

A COMPARISON OF CARDIOPULMONARY RESUSCITATION (CPR) OUTCOMES
BETWEEN TRADITIONAL AND ENDOMORPHIC MANIKINS WITH AND WITHOUT
EQUIPMENT

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A Comparison of Cardiopulmonary Resuscitation (CPR) Outcomes
Between Traditional and Endomorphic Manikins With and Without
Equipment

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ABSTRACT

Emergency responders are expected to perform high-quality CPR on an array of body physiques, regardless of the presence of protective equipment. The purpose of this study was to examine rescuers' administration of CPR on traditional and endomorphic manikins with and without football shoulder pads (FBSP). Fifty emergency responders completed two compression-only scenarios following 2015 AHA CPR Guidelines: 1) removal of FBSP before initiating chest compressions, and 2) performing chest compressions over FBSP. There was a statistically significant effect with a decrease in compression rate and depth with the presence of FBSP. For chest recoil, there was a statistically significant effect due to manikin type and presence of FBSP. Based on these findings, emergency responders are not equipped to perform high-quality CPR in all scenarios. Additionally, utilization of a diverse range of manikin physiques should be a consideration in the advancement of CPR education for emergency responders.

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1. INTRODUCTION

1.1. Overview

There are over 79 million people who are classified as obese in the United States, subsequently leading to a rise in premature mortality resulting from chronic disorders such as diabetes, cardiovascular dysfunction, sudden cardiac arrest, or even cancer (Tellson, Qin, Erwin, & Houston, 2017). Individuals with an endomorphic physique who compete in high-risk, contact sports have a higher cardiac load due to higher body mass index (BMI) combined with vigorous workouts, resulting in greater stress placed on the body (Schmeid, 2014). With mortality rates ranging from 2.3 to 4.4/100,000 per year, sudden cardiac arrest (SCA) is infrequent within athletics, however, risk is still present (Chandra et al., 2014).

Due to individuals with endomorphic physiques having extra adipose tissue surrounding the thoracic region, emergency responders may not be able to administer high-quality cardiopulmonary resuscitation (CPR) following current American Heart Association (AHA) CPR Guidelines. One concern emergency responders may encounter is applying enough force to reach the minimum depth requirements. When searching for completed studies pertaining to obesity and athletics, there are limited research studies encompassing CPR performance on obese athletes wearing football shoulder pads (Del Rossi, 2011; Tanaka et al., 2017; Waninger et al., 2014). Emergency responders have the responsibility of executing life-saving CPR skills while following current AHA CPR Guidelines for those individuals suffering from a cardiac arrest episode. Further research needs to be conducted to expand upon information related to administering high-quality CPR on individuals with an endomorphic body physique as well as over and under football shoulder pads for athletes with an endomorphic physique.

1.2. Statement of Purpose

The primary purpose of this study was to investigate emergency responders' ability to provide high-quality CPR for individuals with an endomorphic body physique. The secondary purpose was to evaluate emergency responders' ability to perform CPR on athletes with an endomorphic body type who are equipment-laden.

1.3. Research Questions

Q1: What proportion of participants attain satisfactory performance on overall number of compressions, compression rate/depth, chest recoil, and mean depth/rate?

Q2: What is the relationship between participant demographics (age, gender, and years of experience in emergency medicine) and performance of dependent variables of CPR performance?

Q3: To what extent, if any, does the inclusion of football pads affect dependent variables of CPR performance?

Q4: To what extent, if any, does the endomorphic manikin condition affect dependent variables of CPR performance?

Q5: What is the difference between equipment versus no equipment conditions in time to delivering compressions?

1.4. Definitions

Cardiac arrest: The lack of responsiveness, breathing, and pulse felt on the individual within ten seconds. The heart undergoes ventricular fibrillation (VF), meaning the lower chambers of the heart (ventricles) suddenly begin beating chaotically so blood cannot pump to the rest of the body (Kleinman et al., 2015).

Cardiopulmonary resuscitation (CPR): This was defined as an emergency lifesaving procedure performed on a patient whose heart stops beating; by administering CPR, blood flow will stay active (or partially) by giving high-quality chest compressions and ventilations at a ratio of 30:2 according to the 2015 AHA CPR Guidelines (“American Heart Association: About Cardiac Arrest,” 2017).

Quality of CPR: For this study, the quality of CPR was defined as having proper number of chest compressions, compression depth/rate, adequate chest recoil, and average depth/rate/peak force. Moreover, measurements for ventilation rate and volume was not observed in this study.

Emergency Medical Technician (EMT): A healthcare provider who was able to perform procedures required in emergency situations such as traumatic injuries, accident scenes, or other medical issues (CPR, shock, etc.) They are allowed to administer oxygen, glucose, asthma inhalers, and epinephrine auto-injectors.

Paramedic: Like an EMT, paramedics are allowed to perform the same procedures but also are allowed to break the skin by administering shots or intravenous medications as well as utilize advanced airway management devices to assist with breathing.

Endomorphic physique: Individuals who have a round physique and display an increase in weight as well as body fat; they will tend to have a larger frame with wider hips (as compared to their shoulders) and have a harder time losing weight due to a slower metabolic rate. Individuals who have a BMI ≥ 30.0 kg/m² will be recognized as obese/endomorph (Tellson et al., 2017).

1.5. Limitations

The first limitation was the act of performing chest compressions on manikins as opposed to real-life scenarios. For this study, all CPR was performed on either a traditional manikin or “Fat Old Fred” (endomorphnic manikin). Another limitation was the limited geographical area of recruitment; participants who were included in this study were emergency responders (emergency medical responders, emergency medical technicians, advanced emergency medical technicians, and paramedics) from ambulance companies within the Midwest region. Limiting recruitment to the Midwest region means findings may not reflect universal outcomes. Third, the manikins did not wear a standardized football helmet since rescue breaths were not administered in this study. This may reflect inaccurate timing because it would take an emergency responder longer to administer their first chest compression because they would need to remove the athlete’s facemask. The athletic equipment the manikins were fitted with were Riddell Evolution football shoulder pads (for an offensive lineman and a wide receiver). Findings from the results were not generalizable to other sports protective equipment.

1.6. Delimitations

Researchers chose to study emergency responders because they have limited knowledge regarding athletic equipment. Furthermore, there are no current recommendations for emergency responders performing CPR on individuals with endomorphnic physiques or over football shoulder pads. To investigate emergency responders’ ability to perform high-quality CPR on endomorphnic athletes as well as endomorphnic athletes wearing football shoulder pads, researchers used Riddell Evolution shoulder pads because these are commonly worn by both linemen. Results of this study may support or reject whether performing CPR over shoulder pads is appropriate.

1.7. Assumptions

It was assumed that the endomorphic manikin accurately mimics a real-life patient an emergency responder may encounter. It was assumed each emergency responder performed CPR to the best of his/her ability during all trials during the data collection phase.

1.8. Variables

There were seven dependent variables in this study; four variables were continuous measurements which included: number of compressions, average depth (mm), average rate (compressions/minute), and average force (kg). The other three dependent variables were measured as percentages, which included compression rate, depth, and recoil. Participants' biological sex as well as months of experience were the two independent variables for this study; additionally, the manikin type (traditional and endomorphic), presence or absence of football shoulder pads, and their interactions were included as independent factors.

1.9. Importance of the Current Study

Among athletes of the younger generation, obesity as well as other common cardiovascular risks are key factors in sudden cardiac arrest. Nearly 60 percent of younger athletes will suffer from sudden cardiac arrest if they acquire one or more health concerns such as elevated blood pressure or hypertension (Georgeson et al., 2017). One consideration an emergency responder should be aware of is whether an individual's body physique may impede appropriate life-saving actions. Endomorphic body types carry more adipose tissue around the torso; thus, chest compressions during CPR may not reach the requirements stated in the 2015 AHA CPR Guidelines. Currently, there are no CPR recommendations for emergency responders performing chest compressions over or under football shoulder pads. Therefore, it was necessary

to consider research that investigated evidence-based recommendations, specific to chest compressions, for endomorphic body types wearing protective equipment.

2. LITERATURE REVIEW

2.1. Introduction

The American Heart Association (AHA) defines cardiac arrest as an abrupt loss of heart function in a person who may or may not have been diagnosed with heart disease (“American Heart Association: About Cardiac Arrest,” 2017). The main cause of sudden cardiac arrest (SCA) is a malfunctioning of the heart’s electrical system that results in an irregular rhythm (arrhythmia) (Kleinman et al., 2015, p. 414). During cardiac arrest, the heart undergoes ventricular fibrillation (VF), meaning the lower chambers of the heart (ventricles) suddenly begin beating chaotically such that blood cannot pump to the rest of the body (Kleinman et al., 2015). Additionally, ventricular tachycardia is characterized by a regular heartbeat but at a rate that does not allow for adequate refilling of blood in the left ventricle. From here, the heart will have no opportunity to build up pressure and blood will stop flowing. Although cardiac arrest is primarily associated with middle-aged men, the occurrence of sudden cardiac arrest is a rare, yet plausible event for a younger athletic population (Landry et al., 2017).

The primary strategy for increasing survivability in out-of-hospital cardiac arrest victims is the delivery of quality cardiopulmonary resuscitation (CPR) through artificial ventilations and chest compressions (AHA 2000; Basic & Support, 2005; Berg et al., 2010; Kleinman et al., 2015). However, because there is limited research on effective CPR mechanics for nontraditional athletic builds, traditional education via standardized manikins may not be sufficient for certain body types (American Heart Association, 2000; Basic & Support, 2005; Berg et al., 2010; Kleinman et al., 2015; Sutton et al., 2016). Thus, healthcare professionals may not deliver suitable CPR ventilations and chest compressions for endomorphic physiques. Endomorphic body sizes are defined as individuals who have a larger mass, higher body fat, wider build, and

sometimes having difficulty losing weight (Schmeid, 2014). Furthermore, emergency responders (emergency medical responders, emergency medical technicians, advanced emergency medical technicians, and paramedics) must have the ability to provide care for athletes with a diverse range of body structures, including endomorphic athletes. The purpose of this literature is to present the information within the existing research related to the history of CPR, CPR techniques, and current practices recommended by the AHA and European Resuscitation Council (ERC). In addition, it will discuss the current literature pertaining to CPR practices on diverse physiques.

2.2. History of CPR

Components of CPR have been documented and adapted to changing scientific breakthroughs for well over 200 years. Evaluation of proper chest compressions began in 1868 when John Hill observed a revival in heart rhythm when force was applied to the chest; this is the foundation of today's guidelines. Later, in 1874, German physiologist Moritz Schiff performed an open thorax procedure and noted presence of a carotid pulse while physically squeezing a canine heart, thus giving rise to the expression cardiac massage (Aitchison et al., 2013). Schiff stressed the fundamental principle that renewed activity of the heart is not merely a result of mechanical irritation, but dependent on an increased supply of oxygenated blood to the myocardium via restored coronary circulation (Hurt, 2005).

External chest compressions were again documented in 1878 by Boehm, however, these findings were discarded due to stronger evidence supporting use of internal chest compressions. This decision to focus on internal chest compressions was due to the belief that performing life-saving actions directly on the heart is more effective than performing external compressions, which can be impacted by several factors including patients' body structure. In 1892, Freidrich

Maass executed the first successful closed-chest cardiac massage on a human, thus resulting in the current principles of CPR including external chest compressions (Aitchison et al., 2013). Due to the less invasive approach with a closed-chest cardiac massage, this is now the standard approach when caring for a victim suffering from cardiac arrest.

Further research regarding chest compressions was conducted by William Kouwenhoven and Guy Knickerbocker in 1957 when they re-evaluated the concept of external chest compressions after observing a pulse when heavy defibrillator pads were placed on animals (Hurt, 2005). By placing heavy defibrillator pads on the animal's chest, the weight itself increased the animal's blood pressure (Hurt, 2005). As a result of their discovery, this experiment was then performed and carried out on over 100 dogs. Upon completion of the experiment, it was concluded that adequate circulation to the brain can be maintained through rhythmic pressure on the dog's sternum (Hurt, 2005). Furthermore, the researchers found when full chest recoil was allowed, the heart was able to refill. As research progressed, human clinical trials were conducted by James Jude; these trials resulted in successful blood circulation. The findings were later published by Kouwenhoven in 1960 (Baskett, 2001; Hurt, 2005). Due to this breakthrough, properly performed external chest compressions became the "gold standard" over internal chest compressions. Properly performed external chest compressions require full chest recoil to ensure sufficient filling of the ventricles occurs to pump blood throughout the body. Although internal chest compressions are a feasible solution for restoring circulation, less invasive external compressions are a more viable option.

Another important consideration in the CPR procedure is rescue breaths. For those in the healthcare profession, rescue breaths are encouraged when administering CPR. Dr. Peter Safar, an anesthesiologist in the mid-twentieth century, devoted his studies to various airway

management theories. He discovered chest compressions alone would not produce significant tidal volume, which is defined as lung volume or air displaced between normal inhalation and exhalation without extra effort being applied. Safar realized significant tidal volume was not reached due to a blocked airway because of jaw malalignment (Baskett, 2001). As a result of his research, Safar determined tidal volume could be restored when the victim's airway was opened, and air was expired from the rescuer into the mouth of the victim. Additionally, he concluded that 50% of victims' airways can be opened by a simple head tilt; the other 50% through either lifting of the mandible in a forward motion or by inserting an oropharyngeal airway (Aitchison et al., 2013). Based off of his findings, Safar chose to combine airway alignment, expired air ventilation and external chest compressions creating the three concepts now known as the ABC's of CPR. Furthermore, the head-tilt-chin-lift maneuver and jaw-thrust technique are standard methods for maintaining a patent airway during CPR, thereby resulting in an increased chance of survival following a cardiac arrest event.

An automated external defibrillator (AED) is a device that analyzes heart rhythm and prompts the rescuer to deliver a shock when the victim's heart is in ventricular fibrillation (VF) or ventricular tachycardia (VT). If not administered promptly, a victim's chance of survival will decrease by seven to ten percent every minute that passes without defibrillation (Hurt, 2005). In 1971, Galvani disclosed electricity is the force contracting the muscle tissue surrounding the heart. This was first studied in 1899 by Prévost and Batelli who demonstrated that electrically-induced fibrillation can be reversed by a 240-volt alternating-current shock when applied to the heart within 15 seconds of an onset cardiac arrest episode (Hurt, 2005). One observation they made during their experiment was if a longer period elapses from cardiac arrest to defibrillation, cardiac massage was necessary to provide myocardial oxygenation. Unfortunately, successful

internal and external defibrillation in humans was not accomplished until half a century later (Hurt, 2005).

