.4085/1062-6050-47.1.96

11. Harmon KG, Drezner JA, Wilson MG, Sharma S. Incidence of sudden cardiac death in athletes: A state-of-the-art review. *Br J Sports Med*. 2014;48(15):1185-1192. doi:10.1136/bjsports-2014-093872

12. Drezner JA, Peterson DF, Siebert DM, et al. Survival After Exercise-Related Sudden Cardiac Arrest in Young Athletes: Can We Do Better? *Sports Health*. 2019;11(1):91-98. doi:10.1177/1941738118799084

13. Maron BJ, Haas TS, Murphy CJ, Ahluwalia A, Rutten-Ramos S. Incidence and causes of sudden death in U.S. college athletes. *J Am Coll Cardiol*. 2014;63(16):1636-1643. doi:10.1016/j.jacc.2014.01.041

14. University of Connecticut. Korey Stringer Institute. Published 2021. https://ksi.uconn.edu/emergency-conditions/cardiac-conditions/commotio-cordis/#

15. Asif IM, Harmon KG. Incidence and Etiology of Sudden Cardiac Death: New Updates for Athletic Departments. *Sports Health*. 2017;9(3):268-279. doi:10.1177/1941738117694153

16. Link MS, Estes NAM. Sudden cardiac death in the athlete: Bridging the gaps between evidence, policy, and practice. *Circulation*. 2012;125(20):2511-2516. doi:10.1161/CIRCULATIONAHA.111.023861

17. Maron BJ, Doerer JJ, Haas TS, Tierney DM, Mueller FO. Sudden deaths in young competitive athletes analysis of 1866 deaths in the united states, 1980-2006. *Circulation*. 2009;119(8):1085-1092. doi:10.1161/CIRCULATIONAHA.108.804617

18. National Athletic Trainers' Association. https://www.nata.org/about/athletic-training

19. Maron, Barry, Gohman, Thomas E, Kyle SB, Iii NAME, Link MS. Clinical Profile and Spectrum of Commotio Cordis. 2002;287(9).

20. Palacio LE, Link MS. Commotio cordis. *Sports Health*. 2009;1(2):174-179. doi:10.1177/1941738108330972

21. Madias C, Maron BJ, Weinstock J, Estes NAM, Link MS. Commotio cordis - Sudden cardiac death with chest wall impact. *J Cardiovasc Electrophysiol*. 2007;18(1):115-122. doi:10.1111/j.1540-8167.2006.00684.x

22. Maron BJ, Poliac LC, Kaplan JA, Mueller FO. Blunt Impact to the Chest Leading to Sudden Death from Cardiac Arrest during Sports Activities. *N Engl J Med*. 1995;333(6):337-342. doi:10.1056/nejm199508103330602

23. Deady B, Innes G. Sudden death of a young hockey player: Case report of commotio cordis. *J Emerg Med*. 1999;17(3):459-462. doi:10.1016/S0736-4679(99)00006-2

24. Ngai KY, Chan HY, Ng F. A patient with commotio cordis successfully resuscitated by bystander cardiopulmonary resuscitation and automated external defibrillator. *Hong Kong Med J*. 2010;16(5):403-405.

25. About International Liaison Committee on Resuscitation. Published 2020. Accessed October 12, 2020. https://www.ilcor.org/about

26. American Heart Association ECC Guidelines Part 3: Adult Basic Life Support. :I-22-I-59. doi:10.1161/circ.102.suppl_1.I-22

27. Lurie KG, Nemergut EC, Yannopoulos D, Sweeney M. The Physiology of Cardiopulmonary Resuscitation. *Anesth Analg*. 2016;122(3):767-783. doi:10.1213/ANE.0000000000000926

28. Ristagno G, Tang W, Weil MH. Cardiopulmonary Resuscitation: From the Beginning to the Present Day. *Crit Care Clin*. 2009;25(1):133-151. doi:10.1016/j.ccc.2008.10.004

29. Fitz-Clarke JR. Effect of tidal volume on gas exchange during rescue ventilation. *Respir Physiol Neurobiol*. 2020;273(October 2019):103335. doi:10.1016/j.resp.2019.103335

