Comparison of Cervical Angle during Different Equipment Removal Techniques Used In Ice Hockey for Suspected Cervical Injuries

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COMPARISON OF CERVICAL ANGLE DURING DIFFERENT EQUIPMENT REMOVAL TECHNIQUES USED IN ICE HOCKEY FOR SUSPECTED CERVICAL INJURIES

By

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Bachelor of Science – Kinesiology of Allied Health
Bachelor of Science – Athletic Training
University of Nevada, Las Vegas
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A thesis submitted in partial fulfillment
of the requirements for the

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Comparison of Cervical Angle During Different Equipment Removal Techniques Used in Ice Hockey for Suspected Cervical Injuries

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ABSTRACT

COMPARISON OF CERVICAL ANGLE DURING DIFFERENT EQUIPMENT REMOVAL TECHNIQUES USED IN ICE HOCKEY FOR SUSPECTED CERVICAL INJURIES

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The purpose of the study was to compare cervical movement between two different methods of removal of the helmet and shoulder pads. Seven college age male subjects (height: 172.54 ± 7.98 cm; weight: 85.70 ± 15.75 kg) with hockey experience volunteered to participate in the study. Each subject agreed to and signed the institutional review board approved informed consent before participation. Subjects used their own game fit hockey helmet and were fitted with a pair of shoulder pads (CCM Tacks 1052 Sr Shoulder Pads). Cervical spine motion was measured using 3D kinematics (Vicon Motion Systems Ltd., UK). Reflective markers affixed to the manubrium, both Anterior Superior Iliac Spine (ASIS), and a custom mouthpiece were used to track the change in cervical angle during two different methods of equipment removal: 1) supine, and 2) semi-fowler techniques. Cervical flexion-extension angle was calculated as the angle between the segment defined by the mouthpiece marker and manubrium and the segment between the manubrium and ASIS. The maximum cervical angle was identified and the average cervical angle from the moment shoulder pad removal began to when the pads were removed.
was calculated. Cervical angle was normalized to the static angle (i.e., before equipment removal began). A paired t-test was used to compare maximum cervical angle between the two conditions. A paired t-test was also used to compare average cervical angle between the two conditions (α=0.05). Maximum cervical angle was not different between supine removal (17.69±7.79 degrees) and semi-fowler removal (15.18±3.77 degrees) techniques (p=0.37). Average cervical angle was not different between supine removal (3.66±1.50 degrees) and semi-fowler removal (4.63±2.80 degrees) techniques (p=0.47). Cervical angle was similar between removal techniques.
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CHAPTER 1: INTRODUCTION

Ice hockey is rapidly growing in popularity in North America and around the world (Automatedinsights.com, 2015). It is a very high impact, even violent, sport having been identified as one of the six major sports with great risk of spinal cord injury (Banerjee et al., 2004). With that in mind, it is easy to see why injuries are so often incurred from on ice collisions. In recent years, changes have been made to the rules that govern on ice collisions (Ausec, 2013). Rules such as hitting from behind, boarding (striking a player who is within a certain distance from the boards), and interference (hitting a player who does not have possession of the puck) are illegal and strictly enforced. These rules are intended reduce the amount of blind-sided hits and head-board collisions (instances where player contact may result in injury due to the head contacting the boards surrounding the ice surface). However, outside of injuries incurred on the ice, there is risk of further injury when being treated by emergency medical technicians who are not educated in the purpose and physical makeup of athletic equipment (Frohna, 1999).

In part two of the article written by Banerjee et al. (2004), the importance of emergency care is outlined. Banerjee (2004) emphasizes the interference in emergency care caused by the helmet and shoulder pads in collision sports. Emergency medical technicians are trained to remove the helmets of motorcyclists upon arrival to the scene of an accident. This poses an issue in athletic scenarios as the removal of the helmet alone may disrupt spinal stabilization. Football and ice hockey protective equipment (helmet and shoulder pads specifically) are built to work together to achieve inline stabilization of the cervical spine, allowing it to rest in a neutral position (Banerjee et al., 2004). Emergency planning should take into account the differences in emergency medical technicians (EMTs) and certified athletic trainers (ATCs) training and
standards, and protocols should be shared and rehearsed with the entire medical team (i.e. EMTs, ATCs, and team Physicians) (Anderson, 2002).

Research has been done to measure cervical motion during football equipment removal using three-dimensional kinematics (e.g., Swartz et al., 2015). To date there is a gap in the literature as studies have not used kinematics for the same purpose with ice hockey. Since there is not a single technique used that is applicable to all sports, the present study used two different techniques of equipment removal and compared the respective cervical movements as measured by three-dimensional kinematics. The two techniques are the supine method of removal, where the helmet is removed first and then the shoulder pads are slid out from under the athlete, and the semi-fowler method where the helmet is removed and then the athlete is propped up slightly to remove the shoulder pad and then set down as one unit. It is presently not clear if cervical movement is similar or different when using the two techniques for equipment removal.

Purpose

The purpose of the study was to compare cervical movement between two different methods of removal of the helmet and shoulder pads.