As decades passed, successful open- and closed-human defibrillation began to emerge in medical journals. Internal defibrillation was first successfully performed in 1947 by Beck after 35 minutes of cardiac massage was performed while operating on a pectus excavatum chest deformity, a condition in which the sternum sinks into the chest cavity (Hurt, 2005). The first internal defibrillation on a nonsurgical patient was done by Reagan in 1953. In contrast, the first mention of external defibrillation was by James Curry who, in 1972, recorded two successful cases of human resuscitations after closely working on small animal experiments (Hurt, 2005). His method consisted of two electrodes (one superior to the clavicle, the other over the lower left chest) while administering an electrical shock from an electrostatic electricity machine. One case supporting Curry's research reported a young child who fell from a window and "appeared dead" when taken to the hospital. An electrical shock from a friction type electrostatic machine was administered through the thorax, successfully restoring circulation to the child and saving her life (Hurt, 2005). Though Kouwenhoven developed an external defibrillator in 1930, the first portable automatic external defibrillator (AED) was not developed until 1978 due to the need for continued testing and alterations over the following decades (Aitchison et al., 2013). As a result of scientific and technological advancements occurring over several decades, victims of cardiac arrest can now effectively be treated both inside and outside of the hospital.

2.2.1. 2000 American Heart Association CPR Guidelines

Before the American Heart Association (AHA) published their updated CPR Guidelines in 2000, all healthcare providers were educated to perform five chest compressions to one ventilation (5:1) when two rescuers are present. In an effort to provide the most effective

compression to ventilation ratio guidelines, researchers enrolled 17 paramedic students in a study assessing the difference between a 5:1 single-rescuer, and a 15:2 two-rescuer compression to ventilation ratio (Wik & Steen, 1996). Trials were completed on an Ambu Mega Code Trainer, which records the care provided and transfers the data to a computer for further evaluation. The students involved in this study were provided a standard two-rescuer scenario concurring with the ERC guidelines in addition to the alternative 15:2 method (Wik & Steen, 1996).

Two participants were randomly assigned to each CPR session where each individual would change between rescuer one and rescuer two positions. CPR was then performed in cycles of 60 seconds with a 15-second break before completing the other tasks (electrocardiogram [ECG] interpretation, intubation, IV cannulation, and administering proper medications). Rescuer one was responsible for completing such tasks between ventilations or during 15-second pauses, while making sure not to interfere with ECG analysis. Rescuer two performed the 5:1 compressions. After completion of each task, the manikin's rhythm converted from asystole to VF (Wik & Steen, 1996).

Once all the data were collected, statistical analysis utilizing an independent two-tailed test and Fisher's exact test were conducted. For the initial assessment consisting of initial ECG evaluation, intubation, or start of ventilation and chest compressions, there were no significant differences between 5:1 and 15:2 CPR method. Fewer CPR cycles were performed during the 15:2 ratio (Mdn = 1.75), compared to the 5:1 ratio (Mdn = 3). Moreover, during 15:2 CPR, three manikins were in sinus rhythm after the first cycle ($p = .229$), and all 18 manikins were in sinus rhythm after the second cycle. In comparison, none of the manikins were in sinus rhythm after the first cycle of 5:1 CPR and only five manikins were in sinus rhythm after the second cycle (Wik & Steen, 1996). There were no significant differences between quality of chest

compressions or ventilations when compared between groups. Rescuers were able to complete the tasks more efficiently for the 15:2 CPR group, and rescuers performing 5:1 CPR fatigued more quickly. When two paramedics are performing CPR, the 15:2 method is more effective because rescuers are able to perform other life-saving tasks during patient care (Wik & Steen, 1996). Based on the aforementioned study, the AHA and ERC recommended that the 15:2 chest compression to ventilation ratio be performed during two-rescuer scenarios and thereby discarding the 5:1 recommendation from the 1990's (Wik & Steen, 1996; AHA, 2000).

Prior to the 2000 AHA CPR Guidelines, the final phase during an initial evaluation for an individual suffering from cardiac arrest was circulation. Circulation is assessed through palpation of the carotid pulse as well as simultaneously evaluating the patient for breathing, coughing, or movement (AHA, 2000). Location of the carotid artery can be attained by a head tilt with one hand on the individual's forehead, while the other hand finds the trachea and moves the fingers laterally into the groove between the trachea and the muscles at the side of the neck (AHA, 2000). If a rescuer misses or delays the diagnosis of cardiac arrest, the victim's chance of survival is reduced to zero within ten minutes. The reliability of the carotid pulse assessment in lay responders, paramedical and medical personnel is poor. Only 50% of BLS medical students, 17% of experienced ambulance crew members, and 3% of BLS-trained lay persons were able to correctly evaluate unresponsiveness and carotid pulse within 30 seconds (Eberle et al., 1996).

Various researchers have examined the reliability of carotid pulse assessment because pulse is the "gold standard" method for determining whether a victim's heart is beating. In one study, 16 patients undergoing coronary artery bypass surgery were selected for intraoperative examinations by four groups of first responders. These first responders consisted of: EMT-1 (n = 107) including lay person (EMT student before an advanced training course but have passed the

BLS course); EMT-2 (n = 16) which consisted of EMT's in training (completed four weeks of theoretical and six weeks practical instruction); PM-1 (n = 74) which are paramedics in training (one year after theoretical and practical training); and finally PM-2 (n = 9) who were certified paramedics after completing their two-year curriculum (Eberle et al., 1996). The participants were exposed to two separate conditions where they were expected to palpate a carotid pulse. The first situation consisted of spontaneous circulation during mobilization of the internal mammary artery (systolic arterial pressures were greater than or equal to 80 mmHg for 30 minutes), while the second scenario consisted of “non-pulsatile cardiopulmonary bypass with the aorta cross-clamped and the arterial and venous pulselessness was a mean arterial pressure between 50 to 80 mmHg” (Eberle et al., 1996, p. 106). Rescuers were randomly assigned to either of the two groups and remained blinded to their assignment. From there, rescuers were instructed to evaluate the presence or absence of a central pulse as quickly as possible, ideally within five to ten seconds in accordance with the AHA guidelines (AHA, 2000; Eberle et al., 1996).

Through statistical analysis, determination of the delay and accuracy of the pulse check was conducted comparing rescuers' readings to a hard copy of concurrent ECG rate and rhythm. Analysis of diagnostic delay was presented in percentiles for every second of delay of a pulse check up to one minute. A comparison of time intervals between the four rescue groups was completed using non-parametric analyses (Eberle et al., 1996). Accuracy of the participant's pulse check was assessed by calculating sensitivity and specificity of the carotid pulse for central pulselessness. Sensitivity is the ability to, “identify patients on cardiopulmonary bypass with closed aortic cross-clamp as pulseless; specificity is the skill to recognize patients with

spontaneous circulation as pulsatile prior to bypass” (Eberle et al., 1996, p. 108). Furthermore, an independent t-test was used to compare heart rate and blood pressure between the four groups.

With a total of 206 participants administering a pulse check to 16 patients, 147 assessments had a pulse while 59 were pulseless. Ten percent of the diagnoses were deemed pulseless and were not recognized within 60 seconds. In contrast, 45% of the 147 total pulses indicated the patient was pulseless, despite a carotid pulse being present with a radial arterial systolic pressure of more than 80 mmHg. Therefore, the sensitivity for central pulselessness was at 90% while specificity was only 55%. Results between the four participant groups indicated both specificity and sensitivity increased with more advanced levels of medical training. Higher levels of training resulted in a statistically significant decrease in time to diagnosis ($p < 005$). Only 16.5% of the participants in this study managed to reach their diagnosis within the allotted time of ten seconds proposed by current international guidelines; however, three of the participants from the 16.5% diagnosed incorrectly (pulseless when there was a pulse). In contrast, one participant was able to identify a patient as pulseless within ten seconds. From this study, researchers concluded that the ability for rescuers to detect pulse is poor. Additionally, recognition of pulseless by rescuers with only basic CPR training is time-consuming and inaccurate. Further intensive retraining for professional rescuers and reconsideration of guidelines about carotid pulse evaluation are necessary (Eberle et al., 1996).

In summary, the studies mentioned above are in support of the 2000 AHA CPR Guidelines making changes concerning assessment of cardiac arrest and performance of CPR. One modification was the compression to ventilation ratio, which changed from 5:1 to 15:2 to decrease over-ventilation and increase the focus on providing adequate compressions. Furthermore, carotid pulse check, specifically in lay persons, was deemed inefficient because of

excessive time spent away from compressions, thereby decreasing the rate of survival. As a result, healthcare providers should undergo further training to assess accurately the carotid pulse in a victim suffering from sudden cardiac arrest. The AHA recognized the need for research to further the advancement of knowledge and training concerning proper chest compression to ventilation ratios to provide the most efficient evidence-based guidelines for rescuers of all levels.

2.2.2. 2005 American Heart Association CPR Guidelines

According to the 2005 American Heart Association CPR Guidelines Part 4: Adult Basic Life Support, there was a change to the compression to ventilation ratio from 15 compressions and two breaths (15:2) to 30 compressions and two breaths (30:2). The reason for this change is based on the agreement of healthcare experts rather than objective data (Basic & Support, 2005). Equally important, other reasons for the new 30:2 ratio included increasing the number of compressions per minute, decreasing over-ventilation precautions, minimizing interruptions, and simplifying directions for teaching purposes (Basic & Support, 2005). In one study, these changes were reinforced when two different ratios of chest compressions and ventilations with 18 basic life support-certified healthcare professionals were performed. One group administered 15:2 chest compression to ventilation ratio while the other performed 30:2 for a total of five minutes. One factor that was not considered during this study was flow time, or amount of time without chest compressions. The measurements recorded before and after each session during this study consisted of: heart rate, capillary lactate, and Rate of Perceived Exertion (RPE). Feedback for each trial was obtained through the QCPR Resusci Anne manikin technology. A repeated-measures ANOVA was calculated, showing a statistical significance with the 30:2 CPR group having more compressions per minute ($p = .007$) as well as a lower no-flow compared to

the 15:2 group ($p < .001$). Interestingly, there was no statistical significance concerning depth, rate, and chest recoil between the two groups (Betz et al., 2008). It was reported first responders should limit the amount of time spent on ventilations and increase the number of chest compressions per minute to improve the survival rate for patients suffering from cardiac arrest.

Similar to the purpose of the previous study, researchers investigated 50 career paramedics who participated in three sessions of CPR for 10 minutes. The purpose of this study was to establish if the quality of CPR decreased when the workload and number of chest compressions per minute increased. Researchers randomly assigned participants to groups with three different compression to ventilation ratios: 15:2, 30:2, and 50:2. Subjects were allowed 25 minutes of rest between each protocol or until the paramedic indicated he/she was ready to begin the next session. Measurements recorded were the mean compression depth and rate, number of compressions, and no-flow time. Researchers analyzed the total number of chest compressions after 10 minutes and found an increase from 604 with 15:2 compressions, to 770 with 30:2 compressions, and 862 for 50:2. There was a higher compression rate for the 15:2 ratio (118 ± 18 per minute) as opposed to both the 30:2 (115 ± 18) and 50:2 (112 ± 16) ratios ($p < .02$ and $p < .0005$, respectively). However, there were no statistically significant differences between all three sessions for compression depth, indicating there was no significant decrease in quality of CPR performed in each trial (Bjørshol et al., 2008). In summary, the results of this study indicate that the total number of compressions increases with a higher ratio and depth is not compromised by increasing the compression to ventilations. Future research should investigate the potential for an even higher number of compressions to ventilations to understand the cut point of total compressions to depth ratio.

Because healthcare experts recommended increasing chest compressions from 15 to 30 in the 2005 AHA CPR Guidelines, one study evaluated the quality of CPR for two different ratios (15:2 and 30:2) as well as continuous chest compressions to determine the effectiveness of new recommendations. Throughout each of the three sessions, the 69 participants were not provided any instruction or feedback concerning the quality of their CPR performance. Researchers found the depth of compression stayed within the recommended 40-50 mm guidelines set by the ERC. However, there was lower compression depth with the continuous chest compressions group (30 ± 8 mm) as compared to the 15:2 and 30:2 groups (41 ± 11 mm, $p < .05$) (45 ± 8 mm, $p < .05$). The compressions per minute increased with continuous chest compressions (73 ± 24 mm) compared to both 15:2 (40 ± 9 mm) and 30:2 (43 ± 14 mm) ratios, however, there was no p-value reported. Additionally, the 15:2 CPR ratio group had a higher ventilation rate (3.1 ± 2.4) compared to the 30:2 group (1.6 ± 1.4) ($p < .05$). The 15:2 group also had a higher no flow time ($49 \pm 13\%$) than the 30:2 group ($38 \pm 20\%$) ($p < .05$). Finally, the group who performed continuous chest compressions had the lowest no flow time ($1 \pm 2\%$) (Odegaard, 2006). Having a decrease in ventilations will increase the amount of chest compressions administered on a cardiac arrest scenario, thereby allowing a higher probability of survival.

The recommendation for chest compressions remained 100 compressions per minute with a depth of one and a half to two inches (1.5-2) when CPR is performed on an adult patient. However, one area that was emphasized in these guidelines concerned chest recoil. By allowing the chest to completely recoil, blood will be able to return to the heart and ensure equal compression and relaxation time has occurred. Furthermore, increasing the number of chest compressions from 15 to 30 allowed healthcare providers to decrease interruption time while also decreasing over-ventilation. Components of CPR such as chest recoil, chest

compression/ventilation ratio, compression depth, and no flow time all play an important role in providing the highest standard of care for those in need of BLS.

2.2.3. 2010 American Heart Association CPR Guidelines

In the 2010 American Heart Association CPR Guidelines, the recommendation for the compression to ventilation ratio remained 30:2, identical to the 2005 AHA CPR Guidelines. This recommendation is based off of both healthcare experts and case series published following the 2005 guidelines (Berg et al., 2010). Another area where no changes were made was the recommendation to perform chest compressions fast, hard, and without interruptions (Yasuda et al., 2013). One major change to the 2010 AHA CPR Guidelines concerns the sequence of actions taken following a cardiac arrest episode. This protocol changed from airway-breathing-circulation (ABC) to circulation-airway-breathing (CAB) (Berg et al., 2010). Healthcare professionals agreed initiation of chest compressions prior to assessing other body systems, such as sufficient breathing, is a better procedure to follow (Berg et al., 2010; Jiang et al., 2015). If two-rescuers are present and an advanced airway is administered, one-rescuer continues chest compressions at 100 compressions/minute and the second rescuer delivers rescue breaths.

