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Kinematic Analysis of Head/Neck Movement Associated with Lacrosse Helmet Facemask Removal

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KINEMATIC ANALYSIS OF HEAD/NECK MOVEMENT ASSOCIATED WITH LACROSSE HELMET FACEMASK REMOVAL

BY

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract

KINEMATIC ANALYSIS OF HEAD/NECK MOVEMENT ASSOCIATED WITH LACROSSE HELMET FACEMASK REMOVAL
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Context: The 2009 NATA Position Statement on Acute Management of the Cervical Spine-Injured Athlete, states that guidelines for management of the lacrosse athlete cannot be made until there is evidence regarding ease and safety of facemask (FM) removal. Athletic trainer work setting and helmet facemask attachment design may influence removal time and head/neck movement. Knowledge of helmet facemask attachment design differences may help athletic trainers provide effective acute management of suspected cervical spine-injured athletes. **Objective:** The purpose of this study was to assess the influence of work setting and helmet facemask attachment design on time and head/neck movement during the FM removal process. **Design:** 2 x 5 factorial design with random assignment of helmet type was used to assess the main effects and interactions of the independent variables [setting: (college, high school)] and [helmet: (Triumph, CPX, Pro7, XR, Venom)] on time and head/neck angle in 3 planes. **Setting:** University biomechanics lab. **Patients or Other Participants:** Twenty-four (12 high school, 12 college) certified athletic trainers (age 35.8 ± 8.9) with at least 1 year experience working with lacrosse athletes. **Interventions:** Subjects completed 1 trial of FM removal for each of the 5 different helmets worn by a human model. Three dimensional kinematic data of the head/neck relative to the trunk were collected using a Vicon Nexus motion capture system. The helmet was stabilized between the participant's knees while removing the FM with an electric screwdriver. Helmet testing order was randomized to control for ordering effect. Two separate 2 x 5 repeated measures ANOVA were used to evaluate main effects and interactions of work setting and helmet design on removal time and head/neck angle. Pairwise comparisons using a Bonferroni correction were used post hoc. **Main Outcome Measures:** The dependent variables were removal time (sec), and maximal head/neck angle (deg) in relation to the trunk measured in three planes. **Results:** There was a significant main effect of helmet facemask attachment design on time. Mean removal times ranged from 31.09 – 79.02 sec. Four helmets (Triumph, CPX, XR, Venom) took significantly less time to remove than the Pro7 helmet. The Triumph, CPX, XR took significantly less time than Venom helmet and the Triumph took significantly less time than the CPX and XR ($p < .05$). Significant differences existed between maximal movement angle in the sagittal plane ($p < .05$). Maximal movement angle in the sagittal plane for the

Triumph helmet (7.08° ± 3.59°) was significantly more than the Pro7 (4.30° ± 2.39°). There were no significant differences between helmets for maximal frontal and transverse plane angle. There was no significant main effect of work setting on any of the outcome measures. There were no significant interactive effects on any of the outcomes. **Conclusion:** Helmet facemask attachment design affected time and maximal head/neck angle.

CHAPTER I

INTRODUCTION

Lacrosse has recently experienced rapid growth in all levels of participation. It is a high-velocity overhead collision sport which requires safety equipment to help prevent injuries. While lacrosse athletes wear helmets and shoulder pads similar to football athletes, the equipment design, materials and construction differ greatly. Currently, strong guidelines exist for the pre-hospital management (PHM) of the cervical spine-injured football athlete; however these guidelines may differ when dealing with lacrosse equipment.

Due to the nature of the sport of lacrosse, injuries to the head and neck are common. According to the NCAA head injuries account for nearly 9% of all men's lacrosse injuries (McCulloch & Bach, 2007). While neck injuries are not that common, a risk exists because of the body checking that occurs in the game. According to the National Center for Catastrophic Sports Injury Research database, there were three cervical spine fractures which resulted in one disability in collegiate lacrosse, and five at the high school level which resulted in two fatalities and two with permanent disabilities between 1982 and 2003 (Mueller & Cantu, 2003). More recently in 2008 and 2009, two high school lacrosse athletes sustained cervical spine fractures with one resulting in a disability (Bostic, 2010; Laxbuzz, 2009). While this number of neck injuries is relatively small, one must realize that the popularity of lacrosse has grown exponentially since that time period.

Guidelines for PHM of an athlete with a cervical spine injury are critical because of the potential catastrophic nature of the injury. A great deal of research has focused attention on pre-hospital management of football athletes with cervical spine injuries (Decoster, Shirley, & Swartz, 2005; Jenkins, Valovich, Arnold, & Gansneder, 2002; Putman, 1992; Swartz, Armstrong, Rankin, & Rogers, 2002; Swartz, Norkus, Armstrong, & Kleiner, 2003; Swartz, Norkus, Cappaert, & Decoster, 2005; Waninger, 2004). Research concerning management of the cervical spine-injured lacrosse athlete is inadequate.

Current guidelines for the PHM of the football athlete recommend keeping the helmet and shoulder pads in place and removing only the facemask, in order to access an airway (Kleiner et al., 2001; Swartz et al., 2002; Swartz, Decoster, Norkus, & Cappaert, 2007; Swartz et al., 2003; Swartz, Norkus, et al., 2005). Additionally, research on removal of football helmet facemasks now recommends the use of a cordless screwdriver to limit movement of the head and neck and increase speed of removal (Swartz, Norkus, et al., 2005). These findings are contrary to the somewhat out of date guidelines published by the Inter-Association Task Force on the pre-hospital care of the cervical spine- injured athlete (Kleiner et al., 2001). Research focusing on the removal of facemasks on football helmets has resulted in providing athletic trainers and other first responders with knowledge of the best tools available for removal and improved helmet design which will result in improved care. While lacrosse equipment is somewhat similar to football since it includes a helmet and shoulder pads, it really is quite different. Unfortunately, there is very limited support in the scientific literature pertaining to care of a cervical spine-injured lacrosse athlete.

Current recommendations for the PHM of a cervical spine-injured lacrosse athlete include keeping the helmet and shoulder pads in place (Burke, 2008; Sherbondy, Hertel, & Sebastianelli, 2006; K. Waninger, J. Richards, W. Pan, A. Shay, & M. Shindle, 2001). According to Sherbondy et al., (2006), removal of the helmet alone will result in an increased mean cervical flexion angle of 4.7 degrees of the upper cervical spine when the athlete is lying supine, compared to leaving the helmet intact. Most recently, Burke (2008) and the US Lacrosse Sports Science and Safety Committee have published the first lacrosse helmet facemask removal hints paper. Undoubtedly, a controversy of PHM of the cervical spine-injured lacrosse athlete exists given that this recent facemask removal hints paper provides the first recommendations made for certified athletic trainers. It is important to note that these recommendations are based solely on the research from Sherbondy et al. (2006). Further research concerning the time and movement associated with facemask removal of the lacrosse helmet is needed. If helmet design impedes removal time or increases head and neck movement, improvements must be made. Research on football helmets has resulted in improved helmet technology which will better allow for more efficient PHM of a cervical spine-injured football athlete. Safety in the sport of lacrosse deserves the same attention as football has received in the past.

Problem Statement

There is a limited body of research concerning the pre-hospital management of the cervical spine-injured lacrosse athlete. Specific guidelines exist for the pre-hospital management of the cervical spine-injured football athlete in terms of recommended tools for facemask removal (Kleiner et al., 2001). Removal success rates, time of facemask removal from the lacrosse helmet and head/neck movement associated with removal using an electric screwdriver are unknown at this time. Data from research performed on these topics will allow clinicians to judge whether this procedure is appropriate for the pre-hospital management of the cervical spine-injured lacrosse athlete.

Purpose

In this study, certified athletic trainers (ATCs) removed facemasks from lacrosse helmets in a single-person rescue simulation using an electric screwdriver. Time of removal and maximal head/neck angle in the sagittal, frontal and axial planes were compared between different helmets. Secondarily, the influence of work setting on time and movement were explored. These data will help in the creation of guidelines for pre-hospital management of the cervical spine-injured lacrosse athlete.

Research Hypotheses

Primary Hypotheses.

Hypotheses 1-4 are based on the theory of speed/accuracy tradeoff. The construct of the index of difficulty (ID) used in speed/accuracy tradeoff is explained by the number and location screws which are used to attach a facemask to a helmet.

H1: Helmets with fewer screws (lower ID) will have faster time of removal.

H_{1a}: Helmets with three screws (Triumph, CPX, XR) will have faster time of removal than those with five screws (Pro7) and those with seven screws (Venom).

H_{1b}: There will be no difference in time of removal between helmets with three screws (Triumph, CPX, XR).

H2: Helmets with fewer screws (lower ID) will have smaller maximal head/neck angles.

H_{2a}: Helmets with three screws (Triumph, CPX, XR) will have smaller maximal head/neck angles than those with five screws (Pro7) and those with seven screws (Venom).

H_{2b}: There will be no difference in maximal head/neck angles between helmets with three screws (Triumph, CPX, XR).

H3: Helmets with screws located closer to each other (lower ID) will have faster time of removal.

H_{3a}: Helmets with screws located closer together (Triumph, CPX, XR) will have faster time of removal than those with screws located further apart (Pro7 & Venom).

H_{3b}: There will be no difference in time of removal between helmets with close screw location (Triumph, CPX, XR).

H4: Helmets with screws located closer to each other (lower ID) will have smaller maximal head/neck angles.

H_{4a}: Helmets with screws located closer together (Triumph, CPX, XR) will have smaller maximal head/neck angles than those with screws located further apart (Pro7 & Venom).

H_{4b}: There will be no difference in maximal head/neck angles between helmets with close screw location (Triumph, CPX, XR).

H5: Collegiate ATCs will have faster time of removal than Secondary School ATCs.

H6: Collegiate ATCs will have smaller maximal head/neck angles than Secondary School ATCs.

Secondary Hypotheses.

H7: Helmets with fewer screws will have smaller peak angular velocities.

H_{7a}: Helmets with three screws (Triumph, CPX, XR) will have smaller peak angular velocities than those with five screws (Pro7) and those with seven screws (Venom).

H_{7b}: There will be no difference in peak angular velocities between helmets with three screws (Triumph, CPX, XR).

H8: Helmets with fewer screws will have smaller peak angular accelerations.

H_{8a}: Helmets with three screws (Triumph, CPX, XR) will have smaller peak angular accelerations than those with five screws (Pro7) and those with seven screws (Venom).

H_{8b}: There will be no differences in peak angular accelerations between helmets with three screws (Triumph, CPX, XR).

H9: Helmets with screws that are closer together will have smaller peak angular velocities.

H_{9a}: Helmets with screws located closer together (Triumph, CPX, XR) will have smaller peak velocities than those with screws located further apart (Pro7, Venom).

H_{9b}: There will be no difference in peak velocities between helmets with close screw location (Triumph, CPX, XR).

H10: Helmets with screws that are closer together will have smaller peak angular accelerations.

H_{10a}: Helmets with screws located closer together (Triumph, CPX, XR) will have smaller peak accelerations than those with screws located further apart (Pro7, Venom).

H_{10b}: There will be no difference in peak accelerations between helmets with close screw location (Triumph, CPX, XR).

H11: Collegiate ATCs will have smaller peak angular velocities than Secondary School ATCs.

H12: Collegiate ATCs will have smaller peak angular accelerations than Secondary School ATCs.

Significance of the Study

Findings from this study will aid clinicians in deciding whether facemask removal in the cervical spine-injured lacrosse athlete is appropriate for pre-hospital management. The results may provide an understanding of the speed/accuracy tradeoff in the facemask removal process which could potentially affect educational competencies. The results can help to determine which helmet characteristics are desirable for effective facemask removal. Additionally, the results will provide empirical evidence which can help in the creation of recommended guidelines for the pre-hospital management of the cervical spine-injured lacrosse athlete. Lastly, this investigation may lead to the identification of other variables to be included in various injury reporting databases.

Operational Definitions:

Pre-hospital management – Care provided to a patient prior to being treated in a hospital. Care is often provided by athletic trainers and other first responders and may include controlling bleeding, immobilization of unstable fractures, airway management and cardiac management.

ATC – Certified athletic trainer- Health care professionals who collaborate with physicians to optimize activity and participation of patients and clients. Athletic training encompasses the prevention, diagnosis and intervention of emergency, acute and chronic medical conditions involving impairment, functional limitations and disabilities.

Helmet – Protective device worn on an athlete's head to help reduce the risk of concussions. It consists of a hard plastic shell, has padding on the inside, a facemask, and is fastened in place with a chinstrap.

Facemask – Part of the helmet that directly covers the face. It is fixated to the helmet using screws and plastic clips.

Direct Catastrophic Injury - Those injuries which resulted directly from participation in the skills of the sport. These include deaths, non-fatal injuries which result in permanent severe functional disabilities and serious injuries which resulted in no permanent functional disability.

Spineboarding- Process by which a patient with an actual or suspected spine injury is placed on a wooden or plastic board to be immobilized for transport to a hospital.

Shoulder Pads- Piece of protective equipment worn in collision sports to protect the shoulders, chest and upper back region of the athlete. It consists of padding inside and has a firm plastic outer surface.

Head/Neck segment- Representation of the head and neck as one entire unit. Due to the limitations of biomechanical modeling this motion analysis study chose to evaluate movement of the combined head/neck segment.

Iatrogenic injury – Inadvertent adverse effect as a result from treatment by a medical professional.

Need for the Study:

Guidelines for pre-hospital management of an athlete with a cervical spine injury are critical because of the potential catastrophic nature of the injury. A great deal of research has focused attention on pre-hospital management of football athletes with cervical spine injuries, however research performed on lacrosse athletes is inadequate. The goal of this study is to provide evidence for the athletic trainer to make decisions regarding their emergency management practices on lacrosse athletes. Understanding the temporal and spatial characteristics associated with lacrosse facemask removal will help shape guidelines for the pre-hospital management of the lacrosse athlete with a suspected cervical spine injury. It is also possible that this project will improve lacrosse helmet design to help with the overall safety of the lacrosse athlete and make facemask removal more efficient for the athletic trainer.

Theoretic Basis for the Investigation

The facemask removal process is a rather complex motor task. Athletic trainers and other first responders are instructed to complete the task as quickly as possible, while creating minimal movement of the head and neck (Kleiner et al., 2001) which creates a Fitts' Paradigm. According to Fitts' Law of speed/accuracy tradeoff, movement time is related to the amplitude and the target width of a movement (Schmidt & Lee, 1999). The amplitude and the target width of a movement create what is termed the index of difficulty (Schmidt & Lee, 1999).

Quick facemask removal is essential during the management of the cervical spine-injured athlete. A facemask will block access to an injured athlete's airway. If a patient ceases breathing for a period greater than two minutes, brain tissue death is likely to occur (Schottke, 2006). Creating little or no head and neck movement is also critical during the management of the cervical spine-injured athlete. As per the Inter Association Task Force (IATF) guidelines, all injuries should be managed as if a spinal cord injury has occurred (Kleiner et al., 2001). Numerous injuries to the cervical vertebrae may cause secondary injury to the spinal cord, so it is critical to stabilize the head and neck to help reduce the risk of iatrogenic injury.

Certified athletic trainers and first responders performing facemask removal should not place the speed or minimizing of head/neck movement as priority; they are equally important and require a delicate balance. If the first responder only focuses on being quick, they may create too much head and neck movement. If the focus is placed only on minimizing head and neck movement, removal of the facemask may be too slow to provide adequate care to the injured athlete. The facemask removal task has a high index of difficulty for the first responder. To complicate matters, some lacrosse helmet designs have a greater number of screws to remove or screws that are not located close together, which can increase the index of difficulty. The increase in the index of difficulty may lead to longer time of removal, increased head and neck movement, or both.

CHAPTER II

REVIEW OF LITERATURE

Lacrosse

The sport of lacrosse has experienced tremendous growth over the last decade. Between the years of 2001 and 2007, according to US Lacrosse, the number of lacrosse players grew by 89.9% (Sperry Aungst, 2007). Most recently, a large growth (18.6%) was seen in the number of high school players between 2006 and 2007, indicating the addition of many new teams at that level. Additionally, over 152 new NCAA lacrosse programs were added between 1996 and 2006 (Sperry Aungst, 2007). Increased participation in the sport may lead to an increase in reported injuries. Men's lacrosse is a high-speed and high-impact collision sport which requires all players to wear helmets, facemasks, mouth guards, gloves, elbow pads and shoulder pads (Lincoln, Hinton, Almquist, Lager, & Dick, 2007). Player-to-player contact is allowed by rule and players use their sticks as well as their bodies to check opponents and defend the ball. It is not uncommon for a player to get hit in the head, collide with another player or even have contact with his head down in a susceptible position. Due to the perceived violent nature of the sport, serious injuries are expected.