Research Hypothesis

It was hypothesized that there would be a difference in maximal and average change in cervical motion between the two study conditions. The null hypothesis will be no difference being present in cervical movements between the two study conditions.

Dependent Variables

The dependent variables in this study were average and maximum change in cervical motion (flexion/extension).
**Independent Variable**

The technique of removal (1: supine, 2: semi-fowler removal) is the independent variable.
CHAPTER 2: LITERATURE REVIEW

Overview

Since its inception as a national pastime in 1869 (profootballhof.com), football has grown massively in popularity and profit. It is estimated 1.23 million youth athletes participate in football between the ages of six and twelve (Farrey, 2016). In contrast, according to USA Hockey, it is estimated that upwards of 542,000 athletes between the ages of 6 and 18 participated in youth hockey during the 2015-2016 season (USA Hockey Member Stats, 2016). Ice hockey and American football are both sports involving high impact. In football, injuries can be caused by a multitude of impacts and collisions. Hockey athletes are subject to similar impact injury risks, in addition to skate blades, hockey sticks, and glass/board transitions only seen in ice hockey (Sim, 1987). Although football is responsible for the largest amount of catastrophic spinal injuries in American sports (Swartz, 2009; Mueller, 2008), ice hockey is responsible for more nonfatal catastrophic injuries overall with about 15 cases annually between the US and Canada (Muller, 2008; Tator, 1998; Banerjee, 2004). Even though ice hockey is known to have a greater number of these injuries, research and emergency action plans are still largely based around American football.

Currently, the protocol for any medical emergency in the National Hockey League (NHL) involves the direct assistance of an emergency medical team (Edwards, 2016; Emergency Medical Standards, 2013). The article by Columbus Dispatch remarks the training process of the emergency medical staff and athletic training staff of the Columbus Blue Jackets. The OhioHealth medical simulation program brought automated dummies to the on ice training to assist in the practice of handling various medical emergencies. This on ice scenario lead to discoveries such as not delaying a necessary automated external defibrillator (AED) shock until
off the ice surface, and keeping the gurney lowered on the ice for stability when transporting an athlete. According to the Emergency Medical Standards for the Care of the Injured N.H.L. Player, “it is recognized that a ‘one size fits all’ solution may not be practical in all situations” (Emergency medical standards, 2013). These standards address the requirement of two team physicians on site at every home game, who must be within 50 feet of the ice surface and player benches during all regulation play to be readily available for any emergency. It addresses the requirement of a player specific ambulance at ice level during all games, and if the ambulance should depart with a player, play cannot reconvene until the new player specific ambulance is on site and in place. The report also discusses the requirement of all medical staff practicing, reviewing, and rehearsing the emergency action plans for all scenarios at least one month prior to the beginning of the season. This includes athletic training staff, team physicians, security and the accompanying emergency medical provider. With all of these preparations, however, it is still unclear what the most stable method of equipment removal is when dealing with catastrophic cervical spine injuries.

**Anecdotes of Ice Hockey Injuries**

Rules in sports are always subject to change. These changes may be due to safety implications, or to control various aspects of the game. Rules keep the game true to the sport. You cannot catch a ball with your hands and throw it in soccer. In track and field you cannot start before the gun goes off. In hockey, you cannot kick the puck into the net to score a goal. However, arguably a more important role of rules is to ensure the safety of the players, officials and spectators. In hockey and football, the collision aspect of the sport poses a risk to the safety and wellbeing of all involved. The rules that govern the game make an attempt to harness these collisions and make them less traumatic. In hockey, rules such as boarding, the inability to hit a
player who is a certain distance from the boards, and hitting from behind, delivering a check or blow to a player who is not facing you, are an attempt to decrease the number of lethal collisions in the sport (Ausec, 2013). Even with these rules in place, this extremely fast paced game is likely to have its fair share of catastrophic injuries. The following injuries are just a few of these examples.

In October of 1995 a 20 year old hockey player, Travis Roy, took the ice for his first NCAA college hockey game with Boston University. His story is highlighted in a book called Eleven Seconds as well as on the main page of his foundation’s website. Travis was injured when he caught an edge of his skate and was catapulted head first into the boards. He fractured his fourth cervical vertebrae, rendering him paralyzed from the neck down, on the ice (Eleven Seconds, 1998). In a situation like this, the emergency action plan (EAP) is set into motion. The medical personnel must stabilize the cervical spine, gain access to the airway and transport the athlete. That is exactly what happened, but there are times, like this one, where the damage is already done (Eleven Seconds, 1998). This is also an incident where the rules of the game would not have affected the outcome. Travis fell of his own accord and suffered his injuries with no help from an opposing player.