Additionally, using an AED as soon as possible following a cardiac arrest event to assess heart rhythm increases favorable resuscitation outcomes for patients. The AED will enable a rescuer who is not trained in heart rhythm interpretation to provide a potential life-saving shock to a sudden cardiac arrest victim (Berg et al., 2010). In one randomized study, researchers assigned 993 community units (shopping malls, residential areas, etc.) from July 2000 to September 2003 where lay-persons in these locations would need to perform either CPR only or CPR followed by administering an AED during cardiac arrest (Kleinman et al., 2015). The purpose of this study was to determine if CPR followed by AED administration was a more

effective intervention than CPR alone. For this study, the term cardiac arrest was used when more than five chest compressions or two ventilations were administered on a patient. Each lay rescuer was notified of possible cardiac arrest situations through various means of communication (pagers, notifications via security, etc.). Researchers found twice as many patients survived for the CPR and AED scenario than only CPR (31 vs. 16) ($p = 0.03$, 95% CI: 1.07-3.77). Moreover, when utilizing the AED, interruptions in chest compressions should be minimized. Researchers recommend if an AED is readily available, a shock should be administered to a patient as soon as possible before initiating CPR. In order to improve patient outcomes following cardiac arrest, rescuers should focus on performing high-quality CPR following full chest recoil between compressions and apply an AED as soon as it is available while minimizing interruptions in CPR (Kleinman et al., 2015; Soar et al., 2015).

In 2010, the AHA CPR Guidelines changed the chest compression depth to allow the heart to completely compress, thereby allowing the blood to reach vital organs. The 2010 AHA CPR Guidelines recommend performing compressions at a depth of at least two inches, compared to the 2005 guidelines, which recommended one and a half to two inches. Researchers investigated the compression depth recommendations with 81 participants who were randomly assigned to administer the 2005 AHA CPR Guidelines depth of 38 mm to 50 mm (1.5-2 inches) while the other group performed the 2010 AHA CPR Guidelines of a depth greater than 50 mm (2 inches). To assess the quality of chest compressions, recordings of the mean chest compression depth were taken every minute, the number of appropriate chest compressions depth, and the chest compressions depths greater than 38 mm every minute. The compression rate per minute, incomplete chest recoil, and abnormal hand placement were also recorded. Chest compressions were performed for a total of eight minutes. Increasing depth of compressions

increased the compression rate per minute (34 ± 48 compared to 60 ± 57); however, rescuer fatigue also increased with increased compression depth. Fatigue was evaluated through heart rate and blood lactate levels before, during, and after performing chest compressions, as well as rate of perceived exertion (RPE). Researchers found significant differences in fatigue levels between the two protocols (Berg et al., 2010). For the 2010 Guidelines group, there was an overall increase in compression rate but the number of compressions achieving a depth of two inches decreased. There was an overall increase in the 2010 guidelines compression group rate during the study but the number of compressions achieving a depth of two inches decreased. After the initial testing time of eight minutes for chest compressions following the 2010 AHA CPR Guidelines, both heart rate and lactate levels increased. These protocols highlighted the importance of chest compression depth of two inches to have the heart fully compress and increasing blood flow to the rest of the body. An increase in compression depth requires a higher physical demand on the rescuer to perform CPR, thus increasing fatigue, heart rate, and blood lactate levels.

One area of consistency within the CPR guidelines over the last ten years is the recommendation to minimize interruptions during CPR. By decreasing the interruptions, the chance of survival for each patient increases because rescuers are able to spend more time administering CPR. One observational study conducted over nine months (March to December 2005) focused on both in-hospital and out-of-hospital cardiac arrest patients; those who suffered cardiac arrest in the emergency department or operating room were excluded from the study. A total of 13 patients were excluded from this study due to technical difficulties or chest compressions not started before shock was administered. Sixty participants partook in this study where a monitor was used to measure the chest compression rate, compression depth, ventilation rate, ventilation volume and pulse. Measurements of chest compressions were assessed via chest

compression pad with an accelerometer and force detector. Furthermore, pulse and ventilation rates were monitored in the chest wall impedance. Recordings were taken every 30 seconds, and any interruptions or pauses were evaluated by two physicians. Outcomes for each patient after cardiac arrest were then obtained from medical records (Edelson et al., 2006).

Results for the 60 patients in this study were analyzed via t-test, chi-squared analysis, and logistic regression analysis. When administering a shock, successful AED operations were associated with shorter median pre-shock pauses (11.9 seconds versus 22.7 seconds, $p = .002$) and an increase in mean chest compression depth (39 ± 11 mm versus 29 ± 10 mm, $p = .004$). No statistical difference was determined when observing between-groups with variables of ventilation/chest compression rates and no flow time. Patients are more likely to return to spontaneous circulation when the first shock was successfully administered by the AED (55% versus 25%, $p = 0.004$) and an increased chance of survival to hospital discharge despite having no calculated statistical significance (9% versus 0%, $p = .21$). When tending to both in-hospital and out-of-hospital cardiac arrest events, patients are more likely to have a favorable outcome when proper chest compression depth is performed pre-AED shock as opposed to no compressions before AED (Yang et al., 2014).

In 2010, there were significant revisions to the AHA CPR Guidelines focusing on correcting ineffective CPR performance for out-of-hospital cardiac arrest care. Concentrating on lay persons specifically, these parameters emphasized compression-only CPR instead of chest compressions with rescue breaths. If the lay person is unable to administer rescue breaths, compression only CPR should be performed. During a cohort study, examination of out-of-hospital cardiac arrest events for patients over the age of 18 (May 1998-April 2003) was performed. The three forms of CPR recorded by EMS at the time of the incident during this

study were no CPR, standard 30:2 CPR, and continuous chest compression CPR. Once completed, the patients were followed for one-year post event to evaluate neurological outcomes (Iwami et al., 2007). Repeated measures-ANOVA and χ^2 -test were performed to analyze categorical variables, a logistic regression was used to analyze the relationship between the three different types of CPR administered and the outcomes of each survivor, and finally an odds ratio and 95% confidence interval (CI) were conducted as well. With a total of 13,444 events taking place at out-of-hospital locations, only 4,902 cardiac arrest episodes were witnessed (Iwami et al., 2007); 783 patients received standard 30:2 CPR, 544 patients received continuous chest compressions, and 25 were given no CPR at all. When evaluating neurological outcomes, the two groups having favorable results came from both chest compression-only (3.5%) and standard 30:2 CPR (3.6%) compared to no CPR (2.1%). Researchers then analyzed the survival rate one-year after the incident and found favorable results for patients in both CPR-administered groups. Compression-only had 95% CI (1.01-2.95) and standard 30:2 CPR had 95% CI (0.95-2.60) as compared to no CPR performed when analyzing favorable neurological outcomes one-year post cardiac arrest event (Iwami et al., 2007). No significant difference was determined between the two CPR groups; therefore, advising lay-persons to do compression-only CPR is just as effective as the standard 30:2 CPR protocol.

Another study was completed comparing standard CPR, compression only CPR, and no CPR. In this longitudinal study, 1,151 patients were included; 439 (11%) received continuous chest compressions, 712 (18%) received standard CPR, and 2,917 (72%) did not have any CPR performed. According to the Glasgow-Pittsburgh cerebral performance categories, neurological outcomes were assessed 30 days after each cardiac arrest event took place.

Statistical analysis of the data collected involved a χ^2 -test for baseline categorical measurements, while continuous measurements were obtained through a Mann-Whitney U. The relationship between promising neurological outcomes, time between CPR attempts, and the administration of an AED were evaluated via non-linear regression analysis. Patients who received continuous chest compressions had a higher favorable outcome over patients with standard CPR who were apneic ($p = .02$), VF or tachycardic ($p = .04$), or when CPR began within four minutes of cardiac arrest ($p = 0.0221$). Additionally, continuous chest compressions resulted in higher neurological outcomes than standard 30:2 CPR (95% CI: 1.2-4.9; $p = .009$). Researchers determined the administration of continuous chest compression-only is either comparable or more beneficial than standard 30:2 CPR protocol. Patients who received both chest compressions and ventilations resulted in higher favorable neurological outcomes over no CPR; however, chest compression-only CPR showed an increase in favorable outcomes in specific subcategories.

For healthcare providers and first responders, it is still recommended to perform and maintain 30 chest compressions followed by two rescue breaths for a two-rescuer scenario until an advanced airway has been placed. Rescue breaths should be delivered one breath every six to eight seconds while generating a proper yet visible chest rise (Berg et al., 2010). As an advanced airway is placed, rescue breaths should be given in the same accord with one breath every six to eight seconds without excessive interruptions between chest compressions. Due to the likelihood of inadequate rescue breaths and possible hesitation to perform rescue breaths in lay persons, the AHA made significant changes to the CPR Guidelines in 2010, resulting in removal of rescue breaths.

2.2.4. 2015 American Heart Association CPR Guidelines

In the 2015 AHA CPR Guidelines, there was a change in chest compression rate recommendations. Instead of advising a compression rate of 100 compressions/minute as dictated in the 2010 AHA CPR Guidelines, rates were increased to 100-120 compressions/min (Kleinman et al., 2015). Increasing the compression rate allows for more chest compressions to be performed per minute, resulting in more favorable neurological outcomes. Furthermore, extra chest compressions will have the potential to increase spontaneous circulation return and improve survival rates. By providing a minimum rate, rescuers can ensure they are delivering an adequate number of compressions per minute. Providing a maximum rate will decrease the likelihood of performing compressions too quickly, thereby not allowing for adequate depth and chest recoil.

During CPR, adequate compression depth permits the heart to compress fully, while allowing full chest recoil helps replenish the blood to the heart during the relaxation phase. Current guidelines indicate rescuers are advised to depress the chest at least 2 inches but no more than 2.4 inches. If a rescuer depresses the chest more than 2.4 inches, this may lead to injuries to the victim; the overall goal is to avoid such injuries sustained through the performance of CPR. The AHA still provides an upper limit for depth of compressions to make the rescuer aware of potential risks and injuries that can occur if compressing too deep (Kleinman et al., 2015).

When studying emergency medical service providers who treated non-traumatic cardiac arrest events in an out-of-hospital setting, researchers investigated proper chest compression depth in patients over the age of 18. Measurements for compression rate, fraction, and depth were made using a proprietary AED analytic software. From June 2007 to October 2010, 9,136 patients who experienced cardiac arrest were included in the study. At the time of this study, the

recommended chest compression depth was two inches based on the 2010 AHA CPR Guidelines as compared to the more recent 2015 AHA CPR Guidelines recommending increased depth of two to two and half inches. The Resuscitation Outcomes Consortium Prehospital Resuscitation Impedance Valve and Early Versus Delayed Analysis (ROC PRIMED) trial used a partial factorial design where most of the patients were randomly assigned to two concurrent protocols (Stiell et al., 2014). The first protocol compared early rhythm analysis to later rhythm analysis; the second protocol compared the use of impedance threshold devices to a sham threshold device. With the ROC PRIMED network consisting of 36,000 EMS professionals within 260 EMS agencies, the analysis for this experiment included OHCA patients who were treated by EMS and were provided electronic compression depth data. Based off of the results, there was a higher probability of patient survival when the depth of chest compressions was greater than 51 mm (2 inches) (1,530 deaths, 138 survivors; $p < .001$) (Stiell et al., 2014). For the patients who survived a cardiac arrest event, they were given adequate depth range for chest compressions for a longer time frame (69%) as compared to those given proper chest compression during the set time frame and did not survive as an outcome (61%) ($p < .001$). As demonstrated by the aforementioned study, performing CPR with adequate rate and depth of chest compressions (100-200 compressions per minute and 2-2.4 inches respectively) drastically increases the change of patient survival following a cardiac arrest event.

Full chest recoil during CPR allows the blood to refill in the heart's chambers between chest compressions. As the chest is elevated, the negative pressure being exerted causes the blood from the body to be drawn back to the heart. In the 2015 AHA CPR Guidelines, full chest recoil during chest compressions was reemphasized from the 2010 AHA CPR Guidelines. The rescuer administering chest compressions should avoid leaning on the patient because this will

prevent proper chest recoil from occurring (Kleinman et al., 2015). If incomplete recoil of the chest occurs, this increases intrathoracic pressure, reduces venous return, coronary perfusion pressure and myocardial blood flow (Kleinman et al., 2015). There needs to be a balance between chest compression depth and recoil to provide proper life-saving CPR techniques.

There are six primary components that need to be considered when performing CPR to increase blood flow and the likelihood of achieving the return of spontaneous circulation (ROSC); they are as follows: compression depth, compression rate, hand placement, chest recoil, minimized interruptions, and adequate ventilations (Kim et al., 2015). Coronary perfusion pressure (CPP) is the difference in aortic diastolic and right atrial diastolic pressure during the relaxation phase of chest compressions (Sutton et al., 2016). CPP plays an important role in achieving ROSC. To obtain adequate CPP to achieve ROSC, full chest recoil must occur between each chest compression. Emergency responders need to be aware of the importance of all aspects of performing adequate CPR to provide life-saving care.

In one study conducted in the Republic of Korea, the survival rate of out-of-hospital cardiac arrest episodes was a mere 3.3%. The focus of this study was not only to determine a proficient two-rescuer CPR protocol but also identify potential problems for rescuers performing prolonged CPR on a cardiac arrest patient. During this study, 43 EMTs participated who had at least one to two years of experience while attending a high-quality training course on CPR. Laerdal Resusci Anne Skill Station manikins were used while compression depth and accuracy were analyzed using the Laerdal Skill reporting system. As teams of two EMTs were briefed on a mega-ventricular fibrillation scenario for a 62-year-old man with diabetes and hypertension, each pair was told they arrived on-scene to find the patient unconscious. This scenario was prepared in advance and comprised of 16 steps; step 1 involved patient recognition

(responsiveness, respiration and pulse), chest compressions, and initial external defibrillation followed immediately by chest compressions for two minutes by one EMT and laryngeal mask airway insertion by the other (Kim et al., 2015). Steps two through sixteen included each external defibrillation, followed by two-minutes of uninterrupted chest compressions by one EMT and positive-pressure ventilation using a bag-valve mask by the other EMT. Each EMT performed both roles, resulting in 16, two-minute cycles of CPR for a total of 32 minutes (Kim et al., 2015).