In the event of an unconscious athlete or a suspected cervical spine injury, a certified athletic trainer must be efficient in the pre-hospital management of the situation (Swartz et al., 2009). In 2001, the Inter-Association Task Force on the Pre-Hospital Management of the Spine Injured Athlete published guidelines for care based on previous research using football equipment (Kleiner et al., 2001). Currently, no specific guidelines exist in the PHM of the lacrosse athlete. Results of previous research studies has led to the authors' recommendations that it is safest to leave the helmet in place on the cervical spine-injured lacrosse athlete, suggesting that facemask removal may be the best approach to accessing an airway (Sherbondy et al., 2006; K. Waninger et al., 2001). One author has recognized and warned first responders that handling lacrosse helmets and equipment is different than football helmets and equipment (Waninger, 2004). The author recommended facemask removal using a cordless screwdriver for the PHM of the cervical spine- injured lacrosse athlete. Additionally, in February 2008, a facemask removal hints brochure was produced by US Lacrosse (Burke, 2008). This brochure described the recommended facemask removal process for different helmets from an anecdotal perspective. Most recently, a study of FM removal tools found that a cordless screwdriver was quicker than cutting tools (FM Extractor) or a combined tool approach (Frick, Bradney, Aronson, & Bowman, 2011). At this time, no known studies are available concerning the spatial characteristics associated with lacrosse helmet facemask removal.

Epidemiology

A recent study of collegiate men's lacrosse injuries indicated that all injuries occurred four times more frequently in games than in practices. Approximately 48.1% of game injuries occurred in the lower extremity, 26.2% occurred in the upper extremity and 11.7% occurred in the head and neck (Dick, Romani, Agel, Case, & Marshall, 2007). Player contact was reported as the mechanism of injury in 45.9% of all injuries, and 78.5% of all concussions. An increase in the rate of concussions was seen in two longitudinal studies (Hootman, Dick, & Agel, 2007; Mueller & Cantu, 2007). Hootman et al. (2007) reported a 7% increase in the concussion rate in lacrosse athletes between 1988 and 2004, which was greater than that seen in other collision sports like football and hockey. Similarly, Mueller and Cantu (2007) reported a concussion rate of 0.63 per 1000 athlete exposures between 1988-1996, which then rose to 1.47 per 1000 athlete exposures between 1997-2004. One research study speculated that this increased rate was simply from the increased participation and improved concussion recognition and treatment in the sports medicine community (Dick et al., 2007). Another possible cause for the increased rate of concussions may have been the change from traditional helmet designs to contemporary designs. Research demonstrated that the new helmets differed from the traditional designs in the dissipation of forces (Caswell & Deivert, 2002). Specifically, it was found that the contemporary helmets were better at protecting the head from rear-impact forces but worse at attenuating frontal forces. Recently, Bowman (2008) found different rates of concussions for different helmets indicating that some may be safer than others based on the design and materials from which each is made. While the main function of helmets is to protect the athlete's head and face from blunt force trauma which may cause concussions, some researchers believe that wearing helmets may have led to an increase in the number of cervical spine injuries in collision sports (Heck, Clarke, Peterson, & Torg, 2004).

According to the National Center for Catastrophic Sports Injury Research database between 1982 and 2003, three athletes sustained cervical vertebrae fractures at the collegiate level with one resulting in disability; and five fractures were seen at the high school level including two fatalities and two athletes with disabilities (Mueller & Cantu, 2003). The average number of catastrophic injuries in the sport of lacrosse is relatively low, however the fatality rate for high school lacrosse athletes (0.26 per 100,000) is comparable to hockey (0.29 per 100,000) and football (0.30 per 100,000) (Mueller & Cantu, 2007). The fatality rate for college lacrosse athletes far exceeds the rate seen in hockey and football. With the increased participation in lacrosse, it is likely there will be an overall increase in the number of injuries, with catastrophic injury rates increasing as well.

Proper management of a cervical spine-injured athlete is critical for the first responder. Strict guidelines are needed to aid athletic trainers in the management of the cervical spine-injured lacrosse athlete. Studies of PHM of the football athlete have led to improvements in equipment and knowledge of tools available for use by the first responder. Understanding the temporal and spatial characteristics associated with lacrosse helmet facemask removal may lead to similar improvement in equipment and the development of guidelines for the first responder.

Cervical Spine Injury Pathomechanics

Head and neck injuries, while uncommon in sports are serious events which can lead to paralysis, quadriplegia or even death. Within sports however, these injuries occur most often in contact sports such as football, lacrosse, and ice hockey as well as sports such as soccer where a player may incidentally come into contact with another player or head the ball improperly. Axial loading to the spine has been identified as the most frequent mechanism for cervical spine injuries in athletics (Bailes, Petschauer, Guskiewicz, & Marano, 2007; Ghiselli, Schaadt, & McAllister, 2003; Kleiner et al., 2001; Nightingale, Camacho, Armstrong, Robinette, & Myers, 2000; Nightingale, McElhaney, Richardson, & Myers, 1996; Waninger, 2004). An axial load typically occurs from a blow to the top of the head with the neck placed in slight flexion (Bailes et al., 2007; Ghiselli et al., 2003; Kleiner et al., 2001; Nightingale et al., 2000; Nightingale et al., 1996; Waninger, 2004). The normally aligned cervical spine can absorb much of the energy from collisions by dissipation of forces through the normal lordotic curve, the paravertebral musculature and the intervertebral disks (Bailes et al., 2007; Nightingale et al., 2000; Nightingale et al., 1996; Waninger, 2004). However, once the neck is placed in approximately 30° of flexion, the forces are directed axially through the segmented spinal column which may result in vertebral fracture, dislocation, or subluxation which may cause secondary injury to the spinal cord (Bailes et al., 2007; Nightingale et al., 2000; Nightingale et al., 1996; Waninger, 2004). The secondary injury to the spinal cord may create a catastrophic condition such as quadriplegia or tetriplegia (Bailes et al., 2007; Heck et al., 2004).

During compressive loading, the cervical spine may fail because of excessive forces caused by compression, or a combination of compression and bending (Bailes et al., 2007; Nightingale et al., 2000; Nightingale et al., 1996; Waninger, 2004). One study found that increases in vertebral mass and stiffness lead to larger peak loads and impulses (Nightingale et al., 2000). Additionally, the authors determined that faster loading rates caused higher peak loads and higher order buckling modes (Nightingale et al., 2000). The results of this study demonstrated that loading rate substantially changed injury types and mechanisms due to the fact that inertial effects influenced whether the cervical spine failed from compressive or bending forces (Nightingale et al., 2000). Another study evaluated how restrictions of head motion affected impact responses of the neck during axial loading (Nightingale et al., 1996). This study found that head pocketing into a padded impact surface and the head pre-flexion by simulated muscle traction increase the risk of neck injury during compressive loading. Other research by the same authors found that friction between the head and the impact surface created additional loads to the neck (Comacho, Nightingale, & Myers, 1999).

Injury Prevention.

Injuries to the head and neck may occur in collision sports, like lacrosse. US Lacrosse is the official governing body of the sport of lacrosse. The Sports Science and Safety Committee of US Lacrosse is responsible for recommendations made for the overall health and safety of lacrosse athletes. One area they provide information is related to equipment. The committee endorses properly fitted helmets which meet National Operating Committee on Standards for Athletic Equipment (NOCSAE) standards (Putukian, 2004). NOCSAE produces standards which helmet manufacturers must meet prior to retail distribution, which includes passing several helmet drop tests (NOCSAE, 2012). While NOCSAE ensures the standards of newly manufactured lacrosse helmets, it issues no standards or guidelines for reconditioning of used helmets (Crisco, 2004). NOCSAE standards should help with player safety by ensuring that helmets will help to protect a player's head and face from blunt force trauma. Helmets are worn to help protect players from concussions, however some have speculated that this may have led to an increase in cervical spine injuries in collision sports (Heck et al., 2004).

Unfortunately, a helmet and shoulder pads worn by players presents unique problems for the emergency management of cervical spine injuries, which need to be addressed by athletic trainers and other first responders.

Emergency Management of Cervical Spine Injuries

In 1998, representatives from over 30 emergency medicine and sports medicine organizations met and formed the Inter-Association Task Force (IATF) for the Appropriate Care of the Spine-Injured Athlete. The IATF developed recommendations that would help healthcare providers in the PHM of cervical spine-injured athletes. The IATF recommended the following six guidelines for proper care of an athlete with a suspected spinal injury:

1. Manage the athlete suspected of a spinal injury as though a spinal injury exists.
2. Activate EMS.
3. Assess the athlete's airway, breathing and circulation, neurologic status and level of consciousness.
4. Do not move the athlete unless it is absolutely essential to maintain the airway, breathing and circulation.
5. If the athlete must be moved to maintain airway, breathing and circulation, place them in a supine position while maintaining spinal immobilization.
6. When moving a suspected cervical spine-injured athlete, move the head and trunk as a unit (Kleiner et al., 2001).

Current research suggests that helmet removal in an uncontrolled environment can lead to extraneous head movement and disrupt the spinal alignment. If the helmet is removed without concurrent removal of the shoulder pads, the risk of iatrogenic injury is increased (Bailes et al., 2007; Ghiselli et al., 2003; Kleiner et al., 2001; Sherbondy et al., 2006; Waninger, 2004). Current guidelines recommend that a helmet should be removed only when (a) removal of a facemask alone cannot be performed in a reasonable amount of time, (b) the design of the helmet and chin strap will not allow for proper ventilation to be provided after facemask removal, (c) the helmet and chin strap are poorly fitted and fail to immobilize the head, or (d) the helmet prevents immobilization for transport (Kleiner et al., 2001; NCAA, 2008). Waninger (2004) added that a helmet may be removed if there is evidence of a head injury that requires direct inspection, or once the initial radiographs and computed tomography (CT) scans are found to be normal at the emergency department.

Previous research by Waninger et al. (2001) suggested that properly fitted helmets in all collision sports (football, hockey, lacrosse) adequately immobilized the head when spineboarded. This motion analysis study found no significant difference between the three collision sports helmets for the mean lateral head motion that occurred inside a helmet. Lacrosse helmets had a mean of 6.56° motion compared to 4.88° and 5.54° for football and hockey, respectively. This lends support to leaving the helmet in place during the PHM of a cervical spine-injured lacrosse athlete.

Strong evidence exists in support of leaving the football helmet and shoulder pads in place when caring for a cervical spine-injured football player. However, evidence is mixed when dealing with leaving the lacrosse helmet and shoulder pads in place after a suspected head or neck injury. Most authors agree that removal of the football helmet alone will result in a large degree of neck extension, while removal of the football shoulder pads alone would create a large degree of neck flexion (Davidson, Burton, Snowise, & Owens, 2001; Gastel, Palumbo, Hulstyn, Fadale, & Lucas, 1998; Kleiner et al., 2001; Tierney, Mattacola, Sitler, & Maldjian, 2002; Waninger, 2004). Leaving both the football helmet and shoulder pads in place has been shown to provide significantly greater space for the spinal cord in human subjects without spinal pathology (Tierney et al., 2002) and to significantly reduce posterior disk space and angular displacement in a cadaver model with destabilized C5-C6 segments (Gastel et al., 1998). One author suggested that the thickness of the football helmet and shoulder pads offset each other, allowing for the neck to be placed in a neutral position (Gastel et al., 1998). The same may not be true for lacrosse equipment.

Lacrosse helmets tend to be bulky, while the shoulder pads vary greatly in thickness. It is common for offensive players to wear thicker shoulder pads for protection from defenders' stick checks, while defensive players wear thin shoulder pads since they are the players who perform the stick checks. In either instance, the shoulder pads do not tend to have the same bulk as the helmet, which makes the helmet-shoulder pad relationship very different from football. In a computed tomography study of uninjured lacrosse athletes, Sherbondy et al. (2006) found that wearing a helmet and shoulder pads placed the neck in significantly greater cervical extension (6°) compared to no equipment. Helmet removal alone created a mean increase in cervical flexion of 4.7° compared to wearing the helmet and shoulder pads. Removal of a lacrosse helmet alters the neck kinematics differently than removal of a football helmet. The author suggested leaving both the helmet and shoulder pads in place during the PHM of a cervical spine-injured lacrosse athlete, since removal of either piece of equipment created change in the spinal alignment. An unscientific publication from the US Lacrosse Sport Science and Safety Committee supported leaving the helmet and shoulder pads of a cervical spine-injured lacrosse athlete in place (Burke, 2008) and this recommendation was echoed by the NCAA Sports Medicine Handbook (NCAA, 2008).

Two studies disagreed with these recommended conservative procedures for PHM of the cervical spine-injured lacrosse athlete (Higgins, Tierney, Driban, Edell, & Watkins, 2008; Petschauer, Schmitz, Perrin, Williams, & Gill, 2007). A motion analysis study of men's lacrosse athletes who were spineboarded found there was significantly greater head-to-thorax motion in all three planes of movement for subjects wearing properly fitted helmets compared to those wearing no equipment (Petschauer et al., 2007). While the authors concluded that the cervical spine was better stabilized during spineboarding without a helmet, they failed to establish how the head would move during a condition with only shoulder pads. Knowing this information could greatly change the recommendations. A magnetic reasonance imaging (MRI) study of lacrosse athletes wearing different levels of equipment by Higgins et al. (2008) found there was no significant difference in the space available for the spinal cord between the different levels of equipment. This finding was interpreted to mean that wearing shoulder pads alone after a helmet was removed did not significantly change the space available for the spinal cord compared to full equipment removal. It can be suggested that removal of the lacrosse helmet may be a safe and effective way for accessing an airway in a cervical spine-injured athlete. This approach is not supported by the IATF document; however it may lend support to helmet removal if the facemask removal process is too slow. The level of skill provided by the athletic trainer during the PHM of a cervical spine-injured athlete may affect the overall quality of care received.

Athletic Trainer Work Setting Differences.

The National Athletic Trainers' Association (NATA) lists the top three work settings for athletic trainers as professional sports, colleges and universities, and secondary schools (NATA, 2012). The sport of lacrosse is played largely in the collegiate and secondary school settings and continues to experience growth (Sperry Aungst, 2007). Athletic trainers working in both of these settings need to be prepared to provide emergency management for suspected and actual cervical spine injuries to athletes wearing lacrosse equipment. Knowledge of lacrosse helmets and shoulder pads and how they may affect cervical spine positioning is critical to the PHM of the cervical spine-injured athlete. Unfortunately, there may be discrepancies in the preparation for management of cervical spine injuries between collegiate athletic trainers and secondary school athletic trainers. Pfeiffer and Mangus (2005) explained that college athletic trainers typically only work one sport, which allowed them to "specialize", while secondary school athletic trainers have to provide medical coverage to lacrosse and many other sports. This ability for the collegiate ATC to specialize may equip them with the time and skills necessary to provide more efficient emergency management to cervical spine-injured athletes. Research by Donahue (2009) contradicted the idea that collegiate athletic trainers are better prepared to manage injuries to the cervical spine. The study of athletic trainers' perceptions on the importance, preparation and time spent in the athletic training practice domains found no significant differences between high school athletic trainers and collegiate athletic trainers in the domain of acute care of injuries and illness (Donahue, 2009). A five-point Likert scale was used to measure the dependent variables. Specifically, collegiate athletic trainers rated the acute care of injuries and illness as extremely important 5.0 (± 0.0) to the high school athletic trainers 4.9 (± 0.5). Time spent performing skills associated with acute care of injuries and illness were 4.8 (± 0.4) for collegiate athletic trainers and 4.8 (± 0.5) for high school athletic trainers. The results of this study suggested that athletic trainers working in both the collegiate and high school settings should be equally proficient and the PHM of cervical spine injuries.