In 2013, Cole Bardreau sustained a blow from an illegal hit, a check that is explicitly outlawed in the rulebook. This caused him to fall head first into the boards where he sustained two fractures to his seventh cervical vertebrae. The injury ultimately ended his season, even though he returned to play the following season. In an article written by Bob Snow for NHL.com, it was recounted that when he collided with the boards, he got up and returned to the bench where he complained of pain in his chest and difficulty breathing. According to the article, his doctor stated that when a person sustains a serious neck injury “the pain radiates down into
the chest” (Snow, 2013). Bardreau returned to play in that very game and his athletic trainer diagnosed him with a “stiff neck”, and told him to get an x-ray when they returned home. The x-ray showed the fractures and he was rushed into surgery. After about a year of rehabilitation, he was able to return to play. In this situation, the athlete was not initially pulled from play and there was no mention of midline tenderness (tenderness along the middle of the spine as palpated by a medical professional). The injury could very well have turned into a catastrophic cervical spine injury during the course of that game if the athlete was hit again.

In March of 2011, professional hockey player Max Pacioretty of the Montreal Canadiens was the victim of a hit delivered by Boston’s Zdeno Chara. The hit was not considered illegal and received no excess fine or suspension. However, as a result of this hit, Pacioretty collided head first with a stanchion (glass transition) in between the two player benches (McDonald, 2011). The medical staff responded immediately and transported him to the hospital. He suffered a fracture to his fourth cervical vertebrae, but it was not misplaced and caused no problematic pressure on the spinal cord (McDonald, 2011). If the video of the injury is watched, it is easy to see that the helmet is removed immediately as he laid on the ice (Zdeno Chara hits, 2011). The issue of helmet stability will be further discussed in a later section. The player is immobilized, spine boarded and removed from the ice in under two minutes.

In an article shared by NHL.com, a change to stadium structure was mandated later in 2011. The hard ninety-degree angle glass transitions were to be a thing of the past. The new structure would mandate that the transitions between the glass and the benches be rounded allowing a collision to glance off of them much like the rounded design of a football helmet. Brendan Shanahan, NHL league vice president, pushed the change as a direct reaction to the Pacioretty incident in an attempt to make the game safer for its players (NHL.com, 2011).
Changes like these are necessary after catastrophic injuries occur. Research and development teams gather to iron out the details of how to enact them. Teams like this are not only necessary for structural hazards but also for physical and equipment hazards. These teams are responsible for ensuring the high performance and safety standards of player equipment. Thus, it is important for this equipment to be researched in emergency action plan scenarios to ensure the safest way to remove it from an injured player.

**Spinal Anatomy Overview**

Banerjee et al. (2004) defines catastrophic cervical injuries as “a structural distortion of the cervical spinal column associated with actual or potential damage to the spinal cord.” The spinal cord originates from the brainstem on the posterior aspect of the brain itself. It extends downward through the cervical, thoracic and lumbar vertebrae. It lies within the vertebral canal inside each and every vertebra. Branches of nerves exit the spinal column and extend into the extremities. Once the cord reaches the lower part of the lumbar spine it dissipates into the Cauda Equina, which is a series of nerves that extend down into the lower extremities. There is not an excessive amount of space available for the spinal cord. A healthy spinal cord slides through the moving vertebrae without any issue. However, when individual vertebrae are damaged, they may cause obstructions to the normal cord movement. Bones break with sharp edges that can catch on the cord or even sever it. Secondary injuries like this can have life altering repercussions such as loss of sensation, paralysis, and even death.

There are many ways to sustain a vertebral injury. Mechanisms may vary from sport to sport, but catastrophic cervical spine injuries occur through flexion, extension, rotation, lateral bending and compression of the spine (White III & Panjabi, 1978). These mechanisms, with the exception of compression, follow the six degrees of freedom available to the spine. The vertebral
foramen allows for roughly 14mm of space available for the cord. This measurement has been identified as the lowest limit of normal (White III & Panjabi, 1978). When injury occurs, the vertebral translation reduces the space available for the spinal cord. Often, spinal cord damage is induced upon impact, but it can also happen after the athlete has been treated and stabilized. Flexion and extension of the spine under injured circumstances may reduce the space available for the cord. In the case of flexion and extension, the cord is placed under stress both posteriorly and anteriorly. In situations like this, realigning the spine may not reduce the damage that has or will occur, but it may decompress the nerve roots, allowing them to be preserved for healing.

Some factors that may create spinal cord compression include unstable dislocations, vertebral fractures, muscle guarding, ligament ruptures, and uncontrolled inflammation (White III & Panjabi, 1978). The spine acts as a rigid, yet selectively flexible, cage to protect the spinal cord. It is therefore easy to see why any incongruence with the stability of the structure could be detrimental to the state of the cord. When injury occurs in the human body, the muscles react. Skeletal muscle has a reflexive mechanism called muscle guarding that is meant to stabilize otherwise unstable injuries. If an athlete sustains an unstable spinal injury, the muscles could potentially be the cause of secondary injury to the cord by pulling damaged vertebrae out of its normal position and into the area reserved for the spinal cord. This may compress the cord, causing permanent damage to distal sensation and motor control.