The Laerdal Skill reporting system was used to collect information regarding compression depth, compression rate, hand placement, and chest recoil. As the experiment concluded, subjects completed a survey discussing the point at which they felt fatigued, their CPR quality diminished, and perceived obstacles for continuation of CPR (fear of decrease in CPR, complaints of family members, musculoskeletal pain, pressure from team members to “load and go,” and lack of confidence) (Kim et al., 2015). Statistics were expressed as mean \pm SD, median (interquartile range) or median (range) while CPR performance was analyzed using Student’s t-test or χ^2 -test (Kim et al., 2015). The median duration of on-scene CPR performance was 3.7 minutes with a median of two cycles. Additionally, the maximum duration of on-scene CPR was five minutes. As for CPR parameters during each of the 16 steps, the standards of high-quality CPR (adequate ventilation, complete chest recoil, minimized interruptions between chest compressions, compressing the center of the patient’s chest, compression rate $> 100/\text{min}$, and compression depth of $> 5 \text{ cm}$) were met and compression rate significantly increased with time ($p = 001$) (Kim et al., 2015). However, there were no other significant findings in any other parameters. Due to the short duration of CPR provided by EMTs in this experiment, chest compressions were not sufficient due to inadequate compression depth or inability to achieve full chest recoil to achieve prehospital ROSC (Kim et al., 2015). When analyzing gender differences,

compression depth and the incidence of incomplete chest recoil were significantly higher in male subjects ($p < .001$) (Kim et al., 2015). Furthermore, the occurrence of incorrect hand placement during chest compressions was significantly higher in female EMTs ($p < .001$). Lastly, data collected through the post-study survey found the median expected onset of fatigue was four minutes and the expected onset of reduced performance was two and a half minutes. Findings related to participants' concerns regarding continuation of high-quality CPR included: fear of decrease in CPR performance ($n = 26$ [60.5%]), complaints of family members ($n = 25$ [58.1%]), musculoskeletal pain ($n = 19$ [44.2%]), pressure from team members to "load and go" ($n = 4$ [9.3%]), and lack of confidence ($n = 3$ [7.0%]) (Kim et al., 2015). Researchers addressed inconsistencies between countries concerning the appropriate out-of-hospital emergency medical systems. Moreover, management of cardiac arrest patients can also differ amongst countries and regions in the world.

No universal standards have been established for emergency responders to follow while performing on-scene CPR for a patient in cardiac arrest. Kim et al. (2015) suggest that in many parts of the United States, paramedics will perform CPR at the scene of the incident until the victim achieves spontaneous ROSC; however, if ROSC is not obtained, first responders will terminate resuscitation and declare death at the scene. In European countries, doctors are able to travel on ambulances and will treat cardiac arrest patients based on their judgement. In the Republic of Korea and other Asian countries, doctors do not travel in ambulances and thus EMTs are not legally authorized to declare death of a patient. Differences between countries can alter survivability results for patients suffering from a cardiac arrest episode due to differing CPR duration time protocols per region.

According to the 2015 AHA Guidelines, changing the chest compression rate from 100 to 100-120 compressions/min while maintaining the compression depth of two inches minimum to 2.4 inches maximum results in increased likelihood of return of spontaneous circulation, thereby improving survival rate of cardiac arrest victims. Additionally, proper compression depth allows the subject's heart to compress fully to maintain blood flow to vital organs, and full chest recoil permits blood to be replenished to the heart when in its relaxed phase. However, researchers have not studied the effectiveness of performing these same CPR procedures on an individual with an endomorphic physique. With a lack of research focused on quality education concerning individuals with a higher body mass, regulations and protocols for CPR may need to be altered to improve survivability. Future research should include guidelines addressing diverse physiques and the potential for different protocols based on patient's body type.

2.3. Endomorphic Physique

When observing different sporting events, each sport is comprised of a diverse range of body compositions. Factors including sport, position, or competitive division often influence the overall physique of the athletes. Individual's somatotypes can be classified into three categories: endomorphic (increased fat storage, wide waist, difficulty losing weight, bulky/round body), ectomorphic (long/thin musculature, low fat storage, slimmer), and mesomorphic (solid torso, low fat levels, wide shoulders, muscular) (Schmeid, 2014). An individual's physique is one factor that can impede appropriate life-saving actions in the event of a cardiac arrest episode. Emergency responders attend CPR training courses every two years and typically perform CPR on "average-sized" manikins, resulting in underprepared responders in real-life situations. Current CPR Guidelines do not address endomorphic or ectomorphic individuals, thus resulting in inadequate training of emergency responders.

Endomorphic individuals will have a higher body mass index (BMI); this can lead to future health issues such as cardiovascular disease, high blood pressure, type 2 diabetes, osteoarthritis, and certain types of cancer (breast, liver, etc.). When athletes have an endomorphic body type, these features increase cardiac risk due to vigorous workouts increasing their acute cardiac load (Schmeid, 2014). Because of the physical differences associated with endomorphic physiques as well as lack of appropriate research-based guidelines, first responders may not perform adequate CPR on individuals with this body type.

With over 350,000 cardiac arrest episodes occurring annually (whether in or out-of hospital care), obesity is a rising health factor in the United States (Tellson et al., 2017). Concerns with obesity highlight the issue of emergency responders administering high-quality chest compressions and ventilations during CPR on an endomorphic physique. In one study, a randomized controlled design was used to compare chest compressions during CPR on three adult simulation manikins (normal, obese, and morbidly obese) to observe if current AHA CPR Guidelines for chest compression to ventilation ratio was effective on all body types. Additionally, researchers examined any differences in quality of chest compressions performed by emergency responders between the three manikins and the effect of participant characteristics (height, weight, gender, and upper body strength) on the quality of chest compressions, specifically with the obese and morbidly obese manikins (Tellson et al., 2017). Sixty-one healthcare providers performed CPR in one of six orders (123, 132, 213, 231, 312, 321) where one represented a normal manikin, two designated the obese manikin, and three represented the morbidly obese manikin. For this study, obesity was defined as a BMI of $\geq 40 \text{ kg/m}^2$ (Tellson et al., 2017). Adult simulation manikins with an electronic skill reporter were used to measure quality of chest compressions. Each manikin also included lights that provided feedback on

compression depth as well as hand position of the rescuers. The “normal-sized” manikin, consisted of a 16 cm diameter with moderate thorax resistance, which mimicked the average size of an adult female of normal weight. The obese and morbidly obese manikins were manufactured and created using molds of the standard manikin build while adding the calculated amount of foam substance similar to adipose tissue, thus having equivalent proportions to match those specific body physiques (Tellson et al., 2017).

Participants were required to perform two cycles of chest compressions (15 compressions per cycle) on each size manikin at the required 2010 AHA CPR Guidelines of 100 compressions/minute with a depth of two inches and a five-second pause between each cycle of chest compressions. Each manikin was placed on a hospital bed with backboards under each manikin to replicate an in-hospital situation. Measurements of quality chest compressions were indicated by the number of successful compressions (performing appropriate chest compression depth of two inches) out of 30 attempts. There was no significant difference between the number of successful compressions performed on the normal-sized manikin as compared to the AHA CPR protocol ($p = .09$). However, successful compressions performed on the other two manikins were significantly lower than the standard manikin ($p < .0001$) (Tellson et al., 2017).

Table 2.1*Comparison of Successful Compressions After 30 Attempts by Manikin Size*

	Normal	Obese	Morbidly Obese
Average	23	0	0
Range	0-30	0-2	0
P-value	0.09	< 0.001	< 0.001

Furthermore, comparison on the performance of successful compressions over the three manikins was assessed; compressions on the normal-sized manikin were significantly better when compared to the obese and morbidly obese manikins ($p < .0001$ for each comparison). However, there was no significant difference in performance between the two obese manikins ($p = .10$) (Tellson et al., 2017). Finally, when analyzing data between the normal manikin and participants' characteristics, age, BMI, upper body strength, ethnicity, and manikin order were all significantly associated with the amount of successful compressions. Comparing the performance of African American, Asian, and Caucasian participants performed significantly better than Hispanic participants. Additionally, a one-year increase in age was associated with a decrease of 0.0167 in the number of successful compressions. Furthermore, a one-unit increase in BMI resulted in an increase of 0.0159 in the number of successful compressions. Lastly, a one-unit increase in upper body strength resulted in an increase of 0.0038 successful compressions (Tellson et al., 2017). Based off the results from this study, quality CPR diminished for first responders when performed on obese and morbidly obese adult simulation manikins. Though both obese groups displayed poor outcomes related to successful chest compressions, the main issue is with morbidly obese patients because of the excessive amount of adipose tissue around the thoracic region. As obese and morbidly obese patients received shallower chest compressions, adequate CPR training for individuals working in hospital settings

as well as emergency responders should represent potential scenarios they may encounter, specifically with endomorphic physiques. Additionally, as there is research focused on the impact of rescuer characteristics (height, weight, gender, etc.) and CPR performance, consideration of these factors affecting life-saving actions is a concern. In this study, researchers found a significant relationship between specific demographic and personal variables and rescuers' quality of chest compressions on various body sizes. One limitation of this study is the implementation of outdated AHA CPR Guidelines. The 2015 AHA CPR Guidelines recommend 30 compressions per cycle, however, participants in this study performed 15 compressions per cycle.

While this study did have limitations with compression ratio following the outdated 2010 AHA CPR Guidelines and using simulation manikins as a surrogate for obese and morbidly obese CPR patients, the results considering effective CPR on endomorphic physiques warrants further investigation. A specific area needing further examination is the use of mechanical compression and feedback devices that are now available to assist in administering quality compressions (Tellson et al., 2017). Moreover, a study should be conducted looking into the prevalence of survival after discharging an obese or morbidly obese individual after performing in-hospital CPR. Furthermore, future research should examine outcomes as well as effectiveness of compressions in combination with rescuer characteristics. The aim of this content is to increase quality of chest compressions among different individual providers. Researchers need to develop innovative methods for performing successful CPR on obese and morbidly obese patients; if not, the mortality rate, specifically in the endomorphic population, will remain at an unacceptable level (Tellson et al., 2017).

In recent data collected by the Global Burden of Disease Collaborators, the prevalence of obesity has reached new levels, thus increasing a range of cardiopulmonary conditions that predispose individuals to cardiac arrest (Secombe et al., 2018). As the purpose of CPR is to “temporarily maintain circulation sufficient to preserve brain function,” inadequate CPR can be associated with poor clinical outcomes due to delay in treatment or improper chest compressions (Secombe et al., 2018, p. 171). In a recent study evaluating healthcare providers administering CPR on modified obese manikins, participants demonstrated that proper chest compression depth associated with the AHA guidelines of 2.0-2.5 inches was not obtained due to excessive tissue in the chest region. Researchers hypothesized that subcutaneous adipose tissue (SAT) encasing the thoracic region of the morbidly obese individual redistributes the forces applied on the chest wall during CPR; this results in a reduction in accuracy and effectiveness of compressions performed (Secombe et al., 2018).

During the prospective randomized controlled crossover study mentioned above, researchers explored the effect of performing thoracic chest compressions on a manikin modified to emulate a morbidly obese victim ($BMI = 40 \text{ kg/m}^2$). To create these manikins, vacuum sealed bags of porcine fat were inserted into the anterior and posterior compartments of a customized neoprene suit and then placed over a resuscitation Laerdal ALS Sim™ model. Compression sufficiency was assessed and compared between the morbidly obese and a standard manikin body frame. All 101 participants (nurses, paramedics, medical, etc. from the critical care department) were recruited from a critical care department at the Alice Springs Hospital. Participants were then randomized by coin toss to administer two minutes of uninterrupted chest compressions on one model followed by a minimum five-minute break before beginning two minutes of uninterrupted chest compressions on the other manikin (Secombe et al., 2018).

Compression depth (measured in cm), rate (measured as compressions per minute [CPM]), and recoil (measured as mean release velocity [MRV]) were measured using a ZOLL X Series®. For the obese manikin, the accelerometer was placed under the anterior fat pad to measure movement of the sternum. Before each participant began their trial, proper chest compression guidelines were reviewed, and all participants listened to a metronome set to 110 beats per minute for 30 seconds to understand the pace at which they were to administer compressions on the manikin.

The primary outcome measure was sufficient chest compressions, a composite measure of adequate compression rate (100-120 CPM for more than 80% of the time), proper compression depth (more than 80% of compressions reaching a depth of 5 cm), and correct recoil (MRV > 350 mm/second). Secondary outcome measures focused on accuracy of each component, participant-perceived measures of effectiveness, fatigue, and pain via ten-point visual analogue questionnaire (VAQ). Data were analyzed in Statistica™ and reported as a mean for normally distributed data, and median (interquartile range) for abnormally distributed data for categorical variables (Secombe et al., 2018). Additionally, Student's t-test or Mann-Whitney U test were analyzed for continuous parametric and non-parametric data; furthermore, χ^2 analysis was performed for categorical data. ANOVAs were used for multiple within-group analysis. Lastly, multiple linear regressions were used to assess factors that predicted sufficiency of chest compressions on the obese manikin. From this study, researchers concluded the primary outcome was lower than expected for the control group (standard manikin), which can be observed in Table 2. In addition, there was a significant decrease for the obese group ($p < .001$). Finally, there was a significant difference between the control and experimental group for each component of quality CPR (Table 2) (Secombe et al., 2018). There was no significant difference for the mean rate achieved for either group ($p = .18$) or in each quartile (Table 2). However, there

was a significant difference in both groups for overall mean depth achieved and in each quartile ($p < .001$ for all), as well as overall MRV and in each quartile ($p < .001$ for all) (Secombe et al., 2018). During the two minutes of CPR, a reduction in adequate chest compressions was calculated and can be observed in Table 2.

Table 2.2

Outcome Data for Compressions

	Control	Obese	<i>P</i> *
Adequate Compressions, n (%)	30 (29.7%)	4 (4.0%)	<0.001
Adequate rate, n (%)	52 (51.5%)	27 (26.7%)	<0.001
Adequate depth, n (%)	82 (81.2%)	8 (7.9%)	<0.001
Adequate MRV, n (%)	65 (64.4%)	39 (38.6%)	0.003
Mean compression rate, CPR mean (SD)	111.92 (7.42)	110.52 (8.80)	0.18
Mean compression depth, cm, mean (SD)	6.09 (1.3)	3.80 (0.91)	<0.001
MRV, mm/s, mean (SD)	412.59	323.72	<0.001

As researchers analyzed the results of the control group, there were significant deteriorations in adequacy of compression depth and recoil occurring later when compared to the obese group (Table 3) (Secombe et al., 2018). Additionally, there was a significant difference in perceived effectiveness, fatigue, and pain ($p < .001$ for all) in support of the control group, which can be observed in Table 3 (Secombe et al., 2018). Another notable finding among the groups was the inability to achieve sufficient depth of compression (3.1 cm vs. 6.9 cm for the obese and control groups) and failing to allow proper chest wall recoil (323.7 mm/s vs. 412.6 mm/s) (Secombe et al., 2018).