Facemask Removal

Similar to the controversies around full helmet removal in an emergency situation of an athlete wearing equipment, the literature has changed the best practice procedure for facemask removal as well. In the event of a possible cervical spine injury it is important to have access to the patient's airway regardless of their level of consciousness. According to the IATF for Appropriate Care of the Spine-Injured Athlete, the facemask should be removed at the earliest opportunity, regardless of current respiratory status (Kleiner et al., 2001). In sports that require use of helmets, this can prove to be difficult and the recommendations to gain access to the airway vary widely (Bailes et al., 2007). It is important to note that all previous research has been performed on football helmets (Copeland, Decoster, Swartz, Gattie, & Gale, 2007; Decoster et al., 2005; Gale, Decoster, & Swartz, 2008; Jenkins et al., 2002; Knox & Kleiner, 1997; Ray, Luchies, Abfall Frens, Hughes, & Sturmfels, 2002; Ray, Luchies, Bazuin, & Farrell, 1995; Swartz et al., 2002; Swartz et al., 2007; Swartz et al., 2003; Swartz, Norkus, et al., 2005; Swartz, Nowak, Shirley, & Decoster, 2005). Lacrosse helmets differ from football helmets in materials, padding, design, placement of hardware and screws, and facemask anchoring systems. Unfortunately, there is a lack of evidence concerning the temporal and spatial characteristics of lacrosse helmet facemask removal. To date, an anecdotal paper by Burke (2008) exists describing the facemask removal process for a lacrosse helmet, and one other study determined which tool was most appropriate for facemask removal (Frick et al., 2011). The study by Frick et al. (2011) resulted in the first reported temporal data related to lacrosse helmet facemask removal. Specifically, they found that a cordless screwdriver was faster at removing facemasks from Cascade CPX helmets than cutting tools (FM Extractor [FME] and Trainer's Angel). There is a need for further studies on temporal data for lacrosse helmet facemask removal and initial studies on kinematic data during the procedure. Table 1 illustrates facemask removal times using a cordless screwdriver reported in previous lacrosse helmet facemask removal studies.

Table 1.
Lacrosse Helmet FM Removal Times Using Cordless Screw Drivers in Different Studies

	Frick et al.		Boergers et al.		Current Findings	
	Mean	SD	Mean	SD	Mean	SD
Brine Triumph			23.58	10.50	31.09	10.55
Cascade CPX	38.83	11.49	25.03	5.08	37.91	21.73
Cascade Cpro			28.23	7.70		
Cascade Pro7					79.02	35.76
Riddell XR			22.93	6.86	48.01	33.11
Warrior Venom					66.04	38.93
Warrior Viking			48.36	17.02		

(Boergers, Dunn, Lorenzo, Luu, & VanHalle, 2009; Frick et al., 2011)

Numerous researchers have studied the most efficient ways of accessing an airway in a possible cervical spine-injured athlete wearing football equipment. These studies support the safest way to gain access to the airway is to remove only the facemask. According to the Inter-Association Task Force the head and neck should be stabilized while the facemask is removed and the helmet and shoulder pads should be left in place, unless there are circumstances that do not allow for these methods, such as an improperly fitted helmet or the inability to remove the FM in an expedient manner (Kleiner et al., 2001). Removing only the facemask is the simplest way to gain access to an airway with little risk of iatrogenic injury.

Removing the facemask from football helmets with a cordless screwdriver has proven to be more effective than using cutting tools. A cordless screwdriver created less head and neck movement and was less time-consuming than cutting tools (Jenkins et al., 2002;). It is however also apparent there are times when the screws become so damaged or warped that the screwdriver is unable to remove them effectively, and therefore another tool must be readily available (Decoster et al., 2005). In one study, 885 screws were removed from 222 football helmet facemasks. Of the 885 screws, 94% were successfully removed with a cordless screwdriver, however only 82.4% of the facemasks were removed(Decoster et al., 2005). The location of the screws was an important factor in this study since 98% of the screws located above the forehead were removed compared to only 90% of the screws located next to the ear holes of the helmets. Based on this literature, the need exists for other tools to be available in case there are screws that are too warped to be removed or if the T-nut holding the screws in place spins, preventing removal of the screw. Lacrosse helmets have similar screw settings that also include T-nuts which need to be taken into consideration.

Studies have found various factors that contribute to the success or failure of removing screws from helmets. The most common reason for the screws to get stuck in the helmet was that the T-nut spun within the helmet (Swartz et al., 2007). Another leading cause of failure to remove the screws was stripping at the heads of the screws (Swartz et al., 2007). Other variables contributing to the success rate of removing screws were the materials that the screws were made of and the location of the screws (Swartz et al., 2007). The screws of football helmets that are on the sides of the facemask were generally more difficult to remove (Swartz et al., 2007). It was suggested that this may be due to the excessive heat and sweat that these screws are exposed to; however weather has not been found to be a factor in determining if the screws could be removed from the helmets (Swartz et al., 2007). It can be hypothesized that similar results would be found when removing screws from lacrosse helmets since the screw settings are comparable.

In another study, researchers investigated the movement created while removing the facemask of football helmets by using a 3-dimentional analysis (Swartz et al., 2007). "Movement of the head in relation to the helmet was assessed backboard immobilization. A bite-stick marker allowed the identification of rotational head movement versus movement of helmet markers. Results showed that there was less head movement in the football helmet compared to the lacrosse and hockey helmets. An important finding of this study is that there is both movement of the helmet and movement of the head within that helmet that occurs during facemask removal (Swartz et al., 2003). The research suggests that the FME was significantly faster than the anvil pruner, Trainer's Angel, and PVC pipe cutter during facemask removal (Swartz et al., 2003). A cordless screwdriver was not used in this study.

In another study, cutting and removal tools were tested to determine the forces and torques placed on football helmets during facemask removal (Jenkins et al., 2002). For cutting tools the study used the Trainer's Angel and facemask extractor (FME). For removal tools it used a power screwdriver and a quick release system with a flat-head screwdriver. The authors showed that removal tools were quicker and caused less force and torque on the helmet compared to the cutting tools (Jenkins et al., 2002).

In many situations, specifically if the injured athlete is conscious and breathing, it is more important to limit the movement of the helmet and head during facemask removal or retraction, than it is to perform the process very quickly, in order to prevent further injury (Swartz et al., 2003).

Previous studies have shown the importance of facemask removal from football helmets. These studies have determined that cordless screwdrivers can be quick to use and cause little head movement. However, there was a significant failure rate when it came to removing each screw and therefore another tool should be readily available for use. With the design of lacrosse helmets it will be necessary for athletic trainers and first responders to use both the cordless screwdriver and another tool. According to other research the facemask extractor (FME) has been shown to work more quickly to cut the straps when compared to other cutting tools that are commonly used in the field.

Motor Control of Helmet Facemask Removal

The first responder or athletic trainer providing the PHM of a cervical spine-injured lacrosse athlete has to manage a difficult task. In accordance with the IATF guidelines and research by Sherbondy et al (2006), the PHM of a cervical spine-injured athlete should include leaving the helmet and shoulder pads in place and removal of the facemask for access to the airway. The facemask removal process in itself presents a Fitts' Paradigm since the first responder should remove the helmet as quickly as possible while creating the least amount of movement at the head and neck (Kleiner et al., 2001). The task is discrete, beginning with the start of screw removal and ending when all screws have been extracted, allowing for the facemask to be separated from the helmet. A previous study demonstrated that facemask removal time is relatively short (between 22.93 and 48.36 sec.) (Boergers et al., 2009). First responders are not able to make facemask removal a pre-programmed event due to the complexity of the task. Additionally, facemask removal falls under open loop control due to the unpredictable environment in which it occurs (Schmidt & Lee, 1999). In a lab setting, one or two of the screws may be too tight and the bit from the screwdriver slips, causing the first responder to change movement strategies. In a live situation that occurs on a playing field, noise, weather conditions, and actions of players, coaches and officials may greatly affect the removal process. The success of facemask removal in creating a positive result for the patient may lie in the first responder's prioritization of speed and accuracy.

Speed/Accuracy Tradeoff

The guidelines of the IATF document for PHM of the cervical spine-injured athlete specifically do not place prioritization or constraints on the speed or accuracy of the facemask removal task. The goal of the facemask removal process is to remove the facemask quickly, while creating little movement at the head and neck (Kleiner et al., 2001). According to Fitts' Law, movement time is related to the amplitude and the target width of a movement. The amplitude and the target width ratio combine to create the index of difficulty (Schmidt & Lee, 1999). The figure below illustrates how average movement time is a function of the index of difficulty for a given task.

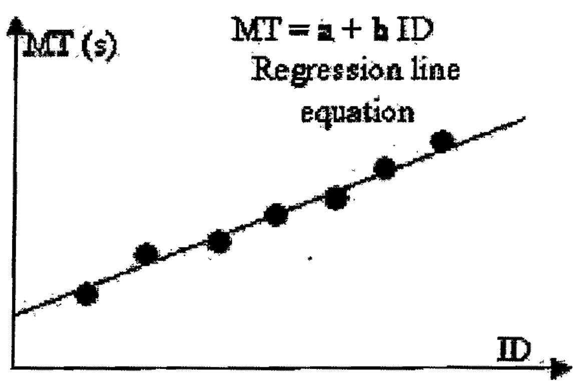

Figure 1. Fitt's Law. Where average movement time (MT) is a direct function of the index of difficulty (ID) (Göktürk, 2008).

In the facemask removal task, amplitudes of movement may vary by helmet due to the number of screws needing removal and the relative distance the screws are situated from one another. The target width would be very small, with the target being the size of a Phillips head screw. The complexity of this task combined with the high index of difficulty and the parameters set for the facemask removal process, lends support to the presence of a speed/accuracy tradeoff in this motor task. While first responders should not prioritize speed of removal in this task because it may create for too much head/neck movement leading to iatrogenic injury, they may not want to prioritize accuracy (limiting head/neck movement) and compromise removal speed in an emergent situation, especially if the patient's airway is compromised. Further differences in speed and accuracy tradeoffs may also be attributed to experience of the first responder and amount of practice time with facemask removal tools in an emergent situation.

Previous research evaluating the speed/accuracy tradeoff in simple motor tasks has shown that time and index of difficulty slopes can be reduced with increased practice sessions (Darling & Cooke, 1987). However, practice has not been shown to improve the speed and accuracy of a complex task, specifically spineboard transfer techniques in a controlled environment (Rossi, Horodyski, & Powers, 2003). This complex motor task performed during the PHM of a cervical spine-injured athlete is similar to the complex motor task of facemask removal performed by first responders.

Previous research has also demonstrated that novices and experts experience the speed/accuracy tradeoff at the same rates (van den Tillaar &

Ettema, 2006). This study compared elite athletes and novices performing a handball throw for accuracy. The authors found both groups had poor accuracy when time constraints were placed on the movement.

Age of the first responder performing facemask removal may also affect the speed/accuracy tradeoff. Studies have linked higher time to index of difficulty slopes in older adults when compared to younger adults. A study which compared movements of a computer mouse-type device over planned distances to restrictive targets found a smaller time to index of difficulty slope in college-aged students when compared to older adults aged 65-75 (Walker, Philbin, & Fisk, 1997). This may be due to delayed reaction times in older adults for various reasons affecting nerve conduction velocity. The researchers also hypothesized that older adults (a) had greater amounts of motor noise, (b) had less efficient feedback systems, (c) used conservative movement strategies and (d) couldn't produce the force needed for rapid movements.

The helmet facemask removal task is complex in nature and requires the athletic trainer to perform the task expediently and accurately (creating as little motion to the head and neck as possible). While it is far too complex to be considered a Fitt's task, it does loosely follow the principles of Fitt's Law of Speed/Accuracy Tradeoff. This information may help explain the temporal and spatial data associated with lacrosse helmet facemask removal.

Summary

Proper management of the cervical spine-injured lacrosse athlete is critical to help reduce the risk of death or permanent disability. Facemask removal is currently recommended for the management of the cervical spine-injured football athlete (Swartz et al., 2009). However, to date, there is a lack of literature pertaining to temporal and spatial parameters related to lacrosse helmet facemask removal, so guidelines are yet to exist. Athletic trainer work setting and helmet design may influence removal time and head/neck movement. Knowledge of helmet design differences may help athletic trainers provide effective acute management of suspected cervical spine-injured athletes. The purpose of this study was to assess the influence of work setting and helmet design on time and head/neck movement during the FM removal process.

CHAPTER III

METHODS

Subjects

Twenty-four certified athletic trainers (ATCs) were recruited for the study. Subjects were recruited by sending an email to all members of the New York State Athletic Trainers' Association. A recruitment flyer with a description of the study and the principle investigator's (PI) contact information was attached in the email (Appendix A). Potential participants were also informed that they would be paid $25 for their participation in the study, which was funded by a research grant from the New York State Athletic Trainers' Association. The first twelve high school athletic trainers and first twelve college athletic trainers to contact the PI with interest in the study were enrolled if they met the inclusion criteria.

Inclusion Criteria

Subjects were included if they had been a board certified athletic trainer for a minimum of one year and if they had a minimum of one year experience working with a male lacrosse team at any level of competition.

Exclusion Criteria

Subjects were excluded if they had a history of knee, hip, or low back musculoskeletal injury or neurological deficit which would preclude them from manipulating the tools used during data collection for this study.

Subject Screening

Prior to data collection, subjects were informed of the physical requirements of the study. They each read and signed the informed consent forms approved by the Seton Hall University (Appendix B & C) and the Stony Brook University (Appendix D) IRBs, respectively. Each participant then completed the Lacrosse Emergency Preparedness Questionnaire (Appendix E), which was followed by participation in a practice session to provide exposure to the tools used for data collection. Also, the human model the participants performed the facemask removal task on, read and signed the informed consent form approved by the Seton Hall University IRB.

The Lacrosse Emergency Preparedness Questionnaire contained questions regarding participants work experience, with many specific questions pertaining to preparing for managing cervical spine-injured athletes. Questions related to frequency of practice with facemask removal and spineboarding of both lacrosse athletes and football athletes, to allow for comparison.

The practice session was included to ensure that all participants were familiar with the tools, helmets, and location of the screws on the helmets. During the practice session each subject was given approximately 30 minutes to examine each helmet and practice removing the screws from each of the five helmets which was to be worn by the human model. Upon completion of the practice session, the subjects were scheduled for a date for data collection. Time between practice session and data collection dates ranged from 1 - 22 days because of geographic and scheduling constraints. The time between practice session and data collection for each subject was recorded so it could be evaluated as a potential covariate.

On the day of data collection, the subjects dominant arm length, upper arm length, forearm length, hand length and trunk length were measured (cm) using a standard cloth tape measure. These measurements were included so they could later be evaluated as covariates. All measurements were performed in a standing anatomical position. Arm length was measured as the distance between the acromioclavicular (AC) joint and radial styloid process. Upper arm length was measured as the distance between the AC joint and the lateral epicondyle of the humerus. Forearm length was measured as the distance between the lateral epicondyle and the radial styloid process. Hand length was measured as the distance from the distal radial-ulnar joint and the distal tip of the third phalange. Trunk length was measured as the distance between the C7 spinous process and the point between the two posterior superior iliac spines (PSIS). Height (m) and mass (kg) were also measured using a standard scale (Detecto, Webb City, MO).

After completing all baseline measures, the subjects were then prepared for the facemask removal data collection process. A standardized set of directions was read to the subjects by the research assistant. Subjects were instructed to stabilize the model's head with their knees as they would if the model had a cervical spine injury in a potential worst case scenario. The research assistant emphasized that the goal of the trial was to remove the facemask with as little movement of the head/neck as possible while completing the task as quickly as possible. These instructions were given to the subjects to indicate that both speed and accuracy were equally important during the facemask removal task.

Instrumentation

Three-dimensional (3-D) video-image data was collected using ten Vicon MXF20 high-speed video cameras (Vicon: Denver, Colorado) at a rate of 100 Hz with data stored to be later analyzed using Vicon Nexus software (Version 1.5.1, Vicon: Denver, Colorado). Two digital video cameras (Basler: Exton, PA) were synced with the Vicon cameras and were used to track time and analyze facemask removal strategy.

High-speed motion capture cameras were positioned in a 360 degree fashion around the area where the human model was lying on the floor, offering good frontal and sagittal plane views with a lack of posterior views. Camera heights were staggered to achieve optimal views of the marker set. Figure 2 illustrates the camera positioning.

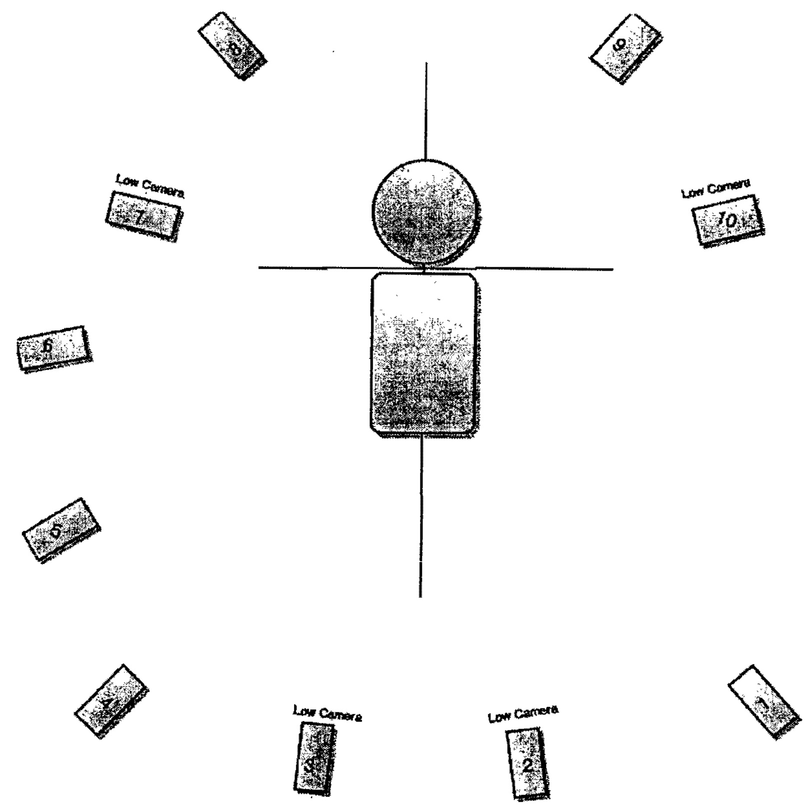

Figure 2. Vicon Camera Placements Around the Human Model

Procedures

Calibration Procedure.