**Emergency Management of Cervical Injuries**

When a person is lying supine on the flat ground with no added equipment, their spine rests in an inline neutral position, allowing the spinal cord to rest without being bent or moved. When a catastrophic spinal injury occurs, the goal of any emergency care is to maintain that neutral alignment of the spine to prevent secondary injury. If the certified athletic trainer (ATC)
is the first responder to the injury, after assessing the athlete’s level of consciousness and vital signs, their first action would be to check for signs of cervical injury such as midline tenderness of the spine. If cervical injury is suspected, they would proceed to provide hands-on inline stabilization of the spine (Swartz, 2009). This is done from the anterior aspect of the athlete by cupping the hands around the occipital protuberance and securing the face with the forearms. From the posterior aspect, inline stabilization is achieved by gripping the trapezius musculature of the athlete on either side of the neck and stabilizing the head between the forearms. This posture may be held until a spine board and adequate help become present, or until emergency medical technicians (EMT) arrive on the scene. It is imperative for emergency responders, whether that is an ATC or EMT, to have access to the airway in case of sudden cardiac situations and the need to commence cardiopulmonary resuscitation (CPR). For this reason, the next step is typically to remove the facemask. The facemask of most athletic helmets blocks direct access to the mouth and nose to perform CPR.

For sports such as football and ice hockey, the helmet and shoulder pads serve a dual purpose. Not only do they protect the head and torso from injury due to blunt force trauma, but together, they act to maintain the natural neutral spinal position. Specifically in football, care has been taken to develop equipment in order to make them the same size and thickness to help achieve this neutral position. Due to this equipment standard, the national athletic trainers association (NATA) has enacted an “all-or-nothing” policy when it comes to the removal of equipment from a cervically injured athlete (Donaldson, 1998; Prinsen, 1995; Metz, 1998). When the helmet is removed while the shoulder pads are still in place, the head is forced to rest on the ground placing the spine in an extended position. On the contrary, if the shoulder pads are removed while the helmet is still in place, the torso drops to the ground forcing the neck into a
flexed position. This issue has spurred an influx of research regarding the most appropriate method of equipment removal.

**Facemask Removal**

When dealing with prospective injuries involving the spine, the foremost important step is to gain access to the airway. The spinal cord does a myriad of jobs in the human body. It controls muscle contractions and distal sensory sensations. When the body encounters a stressful situation, measures are taken to protect its wellbeing. For example, if you accidentally touch a hot cook top, the skin on your hands will detect the heat and send a stimulus to the brain. Voluntary muscles rely on the returned stimulus from the brain to act in accordance to potentially harmful situations by prompting a swift removal of the body part from the heat. However, this is only one way that the spinal cord can act to preserve the wellbeing of the body.

Higher levels of the spine have more important jobs to do. A common study tool used by many young athletic training students is “C3,4,5 keeps you alive”. This clever rhyme refers to the phrenic nerve. These nerve roots innervate the diaphragm, an involuntary muscle that assists with respiration. According to Charles Tator (1984), between the years of 1980-1983, their surveyed group experienced 42 ice hockey related spinal cord injuries. Of these 42 injuries, only three of them occurred in the thoracic and lumbar regions and the most affected spinal levels were between C5-C6 (Tator, 1984). Some of the main controversy surrounding the removal of the helmet and shoulder pads is due to the accessory movement of the spine that happens during the removal process. This led to the standard of removing the facemask, while leaving the helmet and shoulder pads in place for transportation to the hospital (Swartz, 2009).

However, issues have been raised as to the general stability of the head and neck in hockey helmets. Since the chin strap is secured to the full face shield of the hockey helmet, it has
been implied that the helmet impedes the ability to stabilize the cervical spine at all. It has been suggested that at the junior and professional levels, when there is no stabilization provided by a chinstrap, or when the helmet is not properly fitted, that the helmet should be removed to fully stabilized the cervical spine (Mihalik et al, 2008). American football helmets have a surplus of padding that is fitted to not allow for accessory movement within the helmet. These helmets often have air bladders that can be inflated or deflated to properly hug the cranium. Hockey helmets on the other hand, are made up of two rigid parts (a frontal and posterior region) that can collapse or expand to create a snug fit. The pads, however, are usually made up of high-density foam or a honeycomb pattern gel material. For competition fit of a football helmet, the helmet must not move while the athlete vigorously shakes their head. The same Fitting principles apply to hockey helmets, but they are rarely fitted properly for competition at the lower levels (Mihalik, 2008). Many club teams do not have full time equipment managers to properly fit helmets, leaving the players to adjust their own equipment to their personal preferences. Often, competition fit helmets under these circumstances are loosely fitted and not to factory safety specifications, hindering the safety features built into their design (Mihalik, 2008).