Table 2.3*Outcome Data for Compressions Based on Visual Analog Questionnaire*

	Control	Obese	<i>P</i> *
Effective VAQ, median (IQR)	7 [6-8]	5 [3-6]	<0.001
Fatigue VAQ, median (IQR)	5 [3-6]	7 [5-8]	<0.001
Pain VAQ, median (IQR)	2 [1-3]	3 [2-5]	<0.001

Current AHA Guidelines for two-rescuer CPR recommend rotation of rescuers at least every two minutes during CPR to decrease the emergency responder's fatigue. For both groups, fatigue was observed, which was indicated by a significant reduction in rate, depth, and MRV over the two-minute timeframe. Focusing on the obese group, fatigue, compression rate, depth, and MRV occurred at a much faster rate over the two-minute period as compared to the control group. The researchers reported 96% of trained healthcare providers in this study demonstrated chest compressions at the correct rate, depth, and recoil. However, when researchers analyzed findings in the obese group, chest compression rate, depth and recoil were significantly impaired due to the increased depth of SAT surrounding the anterior thoracic wall. Further research must focus on identifying adequate chest compression rate, depth, and recoil on an obese patient to provide proper life-saving measures when a cardiac arrest episode occurs.

In the 2010 International Liaison Committee on Resuscitation, the need to deliver high-quality chest compressions by pushing hard and fast to a depth of at least two inches (or five cm) at a rate of 100 compressions per minute was emphasized. Moreover, allowing full chest recoil with minimal interruptions during each chest compression allows blood flow and oxygen delivery to the myocardium as well as the brain due to increasing intrathoracic pressure and directly compressing the heart (Lee et al., 2015). With the anteroposterior (AP) chest diameter varying from person to person, the chest compression depth of 50 mm or greater cannot be

uniformly applied to all adults. In another study focusing on CPR performed on diverse physiques, the purpose was to evaluate the appropriate chest compression depth recommended by the 2010 AHA Adult CPR Guidelines and to depict optimal chest compression depths for adults with diverse BMIs using chest computed tomography (CT) (Lee et al., 2015).

Additionally, researchers focused on calculating and estimating residual internal chest depth if simulated external chest compressions at one-half, one-third, and one-fourth AP chest depth were administered (Lee et al., 2015). All patients in this study had to be older than 18 years of age; each participant underwent a precontrast low-dose chest CT as a screening for any latent pulmonary diseases. Individuals suffering from severe thorax deformity (funnel chest, pectus excavatum/carinatum, chest hypoplasia) were excluded. A total of 293 consecutive retrospective chest CT scans were reviewed and analyzed for each BMI category: <18.50 , $18.50-24.99$, $25.00-29.99$, and ≥ 30.00 kg/m². Additionally, using CT reconstruction, each individual's internal and external chest depths were measured, and residual internal depth resulting from several simulated chest compression depths were calculated (Lee et al., 2015). Further examination was conducted on the percentage of patients who had less than 20 mm of residual chest depth during a simulated 50-mm, one-half, one-third, and one-fourth external AP chest depth compression. The reason behind using 20 mm of residual chest depth as a cutoff is due to potentially injuring the intrathoracic structures. All continuous values are presented as a mean and standard deviation (SD). One-way analysis of variances among groups and univariate linear regression analysis were used to compare the average depth of chest compressions during one-half, one-third, and one-fourth external chest depth. Additionally, internal AP diameter (IAPD) and external AP diameter (EAPD) along the midpoint of the lower half of the sternum were measured and compared based off of the BMI group (Lee et al., 2015).

As a total of 293 patients underwent precontrast low-dose chest CT during the study period (218 men, 75 women), there was a statistically significant difference in the chest EAPD and IAPD measured along the lower half of the sternum for each BMI group (EAPD: $R^2=0.638$; IAPD: $R^2=0.297$ (Lee et al., 2015). Additionally, with the internal chest depths, the residual internal chest depth measurements available for compression also increased with each BMI group ($p < 01$). Patients in each BMI group had less than 20 mm of residual internal chest depth during a five cm, one-fourth, one-third, and one-half AP external chest compression. Patients who showed a residual internal chest depth less than 20 mm were the one-third external AP chest compressions (6.48% [19 of 293]) and 100% of the patients in the one-half external AP chest compressions (Lee et al., 2015).

In conclusion, current AHA CPR Guidelines regarding chest compression depth of 50 mm or greater is not appropriate in the ratio of EAPD and IAPD based on each BMI group. Over the years, chest compression depth recommendations have changed. In 2010, the AHA and ERC guidelines suggested the adult sternum be depressed to at least two inches (5 cm) for resuscitation, and the first responder should push hard and fast when administering effective chest compressions. Furthermore, deeper chest compressions of 50 mm or greater are needed to help improve short-term outcomes for cardiac arrest episodes (Lee et al., 2015). In this study, the average EAPD and IAPD depths of the chest measured at the lower half of the subject's sternum increased significantly with each BMI group ($p < .001$ for both groups). These results indicate chest compression depth should increase when the patient's BMI is higher to maintain consistent ratio of chest compression depth to AP diameter of the chest (Lee et al., 2015).

Table 2.4*Demographic Data and Internal and External Chest Depth by BMI in Study Group*

Variables	Total	<18.5	18.50-24.99	25.00-29.99	≥ 30.00	<i>P</i>
EAPD (cm), mean ± SD	22.00 ± 2.13	18.52 ± 1.56	21.22 ± 1.65	23.35 ± 1.37	25.32 ± 1.12	<0.001
IAPD (cm), mean ± SD	10.79 ± 1.48	8.87 ± 1.44	10.42 ± 1.36	11.55 ± 1.16	12.09 ± 1.06	<0.001

There are three main theories related to forward blood flow during CPR, the aortic pump theory, the thoracic pump theory, and the cardiac theory. The aortic pump theory was introduced by the analysis of CT images to direct chest compressions predominately at the aorta. However, the idea of forward blood flow remains controversial, resulting in debates of the role of the heart during CPR. Nevertheless, adequate chest compression depth should not only provide optimal cardiac output with maximal coronary and cerebral perfusion, but also stop an increase in unwanted complications of injury to the intrathoracic structures. To maximize cardiac stroke volume (volume of blood pumped from the left ventricle per beat) as well as coronary blood flow (circulation of blood in the blood vessels that supply the heart muscle), manual massage should be administered with high-rate, brief duration compressions using moderate force (Lee et al., 2015). In the aforementioned study, the percentage of patients receiving less than 20 mm of residual chest depth during a simulated 50 mm, and a one-fourth/one-third/one-half EAPD chest depth are as follows: 0.68% for 50 mm, 0.00% for one-fourth EAPD, 6.48% for one-third EAPD, and 100% for one-half EAPD. Theoretically, the chest compression depth of one-half EAPD may not be safe for all adults. In all one-half EAPD BMI groups, patients would have no residual internal depth in the thorax and may be impossible to achieve proper chest compression depth. However, if proper compression depths can be achieved, it can potentially harm internal and external structures being compressed in the chest. These findings may suggest a one-fourth

EAPD chest compression for each BMI group to be a safer alternative for the recommended chest compression depth by current adult CPR guidelines. In conclusion, it is not appropriate to have current chest compression depth of ≥ 50 mm applied uniformly in all adults due to safety and efficacy. Simulated chest compressions targeting between one-third and one-fourth EAPD chest compression depths may be more appropriate for all body physiques.

With a limited amount of studies focusing around endomorphic physiques in the athletic population, emergency responders performing the current CPR chest compression guidelines may not be performing a proper medical intervention. Due to obese individuals having a thicker anterior thoracic wall, researchers suggest chest compression depths of 2.0-2.5 (5 cm) or five cm may not reach adequate compression depth or achieve full chest recoil to achieve sufficient blood flow and oxygen delivery to the remainder of the body, specifically the brain. Further CPR training courses on various manikin body physiques need to be implemented, while CPR guidelines need to be updated for all healthcare providers to make sure all individuals suffering from a cardiac arrest episode are provided the proper life-saving actions to increase survivability for both in-hospital and out-of-hospital patients.

2.4. CPR: Over or Under Athletic Equipment

According to the 2012 National Athletic Trainers' Association (NATA) Position Statement related to the prevention of sudden cardiac death (SCD) in the athletic population, guidelines indicate the removal of protective equipment being the best form of treatment. Reasoning behind this decision is due to the concern that protective equipment will prevent access to the airway or chest when performing CPR (Casa et al., 2012). There is no mention in the NATA Position Statement that protective equipment could prevent quality CPR from being performed on the athlete. In addition, there is a lack of research concerning the limitations an

emergency responder may encounter if performing CPR over protective equipment.

Additionally, with athletes who have an endomorphic physique, CPR training courses already have limited guidelines for such specific individuals related to proper chest compression depth and rate. Emergency responders may not be administering proper life-saving actions during CPR and with shoulder pads being an additional external factor, this may further delay life-saving procedures.

With SCA being an unexpected event for athletes wearing protective equipment, timely initiation of high-quality CPR and early defibrillation are key components to increase survivability. Although SCA is a rare event taking place in young athletes, statistics on survival rate is largely dependent on the start of CPR to defibrillation (Waninger et al., 2014). The most important factor an emergency responder must do is maintain suitable coronary and cerebral blood flow through effective CPR administration. However, the addition of protective equipment (shoulder/chest pads) in sports, such as football, poses an additional challenge to rescuers because the equipment may block access to the chest, thus delaying initiation of CPR chest compressions (Waninger et al., 2014).

In one exploratory study, researchers designed a test to investigate whether chest compression quality over protective equipment was similar to compression quality under pads. Furthermore, researchers wanted to evaluate CPR adequacy during a simulated cardiac arrest event for an equipped football player to investigate whether the equipment impedes CPR performance measures. Participants in this study consisted of 30 BCLS-certified athletic training undergraduates, licensed graduate students and six certified emergency department technicians. Each participant performed CPR on a Laerdal SimMan 3G interactive manikin simulator, which was equipped with Riddell Power shoulder pads and helmet. Before the intervention took place,

baseline data were collected for each subject during a two-minute CPR sequence without equipment; additionally, subjects were instructed to follow the 2010 AHA CPR Guidelines (compressions at 100/minute to 51 mm depth). Once complete, participants were given a standardized rescuer scenario and told perform three sequences of compression-only CPR for two-minute cycles (Waninger et al., 2014). Each participant alternated two-minute sequences of CPR administered either over protective football shoulder pads (“compression over pads”) or under unlaced shoulder pads (“compression under pads”). Three trials of two-minutes of CPR (baseline, over pads, under pads) were completed by all subjects (Waninger et al., 2014). The primary outcomes during this study consisted of: average compression depth (mm), average compression rate (per minute), percentage of the time chest wall appropriately recoiled, and percentage of hands-on contact during compressions (Waninger et al., 2014). Moreover, for exploratory purposes only, with a lack of formal sample size calculation for statistical power, statistical analysis contained separate Wilcoxon signed rank and Kruskal-Wallis tests (Waninger et al., 2014).

Results of this experiment included no statistically significant difference between the certified emergency department technicians, certified athletic training undergraduates, and licensed graduate students. Subgroups were combined ($n = 36$) for analysis of adequate CPR compressions over and under the shoulder pads. Compression depth was much deeper under shoulder pads as compared to compressions performed over the pads ($p = 0.002$), with median depths of 37.0 and 31.50 mm, respectively (Waninger et al., 2014). Interestingly, there were no significant differences found for compression rate ($p = 0.20$) or chest wall recoil (100% for both groups) (Waninger et al., 2014). Although there was no significant effect on chest compression rate or chest wall recoil, there was a 15% decrease of chest compression depth when

administered over pads. The key finding of this study was the fact that none of the participants were able to reach the recommended chest compression depth when the patient was wearing pads.

Table 2.5

Compression Depth and Rate Under and Over Equipment

Group	Median (Interquartile Range)	P**
CPR compression depth (n = 36)		
Under equipment	37 (31-39)	0.002
Over equipment	31.50 (28-35.50)	
CPR compression rate (n = 36)		
Under equipment	113 (101.25-125)	0.20
Over equipment	118 (103.25-130.75)	

When comparing the results from this study to another performed by Del Rossi et al. (2011), Del Rossi et al (2011) found chest compressions over equipment had a faster delivery time than removing the shoulder pads (Waninger et al., 2014). The purpose of Del Rossi’s study was to investigate the average amount of time lost to perform CPR due to the removal of chest protection in athletes (Del Rossi et al., 2011). Furthermore, researchers also evaluated whether or not it would be possible to administer effective chest compressions over chest protector pads. When determining how protective athletic equipment affects the delivery of CPR, Del Rossi and his colleagues performed a prospective, randomized crossover study where both standard and modified rescue protocols were evaluated (Del Rossi et al., 2011). For this investigation, certified athletic trainers are the primary responders for sporting events and are more likely to initiate CPR. Two rescue protocols were evaluated to understand which procedure created a higher chance of survival for athletes during out-of-hospital CPR. The control group consisted of investigating current NATA guidelines of removal of the facemask and unfastening the chest

protector/shoulder pads to gain access to both the airway and chest (Del Rossi et al., 2011). For the experimental group, removal of the facemask was still a requirement for the certified athletic trainers to perform but subjects were instructed to deliver chest compressions over the chest protector (Del Rossi et al., 2011). Results of Del Rossi's (2011) study found the presence of athletic equipment significantly delayed the onset of CPR administration; more specifically, removal of the facemask and shoulder pads considerably delays the initiation of chest compressions (Del Rossi et al., 2011). Although chest compressions were initiated sooner, complete chest recoil was not attained (Del Rossi et al., 2011). When comparing differences in study design, manikins used for each experiment may have played a role in data collection. Additionally, Del Rossi et al (2011) considered the percentage of participants who delivered CPR compressions to the recommended depth where Waninger and fellow researchers focused on average depth of compressions over and under equipment (Waninger et al., 2014). Based off the results found in Waninger's (2014) study, it is recommended that chest protector/shoulder pads be systematically removed or unfastened; however, removal of the equipment does present with a significant time commitment (approximately 24.4 seconds to manage padding) that may impact the athlete's chance of survival. For every one-minute delay in starting CPR, the chances of survival for all individuals suffering from a SCA episode drops 18% per minute. Performing immediate CPR without helmet removal for airway management is supported by recent guidelines suggesting compression-only CPR is as effective as standard CPR with rescue breaths for out-of-hospital cardiac arrest events (Waninger et al., 2014).