Prior to each data collection session, the Vicon Motion Capture System was calibrated according to the manufacturer's directions. Ten Vicon MXF20 high-speed video cameras were placed at different distances and at different heights as recommended for optimal viewing of the markers surrounding the space to be calibrated. The calibration wand, which contains precisely placed 17 mm retro-reflective markers, was used to define the lab coordinate system during the approximate 30 –second-long calibration procedure. In the lab coordinate system for the Vicon system, X-axis marked anterior/posterior movements, Y-axis marked medial/lateral movements, and Z-axis marked vertical movements. All 10 Vicon MXF20 cameras had acceptable calibration measures prior to all data collections.

The human model wore dark, tight clothing (spandex) and Brine Core lacrosse shoulder pads. The helmets used for data collection were changed between trials for each subject. All helmets were fitted according to manufacturer's guidelines to assure "best fit". Thirteen round plastic retro-reflective markers (17 mm) were fixed to the human model's body using sticky backed Velcro ®. Local coordinate systems and segment coordinate systems were created using the retro-reflective markers. To create the segment coordinate system, markers were placed on the equipment in the locations that correlated to the anatomical structures of the right (R) Acromion, left (L) Acromion, (R) Iliac Crest, (L) Iliac Crest, (R) Ear, (L) Ear. To create the local coordinate system, clusters of three or more markers were placed on the torso, and the lacrosse helmet. Two-inch elastic adhesive tape (Andover ® Powerflex) was used to fasten the clusters to the torso over the shoulder pads (chest) (Figure 3). The human model laid down on a FieldTurf (Tarkett Sports) cutout to simulate an "on-field" scenario.

Figure 3. Marker Set.

Static trials contained data of all 13 markers that made up the local and segment coordinate systems over a 2-second time period. These data were saved using a code involving the subject number to be later used in creating the model of the bony skeleton in Visual 3-D. All 13 markers remained on the human model for dynamic trials. Subjects performed one dynamic trial for each helmet all on the same day. Each trial could have a maximum of 180 seconds.

Each of the five helmets (Brine Triumph, Cascade Pro7, Cascade CPX, Riddell XR and Warrior Venom) was properly fitted to the model according to manufacturer's directions by a certified athletic trainer. Testing order of the helmets was randomly assigned to account for order effects which could influence degree of learning or fatigue level of the subjects. An electric screwdriver (Dewalt Heavy-Duty 7.2-Volt Ni-Cad cordless screwdriver) was used as the removal tool for all trials. Subjects were instructed to stabilize the model's head with their knees as they would if the model had a cervical spine injury in a worst case scenario setting. The PI emphasized that the goal of the trial was to remove the facemask with as little movement of the head/neck as possible while completing the task in as short a time as possible, thus identifying the need for both speed and accuracy when carrying out the task.

Kinematic Data Analysis.

Raw marker data for all trials were digitized using the Vicon Nexus software (Version 1.5.1, Vicon: Denver, Colorado). During the digitizing process, the following rule was followed: small gaps (<10 frames) were filled using cubic splines. This was done to allow for continuous tracking of a marker trajectory that may have fallen out of view of multiple cameras momentarily during the data collection process. The cubic spline fill method essentially extrapolates the missing trajectory based on the last known and first reappearing coordinates. The equation used by Vicon Nexus to perform a cubic spline fill is listed below:

$$S_i(x) = a_i(x - x_i)^3 + b_i(x - x_i)^2 + c_i(x - x_i) + d_i \text{ for } x \in [x_i, x_{i+1}]$$

Gaps larger than 10 frames were not filled. Larger gaps were more likely to have an errant result using cubic spline fill. Since the cubic spline fill is based on a mathematical algorithm that extrapolates the unknown trajectory from frames before and after it disappeared, it can potentially miss real changes in the path of the trajectory that were caused by the facemask removal process. It was a more conservative approach to leave these larger gaps unfilled, rather than "create" trajectory data.

Additionally, to confirm that the filtering process for small gaps would still preserve the marker data, one trial from each subject was analyzed with no gap filling and with full gap filling. The maximal head/neck angles in each of the three planes were calculated using each process. A paired samples t test was used to determine if maximal head/neck angles in each of the three planes differed between the two techniques. There were no significant differences between the maximal head/neck angles in each of the three planes between the two techniques. This supported the decision to not fill gaps larger than 10 frames. Additionally, this same process has been used in previous studies and has been found to produce reliable kinematic data. In a personal communication with Dr. Erik Swartz, he stated that he used this approach when completing his kinematic analyses of facemask removal in football helmets (E. Swartz, personal communication, December 8, 2010).

After digitizing, all data were exported in c3d format so that a model could be constructed using Visual 3D software (C-Motion Inc.: Rockville, MD).

Raw signal of markers were evaluated for noise artifact. Power spectrum analysis was conducted on the one trial which displayed the greatest noise artifact upon visual analysis to determine an appropriate lowpass cutoff. This approach was used in an attempt to be most conservative. Calculating power spectral analysis using Visual 3D required a two step process. First, the Discrete Fourier Transform (DFT) was computed for the marker signal. The following formula was used:

> p(t)= p0 + p1 sin(**w** t) + p2 cos(**w** t) + p3 sin(2**w** t) + p4 cos(2 **w** t) + ...
>
> where **w** = 2 * PI * Base_Frequency

Next, the power of the signal was calculated from the DFT coefficients. The following formula was used:

> For example, the power at the Base_Frequency is given by (p1^2 + p2^2) the power at 2 * Base_Frequency is given by (p3^2 + p3^2)

The resulting power spectrum analysis supported a lowpass cutoff of 7 Hz to preserve the signal (Figure 4). Figure 5 is a flow chart which illustrates the processing of the kinematic data.

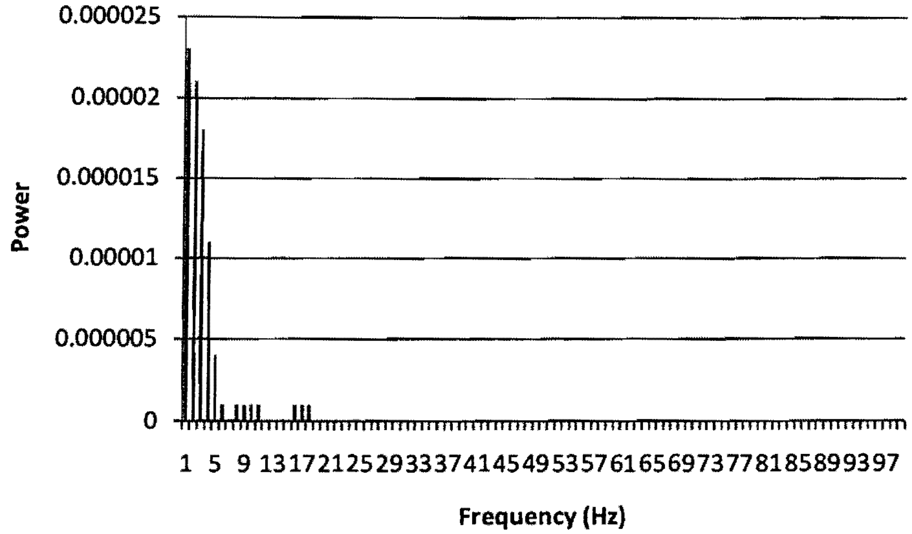

Figure 4. Power Spectrum Analysis of Subject 22 During Removal of the Facemask on the Warrior Venom Helmet supports the use of a low pass cutoff of 7 Hz to filter kinematic data.

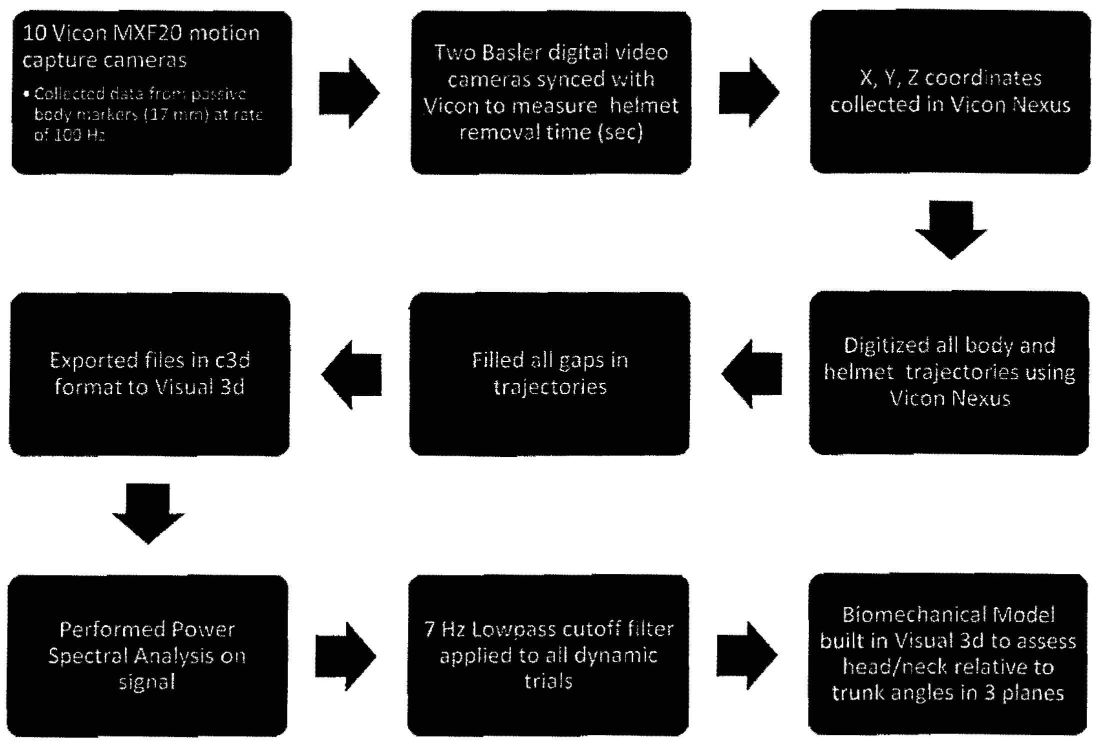

Figure 5. Data Flow Chart.

Modeling.

A model was constructed using the static trial which was collected prior to each dynamic trial for each subject in all helmet conditions. For head/neck to trunk joint motion, a link-model-based format was used in which joint motions were determined by plotting the motion of the head/neck segment and the trunk segment around a joint center as determined by the static capture. For example, the markers over the acromioclavicular joints and over the ears helped define the joint center of the head/neck as it rotates about the trunk. Angles were described according to a local coordinate system, with motion occurring around three joint axes. Unlike Euler angles which describe relative rotations around an axis, orthopedic angles are defined according to clinical terms (Kadaba, Ramakrishnan, & Wootten, 1990). Sagittal plane motion (cervical flexion and extension) consisted of movement about the "X" axis. Frontal plane motion (cervical lateral flexion) consisted of movement about the "Y" axis. Transverse plane motions (cervical rotation) consisted of movement about the "Z" axis.

Changes in joint motion for the head/neck were expressed in degrees according to the local coordinate system (relation of the head/neck segment to the trunk). The Right-hand rule notation convention for three dimensional vectors was used. For motion in the sagittal plane (cervical flexion/extension), zero degrees was represented by a straight line between the segments. Positive measurements in degrees (deg) represented flexion, and negative degrees represented extension. For motion in the frontal plane (cervical lateral flexion), zero degrees were represented by a straight line between the segments. Positive measurements in degrees (deg) represented lateral flexion to the right, and negative degrees represented lateral flexion to the left. For motion in the axial plane (cervical rotation), zero degrees was defined by the position of the line representing each segment during the static trial. Positive measurements in degrees (deg) represented rotation to the right, and negative degrees represented rotation to the left.

Initial angles in the sagittal, frontal and axial planes were recorded at the first frame of each trial. The largest angles in each of the planes during each trial were recorded. The initial angle was subtracted from the largest angle to create the maximal movement angle in each of the three planes of motion. Maximal movement angle is used instead of peak joint angle for two reasons. First, the head/neck segment's articulation with the trunk segment is not a true joint. Second, the highest (peak) degree of motion is not reported since the initial angle is subtracted from it. Peak angular velocity and angular acceleration were reported. Peak angular velocity is the maximum rate of change in angular position. Peak angular acceleration is the maximal rate of change in angular velocity.

Independent Variables

1. Helmet-type (Brine Triumph, Cascade CPX, Cascade Pro7, Riddell XR, Warrior Venom)

2. Work Setting (Collegiate, Secondary School)

Dependent Variables

1. Time (sec)
2. Maximal head/neck flexion angle (deg)
3. Maximal head/neck lateral flexion angle (deg)
4. Maximal head/neck rotation angle (deg)
5. Peak head/neck flexion velocity (deg/s)
6. Peak head/neck lateral flexion velocity (deg/s)
7. Peak head/neck rotation velocity (deg/s)
8. Peak head/neck flexion acceleration (deg/s^2)
9. Peak head/neck lateral flexion acceleration (deg/s^2)
10. Peak head/neck rotation acceleration (deg/s^2)

Data Analysis

Frequency tables and descriptive data were analyzed for the Participant Perception Survey, Lacrosse Preparedness Questionnaire and all kinematic data. Independent samples t-tests were used to explore differences in practice frequency of facemask removal and spineboarding between the collegiate and high school athletic trainers.

A doubly-multivariate analysis of variance was performed on the dependent variables of time and maximal movement angles in the sagittal, frontal and transverse planes. Work setting formed the between-subjects independent variable (IV): college or high school. The within-subjects IV treated multivariately was the five different types of lacrosse helmets. An interactive effect of work setting and helmet on the dependent variables was first explored. Subsequently, the effects of work setting on the dependent variables and the effects of helmet-type on the dependent variables were explored. Significant findings in the MANOVA supported the utilization of ANOVAs to further evaluate the data.

Separate 2 x 5 repeated measures ANOVAs were used to evaluate the main and interactive effects of helmet-type and work setting on time and maximum movement angles in the sagittal, frontal and transverse planes. To test the secondary hypotheses, multiple separate 2 x 5 repeated measures ANOVAs were used. Separate repeated measures ANOVAs were used to evaluate main and interactive effects of helmet-type and work setting on peak angular velocities in the sagittal, frontal and transverse planes. Additionally, separate repeated measures ANOVAs were used to evaluate main and interactive effects of helmet-type and work setting on peak angular accelerations in the sagittal, frontal and transverse planes. An assumption of sphericity was checked using Mauchly's test, and the Bonferroni method was used to perform pairwise comparisons following a significant overall test result. Lastly, MANCOVA was used to evaluate the contributions of subject demographic data on the primary hypotheses. All data were analyzed using SPSS (version 18.0 SPSS Inc, Chicago, IL). All alpha levels were set at $P < .05$.

Power Analysis and Sample Size

Results of a pilot study were used to calculate a power analysis a priori (Appendix F) using G*Power 3.0.10 (Faul, Erdfelder, Lang, & Buchner, 2007). Mean difference and standard deviation between helmets were used to calculate effect sizes. Recommended sample size was calculated using the calculated effect size, the correlation among repeated measures, and alpha levels set at .05 with 5 helmets at 10 repetitions each. Based on the results of the power analysis, a sample size of 24 was determined to find significant differences in the majority of the comparisons in dependent variables between the helmet types.