**Comparative Techniques in Equipment Removal**

Equipment removal has been a topic of controversy for years in the profession of athletic training (Peris, 2002). Should the equipment be left on? Should it be taken off? Should emergency room doctors be trained in the proper removal of equipment? These are common questions in the world of sports medicine. Arguments have been raised to have athletic trainers remove equipment in the field prior to transport. This argument would make sense if in fact, athletic trainers have more specialized knowledge when it comes to the physical make up and fit of their sport’s protective layers than do emergency department physicians who may not see
equipment laden athletes as often. However, more often than not, there is not enough staff with this knowledge on hand to safely execute the removal. For instance, only 35% of secondary schools have an athletic trainer on hand (Lyznicki, Riggs, Champion, 1999). That number has only risen to 42% by 2015 (Pryor, et al., 2015). For major contact sports like football, there may be an emergency medical team on site for transports, but this generally reserved for football games only, not practices. This leaves athletic trainers alone to deal with potentially life threatening situations. Often, the protocol is to stabilize the athlete until a transport team arrives and takes the injured athlete to the hospital for equipment removal and treatment. For instance, Frohna (1999) describes their version of the “all-or-nothing” approach to equipment removal. Once stabilized the injured athlete is to be log rolled into the supine position if needed. Once the airway and breathing are secure, the athlete can be transported. In the hospital’s emergency department, the helmet is removed first by a team of three or four. The head is stabilized at the level of the torso while straps of the shoulder pads are severed. The athlete is then elevated (head and torso simultaneously) while the shoulder pads are removed, and the head and torso are lowered back to the ground at the same time. At this point, the cervical collar is applied.

In 2015, researchers in New Hampshire came out with a study that urged a new position statement (Swartz et al., 2015). This study tested the removal of different football equipment make and models and the motion they inflicted on the head and neck. This study used time and a subjective measure of ease of removal as their dependent variables. Though they found differences in equipment type, they also state in their discussion section, that stabilizing and transport is still the best bet. One type of removal that is questioned in this study is the ripcord system in football equipment. This system allows the shoulder pads to be separated at the midline and slid out from under the athlete laterally. This technology allows the spine to lower to
the ground as a whole, maintaining inline stabilization. This technology also allows the medical professional at the head to maintain stabilization throughout pre-transport procedures, because nothing must be removed over the head (Swartz et al., 2015). This sort of equipment technology is not present in hockey protective gear, requiring the shoulder pads be slid out from under the athlete superiorly. This method could be detrimental to the health of the spinal cord by allowing the thoracic spine to be at the level of the floor, while the head is still elevated, causing spinal flexion. Between equipment design and current standards of equipment removal, there are still holes in the research and current medical practice for the safest way to remove equipment.

**Conclusion**

It is known that American football has a larger number of athlete participation than ice hockey (Tom Farry, ESPN; usahockey.com). It is also known that both sports are accompanied by a high level of physical contact and risk of injury. One such injury of concern to researchers, athletes, and patrons is to the cervical spinal vertebrae. Injury to the vertebrae of the spine can create injury to the underlying spinal column causing severe consequences such as loss of sensation, paralysis, and even death (White III & Panjabi, 1978; Banerjee, 2004). Because of these risks, changes have been made to the rules of ice hockey as well as to the physical structures surrounding the playing surface. These changes have been made in an effort to increase player safety, but have not extended to the emergency medical plans for on-ice equipment removal of a cervically injured athlete (Ausec, 2013; NHL.com). For American football, standards have been set to enact the “all-or-nothing” approach to equipment removal and the process has been studied at length. Although the number of non-fatal catastrophic cervical spinal injuries is higher in ice hockey than that which occur in American football (Swartz, 2009; Mueller, 2008; Tator, 1998; Banerjee, 2004), efforts have not been made to study
the safest way to remove the helmet and shoulder pads to create a standard for equipment removal for hockey. This gap in the literature is problematic because the medical standards are not set, creating emergency action plans that differ from team to team. This becomes an issue when a catastrophic injury occurs and medical personnel from differing teams must work together to manage the situation.
CHAPTER 3: METHODS

Subject Characteristics

Competitive, college-aged male hockey players (n=7) of average height (172.54 ± 7.98 cm) and weight (85.70 ± 15.75 kg) were recruited from the local hockey community. The subjects were past and present competitive collegiate hockey players. This stipulation was made to accurately simulate the hockey population that will benefit from this research.

Table 1- Anthropometric data of individual subjects

<table>
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<th>weight (kg)</th>
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<tr>
<td>Standard Deviation</td>
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</tr>
</tbody>
</table>

Instrumentation

All subjects were fitted with a pair of hockey shoulder pads (CCM Tacks 1052 Sr Shoulder Pads) and wore their own game specific helmet. They wore their own helmet because it more realistically depicted a game-time, competition fit. Cervical spine motion was measured using 3D kinematics (Vicon Motion Systems Ltd., UK). A three-marker cluster was fixed to a custom fabricated low-density polyethylene mouthpiece worn on by each subject (figure 1). A three-marker cluster was also placed on the manubrium and sternoclavicular joints of each subject above the top of the chest protector as well as around each anterior superior iliac spine
(ASIS). Markers from the mouthpiece, chest, and ASIS clusters were used to determine angle of cervical flexion and extension using the law of cosines.

Figure 1- Cluster marker setup used for data collection.

Test Protocol

Subjects reported to the Sports Injury Research Center main lab and signed a university approved informed consent. Anthropometric data was then collected. After collecting anthropometrics, subjects were fitted with the proper size shoulder pads. A single marker was fixed to the front of the shoulder pads and anterior surface of the helmet. These markers were only used to assist with protocol time in post-processing. Once the subjects were fitted with the shoulder pads and helmet, equipment was removed, and reflective markers were placed on their chest. They were also instructed to bite down on a mouthpiece with reflective markers fixed to the end of it.