While administering chest compressions over shoulder pads does initiate chest compressions sooner for an individual, timing and depth are factors that need to be taken into consideration. From the study mentioned above, chest compressions under equipment were

performed deeper as compared to over the pads. Additionally, incomplete decompression of the chest (recoil) has been shown to have a harmful effect to both coronary and cerebral perfusion pressures. If coronary and perfusion pressures are not met, a negative impact to the patient's cardiac ability to draw venous blood back to the heart will not occur (Waninger et al., 2014). Although this study found most of the rescuers not meeting the 2010 AHA CPR Guidelines for compression depth, results indicated more consistent compression depth with CPR being performed under the shoulder pads as compared to over the pads. However, there is limited CPR research concerning chest compressions on actual patients with equipment, thus clinical significance of changes to compression rate and depth are unclear. Although clinical outcomes observed a 15% difference in compression depth, chest compressions under the pads will significantly increase depth of compressions and more closely reach AHA Guidelines for chest compression depth in cardiac arrest patients. Furthermore, with athletic trainers taking on average (24.4 ± 7 seconds) to manage equipment and achieve access to the chest for hands-on placement for CPR, survival rates after ventricular fibrillation decreases approximately 7-10% with every minute defibrillation is delayed (Waninger et al., 2014).

Out-of-hospital cardiac arrest (OHCA) events are a global health concern, in the United States alone there are over 350,000 people experiencing a cardiac arrest episode every year. The 2015 AHA CPR Guidelines highlighted the first line of the OHCA Chain of Survival, which is recognition of cardiopulmonary arrest (CPA) by bystanders. This is important because these individuals are the first line of care and can provide high-quality CPR for improved survival rates (Tanaka et al., 2017). High-quality CPR is defined as: a rate between 100 and 120 compressions per min (cpm), allowing complete chest recoil after each compression, minimizing interruptions between chest compressions, and avoiding excessive ventilation to the patient.

Additionally, to increase survival rate, chest compressions must meet at least 50 mm when performed. When administering chest compressions, if a rescuer goes farther than 6 cm in depth, this can result in internal organ injuries. However, if an individual has a larger body mass, these guidelines may not produce the same results of injuries to the chest because of the extra adipose tissue surrounding the thoracic region. Even though there is a suggested universal chest compression depth, guidelines determined by the AHA have yet to be considered for other body types.

In a recent study, the purpose was to investigate if previous CPR training, the presence of an audiovisual feedback, and the presence of wearing football shoulder pads (FSP) effects the compression depth and rate when administering CPR on a football athlete (Tanaka et al., 2017). Researchers hypothesized there would be no significant differences in CPR quality between all groups, CPR quality would significantly increase with the use of audiovisual feedback, and all individuals would be able to perform the recommended depth of chest compressions accurately. With a single rescuer, the level of chest compressions would decrease as fatigue level increased; therefore, high-quality CPR would not be performed. However, by using the audiovisual feedback device, this may increase CPR proficiency by helping rescuers achieve optimal chest compression depth and rate (Tanaka et al., 2017). A total of 18 participants were divided into three groups as follows: six BLS-ATS, six BLS-EMS, and six ACLS-EMS (advanced cardiovascular life support). A Little Anne CPR® manikin was used in this study and FSP were fitted to each manikin according to the manufacturer's guidelines.

Data collection for chest compressions was measured using two AED Pro's while the audiovisual feedback system (Real CPR Help) was installed; the CPR Stat-padz was configured to the 2015 AHA CPR Guideline recommendations of five to six centimeters for compression

depth and a rate of 100-120 cpm (Tanaka et al., 2017). Regarding the Real CPR Help, feedback was given both visually and audibly. However, due to the start time of data collection, audio feedback did not follow the 2015 AHA CPR Guidelines rather 2010 AHA CPR Guidelines of compression rate for the audio feedback. The dependent variables for this experiment included chest compression depth (cm), rate (cpm), depth accuracy (%) and rate accuracy (%); captured data during the trials were analyzed using ResueNet Code Review. Compression depth was calculated as the depth of each compression divided by the number of compressions per second; moreover, compression rate was calculated by the rate of each compression divided by the number of compressions per second. The number of performed compressions within the target zone (depth of five to six centimeters) was divided by the total number of compressions equal to the depth accuracy. Furthermore, rate accuracy was calculated by the number of performed compressions within the target zone rate (100-120 cpm) divided by the total number of compressions performed (Tanaka et al., 2017).

A quasi-experimental, repeated measures design was used to examine the quality of CPR performance by trained emergency responders when performed on the following conditions: audiovisual feedback and FSP. Each participant visually and verbally reviewed the current 2015 AHA CPR Guidelines and were instructed to administer chest compressions for three different conditions (after baseline measurements were administered [two-minute chest compressions without audiovisual feedback and FSP]): two minutes of chest compressions with audiovisual feedback, two minutes of compressions with feedback and FSP, and finally compressions with only FSP and no feedback. Each subject was allowed a one-minute break between each condition. Results of all participants' compression depth are as follows: 5.7 cm at baseline, 5 cm on FSP, 5.9 cm with feedback, and 5.1 cm with feedback and FSP. For depth accuracies, the

median results included: 13.8% at baseline, 23% with FSP, 69.6% with feedback, and 40.6% for FSP and feedback (Tanaka et al., 2017). When comparing groups, both the BLS-ATS and BLS-EMS groups were able to compress to the recommended depth of five to six centimeters as stated by the 2015 AHA CPR Guidelines and median values were similar (Tanaka et al., 2017).

Table 2.6

Baseline CPR Performance

	Total	BLS-ATS	BLS-EMS	ACLS-EMS	P-value
Depth, median (IQR), cm	5.7 (4.7-6.4)	5.0 (4.4-6.1)	5.4 (4.1-6.4)	6.4 (5.7-6.7)	0.10
Rate, median (IQR), cpm	117 (103-139)	114 (96-131)	112 (99-131)	138 (113-140)	0.37

When evaluating effectiveness of audiovisual feedback while performing chest compressions, the BLS-ATS group had significant increases in depth accuracy to 71.3% (35.4-86.5) from 22.0% (7.3-36.2) ($p = 002$). However, all three groups had no significant differences with their ability to deliver accurate depth of chest compressions with which intervention they were performing. With conditions using FSP, participants compression depth was significantly shallower compared to baseline with each subject performing 5.7 cm (4.7-6.4 cm) at baseline and 5.0 cm (4.2-5.8 cm) with FSP ($p = 0.104$). With FSP, depth accuracies included: 13.8% (0.9-49.2) at baseline and 23.0% (2.3-50.7) with FSP ($p = 991$). There was no significant difference with FSP and the quality chest compression depth measurements. Analysis of the depth accuracy measurements for FSP with feedback are as follows: 13.8% (0.9-49.2%) at baseline and 69.6% (32.2-85.8%) with feedback, showing a significant difference ($p = 002$) in the quality of chest compression depth (Tanaka et al., 2017). Analysis of median rate measurements for all participants include: 117 cpm at baseline, 113 cpm with FSP, 106 cpm with feedback, and 105 cpm with FSP and feedback. As for median rate accuracy, the calculations are as follows: 17.1%

at baseline, 60.4% with FSP, 59.2% with feedback, and 57.7% with FSP and feedback (Tanaka et al., 2017). The researchers reported no change in rate accuracy between groups. Finally, in the FSP and feedback group, compression rate measurements were not affected significantly; participants recorded median rate accuracies of 17.1% (0-80.7%) at baseline and 60.4% (3.1-95.4%) on FSP ($p = .44$). Moreover, when feedback was given, participants performed 59.2% (17.3-74.3%) ($p = .50$) (Tanaka et al., 2017). Overall, researchers found medically trained personnel are able to perform appropriate chest compression rate and depth regardless of which trial group they were in. The addition of feedback improved the effective chest compression depth accuracy ($p = .0003$).

Table 2.7

CPR Performance Conclusions

	Baseline	FSP	p-value	Feedback	FSP+Feedback
Depth (cm)	5.0 cm (4.2-5.8 cm)	5.7 (4.7-6.4)	0.104	5.9	5.1
Depth Accuracy (%)	13.8 (0.9-49.2)	23.0 (2.3-50.7)	0.991	69.6% (32.2-85.8%)	40.6
Rate (cpm)	117	113		106	105
Rate Accuracy (%)	17.1	60.4	0.44	59.2	57.7

Contrary to the data reported by previous researchers, the data of the current study suggest initiating chest compressions over the FSP without hesitation, especially within the first two minutes of a cardiac arrest event. While an emergency responder is readily available to perform CPR in the first two minutes of collapse, other individuals (coaches, players, staff, etc.) have time to gather the AED and other tools needed to increase the individual's chance of survival. In the event of a single-rescuer scenario during a football game/practice, researchers suggest the following protocol based after their recent findings: verify scene safety, check level of consciousness, activate EMS and have bystander locate an AED, look/listen/feel for breath

sounds/chest movement/pulse, initiate chest compressions over FSP until other individuals can help, have others cut uniform and remove side strap of FSP during ongoing chest compressions, remove hands from chest and cut anterior portion of FSP with minimal interruptions in chest compressions, resume chest compressions within ten seconds, and finally apply AED during ongoing chest compressions (Tanaka et al., 2017). As certification levels between first responders and EMS personnel did not show any significant differences in CPR performance, the use of an audiovisual feedback device during chest compression-only CPR resulted in administering higher quality chest compressions. Introducing a feedback system into CPR training courses will allow emergency responders a chance to learn and alter their compression depth and rate to adapt to a diverse range of conditions (shoulder pads, body physiques, etc.) they may encounter.

2.5. Conclusion

In conclusion, future research is necessary to ensure emergency responders are able to administer adequate chest compressions during a cardiac arrest episode, not only for a patient with an endomorphic physique, but also for athletes wearing football shoulder pads. With limited research pertaining to these two factors, proper life-saving actions may be diminished, thereby decreasing the survival rate in this population. With an array of different body sizes emergency responders encounter, each rescuer must understand current AHA CPR guidelines do not provide the same outcomes for each patient. Currently, there is no universal regulation concerning chest compression depth or rate that works for each body type. Therefore, it is necessary for future research to develop evidence-based recommendations for cardiopulmonary resuscitation specific to chest compressions for endomorphic body sizes as well as those individuals wearing football shoulder pads.

3. METHODOLOGY

3.1. Purpose of the Study

The primary purpose of this study was to investigate emergency responders' ability to provide high-quality cardiopulmonary resuscitation (CPR) on individuals with an endomorphic body physique. The secondary purpose was to analyze whether emergency responders had the ability to meet current American Heart Association (AHA) CPR Guidelines on individuals with endomorphic physiques over football shoulder pads. The National Athletic Trainers' Association (NATA) position statement related to preventative actions for sudden death recommends removing all equipment (helmet, shoulder pads, etc.) that could inhibit access to the airway or chest for compressions (Casa et al., 2012). However, limited research is available regarding CPR parameters on endomorphic physiques, and the AHA does not have recommendations associated with CPR over athletic protective equipment. Thus, athletes with endomorphic physiques may not be receiving adequate care due to lack of information. The available research indicates CPR over football pads prevents rescuers from being able to perform full chest compressions that meet current compression depth requirements (Waninger et al., 2014). This study was designed to determine the appropriate protocol in the event of cardiac arrest in an endomorphic football player; furthermore, it answered the following questions:

Q1: What proportion of participants attain satisfactory performance on overall number of compressions, compression rate/depth, chest recoil, and mean depth/rate?

Q2: What is the relationship between participant demographics (age, gender, and years of experience in emergency medicine) and performance of dependent variables of CPR performance?

Q3: To what extent, if any, does the inclusion of football pads affect dependent variables of CPR performance?

Q4: To what extent, if any, does the endomorphic manikin condition affect dependent variables of CPR performance?

Q5: What is the difference between equipment versus no equipment conditions in time to delivering compressions?

3.2. Participants

A convenience sample of 50 emergency responders (5 emergency medical responders, 28 emergency medical technicians, 3 advanced emergency medical technicians, and 14 paramedics) between the ages of 18-65 were recruited via online recruitment flyer throughout the Midwest region. Inclusion requirements included current CPR/first-aid certification and association with the ambulatory systems in North Dakota: Jamestown, Lisbon, Casselton, and Valley City; Minnesota: Elbow Lake. Exclusion criteria for this study included any individuals who have current cardiovascular, respiratory, or musculoskeletal conditions that inhibited the participant from administering high-quality CPR at the time of each trial. Participants were provided with an informed consent form prior to participation, and a participant demographic form was completed to collect baseline demographic and clinical data for each participant. Each subject was rewarded for their participation with ten dollars following the completion of this study.

3.3. Equipment and Instruments

To measure the quality of CPR performed by each participant, the traditional manikin (Laerdal, Stavanger, Norway) as well as “Fat Old Fred” (endomorphnic) manikin (Life/form® Bariatric Manikin, Dublin, OH, USA) were used along with the Laerdal CPRmeter™ 2 (Laerdal Medical AS, Stavanger, Norway) software to measure CPR performance. Before the

experimental trial began, the endomorphic manikin as well as traditional manikin were fitted with Riddell Evolution football shoulder pads. Two different varieties of football shoulder pads were used to provide each manikin with appropriately sized protective equipment. Ventilations were not performed or measured during this study.

Measurements for quality of CPR were obtained through the Laerdal CPRmeter™ 2 software system, which was hand placed on both the traditional and endomorphic manikin's chest by the participants. This software analyzed compression rate/depth, chest recoil, mean depth, mean rate, mean peak force, and total number of compressions.

3.4. Procedures

Prior to participating, each subject completed the required informed consent and demographic forms. During this randomized and counterbalanced experiment, all participants were required to administer single-rescuer CPR for two-minutes on both the traditional manikin over and without Riddell Evolution shoulder pads as well as an endomorphic CPR manikin over and without Riddell Evolution shoulder pads. A total of four experimental trials were completed and recorded. For the trials that required the removal of jersey and protective equipment, participants were timed from the start of removal until they administered their first chest compression. Before each trial began, researchers read a script to the participant indicating the trial they were performing. Next, the researcher handed the participant a CPRmeter™ 2 device, which they placed on the manikin's chest in the location where they would place their hands during chest compressions. Each trial was conducted for two-minutes with three-minutes of rest between each trial. To keep consistency throughout the trials, participants were unable to view any visual feedback data on the CPRmeter™ 2 device regarding their overall performance. Furthermore, participants were not allowed to see a clock to prevent changes in their

performance due to objective feedback. Researchers did not provide any feedback or encouragement to the participants because such actions had the potential to influence participants' CPR performance or self-efficacy in completing the task.