CHAPTER IV

RESULTS

The participants were 24 certified athletic trainers. Twelve were working in the secondary school setting and twelve in the collegiate setting at the time of data collection. The participants in the collegiate setting were from multiple competition levels (Junior College – 1, Division III – 1, Division II – 5, Division I – 5). Of the total participant pool, 62.5% were male and 37.5% were female. In terms of hand dominance, 87.5% reported being right hand dominant and 12.5% reported being left hand dominant. Independent samples t-tests used to compare the subject characteristics of the high school and college groups revealed no statistically significant differences between the groups [Age (p =0.92); athletic training (AT) Experience (p=0.66); Men's lacrosse (MLAX) Experience (p =0.83); Height (p= 0.43); Mass (p=0.84)]. Descriptive statistics of the subject characteristics are provided in Table 2.

Table 2.
Subject Characteristics

	High School		College		Overall	
	Mean	SD	Mean	SD	Mean	SD
Age (yrs)	36.00	10.14	35.67	7.95	35.83	8.91
AT Experience (yrs)	13.42	9.87	12.63	7.85	13.02	8.73
MLAX Experience (yrs)	10.58	10.43	9.88	9.13	10.23	9.59
Height (m)	1.71	0.10	1.73	0.15	1.72	0.13
Mass (kg)	87.38	20.14	94.83	23.09	91.10	21.53

In order to ensure homogeneity of the two groups, various anthropometric measurements were taken on the subjects. Dominant arm length, upper arm length, forearm length, hand length and trunk length were measured (cm) so they could be assessed as potential covariates. Height (m) and mass (kg) were also measured to be assessed as potential factors that could impact FM removal. Independent samples t-tests used to compare the subject anthropometric measures of the high school and college groups revealed no significant differences between the groups [Arm (p=0.33); Upper arm (p=0.63); Forearm (p=0.20); Hand (p=0.24); Trunk (p=0.36)]. Descriptive statistics of the subject anthropometric measures are provided in Table 3.

Table 3.
Subject Anthropometric Measures of the Dominant Limb

	High School		College		Overall	
	Mean	SD	Mean	SD	Mean	SD
Arm Length (m)	.006	.005	.006	.004	.006	.004
Upper Arm Length (m)	.003	.003	.003	.004	.003	.003
Forearm Length (m)	.003	.002	.003	.001	.003	.002
Hand Length (m)	.002	.001	.002	.001	.002	.001
Trunk Length (m)	.005	.004	.005	.005	.005	.004

It was hypothesized that work setting and helmet type would affect time and maximum movement angles during the lacrosse helmet facemask removal process. The first independent variable (IV); athletic trainer work setting had two groups (high school and college). The literature suggests that collegiate athletic trainers may be more specialized in the sport that they work and therefore may be more skilled at dealing with injuries that occur to athletes wearing lacrosse equipment (Pfeiffer & Mangus, 2005). The other independent variable, helmet-type had five different brand models (Brine Triumph, Cascade CPX, Cascade Pro7, Riddell XR and Warrior Venom). Each of these helmets differed in construction, design, and materials. The helmet characteristics collectively made up an index of difficulty that affected the facemask removal process. The Helmet Index of Difficulty is illustrated in Appendix G. The index of difficulty took into account screw lengths, distance between each of the screws and additional steps needed for the removal process. The formula was: ID = (total screw length * total distance of screws / 100) + (1 for each additional step needed). The helmet ID did have an effect on many of the results of this investigation. Table 4 provides a list of the hypotheses that were tested and whether or not they were supported by the data.

Table 4.
List of All Tested Hypotheses: Supported or Unsupported

Hypotheses	Status
H1: Helmets with fewer screws (lower ID) will have faster time of removal.	Supported
H2: Helmets with fewer screws (lower ID) will have smaller maximal head/neck angles.	Unsupported*
H3: Helmets with screws located closer to each other (lower ID) will have faster time of removal.	Supported
H4: Helmets with screws located closer to each other (lower ID) will have smaller maximal head/neck angles.	Unsupported*
H5: Collegiate ATCs will have faster time of removal than Secondary School ATCs.	Unsupported
H6: Collegiate ATCs will have smaller maximal head/neck angles than Secondary School ATCs.	Unsupported
H7: Helmets with fewer screws will have smaller peak angular velocities.	Unsupported
H8: Helmets with fewer screws will have smaller peak angular accelerations.	Unsupported
H9: Helmets with screws that are closer together will have smaller peak angular velocities.	Unsupported
H10: Helmets with screws that are closer together will have smaller peak angular accelerations.	Unsupported
H11: Collegiate ATCs will have smaller peak angular velocities than Secondary School ATCs.	Unsupported
H12: Collegiate ATCs will have smaller peak angular accelerations than Secondary School ATCs.	Unsupported*

* Instead, the opposite was found to be statistically significant

Multivariate Analysis of Helmet-type and Work Setting on Time and Maximal Movement Angle (H1-H6)

A doubly-multivariate analysis of variance (MANOVA) was performed on the dependent variables time and maximal movement angles in the sagittal, frontal and transverse planes. Work setting formed the between-subjects IV: college and high school. The within-subjects IV of the five different types of lacrosse helmets was treated using the multivariate approach.

No significant interactive effect was found between helmet type and work setting on the combined dependent variables of time and maximal movement angle in the three planes of movement: [Pillai's F (12, 11) = 0.77, p =0.67]. There was no significant effect of setting on the combined dependent variables of time and maximal movement angle in the three planes of movement: [Pillai's F (3, 20) = 1.22, p = 0.33]. There was however, a significant effect of helmet type on the combined dependent variables of time and maximal movement angle in three planes: [Pillai's F (12, 11) = 11.70, p = 0.00]. Since a significant effect was seen in the MANOVA by the helmet-type, separate 2 x 5 ANOVAs were performed as post hoc tests.

Univariate Analysis of Work Setting on Time (H5)

No significant interactive effect was found between helmet-type and work setting when evaluating the length of time for helmet facemask removal (p=0.84). There was no significant difference between the work settings [(collegiate, high school)(p = 0.80)]. Mauchly's test was significant (p = 0.00), indicating a lack of sphericity, therefore the Greenhouse Geisser correction was used to analyze the ANOVA.

Univariate Analysis of Helmet-type on Time (H1 & H3)

The overall test for differences in mean facemask removal times in the repeated-measures ANOVA was significant, [F= (2.7, 59.56) = 28.4, p =0.00] indicating a helmet effect. Pairwise comparisons indicated significance at the overall p = 0.05 level. A priori statistical methods suggested the use of a paired samples t-test, however because the data lacked normality a Wilcoxon Signed Ranks Test with Bonferroni correction was used. The results are shown in Table 5.

Table 5.
Wilcoxon Signed Ranks tests for Time Differences by Helmet-type

Helmet Pairings

	Z	Sig.
Triumph - CPX	-2.80	.005*
Triumph - XR	-3.74	.000*
Triumph – Pro7	-4.29	.000*
Triumph – Venom	-4.29	.000*
CPX– XR	-1.96	.050
CPX – Pro7	-4.29	.000*
CPX – Venom	-4.29	.000*
XR – Pro7	-3.86	.000*
XR – Venom	-3.46	.000*
Pro7 - Venom	-3.20	.001*

* p < 0.005. Because of the Bonferroni adjustment significance had to fall below 0.005 to reject the null hypothesis.

Specifically, the Triumph was removed more quickly than all other helmets. The CPX was removed faster than the Pro7 and Venom. The XR was removed faster than the Pro7 and the Venom. Finally, the Venom was removed more quickly than the Pro7. Figure 6 illustrates these findings. These results support the hypothesis that facemasks fastened to helmets with fewer screws and screws that are positioned closer together would be removed more quickly than the facemasks of other helmets. These results do not support the hypothesis that collegiate athletic trainers would remove helmet facemasks more quickly than high school athletic trainers. Table 6 below illustrates these findings.

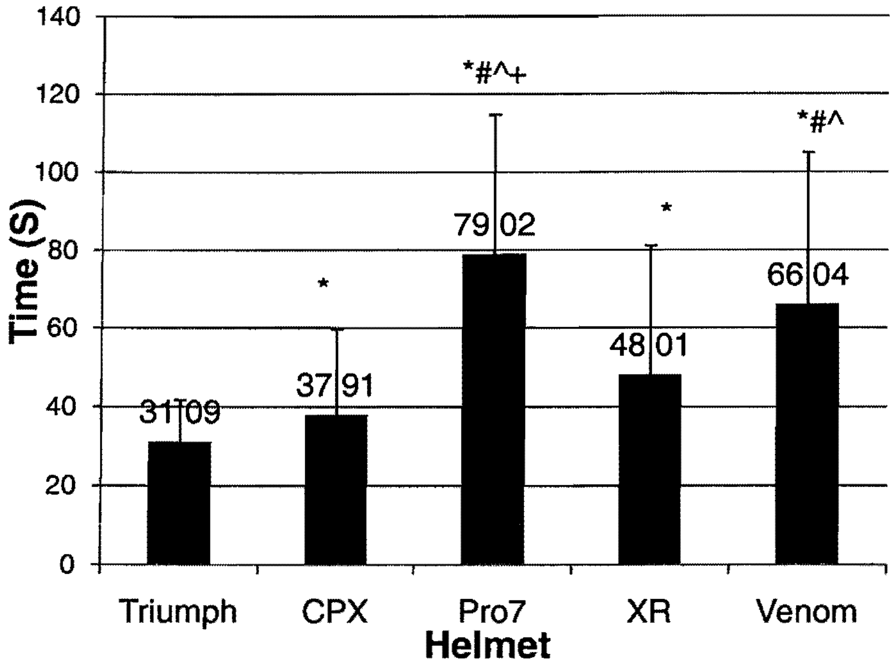

Figure 6. Differences in Mean Values for Facemask Removal Time by Helmet-type. The Triumph was removed in significantly less time than the CPX, Pro7, XR and Venom (*). The CPX was removed in significantly less time than the Pro7 and Venom (#). The XR was removed in significantly less time than the Pro7 and Venom (^). The Venom was removed in significantly less time than the Pro7 (+)($p < 0.005$).

Table 6.
Differences in Mean Values for Time (s) During Facemask Removal by Helmet-type and Work Setting

	High School		College		Overall	
	Mean	SD	Mean	SD	Mean	SD
Brine Triumph	30.28	11.56	31.89	9.89	31.09	10.55
Cascade CPX	37.57	24.76	38.24	19.35	37.91[a]	21.73
Cascade Pro7	79.31	37.78	78.74	35.31	79.02[abcd]	35.76
Riddell XR	46.52	20.68	49.49	43.13	48.01[a]	33.11
Warrior Venom	61.66	33.56	70.43	44.73	66.04[abc]	38.93

The Triumph helmet was removed in significantly less time than this helmet[a] ($p<0.005$). The CPX helmet was removed in significantly less time than this helmet[b]($p<0.005$). The XR helmet was removed in significantly less time than this helmet[c] ($p<0.005$). The Venom helmet was removed in significantly less time than this helmet[d] ($p<0.005$).

Univariate Analysis of Work Setting on Maximal Movement Angle (H6) in the Sagittal Plane

No significant interactive effect was found between helmet-type and work setting when evaluating maximal movement angle in the sagittal plane during helmet facemask removal ($p = 0.053$). Again, there was no significant difference between the work settings of college and high school ($p = 0.08$). Mauchly's test was significant ($p = 0.02$), indicating a lack of sphericity, therefore the Greenhouse Geisser correction was used to analyze the ANOVA.

Univariate Analysis of Helmet-type on Maximal Movement Angle (H2 & H4) in the Sagittal Plane

The overall test for mean differences in maximal movement angle in the sagittal plane in the repeated-measures ANOVA was significant, [F=(2.76, 60.78) = 2.95, p = 0.01] indicating that a helmet effect existed. Pairwise comparisons indicate significance at the overall p=0.05 level. A priori statistical methods suggested the use of a paired samples t-test, however because the data lacked normality a Wilcoxon Signed Ranks Test with Bonferroni correction was used. The results are shown in Table 7.

Table 7.
Wilcoxon Signed Ranks tests for Maximal Movement Angle Differences in the Sagittal Plane by Helmet-type

Helmet Pairings

	Z	Sig.
Triumph - CPX	-1.29	.199
Triumph – Pro7	-3.37	.001*
Triumph – XR	-2.63	.009
Triumph – Venom	-2.10	.036
CPX– XR	-1.31	.189
CPX – Pro7	-0.86	.391
CPX – Venom	-0.60	.549
XR – Pro7	-0.43	.668
XR – Venom	-0.60	.549
Pro7 - Venom	-0.34	.732

* $p < 0.005$. Because of the Bonferroni adjustment significance had to fall below 0.005 to reject the null hypothesis.

Specifically the Triumph helmet had a larger maximal movement angle than the Pro7 helmet. These results do not support the hypothesis that facemasks fastened to helmets with fewer screws and screws that are positioned closer together would create smaller maximal movement angles than the facemasks of other helmets. So, while fewer screws and screws that are located closer together result in faster removal times, the maximal movement angle produced by the participants during the FM removal process was not the smallest angle as hypothesized. Additionally, these results do not support the hypothesis that collegiate athletic trainers would create less movement during helmet facemask removal than high school athletic trainers. Table 8 below illustrates these findings.

Table 8.
Differences in Mean Values for Maximal Movement Angle (deg) in Sagittal Plane During Facemask Removal by Helmet-type and Work Setting

	High School		College		Overall	
	Mean	SD	Mean	SD	Mean	SD
Brine Triumph	5.32	3.05	8.83	3.31	7.08[a]	3.59
Cascade CPX	4.25	3.10	7.67	5.41	5.96	4.65
Cascade Pro7	3.93	2.00	4.67	2.78	4.30	2.39
Riddell XR	5.01	2.92	4.09	1.18	4.55	2.23
Warrior Venom	4.72	3.41	4.85	2.63	4.78	2.98

The Pro7 helmet was removed with significantly less maximal joint angle than this helmet[a] ($p<0.005$).

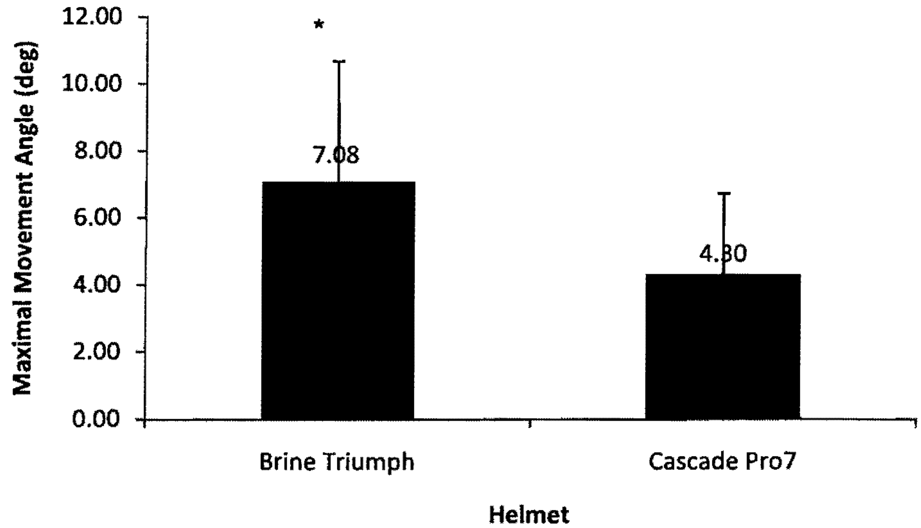

Figure 7. Differences in Mean Values for Maximal Movement Angles in the Sagittal Plane During Helmet Facemask Removal. The Triumph has significantly greater movement than the XR and Pro7 helmets *($p < 0.005$).

Univariate Analysis of Work Setting on Maximal Movement Angle (H6) in the Frontal Plane

No significant interactive effect was found between helmet-type and work setting when evaluating maximal movement angle in the frontal plane during helmet facemask removal ($p=0.31$). Again, there was no significant difference between the work settings of college and high school ($p = 0.71$). Mauchly's test was significant ($p = 0.00$), indicating a lack of sphericity, therefore the Greenhouse Geisser correction was used to analyze the ANOVA.

Univariate Analysis of Helmet-type and on Maximum Movement Angle (H2 & H4) in the Frontal Plane

The overall test for mean differences in maximal movement angle in the frontal plane in the repeated-measures ANOVA was not significant, [F= (2.14, 47.06) = 1.05, p = 0.36]. These results do not support the hypothesis that facemasks fastened to helmets with fewer screws and screws that are positioned closer together would create smaller maximal movement angles than the facemasks of other helmets. These results also do not support the hypothesis that collegiate athletic trainers would create less movement during helmet facemask removal than high school athletic trainers. The table below illustrates these findings.