After marker and equipment fitting, the subjects were asked to lie down in a supine position where a static calibration was collected. Following the static calibration, two testing conditions were completed in a counterbalanced order. Three research team members (3 second
year athletic training students, 3 licensed/certified athletic trainers, and one graduate student with no prior experience who were recruited as research assistants) acted as rescuers for both conditions. It was thought that this mix of personnel would depict a common mix of medical assistance when dealing with an emergency situation (i.e. 1-2 ATCs and probably a coach or equipment manager who has rehearsed an emergency action plan). Three pilot data collections were performed with all volunteer research members to ensure procedures were performed accordingly. These pilot sessions were run much like any emergency action plan rehearsal would be, with ATC’s instructing other team personnel on steps and actions in the process. The first condition was a supine equipment removal. In this condition, rescuer 1 (R1) stabilized the head from the anterior position. Rescuers 2 and 3 (R2 and R3) used scissors to cut the shoulder pads at the clavicular region and removed the Velcro straps from across the chest (figure 2). While R1 continued to stabilize the head, R2 carefully removed the helmet, pulling the ear pieces of the helmet outward to allow to it to slide off smoothly and without sticking. After the helmet was removed and placed to the side, R2 moved back into position at the shoulder opposite from R3. R2 and R3 then slid the shoulder pads out from underneath the subject. After the shoulder pads were removed, R1 slowly replaced the subject’s head back on the ground. Each rescuer completed a trial at each position of the data collection to reduce any possible bias.

The second condition required the three rescuers to sit the subject up into a semi-fowler position. Just as in the first condition, R1 stabilized the subject’s neck from an anterior position. R2 then, again, cut the shoulder pads at the clavicular region and the Velcro chest straps were removed. Following cutting the shoulder pads, R2 removed the helmet of the subject. They then positioned themselves at one shoulder of the subject while R3 positioned themselves at the other shoulder. The rescuers then sat the subject up (to an angle high enough to free the shoulder pads)
in unison from the supine position making sure to create movement at the lumbar spine and hip. Once in the semi-fowler position, the shoulder pads were removed and cast aside. Once the shoulder pads were removed, the rescue team lowered the subject back down to a supine position, the thoracic and cervical spines moving in unison to maintain inline stabilization.

Figure 2- Position of rescuers during equipment removal.

Data Reduction

Using the markers on the mouthpiece, chest, and ASIS, relative angles between the three cluster positions were calculated using the law of cosines. Changes in the relative angle between the markers in the sagittal plane were used to determine average and maximum change in cervical flexion and extension.
Figure 3- Example raw angle data. Time ‘0 s’ represents the moment shoulder pad removal began with the end point representing when the pads were fully removed. Maximum and average change in angle were calculated as the difference between cervical angle and neutral c-spine (i.e., the cervical angle at time 0).

**Statistical Analysis**

The dependent variables for this study were average and maximum change in cervical flexion/extension. A paired t-test was used to compare the difference in maximum change in cervical angle between the two testing conditions. A paired t-test was also used to compare the difference in average change in cervical angle between the two testing conditions. The alpha level was set at $\alpha=0.05$. 
CHAPTER 4: RESULTS

There was no significant difference observed in maximum change in angle between supine removal (17.69±7.79 degrees) and semi-fowler removal, (15.18±3.77 degrees) (p=0.37).

There was also no significant difference observed in average change in angle between supine removal (3.66±1.50 degrees) and semi-fowler removal (4.63±2.80 degrees) (p=0.47).

Table 2- Results, means and standard deviations for supine and semi-fowler removal techniques.

<table>
<thead>
<tr>
<th></th>
<th>Maximum Change in Angle</th>
<th>Average Change in Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supine Removal</td>
<td>17.69±7.79°</td>
<td>3.66±1.50°</td>
</tr>
<tr>
<td>Semi-Fowler Removal</td>
<td>15.18±3.77°</td>
<td>4.63±2.80°</td>
</tr>
</tbody>
</table>

Table 3- Individual data for Maximum change in angle for both supine and semi-fowler techniques of equipment removal. Individual data for Mean change in angle over time for both supine and semi-fowler techniques.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Supine Removal</th>
<th>Semi-Fowler Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Avg</td>
</tr>
<tr>
<td>2</td>
<td>15.63°</td>
<td>3.50°</td>
</tr>
<tr>
<td>4</td>
<td>10.82°</td>
<td>3.24°</td>
</tr>
<tr>
<td>5</td>
<td>32.00°</td>
<td>3.15°</td>
</tr>
<tr>
<td>6</td>
<td>22.60°</td>
<td>6.19°</td>
</tr>
<tr>
<td>8</td>
<td>18.71°</td>
<td>2.83°</td>
</tr>
<tr>
<td>9</td>
<td>8.95°</td>
<td>1.63°</td>
</tr>
<tr>
<td>11</td>
<td>15.12°</td>
<td>5.05°</td>
</tr>
<tr>
<td>Mean</td>
<td>17.69°</td>
<td>3.66°</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>7.79°</td>
<td>1.50°</td>
</tr>
<tr>
<td></td>
<td>3.77°</td>
<td>2.80°</td>
</tr>
</tbody>
</table>
CHAPTER 5: DISCUSSION

The purpose of the study was to compare cervical movement between two different methods of removal of the helmet and shoulder pads. The most important finding of this study is that, while the currently accepted and supported all-or-nothing principle is still supported by our research, neither method of equipment removal was demonstrated to be more stable than the other in our research. The hypothesis that the semi-fowler method of removal would result in less motion at the cervical level of the spine was refuted and our null hypothesis that there would be no difference between the two techniques was supported.