Measurements of participants' overall performance were saved and recorded in Laerdal CPRmeter™ 2 software with a deidentified number. The values documented from each testing trial consisted of: chest compression depth/recoil, compression rate, mean depth, mean rate, mean peak force, and total number of chest compressions. Upon completion, subjects were paid ten dollars for their time and participation.

3.5. Documentation

Preceding data collection, this study was approved by the Institutional Review Board at North Dakota State University. Subjects were instructed to read and sign the informed consent provided to them. In addition, participants completed a demographics form that addressed factors including age, gender, level of experience, years of experience, and years of CPR certification for data analysis purposes.

3.6. Statistical Analysis

Data were analyzed for each of the four conditions using descriptive statistics to measure mean and standard deviation of the participants' performance related to average depth, average force, average rate, and overall number of compressions. Mixed-effect linear models were estimated to reflect the repeated measure experimental design. The use of hierarchical regression models were fitted to determine whether or not the condition had a statistically significant effect. Next, a chi-squared (χ^2) test was conducted with manikin type, presence or absence of shoulder pads, and their interaction as independent factors with biological sex and months of experience

as covariates. Finally, three percent variables were not normally distributed, so data was transformed into binary observations at the midpoint of 50%.

3.7. Conclusion

The primary purpose of this study was to investigate emergency responders' ability to provide high-quality CPR on individuals with an endomorphic body physique. The secondary purpose was to research participants' ability to perform CPR that meets the current AHA CPR Guidelines. Emergency responders encounter a plethora of body types and need to be prepared to administer high-quality CPR at any given moment for all individuals. Results from this study should be added to existing evidence-based recommendations for future CPR protocols. In addition, statistical findings are valuable to determine if football pads on either standard body types or endomorphic individuals should be removed instantaneously or remain in place as a rescuer administers chest compressions without hesitation. With a deeper understanding of how football pads influence the efficiency of CPR performance, as well as the effect of an endomorphic physique on the adequacy of CPR performance, best-practice guidelines can be identified to increase the cardiac arrest survival rate.

4. MANUSCRIPT

4.1. Introduction

Although emergency medical service (EMS) personnel typically attend high school and collegiate football games to assist with medical coverage, there are currently no national requirements mandating emergency responders to be present at athletic events (Robertson, 2016). However, the National Collegiate Athletic Association (NCAA) has made it common practice for EMS personnel to be readily available on the sidelines during American Football games (Parsons, 2014). EMS personnel are required to attend all football championship games, but not during regular season within the National Association of Intercollegiate Athletics (NAIA). Furthermore, NAIA guidelines vary from conference to conference depending on the sporting event (NAIA Championship Event Emergency Action Plan, n.d.). As a result, due to lack of mandated requirements for EMS coverage for all sporting events, appropriate medical coverage may not be readily available when an athlete suffers a sudden cardiac arrest episode (SCA).

During emergency responders' cardiopulmonary resuscitation (CPR) training curriculum, rescuers are assessed on both their knowledge of CPR Guidelines and overall CPR skill performance (Brown et al, 2006). In the event of SCA, emergency responders are expected to provide CPR following current American Heart Association (AHA) CPR Guidelines, which include: chest compression depth of 2-2.4 inches (50-61mm), 100-120 compressions/minute, and full chest recoil between each compression (Kleinman et al., 2015). Interestingly, research suggests knowledge of CPR has little impact on psychomotor skill performance and ability to meet the guidelines set forth by the AHA (Aufderheide et al., 2005; Brown et al., 2006). Though emergency responders attend biannual CPR training courses, studies have suggested they are not

proficient with their performance (Aufderheide et al., 2005; Brown et al., 2006). Specifically, emergency responders struggle to meet CPR guidelines for chest compression depth and recoil as well as ventilation volume, thereby decreasing survivability rate amongst individuals suffering from SCA (Aufderheide et al., Brown et al., 2006; Tomlinson et al., 2007; Beesems et al., 2015).

Within the athletic population, the protective equipment used in contact sports, such as football, poses a unique challenge for emergency responders. For instance, protective equipment blocks access to an athlete's airway and chest, thus delaying initiation of CPR or potentially providing a barrier for performance of chest compressions (Del Rossi, 2011). In an investigation of athletic trainers, researchers found it took approximately 24.4 seconds, on average, to remove protective equipment from an athlete suffering a SCA episode before administering the first chest compression (Del Rossi, 2011). However, limited research has investigated emergency responders' ability to remove protective equipment from equipment-laden athletes (Waninger et al., 2014; Tanaka et al., 2017). The current curriculum for paramedics or emergency medical technicians (EMTs) does not address the education needed for suitable protective equipment removal (Jones & Bartlett, 2016). The absence of guidelines and education may contribute to emergency responders taking longer to initiate chest compressions on an equipment-laden athlete suffering from a SCA episode.

Equally important, researchers also compared CPR performance over and under protective equipment and found chest compression depth decreased approximately 15% when performed over protective equipment as compared to directly on the chest (Waninger et al, 2014; Tanaka et al., 2017). Further, research suggests performing shallow chest compressions over protective equipment has a similar effect to no chest compressions. As a result, a reduction in overall functional cardiac output as well as a decrease in blood flow can occur to vital organs and

the brain (Edelson et al., 2006). Due to limited research focusing on equipment-laden athletes suffering from SCA, emergency responders are unaware whether performing chest compressions directly on the chest or over protective equipment will increase survivability.

During coverage of sporting events, EMS personnel are likely to encounter a diverse range of body physiques. An individual's physique can be associated with body mass index (BMI) and be correlated to the amount of adipose tissue found within the body. BMI classifies individuals into the following categories: obese (endomorph), overweight, normal/healthy, and underweight. Within the sport of football, players may range in BMI from obese to normal/healthy depending on a player's position; thus, emergency responders must be prepared to perform CPR on all BMI categories. For example, linemen average a BMI of 35.85 kg/m² or higher, classifying them as obese (≥ 30 kg/m²). Excessive adipose tissue in obese athletes is primarily found within the thoracic region, so administration of CPR requires increased force on the chest to reach an appropriate compression depth of 50-61 mm (Kraemer et al., 2005; Lee et al., 2015; Tellson et al., 2017; Elagizi et al., 2018). Due to the vast array of body physiques within the sport of football, it is imperative emergency responders understand how to alter their force during chest compressions to reach the appropriate depth of 50-61 mm on all body physiques.

Out-of-hospital SCA may occur during sporting events, and effective CPR must be initiated as soon as possible to increase the likelihood of a positive outcome (Ristagno et al., 2007; Meaney et al., 2013). There is minimal research investigating emergency responders' ability to perform CPR over athletic protective equipment (Waninger et al., 2014; Tanaka et al., 2017). Equally important, current evidence suggests emergency responders are unable to meet CPR Guidelines for both traditional and endomorphic body physiques (Aufderheide et al., 2005;

Brown et al., 2006; Tomlinson et al., 2007; Waninger et al., 2014; Tanaka et al., 2017).

Therefore, the purpose of this study was to evaluate whether emergency responders had the ability to meet 2015 AHA CPR Guidelines on equipment-laden athletes. Furthermore, this study investigated emergency responders' ability to provide high-quality CPR on individuals with both traditional and endomorphic body physiques. Based on existing literature, we hypothesized emergency responders would meet current CPR requirements on a traditional manikin but would fail to achieve appropriate depth and recoil for manikins with equipment or endomorphic manikins.

4.2. Methods

4.2.1. Study Design and Population

This was a randomized and counterbalanced experiment utilizing a population of 50 emergency responders (5 emergency medical responders, 28 emergency medical technicians, 3 advanced emergency medical technicians, and 14 paramedics) (Mean age: 36.18 ± 12.24 ; Mean years of experience: 8.39 ± 8.35) with level of experience ranging from emergency medical responder (EMR) to paramedic. Table 4.1 represents the number of participants in each EMS category who completed all four trials during this study. Inclusion criteria consisted of current CPR/first-aid certification and association with ambulance services in the Midwest region. Exclusion criteria included any current cardiovascular, respiratory, or musculoskeletal conditions that inhibited the participant from administering high-quality CPR at the time of the trial.

Table 4.1

Number of Participants for Each EMS Category

Category	Number of participants
Advanced emergency medical technician (AMET)	3
Emergency medical responder (EMR)	5
Emergency medical technician (EMT)	28
Paramedic	14

4.2.2. Procedures

Prior to participant recruitment, this study was approved by the Institutional Review Board at a Land Grant university. After finalizing the informed consent form, participants completed a demographics form, which included the following information: location of employment, gender, age, years of employment, years of CPR/first-aid certification, how many times participants performed CPR, and level of experience. Following the completion of paperwork, participants completed two-minute trials of single-rescuer CPR under four separate conditions following the 2015 AHA CPR Guidelines (compression depth of 2-2.4 inches [50-61 mm]; compression rate of 100-120 compressions per minute; full chest recoil after compression). In lieu of ventilations, participants were given a 10-second break to simulate the time it would take a second rescuer to provide ventilations.

The four conditions included a traditional manikin over protective equipment (TOPE), traditional manikin under protective equipment (TUPE), endomorphic (“Fat Old Fred”) manikin over protective equipment (EOPE), and endomorphic manikin under protective equipment (EUPE). The athletic equipment each manikin was fitted with were Riddell Evolution football shoulder pads (specifically for an offensive lineman and a wide receiver). At the end of each trial, participants were allowed a three-minute break before beginning the next trial. Two

different manikins were used to simulate different body types emergency responders may encounter (Laerdal, Stavanger, Norway; Life/form® Bariatric Manikin, Dublin, OH, USA).

Before each of the four trials, researchers read an oral script to the participant, which indicated the condition they were expected to perform. To evaluate jersey and equipment removal during the TUPE and EUPE conditions, researchers recorded the time (in seconds) from the start of equipment removal to the initiation of the first chest compression. Chest compression data were obtained by a CPRmeter™ 2 device (Laerdal Medical AS, Stavanger, Norway), a handheld tool that provides real-time measured feedback on components of CPR that include: number of chest compressions, compression rate percentage, compression depth percentage, compression recoil percentage, average peak force (kg), mean rate (mm), and mean depth (compressions/minute).

After reading the oral script, researchers handed the CPRmeter™ 2 device to the participant and instructed them to apply the device directly on the manikin's chest in the location they would place their hands for chest compressions. After each trial was completed, researchers transferred the data to the Laerdal software system via mobile phone application with a deidentified number. Throughout the entirety of the study, participants were unable to view any visual feedback on the CPRmeter™ 2 device because researchers wanted to observe participants' performance as opposed to receiving feedback that could have allowed them to adjust their technique. Furthermore, researchers did not provide oral feedback or encouragement during the trials, as this could have influenced participants' overall performance.

4.2.3. Data Documentation

Information documented from the CPRmeter™ 2 device included: number of chest compressions, compression rate percentage, compression depth percentage, compression recoil

percentage, average peak force (kg), mean rate (mm), and mean depth (compressions/minute). For qualitative analysis of participants' performance, researchers documented the participant's techniques for jersey and equipment removal (e.g. cutting center strings, untying center strings, unbuckling side straps) when they performed chest compressions under football shoulder pads.

4.2.4. Statistical Analysis

Data were analyzed for each of the four conditions using descriptive statistics to measure mean and standard deviation of the participant's performance related to average depth, average force, average rate, and overall number of compressions. Mixed-effect linear models were estimated to reflect the repeated measure experimental design. The use of hierarchical regression models were fitted to determine whether or not the condition had a statistically significant effect. Next, a chi-squared (χ^2) test was conducted with manikin type, presence or absence of shoulder pads, and their interaction as independent factors with biological sex and months of experience as covariates. Finally, three percent variables were not normally distributed, so data was transformed into binary observations at the midpoint of 50%.

4.3. Results

The data are comprised of two independent variables, namely biological sex (32 men and 18 women) and months of experience (M=100, SD=99.4). Data were collected in four conditions: TOPE, TUPE, EOPE, and EUPE. Results of seven dependent variables were recorded. In four cases, the dependent variables are continuous measures which include: number of compressions, average depth (mm), average rate (compressions/minute), and average force (kg). The other three dependent variables were measured as percentages: compression rate, depth, and recoil.

The seven dependent variables are summarized in Table 4.2. The means and standard deviations are provided for each of the four conditions. Data exploration revealed the three percentage variables were not normally distributed, and with most observations nearing zero or one, the data were transformed into binary observations at the midpoint of 50%. Additionally, Table 4.2 provides the number of participants who had successful CPR performances, which was defined as a percent greater than 50%.

Table 4.2

Descriptive Data for All Four CPR Conditions

	TOPE	TUPE	EOPE	EUPE
Average rate	109.90 (14.46)	109.78 (20.31)	109.38 (15.98)	110.02 (15.21)
Number of compressions	148.20 (16.44)	147.62 (14.55)	147.02 (15.41)	146.26 (15.13)
Average depth	40.04 (10.85)	40.8 (14.80)	32.84 (9.15)	38.22 (9.07)
Average force	53.46 (13.39)	56.84 (15.16)	55.5 (15.37)	67.52 (14.50)
Compression rate	0.510 (0.376)	0.459 (0.393)	0.397 (0.369)	0.465 (0.400)
Number of successes	28	21	18	24
Depth	0.221 (0.360)	0.186 (0.322)	0.069 (0.189)	0.143 (0.279)
Number of successes	11	9	3	7
Recoil	0.611 (0.405)	0.516 (0.377)	0.848 (0.261)	0.705 (0.346)
Number of successes	30	26	45	35

For the four continuous variables, mixed effect linear models were estimated to reflect the repeated measure experimental design. The manikin type, presence or absence of protective equipment, and their interaction were included as independent variables. Additionally, sex and months of experience were included as independent variables. Hierarchical regression models were fit to determine whether or not the condition had a statistically significant effect.

Table 4.3 presents the results for the measured variables. The independent factors had no statistically significant effect on the number of compressions or average rate. However, all factors were statistically significant for average depth and force. For the average depth, the difference is primarily reflected in the relatively poor performance in the condition of the EOPE. For average force, the difference occurs primarily due to the outperformance with the EUPE condition.