Table 9.
Differences in Mean Values for Maximal Movement Angle (deg) in Frontal Plane During Facemask Removal by Helmet-type and Work Setting

	High School		College		Overall	
	Mean	SD	Mean	SD	Mean	SD
Brine Triumph	1.61	0.79	2.79	2.19	2.20	1.70
Cascade CPX	3.23	5.08	2.93	2.70	3.08	3.98
Cascade Pro7	2.99	1.06	3.63	2.26	3.31	1.76
Riddell XR	3.53	3.19	2.24	1.59	2.88	2.55
Warrior Venom	1.86	1.04	2.51	1.77	2.19	1.45

Univariate Analysis of Work Setting on Maximal Movement Angle (H6) in the Transverse Plane

Consistent with the findings in the frontal plane, no significant interactive effect was found between helmet-type and work setting when evaluating maximal movement angle in the transverse plane during helmet facemask removal ($p=0.09$). There was no significant difference between the work settings of college and high school ($p = 0.06$). Mauchly's test was significant ($p = 0.00$), indicating a lack of sphericity, therefore the Greenhouse Geisser correction was used to analyze the ANOVA.

Univariate Analysis of Helmet-type and on Maximal Movement Angle (H2 & H4) in the Transverse Plane

The overall test for mean differences in maximal movement angle in the transverse plane in the repeated-measures ANOVA was not significant, [$F=(2.65, 58.30) = 2.63$, $p = 0.07$]. These results do not support the hypothesis that facemasks fastened to helmets with fewer screws and screws that were positioned closer together would create smaller maximal movement angles than the facemasks of other helmets. Additionally, these results do not support the hypothesis that collegiate athletic trainers would create less movement during helmet facemask removal than high school athletic trainers. The table below illustrates these findings.

Table 10.
Differences in Mean Values for Maximal Movement Angle (deg) in Transverse Plane During Facemask Removal by Helmet-type and Work Setting

	High School		College		Overall	
	Mean	SD	Mean	SD	Mean	SD
Brine Triumph	1.22	0.66	2.00	2.14	1.61	1.60
Cascade CPX	1.62	0.69	2.79	3.49	2.21	2.53
Cascade Pro7	2.39	1.02	3.86	2.67	3.12	2.12
Riddell XR	2.36	1.39	1.89	0.94	2.13	1.19
Warrior Venom	1.55	0.73	2.13	1.64	1.84	1.27

Multivariate Analysis of Helmet-type and Work Setting on Peak Angular Velocity (H7, H9, H11)

The secondary hypothesis that helmet type and work setting would affect peak angular velocity was also explored. A doubly-multivariate analysis of variance was performed on the dependent variable's peak angular velocity in the sagittal, frontal and transverse planes. Work setting formed the between-subjects IV: college and high school. The within-subjects IV of the five different types of lacrosse helmets was treated using the multivariate approach.

Similar to the primary hypothesis, no significant interactive effect was found between helmet-type and work setting on the combined dependent variables of peak angular velocity in the three planes of movement: [Pillai's F (8, 15) = 1.08, p = 0.42]. Also, there was no significant effect of work setting on the combined dependent variables of peak angular velocity in the three planes of movement: [Pillai's F (2, 21) = 1.86, p = 0.18]. Similar to the primary hypothesis, there was a significant effect of helmet-type on the combined dependent variables of peak angular velocity in three planes: [Pillai's F (8, 15) = 14.30, p = 0.00]. Since a significant effect was seen in the MANOVA of the helmet-type, separate 2 x 5 ANOVAs were performed as post hoc tests.

Univariate Analysis of Work Setting on Peak Angular Velocity (H11) in the Sagittal Plane

The 2 x 5 ANOVA found no significant interactive effect between helmet type and work setting when evaluating peak angular velocity in the sagittal plane during helmet facemask removal (p=0.46). There was no significant difference between the work settings of college and high school (p = 0.053). Mauchly's test was significant (p = 0.00), indicating a lack of sphericity, therefore the Greenhouse Geisser correction was used to analyze the ANOVA.

Univariate Analysis of Helmet-type on Peak Angular Velocity (H7 & H9) in the Sagittal Plane

The overall test for mean differences in peak angular velocity in the sagittal plane in the repeated-measures ANOVA was not significant, [F= (2.08, 52.89) = 1.25, p = 0.30]. These results do not support the hypothesis that facemasks fastened to helmets with fewer screws and screws that are positioned closer together would create smaller peak angular velocities than the facemasks of other helmets. Additionally, these results do not support the hypothesis that collegiate athletic trainers would produce less peak angular velocity during helmet facemask removal than high school athletic trainers. The table below illustrates these findings.

Table 11.
Differences in Mean Values for Peak Angular Velocity (deg/s) in Sagittal Plane During Facemask Removal by Helmet-type and Work Setting

	High School		College		Overall	
	Mean	SD	Mean	SD	Mean	SD
Brine Triumph	13.47	8.25	32.16	38.10	22.81	28.60
Cascade CPX	19.90	15.89	64.85	117.67	42.37	85.27
Cascade Pro7	33.26	23.18	66.48	112.09	49.87	80.96
Riddell XR	27.20	17.80	27.28	11.52	27.24	14.66
Warrior Venom	22.02	19.22	21.57	14.66	21.79	16.79

Univariate Analysis of Work Setting on Peak Angular Velocity (H11) in the Frontal Plane

No significant interactive effect was found between helmet-type and work setting when evaluating peak angular velocity in the frontal plane during helmet facemask removal ($p=0.43$). There was no significant difference between the work settings of college and high school ($p = 0.06$). Mauchly's test was significant ($p = 0.00$), indicating a lack of sphericity, therefore the Greenhouse Geisser correction was used to analyze the ANOVA.

Univariate Analysis of Helmet-type on Peak Angular Velocity (H7 & H9) in the Frontal Plane

The overall test for mean differences in peak angular velocity in the frontal plane in the repeated-measures ANOVA was not significant, [F= (1.86, 40.90) = 0.82, p = 0.44]. These results do not support the hypothesis that facemasks fastened to helmets with fewer screws and screws that are positioned closer together would create smaller peak angular velocities than the facemasks of other helmets. Additionally, these results do not support the hypothesis that collegiate athletic trainers would produce less peak angular velocity during helmet facemask removal than high school athletic trainers. The table below illustrates these findings.

Table 12.
Differences in Mean Values for Peak Angular Velocity (deg/s) in Frontal Plane During Facemask Removal by Helmet-type and Work Setting

	High School		College		Overall	
	Mean	SD	Mean	SD	Mean	SD
Brine Triumph	88.48	43.43	198.19	193.98	143.33	148.45
Cascade CPX	69.68	61.01	474.57	1042.68	272.13	751.33
Cascade Pro7	72.15	60.45	333.25	932.72	202.70	660.00
Riddell XR	82.46	37.61	69.82	39.38	76.14	38.21
Warrior Venom	58.29	30.15	102.35	142.95	80.32	103.51

Univariate Analysis of Work Setting on Peak Angular Velocity (H11) in the Transverse Plane

No significant interactive effect was found between helmet-type and work setting when evaluating peak angular velocity in the transverse plane during helmet facemask removal ($p=0.48$). There was no significant difference between the work settings of college and high school ($p = 0.15$). Mauchly's test was significant ($p = 0.00$), indicating a lack of sphericity, therefore the Greenhouse Geisser correction was used to analyze the ANOVA.

Univariate Analysis of Helmet-type and on Peak Angular Velocity (H7 & H9) in the Transverse Plane

The overall test for mean differences in peak angular velocity in the transverse plane in the repeated-measures ANOVA was not significant [$F=(2.16, 47.60) = 1.74$, $p = 0.19$]. These results do not support the hypothesis that facemasks fastened to helmets with fewer screws and screws that were positioned closer together would create smaller peak angular velocities than the facemasks of other helmets. Additionally, these results do not support the hypothesis that collegiate athletic trainers would produce less peak angular velocity during helmet facemask removal than high school athletic trainers. The table below illustrates these findings.

Table 13.
Differences in Mean Values for Peak Angular Velocity (deg/s) in Transverse Plane During Facemask Removal by Helmet-type and Work Setting

	High School		College		Overall	
	Mean	SD	Mean	SD	Mean	SD
Brine Triumph	23.29	15.41	45.20	59.45	34.24	43.92
Cascade CPX	27.23	19.80	66.79	100.69	47.01	73.79
Cascade Pro7	49.35	37.44	78.24	120.93	63.80	88.79
Riddell XR	44.34	34.57	34.09	29.24	39.21	31.75
Warrior Venom	21.92	15.15	24.44	15.89	23.18	15.24

Multivariate Analysis of Helmet-type and Work Setting on Peak Angular Acceleration (H8, H10, H12)

In order to assess the study's secondary hypothesis, that helmet-type and work setting would affect peak angular acceleration, a doubly-multivariate analysis of variance was performed on the dependent variables of peak angular acceleration in the sagittal, frontal and transverse planes. Work setting formed the between-subjects IV: college and high school. The within-subjects IV of the five different types of lacrosse helmets was treated using the multivariate approach. Similar to the primary hypothesis, no significant interactive effect was found between helmet-type and work setting on the combined dependent variables of peak angular acceleration in the three planes of movement: [Pillai's F (8, 15) = 0.86, p = 0.57]. Also, work setting was not found to demonstrate a significant effect on the combined dependent variables of peak angular acceleration in the three planes of movement:

[Pillai's F (2, 21) = 1.79, p = 0.19]. Similar to the significant findings for the primary hypothesis, there was a significant effect of helmet-type on the combined dependent variables of peak angular acceleration in the three planes of movement: [Pillai's F (8, 15) = 7.28, p = 0.00]. Since a significant effect was seen in the MANOVA by the helmet-type, separate 2 x 5 ANOVAs were performed as post hoc tests.

Univariate Analysis of Work Setting on Peak Angular Acceleration (H12) in the Sagittal Plane

The 2 x 5 ANOVA found no significant interactive effect between helmet-type and work setting when evaluating peak angular acceleration in the sagittal plane during helmet FM removal (p=0.31). However, there was a significant difference between work settings (p = 0.05), which suggested that the high school athletic trainers produced smaller peak angular accelerations during the facemask removal process than did the college athletic trainers. Mauchly's test was significant (p = 0.00), indicating a lack of sphericity, therefore the Greenhouse Geisser correction was used to analyze the ANOVA.

Univariate Analysis of Helmet-type on Peak Angular Acceleration (H8 & H10) in the Sagittal Plane

The overall test for mean differences in peak angular acceleration in the sagittal plane in the repeated-measures ANOVA was not significant, [F=(1.92, 42.18) = 1.17, p = 0.32]. These results do not support the hypothesis that facemasks fastened to helmets with fewer screws and screws that are positioned closer together would create smaller peak angular accelerations than the facemasks of other helmets. These results do not support the hypothesis that collegiate athletic trainers would produce less peak angular acceleration during helmet facemask removal than high school athletic trainers. In fact, the results indicate the opposite occurred during data collection. High school athletic trainers produced less peak angular acceleration during facemask removal than college athletic trainers. The table below illustrates these findings.

Table 14.
Differences in Mean Values for Peak Angular Acceleration (deg/s^2) in Sagittal Plane During Facemask Removal by Helmet-type and Work Setting

	High School		College		Overall	
	Mean	SD	Mean	SD	Mean	SD
Brine Triumph	430.55	262.29	1303.79	1725.92	867.17	1287.06
Cascade CPX	761.92	783.86	2674.15	5051.04	1718.04	3667.38
Cascade Pro7	1282.94	1037.02	3004.34	6304.65	2143.14	4505.38
Riddell XR	831.27	455.59	1078.14	590.43	954.70	530.94
Warrior Venom	780.02	946.94	832.01	512.55	806.02	745.12

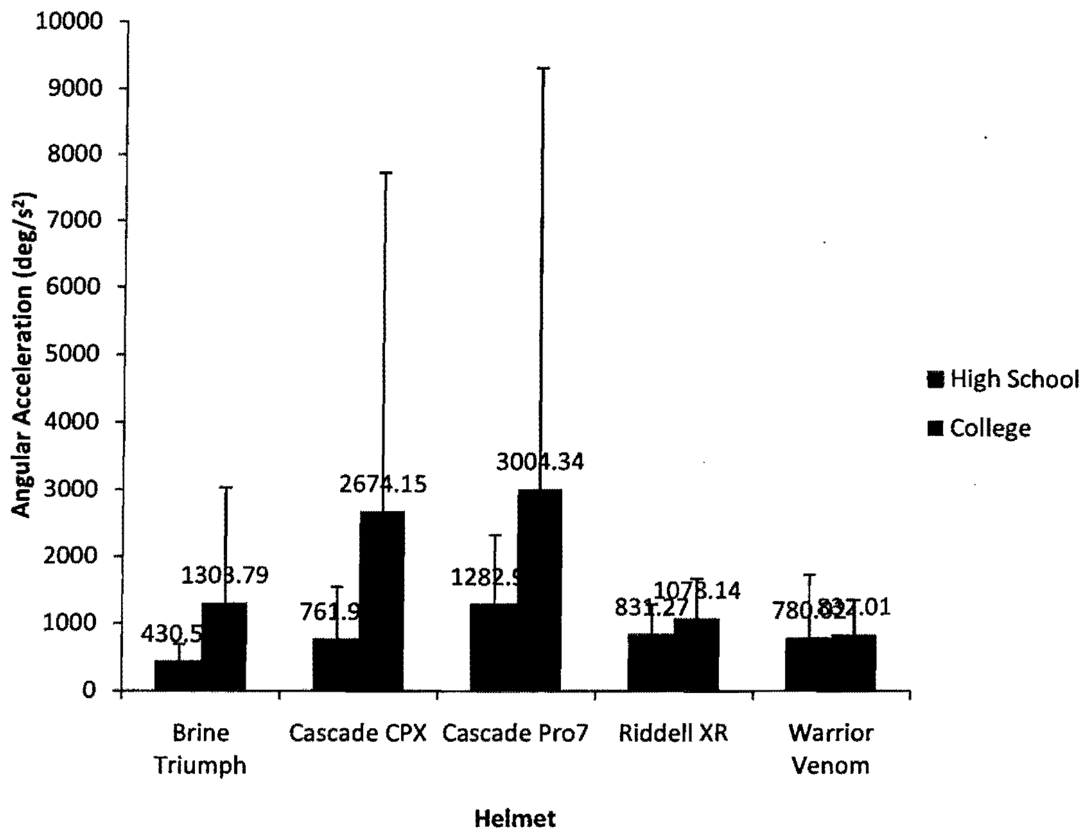

Figure 8. Mean Differences in Peak Angular Acceleration in the Sagittal Plane During Helmet Facemask Removal. High School Athletic Trainers had significantly lower angular accelerations than College Athletic Trainers during the helmet facemask removal task (p = 0.05)*.

Univariate Analysis of Work Setting on Peak Angular Acceleration (H12) in the Frontal Plane

No significant interactive effect was found between helmet-type and work setting when evaluating peak angular acceleration in the frontal plane during helmet facemask removal (p=0.07). There was no significant difference between the work settings of college and high school (p = 0.12). Mauchly's test was significant ($p = 0.00$) indicating a lack of sphericity therefore, the Greenhouse Geisser correction was used to analyze the ANOVA.

Univariate Analysis of Helmet-type on Peak Angular Acceleration (H8 & H10) in the Frontal Plane

The overall test for mean differences in peak angular acceleration in the frontal plane in the repeated-measures ANOVA was not significant, [$F=(1.47, 32.42) = 0.91$, $p = 0.38$]. These results do not support the hypothesis that facemasks fastened to helmets with fewer screws and screws that are positioned closer together would create smaller peak angular accelerations than the facemasks of other helmets. Additionally, these results do not support the hypothesis that collegiate athletic trainers would produce less peak angular acceleration during helmet facemask removal than high school athletic trainers. The table below illustrates these findings.

Table 15.
Differences in Mean Values for Peak Angular Acceleration (deg/s^2) in Frontal Plane During Facemask Removal by Helmet-type and Work Setting

	High School		College		Overall	
	Mean	SD	Mean	SD	Mean	SD
Brine Triumph	2970.82	1525.00	7118.93	7487.14	5044.88	5693.06
Cascade CPX	3048.30	3043.95	18625.42	45091.74	10836.86	32251.54
Cascade Pro7	2737.34	2366.89	25119.68	79704.08	13928.51	56317.26
Riddell XR	2796.43	1365.78	2955.57	3388.37	2876.00	2527.78
Warrior Venom	2146.49	1183.55	4040.23	5204.33	3093.36	3193.94

Univariate Analysis of Work Setting on Peak Angular Acceleration (H12) in the Transverse Plane

No significant interactive effect was found between helmet-type and work setting when evaluating peak angular acceleration in the transverse plane during helmet facemask removal ($p=0.18$). There was no significant difference between the work settings of college and high school ($p = 0.054$). Mauchly's test was significant ($p = 0.00$), indicating a lack of sphericity, therefore the Greenhouse Geisser correction was used to analyze the ANOVA.