30. Fitz-Clarke JR. Fast or slow rescue ventilations: A predictive model of gastric inflation. *Respir Care*. 2018;63(5):502. doi:10.4187/respcare.05620

31. Berg RA, Hemphill R, Abella BS, et al. Part 5: Adult basic life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2010;122(SUPPL. 3). doi:10.1161/CIRCULATIONAHA.110.970939

32. Newell C, Grier S, Soar J. Airway and ventilation management during cardiopulmonary resuscitation and after successful resuscitation. *Crit Care*. 2018;22(1):1-9. doi:10.1186/s13054-018-2121-y

33. Della Valle JM, Newton C, Kline RA, Spain DA, Pirrotta E, Ewen Wang N. Emergency Medical Services Response Times in Rural, Suburban, and Urban Areas. *JAMA Surg*. 2017;152(10):983-984. doi:10.1001/jamasurg.2017.2178

34. Robert P. Sands, Jr. DRB. An Inventive Mind. *Anesthesiology*. 1998;88:1107-1112. doi:https://doi.org/10.1097/00000542-199804000-00032

35. Adelborg K, Dalgas C, Grove EL, Jørgensen C, Al-Mashhadi RH, Løfgren B. Mouth-to-mouth ventilation is superior to mouth-to-pocket mask and bag-valve-mask ventilation during lifeguard CPR: A randomized study. *Resuscitation*. 2011;82(5):618-622. doi:10.1016/j.resuscitation.2011.01.009

36. Khoury A, Hugonnot S, Cossus J, et al. From mouth-to-mouth to bag-valve-mask ventilation: Evolution and characteristics of actual devices - A review of the literature. *Biomed Res Int*. 2014;2014:1-6. doi:10.1155/2014/762053

37. Simmons M, Deao D, Moon L, Peters K CS. Bench Evaluation: Three face-shield CPPR barrier devices. *Resuscitation*. 1995;30:280-281.

38. 2000- The First International Conference on Guidelines for CPR and ECC. *Circulation*. 2000;102(1):1-11. doi:10.1161/circ.102.suppl_1.I-1

39. Eberle B, Dick WF, Schneider T, Wisser G, Doe S, Tzanova I. Checking the carotid pulse check : diagnostic accuracy of first responders in patients with and without a pulse. 1996;33:107-116.

40. Nakagawa Y, Inokuchi S, Morita S, et al. Accuracy of pulse checks in terms of basic life support by lifesavers, as lay persons. *Circ J*. 2010;74(9):1895-1899. doi:10.1253/circj.CJ-10-0081

41. Part 4: Adult Basic Life Support. *Circulation*. 2005;112(24_suppl):IV-19-IV-34. doi:10.1161/CIRCULATIONAHA.105.166553

42. Basic A, Support L. Part 4: Adult basic life support. *Circulation*. 2005;112(24 SUPPL.). doi:10.1161/CIRCULATIONAHA.105.166553

43. Deschilder K, De Vos R, Stockman W. The effect on quality of chest compressions and exhaustion of a compression-ventilation ratio of 30:2 versus 15:2 during cardiopulmonary resuscitation-A randomised trial. *Resuscitation*. 2007;74(1):113-118. doi:10.1016/j.resuscitation.2006.12.004

44. Hasselqvist-Ax I, Riva G, Herlitz J, et al. Early Cardiopulmonary Resuscitation in Out-of-Hospital Cardiac Arrest. *N Engl J Med*. 2015;372(24):2307-2315. doi:10.1056/nejmoa1405796

45. Zhan L, Yang LJ, Huang Y, He Q, Liu GJ. Continuous chest compression versus interrupted chest compression for cardiopulmonary resuscitation of non-asphyxial out-of-hospital cardiac arrest. *Cochrane Database Syst Rev*. 2017;2017(3). doi:10.1002/14651858.CD010134.pub2