Table 4.3

Results of the Measured Variables

		Manikin type	Pads	Interaction
Average rate	chi-squared	0.108	0.139	0.095
	p-value	0.948	0.933	0.758
Number of compressions	chi-squared	1.711	0.484	0.009
	p-value	0.425	0.785	0.926
Average depth	chi-squared	22.782	11.929	4.423
	p-value	<.001	0.003	0.035
Average force	chi-squared	32.426	41.443	11.014
	p-value	<.001	<.001	0.001

For interaction tests, the chi-squared statistic has 1 degree of freedom, and for the manikin type and presence of protective equipment, there are 2 degrees of freedom. The results are based on a mixed-effects linear model for manikin type, presence or absence of protective equipment, and their interaction as independent factors, sex and months of experience as covariates, and an error term that accounts for the repeated measures design.

The three binary-transformed variables were modeled with mixed effects logistic regression models, and statistical significance was assessed with Type III Wald chi-squared tests. For chest recoil, there was a statistically significant effect due to manikin type ($\chi^2[1]=5.723$,

$p=.017$) and presence of protective equipment ($\chi^2[1]=8.563, p=.003$), while the interaction was significant at the 10% level ($\chi^2[1]=3.227, p=.072$). For chest compression depth, the manikin type did not have a statistically significant effect ($\chi^2[1]=0.588, p=.443$), while the presence of protective equipment ($\chi^2[1]=2.876, p=.090$) and the interaction term ($\chi^2[1]=3.111, p=.078$) were both statistically significant only at the 10% level. Finally, for chest compression rate, manikin type did not have a statistically significant effect ($\chi^2[1]=0.700, p=.403$), the presence of protective equipment was significant at the 10% level ($\chi^2[1]=2.745, p=.098$), and the interaction term was statistically significant ($\chi^2[1]=6.052, p=.014$). As a whole, the most notable finding occurred in the EOPE condition. For this condition, participants' performance tended to be quite poor in terms of chest compression depth and slightly slower in terms of chest compression rate, while also showing outperformance for chest recoil.

The different techniques participants used to remove protective equipment are summarized in Table 4.4. In addition, Table 4.4 displays the means and standard deviations regarding the time participants took to remove protective equipment on both traditional and endomorphic manikins.

Table 4.4*Different Techniques for Removal of Protective Equipment*

	Traditional manikin		Endomorphic manikin	
Cutting center strings	34		34	
Un-tie center strings	6		7	
Undo side buckles	6		5	
Untie then cut with scissors	3		2	
Untie center string, unbuckle side straps	1		2	
Time spent removing equipment (seconds)	Mean	SD	Mean	SD
	22.6	8.53	23.05	11.49

4.4. Discussion

With roughly 350,000 cardiac arrest episodes occurring each year within the United States, cardiopulmonary resuscitation (CPR) education is crucial for emergency responders (Tellson et al., 2017). To meet the guidelines comprising high-quality CPR, emergency responders are mandated to participate in recertification sessions a minimum of every two years. However, during CPR training courses, few or no opportunities exist to practice on manikins with a diverse range of body physiques, thus resulting in underprepared responders in real-life scenarios. With obesity rates continuing to rise (27.5% for adults and 47.1% for children), health concerns such as cardiovascular disease predispose obese individuals to SCA (Elagizi et al., 2018). Within the athletic population, there is a wide range of body physiques, and emergency responders should be prepared to intervene in the event of SCA. Furthermore, based on the sport, individuals may don protective equipment to minimize the risk of injury.

In the present study, emergency responders were unable to meet compression depth requirements set by the AHA of 2-2.4 inches (50-61 mm) on a traditional manikin, either with or without protective equipment (Kleinman et al., 2015). In comparable investigations evaluating rescuers' ability to perform CPR over athletic protective equipment on traditional manikins,

findings mirrored the current study, thus supporting the notion that chest compression depth over athletic equipment are often insufficient (Waninger et al., 2014; Tanaka et al., 2017). In addition, outcomes from the present study are similar to those of Waninger et al. (2014), where compression depth increased when the equipment barrier was removed. However, overall depth was still insufficient for both studies (Waninger et al., 2014). Further supporting our findings, in several investigations of CPR performance using athletic protective equipment, researchers reported the lowest compression depth occurs when compressions are performed over protective equipment (Lynall et al. 2014; Mihalik et al. 2016). Results from current literature as well as our study reveal a weakness in rescuers' CPR psychomotor skill performance (Waninger et al., 2014; Tanaka et al., 2017). CPR training courses for emergency responders include skill practice directly on the chest of traditional manikins resulting in a lack of training specific to appropriate interventions for equipment-laden athletes.

We hypothesized emergency responders would struggle to meet the recommended chest compression depth guidelines on the endomorphic manikin both with and without protective equipment. One potential cause of poor compression depth could be related to physical strength. The strength required to compress the chest of the endomorphic manikin exceeds that of the traditional manikin; thus, rescuers are more likely to struggle to meet the minimum compression depth requirements. In a study performed by Tellson et al. (2017), researchers compared healthcare providers' ability to perform chest compressions on normal-sized, obese, and morbidly obese manikins. Findings of the present study align with those of Tellson et al. (2017), demonstrating a significant decrease in chest compression depth. Although there is limited research investigating emergency responders' ability to administer chest compressions on endomorphic manikins, outcomes in the available research remain consistent indicating a

decrease in chest compression depth on obese manikins (Tellson et al., 2017). The decrease in chest compression depth on endomorphic manikin observed in the current study as well Tellson et al. (2017) is suggestive of a potential decrease in survivability for individuals with higher BMI's. It is crucial to reach proper chest compression depth during CPR because the heart needs to fully compress and recoil to pump blood to vital organs (Edelson et al., 2006; Berg et al., 2010; Kleinman et al., 2015). Unfortunately, outcomes of the current study, suggest emergency responders are unable to produce appropriate force to the thoracic region on endomorphic manikins.

Participants averaged 109-110 compressions/minute for all conditions, demonstrating emergency responders are able to meet AHA CPR Guidelines of 100-120 compressions/minute (Kleinman et al., 2015). In multiple studies, researchers found emergency responders are proficient in compression rate on traditional manikins regardless of an equipment barrier to the chest (Waninger et al., 2014; Tanaka et al., 2017). Similarly, researchers examining compression rate on endomorphic manikins without an equipment barrier have reported rescuers are able to achieve the recommended rate (Secombe et al. 2014; Tellson et al. 2017). While the general consensus among researchers is body type and equipment barriers do not appear to impede rate, future research needs to assess how emergency responders can improve all aspects of CPR psychomotor skills on an array of body physiques who are equipment laden.

In addition to investigating participants' psychomotor skills associated with CPR, we analyzed the amount of time spent removing football shoulder pads from both manikins to administration of the first chest compression. We found emergency responders took an average of 22.60 seconds on the traditional manikin and 23.05 seconds on the endomorphic manikin. In comparison, Del Rossi et al. (2011) evaluated a population of athletic trainers who were trained

and had protocols to follow regarding removal of football protective equipment. Del Rossi et al. (2011) found it took roughly 24.4 seconds to remove football shoulder pads from a manikin before participants were able to complete their first chest compression. Unlike Del Rossi's study where participants were instructed on appropriate equipment removal beforehand, emergency responders in the current study were not informed of proper procedures to remove protective equipment to create a life-like scenario. Surprisingly, both populations had similar time spent removing shoulder pads even though emergency responders were not trained on proper techniques to remove equipment. Additionally, one feature not incorporated in the present study was helmet removal. In contrast to the study conducted by Del Rossi et al. (2011), the present study did not assess helmet removal. Del Rossi et al. (2011) found inclusion of helmet removal increased time spent before beginning CPR by one minute, potentially delaying life-saving actions performed on an individual who experiences SCA. As a result, exclusion of using a helmet in our study and only instructing football shoulder pads be removed does not accurately represent the time spent before an athlete receives resuscitative care during a SCA episode.

As with any research, this study was subject to limitations. Although emergency responders' ability to perform CPR in various conditions was analyzed, ventilations were not incorporated in the measurements. The CPRmeter 2 device used is not capable of recording ventilations unlike other CPR feedback systems such as the Laerdal SkillReporter™. In the present study, the CPRmeter2 device was used instead of the Laerdal SkillReporter™ because unlike traditional manikins used in many CPR investigations, endomorphic manikins do not come equipped with the same feedback system. As a result, we were unable to evaluate emergency responders' ability to provide ventilations. Another limitation was the lack of helmet removal incorporated into each condition. In a real-life SCA incident, all protective equipment

must be removed from an equipment-laden athlete to allow emergency responders access to both the airway and chest for CPR. In addition, without incorporating helmet removal into all scenarios, our findings regarding equipment removal do not accurately reflect time spent prior to emergency responders administering their first chest compression.

In conclusion, we found emergency responders are not able to meet AHA CPR Guidelines, specifically for chest compression depth, on both traditional and endomorphic manikins. In contrast, responders were able to meet AHA CPR Guidelines for average rate for all conditions. One of the most surprising findings was that emergency responders did not perform sufficient chest compressions on a traditional manikin, even after the removal of equipment. This finding is concerning as it demonstrates that rescuers are either not receiving effective education related to CPR performance or are unable to retain their skills. To ensure emergency responders are meeting CPR Guidelines, both traditional and endomorphic manikins as well as manikins donned with protective equipment should be incorporated into CPR training courses so emergency responders are prepared to provide quality CPR during all SCA events.

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APPENDIX A. PARTICIPANT DEMOGRAPHICS FORM

NDSU North Dakota State University
Health, Nutrition, and Exercise Sciences
Department # 2620, PO Box 6050
Fargo, ND 58108-6050
218-443-644

Participant Demographics Form

Participants Assigned Identification Number (#1-50) (ID): _____

Location of work: _____

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

How many years have you been employed as an emergency responder?

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

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

Do you have any current cardiopulmonary, musculoskeletal, or respiratory conditions that would inhibit performance of high-quality CPR during this study?
Yes ___ **No** ___

Please circle your highest level of experience.
Emergency Medical Response Emergency Medical Technician
Advanced Medical Technician Paramedic

APPENDIX B. CPR PERFORMANCE OVER EQUIPMENT SCENARIO (1, 3)

During a college football game, before the play begins, a defensive lineman collapses to the turf and is not moving. As you run onto the field, the scene is safe and all personal protective equipment (PPE) is applied. The athlete presents as unresponsive, apneic, and pulseless. For this trial, you will perform two-minutes of single-rescuer CPR over the protective equipment following 2015 AHA CPR Guidelines of 30 chest compressions to 2 ventilations. However, instead of ventilations, you will have a 10 second break; once the 10 seconds is up, I will inform you to continue with your chest compressions. I will hand you a CPRmeter™ 2 device which you will apply directly to the manikin where you will place your hands for chest compressions. Your time will begin when you administer your first chest compression. When the two-minutes is up, I will say ‘stop,’ indicating the completion of this trial. You will not be able to view any visual feedback data regarding performance nor will you be allowed to see a clock to prevent changes in your administration due to objective feedback.

1- Traditional over

2- Traditional under

3- Endomorphic over

4- Endomorphic under

APPENDIX C. CPR PERFORMANCE UNDER EQUIPMENT SCENARIO (2, 4)

During a college football game, before the play begins, a defensive lineman collapses to the turf and is not moving. As you run onto the field, the scene is safe and all personal protective equipment (PPE) is applied. The athlete presents as unresponsive, apneic, and pulseless. For the trial, you will perform two-minutes of single-rescuer CPR under the protective equipment following 2015 AHA CPR Guidelines of 30 chest compressions to 2 ventilations. However, instead of ventilations, you will have a 10 second break; once the 10 seconds is up, I will inform you to continue with your chest compressions. If you feel it is necessary to remove the jersey, you may do so. The jersey is held together at the sternum with Velcro; please verbalize if you were to cut the jersey you would do so. Furthermore, if you chose to remove any equipment, prior to removal, you will verbalize what and how you are removing it. I will hand you a CPRmeter™ 2 device which you will apply directly to the manikin in the location you will place your hands for chest compressions. We will be first timing you from the start of removing the jersey and equipment to the beginning of your first chest compression. From here, your two-minutes of CPR will begin. When the two-minutes is up, I will say ‘stop,’ indicating the completion of this trial. You will not be able to view any visual feedback data regarding performance nor will you be allowed to see a clock to prevent changes in your administration due to objective feedback.

1- Traditional over

2- Traditional under

3- Endomorphic over

4- Endomorphic under

APPENDIX D. IRB APPROVAL



December 17, 2019

Dr. Katie J. Lyman
Health, Nutrition & Exercise Sciences

IRB Approval of Protocol #HE20101, "A Comparison of Cardiopulmonary Resuscitation (CPR) Outcomes between Traditional and Endomorphic Manikins With and Without Equipment"
Co-investigator(s) and research team: Danica L. Tarabanovic

Protocol Reviewed: 11/17/2019
Protocol Status Update Due prior to: 11/16/2022

Research site(s): NDSU and other varied locations Funding Agency: n/a
Review Type: Expedited category # 4
IRB approval is based on the revised protocol (received 12/13/2019). Please use the approved consent, version received 12/13/2019.

Additional approval from the IRB is required:
o Prior to implementation of any changes to the protocol (Protocol Amendment Request Form).
o For continuation of the project beyond the approval period (Continuing Review Report Form). A reminder is typically sent approximately 4 weeks prior to the expiration date; timely submission of the report the responsibility of the PI. To avoid a lapse in approval, suspension of recruitment, and/or data collection, a report must be received, and the protocol reviewed and approved prior to the expiration date.

Other institutional approvals:
• Research projects may be subject to further review and approval processes.

A report is required for:
o Any research-related injuries, adverse events, or other unanticipated problems involving risks to participants or others within 72 hours of known occurrence (Report of Unanticipated Problem or Serious Adverse Event Form).
o Any significant new findings that may affect risks to participants.
o Closure of the project (Protocol Termination Report).

Research records are subject to random or directed audits at any time to verify compliance with human subjects protection regulations and NDSU policies.

Thank you for cooperating with NDSU IRB procedures, and best wishes for a successful study.

Sincerely,

A handwritten signature in blue ink that reads "Kristy Shirley".

Kristy Shirley, CIP, Research Compliance Administrator

For more information regarding IRB Office submissions and guidelines, please consult https://www.ndsu.edu/research/for_researchers/research_integrity_and_compliance/institutional_review_board_irb/. This Institution has an approved FederalWide Assurance with the Department of Health and Human Services: FWA00002439.

INSTITUTIONAL REVIEW BOARD

NDSU Dept 4000 | PO Box 6050 | Fargo ND 58108-6050 | 701.231.8995 | Fax 701.231.8098 | [ndsu.edu/irb](https://www.ndsu.edu/irb)

Shipping address: Research 1, 1735 NDSU Research Park Drive, Fargo ND 58102

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