Univariate Analysis of Helmet-type on Peak Angular Acceleration (H8 & H10) in the Transverse Plane

The overall test for mean differences in peak angular acceleration in the transverse plane in the repeated-measures ANOVA was not significant [F=(1.99, 43.88) = 1.48, p = 0.24]. These results do not support the hypothesis that facemasks fastened to helmets with fewer screws and screws that are positioned closer together would create smaller peak angular accelerations than the facemasks of other helmets. Additionally, these results do not support the hypothesis that collegiate athletic trainers would produce less peak angular acceleration during helmet facemask removal than high school athletic trainers. The table below illustrates these findings.

Table 16.
Differences in Mean Values for Peak Angular Acceleration (deg/s^2) in Transverse Plane During Facemask Removal by Helmet-type and Work Setting

	High School		College		Overall	
	Mean	SD	Mean	SD	Mean	SD
Brine Triumph	809.86	678.81	1833.56	2397.62	1321.71	1800.85
Cascade CPX	1084.25	826.34	2604.33	4208.61	1844.29	3066.02
Cascade Pro7	1522.23	1070.78	3253.78	5321.35	2388.00	3856.59
Riddell XR	1356.89	1056.45	1492.00	1583.70	1424.45	1318.36
Warrior Venom	718.34	501.27	874.29	480.85	796.32	486.93

Assessing Potential Effects of Other Factors

The influence of covariates on the dependent variables from the primary hypothesis (time, maximal movement angle in the sagittal, frontal, and transverse planes) was evaluated using MANCOVA. Specifically, the influence of age, sex, hand dominance, and experience were evaluated first. Interestingly, none of these factors were found to significantly influence the independent variables: age (p = 0.95), sex (p = 0.28), hand dominance (p = 0.78), years experience as an athletic trainer (p = 0.20), years experience working male lacrosse (p = 0.13), practice experience removing lacrosse helmet facemasks (p = 0.54), practice experience removing football helmet facemasks (p =0.09).

Additionally, factors related to body size were examined to determine if they had a confounding effect on the dependent variables. MANCOVA results revealed no significant effect of the following factors: height (p = 0.95), weight (p= 0.29), arm length (p= 0.29), upper arm length (p= 0.38), forearm length (p= 0.23), hand length (p= 0.07), trunk length (p= 0.40).

Lacrosse Emergency Preparedness Questionnaire Results

In order to assess athletic trainers' overall preparedness for the pre-hospital management of a cervical spine-injured lacrosse athlete, the "Lacrosse Emergency Preparedness Questionnaire" was completed by the subjects at the practice session for lacrosse helmet facemask removal. The questionnaire contained questions regarding emergency procedures for both football and lacrosse athletes. Ninety-one percent of the subjects "practiced" spineboarding an athlete in football equipment. The total number of times that they "practiced" was between two and 50. Fifty-four percent indicated that they had not "practiced" spineboarding for more than one year. Conversely, only twenty-nine percent of subjects had ever "practiced" spineboarding an athlete in lacrosse equipment. These participants reported practicing spineboarding a lacrosse athlete far fewer times (ranged from 2 to 10) than a football athlete. All participants' practice sessions were also much more recent for football than lacrosse. Practice sessions for spineboarding an athlete in football equipment were reported as follows: less than 3 months ago- 4%, less than a year ago- 33%, longer than a year ago- 54%. Practice sessions for spineboarding an athlete in lacrosse equipment were reported as: less than 3 months ago- 13%, less than a year ago- 0%, longer than a year ago-17%. Spineboarding practice is only one part of being prepared for an emergency situation with a potentially cervical spine-injured athlete. Practicing the equipment removal process in order to access an airway is of equal importance.

The questionnaire responses regarding the questions related to practice procedures for football or lacrosse helmet facemask removal were also of concern. Seventy-one percent of respondents reported having practiced football facemask removal using an electric screwdriver, while 29% reported not practicing this technique of facemask removal. The number of times practiced using this technique was reported to be between two and 50 for those who had practiced removing a football facemask with an electric screwdriver. Only 46% of the respondents reported practicing lacrosse helmet facemask removal using an electric screwdriver, while 54% reported not practicing this technique of facemask removal. The number of times practiced using this technique was reported to be between one and 30 times. Ninety – two percent of the respondents reported having practiced football helmet facemask removal using a cutting tool, while only 29% reported having practiced lacrosse helmet facemask removal using a cutting tool. An independent t-test of the amount of practice on lacrosse helmet facemask removal indicated that collegiate ATCs had significantly more practice than high school ATCs ($p = 0.04$). An independent t-test of the amount of practice on football helmet facemask removal indicated that high school ATCs had significantly more practice than college ATCs ($p = 0.04$).

The results from the questionnaire regarding athletic trainers overall preparedness were also concerning in that only 92% of the respondents reported that they were confident in their procedures for handing a potentially catastrophic injury to a lacrosse athlete. When asked if they carried an electric screwdriver or a cutting tool with them at all games the responses were as follows: 17% always had an electric screwdriver, 17% always had a cutting tool, 58% always carried both, and 4% did not always have a tool with them to use in an emergency at games. The numbers were slightly lower when asked what their normal habits were for practices. Fifty-four percent reported carrying both an electric screwdriver and cutting tools while 12% reported not having either tool available at practices. When asked how they would manage an emergency situation involving an unconscious athlete wearing lacrosse equipment, 21% reported that they would remove the helmet completely, 75% reported that they would remove the facemask only, and 4% reported that they would remove both the helmet and the shoulder pads. Of the group that reported that they would remove the facemask only, 82% would use a cordless screwdriver, while 18% reported that they would use a cutting tool (Trainers' Angel or FM Extractor). Overall, these results demonstrated that there was no consensus on how to prepare for, and properly manage, a cervical spine-injured athlete wearing lacrosse equipment.

Participant Perception Survey Results

After participants finished performing the facemask removal of all five helmets, they completed the Participant Perception Survey (Appendix H) to assess the relative ease of removal of the helmets. The survey asked the participants to rank the helmets in the order of easiest to hardest for facemask removal. For purposes of ranking order, a value of 1 was assigned to the facemask that was perceived to be the easiest to remove and a value of 5 was assigned to the facemask that was perceived to be the most difficult to remove. Table 18 illustrates the responses to the Participant Perception Survey.

Table 17.
Participant Perceived Ease of Facemask Removal by Helmet-type.

	Percentage					
	1	2	3	4	5	Total
Brine Triumph	37.50	29.20	25.00	8.30	0.00	100.00
Cascade CPX	29.20	41.70	29.20	0.00	0.00	100.00
Cascade Pro7	0.00	0.00	8.30	25.00	67.70	100.00
Riddell XR	29.20	29.20	33.30	8.30	0.00	100.00
Warrior Venom	4.20	0.00	4.20	58.30	33.30	100.00

There were similarities between the index of difficulty (ID) and the perceived ease of removal by the subjects. Helmets with facemasks fastened by three screws (lower ID) were perceived as being easier to remove than those with five or seven screws (higher ID). Responses to the Participant Perception Questionnaire supported the data collection results. After data collection, subjects were asked to rank ease of the facemask removal process for the 5 helmets (1=easiest facemask to remove, 5= most difficult facemask to remove). No subject rated the Triumph helmet as a 5. In fact 91.7% rated this helmet as either 1, 2, or 3. The human model's opinion of the facemask removal process was also recorded. He stated that the Triumph was "the most comfortable" out of the five helmets. During the facemask removal process he felt "the safest" since the t-nut system was integrated into the helmet and did not press against his face at all.

The Cascade CPX and Riddell XR helmets had an identical index of difficulty (2.07). However the Cascade CPX had a faster time of removal than the XR helmet and the other helmets with higher IDs (Venom and Pro7). While the difference was not significant, it was somewhat unexpected. Evaluation of the data collection notes revealed that three of the subjects experienced t-nut spin with the Riddell XR helmet. Subjects 3, 9 and 11 all experienced some degree of t-nut spin. Subject 3's time of 181.32 sec was almost four times longer than the mean of 48.01sec. An outlier of this size likely affected the overall mean, driving that score higher than it should have been without the high value. Both of these helmets (CPX and XR) had the same number and length of screws. The screws on the sides of both helmets were fastened using a t-nut and plastic washer. The results of the Participant Perception Questionnaire further support these results. The CPX helmet received rankings from 1-3 and the XR helmet received rankings from 1-4. Seventy-one percent of the subjects ranked the CPX a 1 or 2, while 91.7% of the subjects ranked the XR 1, 2, or 3. The human model reported that the CPX helmet was comfortable; however he felt the shape of the helmet placed his neck in slight flexion. He reported feeling pressure on the side of his face during removal of the side screws. The forces of the t-nuts on the inside of the helmet created this pressure. The human model also believed that the XR helmet was heavy and found the padding to be uncomfortable. He experienced similar pressure on the side of his face during the removal of the side screws and also mentioned that the facemask of this helmet was positioned closest to his nose and face. The human model also reported that at the end of the removal process the subjects had to slightly flex the facemask of the XR helmet so that it could clear the helmet during the removal process. This flexion movement created pressure at his temple.

The Warrior Venom helmet had the fourth highest ID and also a removal time significantly longer than Triumph, CPX and XR. The total number of 7 screws to remove was much higher than the other helmets (3 screws). The results supported the hypothesis. The Warrior Venom helmet with the fourth highest ID took the fourth longest time to remove. The results of the Participant Perception Questionnaire indicated that the subjects felt that this helmet's facemask was difficult to remove. Only two of the 24 subjects ranked the Venom a 1 or 3. Ninety-two percent of the subjects ranked this helmet a 4 or 5, indicating they felt it was difficult to remove. The human model found this helmet to be comfortable, however did mention that its having 7 screws made the time of removal noticeably longer.

The Cascade Pro7 was by far the most complex helmet to perform facemask removal. It contained an ID of 7.48 and took significantly longer to remove than all other helmets. The characteristics of this helmet added to the difficulty of the removal process. There were a total of five screws to remove, two of these five screws were located under the snaps of the low hook-up point for the chin strap, and a bulky plastic clip was used to fasten the facemask to the sides of the helmet. These features created more steps for the athletic trainer and seemed unfavorable for the facemask removal process.

The results did support the hypothesis since this helmet had a higher time of removal than all other helmets. The Participant Perception Questionnaire further supports that the subjects felt that the facemask removal process for the Pro7 helmet was difficult. Subjects gave this helmet a ranking of 3, 4, or 5. Ninety-two percent of the subjects ranked this helmet a 4 or 5. The human model included that he felt "quite uncomfortable" during the facemask removal process of the Pro7. He stated that the plastic clips that attached the facemask to the helmet often fell and hit him in the face.

Effects of Outliers

The findings above may have been influenced by data outliers, influencing the statistical findings. Outliers were considered to be any number further than three standard deviations from the mean (Portney & Watkins, 2000). Data from 15 of the subjects were free of outliers. Thirteen of the subjects produced data containing at least one outlier related to the dependent variables, but only seven of those had multiple outliers. Each outlier was independently evaluated. Based upon these evaluations it was determined that all the data were accurate and valid and that the outliers were a product of individual subject skill.

For example, subject 6 who was a 41 year-old male collegiate athletic trainer with 15 years of work experience had an outlier in time for the Cascade CPX helmet. The author's data collection notes revealed that there was t-nut spin that occurred in the helmet. The T-nut is the anchoring mechanism for a screw and is illustrated in Figure 9.

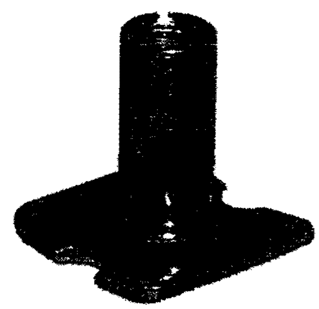

Figure 9. Helmet T-nut.

T-nut spin is a complication that can occur during screw removal and can most certainly occur in the clinical setting. The athletic trainer has to react to the spin and solve the problem during the removal process to complete the task, and the subject did just that. His time to complete the task was significantly longer than the other subjects, however it was a true reflection of his completion of the facemask removal process.

Other examples of outliers that were found to be valid were the time data for four helmets for Subject 9. Subject 9 was a 31 year-old female high school athletic trainer with nine years of work experience. Since this individual had outliers in the time data in four of the five helmets it was reflective of her slow and cautious approach. It appears that a true speed/accuracy tradeoff occurred in this situation, in that the subject opted to focus on limiting the head/neck movement in exchange for a longer removal time.

CHAPTER V

DISCUSSION

Overview

The major findings of present study included that there was statistically significant difference in facemask removal time by helmet-type, there was a statistically significant difference in maximal movement angle in the sagittal plane by helmet-type, and there was a statistical significant difference between the high school ATCs and collegiate ATCs in peak angular acceleration in the sagittal plane.

In the present study, the finding that helmets with fewer screws located closer together resulted in faster removal times supports the findings of a pilot study performed (Boergers et al., 2009). Reflecting upon these findings, Fitt's Law of speed/accuracy tradeoff which is based on index of difficulty (ID) may be considered in the interpretation of facemask removal biomechanics and preference. The ID impacted facemask removal resulting in higher values associated with longer times and more accuracy during removal. Given the importance of being accurate in facemask removal, a scenario where there is an increase in removal time accompanied with an increase in head movement could compromise the safety of the cervical spine-injured athlete.

During field management of a cervical spine-injured athlete, it is critical for ATCs to avoid any events that may lead to iatrogenic injury. Identifying helmet design features which may cause differences in time or movement during facemask removal is clearly important for maintaining quality of care. In-depth study of the helmet characteristics revealed the number of screws, length of screw removed, location of the screws, and presence of additional facemask fasteners were factors which influenced the ID (see Appendix H – Helmet Index of Difficulty), and ultimately impacted removal time, but not accuracy.

An overview of the study results indicated that the hypothesis that helmets with fewer screws located closer together, resulting in a lower ID, would have smaller maximal joint angles was not supported. In fact the opposite effect occurred. The only significant difference between helmets indicated that the Brine Triumph helmet (smallest ID) had a greater maximal movement angle of the head/neck segment in relation to the trunk in the sagittal plane than the Cascade Pro7 helmet (largest ID) and Riddell XR (second smallest ID). While this did not meet the expectation based on the pilot study, this result does support the existence of a speed/accuracy tradeoff in the facemask removal process. Since the Brine Triumph helmet facemask was removed in significantly less time than the Cascade Pro7, but had larger maximal movement angles, it appears that the subjects approached the Brine Triumph helmet with more of an emphasis on speed than accuracy. The facemask removal task was accomplished sacrificing accuracy due to the close proximity of the screws (lower ID).

The impact of ATC work setting on removal time and maximal movement angle of the head/neck in relation to the trunk was also studied. Although, it was expected that experience working at the collegiate level would enhance the collegiate athletic trainers' abilities such that they would be faster and create smaller maximum movement angles when compared to high school athletic trainers, no differences were found. These finding parallels the findings of Donahue (2009), indicating that there is no difference in how each of the work settings view the importance of preparation for emergency management of injuries. Findings from the current study support that athletic trainers in both work settings can perform facemask removal tasks similarly.

Secondary to evaluating the time and maximal movement angles created during the facemask removal process, the effects of the helmet-type and work setting on peak angular velocities and peak angular accelerations in all three planes of motion was evaluated. During the multivariate analysis a significant main effect for helmet on peak angular velocities was found, indicating that when peak angular velocities in all three planes of motion were evaluated together, significant differences were seen between the helmets. However, univariate analysis did not find significant differences between the helmets, which can be explained by the large standard deviations. These results do not support the hypotheses that helmets with fewer screws and screws that are located closer together would have the smallest peak angular velocities. When looking at the descriptive statistics, it is apparent that some of the helmets with more screws that were further apart (higher ID) actually had smaller peak angular velocities. Peak angular velocity is the maximum rate of change in angular position. It does not appear that the theory of speed/accuracy tradeoff applies to peak angular velocity. Even though a helmet may have had a higher ID, the rate at which the head/neck angle moved may have been slower than a helmet with a lower ID.