46. Wang HE, Simeone SJ, Weaver MD, Callaway CW. Interruptions in Cardiopulmonary Resuscitation From Paramedic Endotracheal Intubation. *Ann Emerg Med*. 2009;54(5):645-652.e1. doi:10.1016/j.annemergmed.2009.05.024

47. Marsch S, Tschan F, Semmer NK, Zobrist R, Hunziker PR, Hunziker S. ABC versus CAB for cardiopulmonary resuscitation: A prospective, randomized simulator-based trial. *Swiss Med Wkly*. 2013;143(September):1-11. doi:10.4414/smw.2013.13856

48. Stiell IG, Brown SP, Nichol G, Davis DP. What is the role of chest compression depth during out of hospital. *Crit Care Med*. 2013;40(4):1192-1198. doi:10.1097/CCM.0b013e31823bc8bb.What

49. Pepe PE, Duval S, Aufderheide TP, et al. Optimal Combination of Compression Rate and Depth during Cardiopulmonary Resuscitation for Functionally Favorable Survival. *JAMA Cardiol*. 2019;4(9):900-908. doi:10.1001/jamacardio.2019.2717

50. Kleinman ME, Brennan EE, Goldberger ZD, et al. Part 5: Adult basic life support and cardiopulmonary resuscitation quality: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation*. 2015;132(18):S414-S435. doi:10.1161/CIR.0000000000000259

51. Zou Y, Shi W, Zhu Y, et al. Rate at 120/min provides qualified chest compression during cardiopulmonary resuscitation. *Am J Emerg Med*. 2015;33(4):535-538. doi:10.1016/j.ajem.2015.01.024

52. Lee SH, Ryu JH, Min MK, et al. Rate at 120/min provides qualified chest compression during cardiopulmonary resuscitation. *Am J Emerg Med*. 2015;33(4):535-538. doi:10.1016/j.ajem.2015.01.024

53. Huggins RA, Scarneo SE, Casa DJ, et al. The inter-Association task force document on emergency health and safety: Best-practice recommendations for youth sports leagues. *J Athl Train*. 2017;52(4):384-400. doi:10.4085/1062-6050-52.2.02

54. Drezner JA, Courson RW, Roberts WO, Mosesso VN, Link MS, Maron BJ. Inter-association task force recommendations on emergency preparedness and management of sudden cardiac arrest in high school and college athletic programs: A consensus statement. *J Athl Train*. 2007;42(1):143-158.

55. Del Rossi G, Bodkin D, Dhanani A, Courson RW, Konin JG. Protective athletic equipment slows initiation of CPR in simulated cardiac arrest. *Resuscitation*. 2011;82(7):908-912. doi:10.1016/j.resuscitation.2011.02.022

56. Waninger KN, Goodbred A, Vanic K, et al. Adequate performance of cardiopulmonary resuscitation techniques during simulated cardiac arrest over and under protective equipment in football. *Clin J Sport Med*. 2014;24(4):280-283. doi:10.1097/JSM.0000000000000022

57. Boergers RJ, Bowman TG, Lininger MR. The ability to provide quality chest compressions over lacrosse shoulder pads. *J Athl Train*. 2018;53(2):122-127. doi:10.4085/1062-6050-346-16

58. Paal P, Falk M, Sumann G, et al. Comparison of mouth-to-mouth, mouth-to-mask and mouth-to-face-shield ventilation by lay persons. *Resuscitation*. 2006;70(1):117-123. doi:10.1016/j.resuscitation.2005.03.024

59. Estabrooks A. North Dakota State University. 2018;(November):212-213. doi:10.4324/9781315721606-101

60. Cortegiani A, Russotto V, Montalto F, et al. Use of a real-Time training software (Laerdal QCPR®) compared to instructor-based feedback for high-quality chest compressions acquisition in secondary school students: A randomized trial. *PLoS One*. 2017;12(1):1-11. doi:10.1371/journal.pone.0169591

61. Hortz B. Scope of Practice: Factors to Consider. *Natl Athl Trainers Assoc*. Published online 2017. https://www.nata.org/sites/default/files/scope-of-practice.pdf