When cervical spine injury is suspected, previous research supports the all-or-nothing principle of equipment removal (Swartz, 2015). Meaning, in an emergency scenario, either all the equipment must be removed, or all the equipment must stay in place. Specific exceptions such as the inability to remove the facemask to allow access to the airway or lack of personnel to allow for all the equipment to be removed simultaneously, may dictate the removal of just the helmet (Swartz, et al. 2009). In these cases it is recommended that a bolster of some sort (e.g. folded towel or foam pieces) may be used under the athletes head to maintain neutral alignment of the cervical spine (Prinsen, et al. 1995; Jacobson, 2014).

The measure of cervical angle observed in the present study is in line with other research (Higgins, 2010). For example, Higgins 2010 examined cervical-thoracic angles between conditions (full equipment, no equipment, and shoulder pads only), the angle between the thoracic spine and the cervical spine (when laying supine on the floor with no equipment and with both helmet and shoulder pads in place) was about 23 degrees. When the helmet was removed, and the subject lay in the same position, the angle increased to 26.6 degrees (Higgins, 2010). This explains why a maximum change in angle of 15 degrees observed in the current
study is not unreasonable. Further, Donaldson and Lauerman (1998) studied an equipment removal protocol in cadavers with cervical injuries. It was reported that the average change in cervical angle during equipment removal was 5.47 degrees. In contrast, in our study the average change in cervical angle was 3.66±1.50 and 4.63±2.80 degrees respectively for the supine and semi-fowler equipment removal techniques. Therefore, it seems that the data that are reported in the present study are reasonable and in line with other published studies.

The long term goal of this research is to understand the appropriate technique for equipment removal for ice hockey players while on ice. A main limitation of this study was the surface that the techniques were performed on. Specifically, the surface upon which data were collected was a concrete floor in a biomechanics testing lab. This surface provides markedly more friction than that of an ice hockey rink. This approach was used in order to use a multi-camera 3D kinematic system. It is not clear how the data collected on this surface are generalizable to a surface like ice. Additional research needs to be completed to test helmet removal techniques on a variety of surfaces.

It is also recognized that researcher experience may have played a role in the outcome of the study. It is not clear if the outcome of the study would be influenced if researchers with different levels of training for equipment removal were used.

Along with researcher experience, the coordination of research team members in the helmet removal techniques would seem to play a critical role in the outcome of the study. For example, cervical angle may be influenced by factors such as fatigue in the researcher’s arms and hands or how a team works together. Given the complexity of the coordination between research members, future research should be directed to understand if cervical angle is influenced by technique when research team members are not trained to work together, for example.
Measuring cervical angle is complicated when subjects wear equipment such as helmets and shoulder pads. In the present study, a 3D kinematic camera based system was used which required placement of reflective markers on specific land marks. Placement of the markers needs to be done in a way to account for equipment removal. Future considerations for research could be to use an instrumentation method that does not require marker visibility as the researcher’s bodies masked the markers during collection. If using a 3-D kinematic camera system, it would be recommended that more cameras or different placement of cameras be heavily investigated prior to beginning collection. It may also be possible to use inertial measuring units (i.e., accelerometers and gyroscopes) that do not require the use of cameras to measure cervical angle.

The objective of the study was to determine how movement compared between two different methods of removal of the helmet and shoulder pads by analyzing real-time cervical position. Given that change in cervical angle between techniques was not different, it appears that the research team was able to remove equipment using both techniques in a way that resulted in similar cervical angles during the removal process. Though there was a lack of significance between conditions leading to an impossibility to recommend one method of equipment removal over another, it can be deduced that both methods of removal may be appropriate in different scenarios. The conclusion of our study is that neither method of removal was demonstrated to be more stable than the other and that more research is required to truly understand the best method of equipment removal in ice hockey.
APPENDIX A: IRB INFORMED CONSENT FORM

UNLV

INFORMED CONSENT
Department of Kinesiology and Nutrition Sciences

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TITLE OF STUDY: Equipment Removal in Ice Hockey Players with Cervical Injuries

INVESTIGATOR(S): John Mercer, PhD, FACSM; Kendell Galor, LAT, ATC, CSCS

For questions or concerns about the study, you may contact John Mercer at john.mercer@unlv.edu (702) 895-4672 or Kendell Galor at galork@unlv.nevada.edu (970) 391-6408.

For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted, contact the UNLV Office of Research Integrity – Human Subjects at 702-895-2794, toll free at 877-895-2794 or via email at IRB@unlv.edu.

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Purpose of the Study
You are invited to participate in a research study. The purpose of these study is to determine how movement compares between two different methods of removal of the helmet and shoulder pads by analyzing real-time head and neck position.

Participants
You are being asked to participate in the study because you fit this criteria: College aged male (ages 18-30 years). You’ll have to have your own helmet (and we’ll need to take the face mask off the helmet).

Procedures
If you volunteer to participate in this study, you will be asked to do the following: If you decide to participate in this study, we will record your height, weight, and age. We will then fit you with shoulder pads and remove the face shield of your helmet. The research team will affix reflective markers to your helmet and shoulderpads with double sided tape. You’ll also be asked to bite down on a mouth piece (brand new) once we start data collection. We will have you lie relaxed on the floor while having three research team members remove your helmet and shoulder pads. They will be following standard equipment removal procedures and will be trying to minimize any movement to you. During this time we will be measuring the movement of the markers we have placed on your skin and equipment.
**Benefits of Participation**
There may not be direct benefits to you as a participant in this study. However, we hope to learn the safest way to handle sport specific equipment to better care for athletes with cervical spine injuries in ice hockey.

**Risks of Participation**
There are risks involved in all research studies. This study may include only minimal risks.

**Cost/Compensation**
There may not be financial cost to you to participate in this study. The study will take 1.5 hours of your time. You will not be compensated for your time.

**Confidentiality**
All information gathered in this study will be kept as confidential as possible. No reference will be made in written or oral materials that could link you to this study. All records will be stored in a locked facility at UNLV for 3 years after completion of the study. After the storage time the information gathered will be shredded.

**Voluntary Participation**
Your participation in this study is voluntary. You may refuse to participate in this study or in any part of this study. You may withdraw at any time without prejudice to your relations with UNLV. You are encouraged to ask questions about this study at the beginning or any time during the research study.

**Participant Consent:**
I have read the above information and agree to participate in this study. I have been able to ask questions about the research study. I am at least 18 years of age. A copy of this form has been given to me.

_____________________________  ______________________________
Signature of Participant               Date

Participant Name (Please Print)

If your study includes the use of audio/video taping, you must include a separate signature line for the consent to audio or video tape. Otherwise, delete this section.

Audio/Video Taping:
Use language similar to:
I agree to be audio or video taped for the purpose of this research study.
Signature of Participant

Date

Participant Name (Please Print)
REFERENCES


Boergers, R., J. (2012). *Kinematic analysis of Head/Neck movement associated with lacrosse helmet facemask removal*. Unpublished PhD, Seton Hall University, Seton Hall University Dissertations and Theses (ETDs). (1812)


Paramedics train NHL team's staff for game emergencies. (2016, Columbus Dispatch)


*The American Journal of Sports Medicine, 15*(1)


CURRICULUM VITAE

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School of Allied Health Sciences
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galorkatc@gmail.com

Education

M.S. University of Nevada, Las Vegas 2015-Present
Kinesiology and Nutrition Sciences
Biomechanics (concentration)

B.S. University of Nevada, Las Vegas 2011-2015
Kinesiology of Allied Health (Major)
Kinesiology, Athletic Training (Major)

Academic Experience

UNLV Graduate Research Assistant Fall 2016-Spring 2017

Part Time Lecturer Spring 2016
Biology 223- Anatomy and Physiology

Volunteer Teaching Assistant- UNLV Fall 2015-Spring 2016
Sports Injury Management 150- Beginning Athletic Training

Student Research Assistant Fall 2015
Parkinson’s Research Project with UNLVPT

Guest Lecturer October, 2015
Nevada Athletic Trainers Association Annual State Meeting

Professional Experience

Strength and Conditioning Intern Fall 2017-Present
Vegas Golden Knights

Concussion Program Coordinator Spring 2016-Present
Nevada Amateur Hockey Association- USA Hockey Pilot Program for Concussion Management in youth hockey
Pilates Instructor       Summer 2017-Present

Head Athletic Trainer       Fall 2015-Fall 2018
    UNLV Ice Hockey

Head Athletic Trainer       Fall 2015-Spring 2017
    UNLV Roller Hockey, LV Storm Junior A Ice Hockey

Head Athletic Trainer       Summer 2017
    Team USA Ice Hockey 20th Maccabiah Games- Israel

RRIPG Rugby Research Group       Spring 2016
    Data collection for Rugby Injuries- Rugby 7s Invitational

Licensed and Certified Athletic Trainer       Summer 2015- 2016
    Select Physical Therapy

Athletic Training Intern       2012-2015
    High School, Collegiate, and Professional Athletics

Internship – Nevada Orthotics and Prosthetics       Fall 2014

Publications


Conference Presentations


**Funding**

Graduate Assistantship Stipend- Cirque Du Soleil  
July 2016-May 2017

GPSA Research Grant  
Fall 2016

Is variability of stride frequency a factor that determines preferred stride frequency during running? (2015) INBRE Undergraduate Research Grant

**Instrumentation**

Vicon 3-D Motion Capture, Bertec Instrumented Treadmill, Noraxon and Delsys Trigno Wireless EMG Systems, Kistler Force Platforms and AMTI Force Platforms