Interestingly, the results for peak angular acceleration were very similar to those seen for peak angular velocity. Multivariate analysis indicated a significant main effect for helmet-type only, but not worksetting. However, univariate analysis found a significant difference between work settings for peak angular acceleration in the sagittal plane, indicating that the high school athletic trainers produced smaller peak angular accelerations during facemask removal. Multivariate analysis included the peak angular acceleration in all three planes of motion, while the univariate analysis accounted for data only in one plane. The peak angular accelerations for all helmets in the sagittal plane were larger in the college setting. This pattern was not seen in the peak angular accelerations in the frontal and transverse planes which explains why there was no significant main effect of work setting on peak angular velocity when multivariate analysis was performed. Surprisingly, high school athletic trainers were found to have smaller peak angular accelerations even though they had similar facemask removal times for all helmets. These results need to be interpreted with caution as the calculation for angular velocity and acceleration may be responsible for the significant differences. As stated previously, peak angular velocity is the maximum rate of change in angular position, and peak angular acceleration is the maximum rate of change in angular velocity. The two terms, angular velocity and angular acceleration are often referred to as the first and second derivative, respectively. Acceleration results should be interpreted with caution as second derivatives magnify errors (variability) compared to velocity (1st derivative). Further research is needed to minimize measurement error of angular data to allow for a more robust interpretation of the angular acceleration data.

A detailed explanation of the data will be offered, followed by a comparison of the significant findings to the existing literature follows next. A final chapter will summarize the main findings and offer potential clinical implications.

Time of Facemask Removal

As hypothesized, the removal times were significantly affected by the helmet-type. Therefore, all lacrosse helmet facemasks may not be removed equally expediently in an emergency situation, potentially compromising the quality of pre-hospital management of the cervical spine-injured athlete. Helmet design, screw location and number of screws that needed to be removed during the facemask removal process varied greatly. Helmet manufacturers and organizations like the National Operating Committee on Standards for Athletic Equipment (NOCSAE) exist to ensure the safety of athletic equipment. These organizations need to be aware of optimal features in helmet designs that lead to more expedient facemask removals in the instance of a cervical spine injury. Additionally, it is important for athletic trainers and other first responders to know the location of facemask fasteners (screws) and practice facemask removal routinely so they are properly prepared for on-field emergency situations (Swartz et al., 2009). The results supported that helmets with a smaller ID (fewer screws, closer together) were removed quicker. The Brine Triumph, Cascade CPX, and Riddell XR which all had smaller IDs (3 screws) were removed significantly faster than the Pro7 and Venom (more than 3 screws). These results support the use of a simple three screw facemask attachment on the helmets. Additionally, the Brine Triumph, which was removed the quickest, contained some design features that could be viewed as advantageous in an emergency situation. The locations of the screws were easy to access and had the shortest total distance between screws. Also, the Brine Triumph contained integrated t-nuts that had a square phalange. When inserted into the plastic of the helmet, this square design would prevent t-nut spin, which is a common problem experienced in other helmets during the screw removal process. T-nut spin may add time or may cause the athletic trainer to apply greater force to the helmet, thus increasing motion in the frontal and transverse planes during screw removal. The results suggest that the integrated t-nut design feature was advantageous because it produced the lowest removal time. This evidence supports the idea that all helmet manufacturers should apply these design features to ensure the expedient removal of the facemask in emergency situations.

When compared to other research studies involving lacrosse helmet facemask removal, the results for time of removal are very similar (Boergers et al., 2009; Frick et al., 2011). A study by Frick et al. (2011) evaluated timeliness of facemask removal using different removal tools by certified athletic trainers and athletic training students. This study had a mean time of 38.83 seconds to remove the facemask from the CPX helmet, while current findings indicated a similar mean removal time of 37.91 seconds. The results from the author's pilot study were lower, with a mean removal time of 25.03 seconds for the facemask of the CPX helmet (Boergers et al., 2009). It is important to note that the subjects for the pilot study were given extensive practice time prior to the data collection, which may have positively influenced the speed of facemask removal times during that study. It is also important to note that the CPX helmet is a helmet with a low ID, and has a similar design to the Brine Triumph. Specifically, both helmets have the same number (three) and total length (4.5 cm) of screws which fasten the facemask to the helmet, and similar distances between the screws (44 cm – Triumph; 46 cm – CPX). These helmet characteristics resulted in expedient facemask removal. These shorter times for removal in these two helmets lend support to the use of helmet facemask removal in the management of the cervical spine-injured lacrosse athlete.

In 2009, the NATA position statement on the acute care for cervical spine-injured athletes did not suggest guidelines for on-field management of the lacrosse athlete since there was a lack of evidence supporting the use of facemask removal or full helmet removal (Swartz et al., 2009). The current findings, in conjunction with previous works now suggest that facemask removal can be performed expediently and is appropriate during the acute management of lacrosse athletes with cervical spine injuries. When comparing the time for lacrosse helmet facemask removal using a cordless screwdriver in the current study to studies of football helmet facemask removal, results were somewhat similar (Copeland et al., 2007; Decoster et al., 2005; Jenkins et al., 2002; Knox & Kleiner, 1997; Ray et al., 1995; Swartz, Norkus, et al., 2005). These previous studies on football helmet facemask removal eventually led to the creation of strong guidelines for pre-hospital management of the cervical spine-injured football athlete.

In 2009 the NATA position statement set strong guidelines for athletic trainers to follow regarding management of football athletes with possible cervical spine injuries based on an abundance of evidence. The studies performed on facemask removal time in football helmets using a power screwdriver yielded pooled mean removal times between 26.8 seconds and

68.8 seconds (Copeland et al., 2007; Decoster et al., 2005; Jenkins et al., 2002; Knox & Kleiner, 1997; Ray et al., 1995; Swartz, Norkus, et al., 2005). Given these studies indicate that facemask removal times were far less than the recommended minimum of three minutes, facemask removal in the acute management of a cervical spine-injured athlete is further supported. Based on the limited evidence in lacrosse and that the time of removal for lacrosse helmet facemask is similar to football helmet facemasks, one might infer that facemask removal in the acute management of cervical spine-injured lacrosse athletes can be supported and should lead to similar guidelines as those created for cervical spine-injured football athletes.

Similar to the current study, Swartz et al., (2005) investigated differences in facemask removal time in different types of football helmets. They found that facemask removal times ranged from 42.1 seconds and 68.8 seconds between six different types of helmet designs. Consistent with the findings in this current study, the location of the facemask fasteners and type of facemask fastener made a significant difference in the ease of access to the screws, thus affecting removal times. Based upon their findings, the authors suggested that certain facemask fasteners not be used since they inhibit expedient facemask removal (Swartz, Norkus, et al., 2005). Additionally, the development of a quick release facemask fastener, which has been incorporated into football helmet designs, was based upon their investigation. Considering the findings in this current study, it can be stated that certain lacrosse helmet designs do inhibit the facemask removal process and therefore should not be used. Specifically, helmets should have a maximum of three screws fastening the facemask directly to the helmet, and all other plastic fasteners should be avoided in the design, as they increase the ID for facemask removal.

The mean time of facemask removal for the Pro7 helmet (79 seconds) was the only time that fell outside the mean times of removal reported by all football facemask removal studies. However, it was still considerably lower than the three minute maximum removal time as recommended by the NATA in their position statement on the management of acute spinal injuries in athletes (Swartz et al., 2009), thus lending support to facemask removal for management of these injuries, regardless of helmet design. The findings of this study should be included in the next edition of the NATA Position Statement: Acute Management of the Cervical Spine- Injured Athlete.

Current findings have repeatedly linked a large index of difficulty (ID) to longer removal times during the facemask removal process, and require further explanation. According to Fitt's law of speed/accuracy tradeoff, ID is directly related to movement time in simple motor tasks (Schmidt & Lee, 1999). While the lacrosse helmet facemask removal task is not a simple, discrete motor task, but rather a serial type task, Fitt's law can be applied since the instructions given to participants contained statements emphasizing the importance of both speed and accuracy (limiting motion of the head and neck), equally. It is imperative that we recognize that how the subject may have perceived or interpreted the importance of the instructions could have influenced their task completion strategy, and thus, the findings. The literature indicates that when accuracy is perceived as more important, there is a significant deficit seen in time to complete simple movement tasks (Rival, Olivier, & Ceyte, 2002). It is important to remember that all subjects in the current study were allowed to practice with the helmets prior to data collection so they were able to individually perceive which helmet facemask was more difficult for them to remove, which would in turn affect the results of the study. The practice session in this study was brief and could compare with pre-season practice of facemask removal which should be performed yearly so the athletic trainers are familiar with the helmets worn by their athletes. Additionally, when in a truly emergent situation one's perceptions of what is important may also be further challenged or compromised and thus impact their actions and behaviors.

Maximal Movement Angle During Facemask Removal

To date, the pilot study performed by Boergers et al. (2009) was the only study which attempted to evaluate head/neck movement created during the lacrosse helmet facemask removal process. Based on the results of the pilot study, it was expected that the maximum movement angles would differ significantly by helmet in the frontal and sagittal planes, but not the transverse plane. During the current study, significant differences existed between only two helmets (the Triumph and Pro7) in maximum movement angles in the sagittal plane, which may indicate that facemasks of all helmets can be removed while creating similar minimal movements. Incidentally, these helmets differed the greatest in ID and in time of removal. The relatively small maximal movement angles found in this study supports facemask removal during the acute management of a cervical spine-injured lacrosse athlete. Current findings for maximal movement angles were actually smaller than those found in all planes of motion in the pilot study. Specifically, in the pilot study, maximum angles in the sagittal plane ranged from 10.33 to 15.27 degrees, while in the current study there was a range from 4.30 to 7.08 degrees in the sagittal plane. In the pilot study, the maximum movement angle for the Brine Triumph helmet was 10.33 degrees, while in the current study the maximum movement angle for the Brine Triumph was 7.08 degrees. Although the maximal movement angle of this helmet was less in the current study, it did have a significantly greater maximal movement angle than the Cascade Pro7 helmet. The significant differences between the Brine Triumph and the Cascade Pro7 helmet in the sagittal plane must be explained. After careful review of the data, the researcher has the following suggestions for this significant finding: 1.) Unique design characteristic of Brine Triumph Helmet 2.) speed/accuracy tradeoff 3.) outlier data. These possibilities are explained below.

Helmet Characteristics.

The unique design of each of the helmets affected the time and head/neck movement created during the facemask removal task. One helmet specifically, the Brine Triumph contains a unique dial adjustment to ensure a tight fit. The dial used to adjust the circumferential fit of this helmet is located near the base of the helmet by the occiput. It protrudes approximately 1 cm from the helmet and may have created an unstable contact area for the helmet on the artificial turf surface of the lab floor. This may have lead to increased flexion or extension of the head/neck segment relative to the trunk during data collection. It is the only helmet of the five tested that had a design feature like this located on the posterior aspect of the helmet. It is quite possible that this design characteristic created the increased maximal movement angle in the sagittal plane. Manufacturers should reconsider the placement of this dial so that the helmet can have a more stable point of contact with the ground, or with a spineboard, in emergency situations. This design feature is potentially hazardous and may lead to increased movement when an athletic trainer or first responder attempts to manage an acute cervical spine injury.

Speed/Accuracy Tradeoff.

Another possibility for the significant difference in maximal movement angle in the sagittal plane between the Brine Triumph and the Pro7 helmets is the vast difference in their index of difficulty scores. It is quite possible that the subjects moved quickly with the Brine Triumph helmet since it was perceived to be less difficult, leading to greater movement error. Conversely, based upon the longer time of removal for the facemask of the Pro7 one can infer the subjects took their time knowing that it was relatively difficult to remove and thus limited motion more effectively. Although the instructions given to each subject were standardized to emphasize the equal importance of speed and accuracy (reducing head/neck movement), it is possible that the increased ID of the Pro7 helmet led the subjects to perceive being accurate as more important than being fast. This phenomenon is well supported in the speed-accuracy trade-off literature and is offered as a plausible hypothesis for this study's findings (Rival et al., 2002; Schmidt & Lee, 1999).

Outlier Data.

Wide ranges in the data in this relatively small sample resulted in some outliers. In a larger sample, these wide ranges of data would likely have fit a more normal bell shaped curve. Evaluation of the raw data shows that subjects 2, 3, 13, 14, 23, and 24 had scores that would be considered outliers in multiple dependent variables and likely affected the data. However, removal of the subjects that contained outlier data would have resulted in a very small sample of only 11 subjects for evaluation. While removing the outliers would result in the data being more normally distributed, the actual findings and significance would change as well. This approach was viewed as too radical, as it would change the entire meaning of the data and would not be a true representation of what was observed in the study. Therefore, the author instead chose to evaluate the data with the outliers included.

The current study's findings differed from the pilot study (Boergers et al., 2009) findings in that no significant differences in maximal movement angle in the frontal plane between helmets was noted. Maximal movement angle ranged from 3.11 to 6.23 degrees and 2.19 to 3.31 degrees in the frontal plane in the pilot study and the current study, respectively. The pilot study found that the Triumph helmet had significantly less movement compared to the Viking and CPX helmets (Boergers et al., 2009). Both the current study and the pilot study did not have any significant differences in maximal movement angle in the transverse plane between helmets. Maximal movement angles ranged from 3.84 to 7.13 degrees and 1.61 to 3.12 degrees in the transverse plane in the pilot study and this study, respectively. These results suggest that helmet design did not affect the maximal movement angles in the frontal and transverse planes. However, it is important to remember the significant impact design had on facemask removal time and determine if the work setting of the athletic trainer, may have contributed to these results.

Work Setting

Results from the current study suggest that both high school and college athletic trainers were equally skilled at helmet facemask removal. Although it may be argued the two groups were different, the data suggests they were homogeneous in terms of age, athletic training experience and men's lacrosse experience, so comparisons of their results should be made without concern for confounding effects of those variables. It is also important to note that subjects in each group were allowed equal practice time and received identical instructions for the facemask removal process, making them more easily comparable.

While these groups were highly comparable, the literature suggests they are somewhat different. All athletic trainers must meet the same educational requirements prior to taking their board certification exam, however post-professional clinical experiences often result in differences in skill levels among practicing professionals. Pfeiffer and Mangus (2005) explained that college athletic trainers typically work only one sport, which allowed them to "specialize". Collegiate ATCs had significantly more practice on lacrosse helmet facemask removal compared to high school ATCs. This finding indicates there is some form of specialization, however the results did not demonstrate this specialization affected their skill level for facemask removal. The contribution of practicing the facemask removal process in football helmets by high school athletic trainers needed to be taken into account.

High School ATCs had a significantly greater amount of practice on football helmet facemask removal than college ATCs. The fact that there was no significant difference in removal time and maximum movement angle during the facemask removal process between the two work settings is positive for the profession of athletic training, and is consistent with the results of a study by Donahue (2009). The author's study of athletic trainers' perceptions on the importance, preparation and time spent in the athletic training practice domains found no significant differences between high school athletic trainers and collegiate athletic trainers (Donahue, 2009). The demographic results of this study further supported the findings that all athletic trainers had similar competence when it came to removal of a lacrosse helmet facemask, which assured proper emergency care for athletes in both work settings.

Secondary Hypotheses – Peak Angular Velocity and Acceleration

This was the first investigation to explore differences in peak angular velocity and peak angular acceleration during helmet facemask removal. When it came to evaluating the peak angular velocities in the sagittal, frontal and transverse planes, no differences were seen between the work settings of college and high school. However, there was a statistically significant difference in peak angular acceleration in the sagittal plane between the two groups. Contrary to the stated hypothesis, the high school athletic trainers had smaller peak angular velocities during the facemask removal process compared to the collegiate athletic trainers. This result is best explained by outlier data. Specifically, the standard deviations were much larger than the means for the college athletic trainers in two of the helmets (Cascade CPX [M

= 2674.2, SD = 5051.0] and the Cascade Pro7 [M = 3004.3, SD = 6304.7]). Since means and standard deviations of both groups were similar in the other helmets, it is likely that those outliers created the statistically significant result. It is important to understand that angular acceleration is the second derivative of angular time data, therefore small outliers are greatly increased to very large outliers. Angular acceleration is defined as:

$$\alpha_i = \frac{\theta_{i-1} - 2\theta_i + \theta_{i-1}}{\Delta t^2}$$

where θ = (deg), t = (s)

This finding of statistical significance should not be interpreted as a meaningful finding in the study as it is easily explained by the magnification of outlier data per the mathematical formula used in the calculation of angular acceleration.

CHAPTER VI

SUMMARY AND CONCLUSIONS

There is limited evidence available to inform and direct the practice of helmet facemask removal to access an airway when managing a cervical spine-injured lacrosse athlete. Additionally, there is no evidence that suggests which helmet designs are preferable for efficient facemask removal while limiting motion caused by the task. Results from this study provide evidence to support that helmet facemask removal can take place in an efficient and safe manner, as recommended by the NATA Position Statement (< 3 min). The findings also support that helmet design does affect time (speed) and maximum movement angle (accuracy), and thus the index of difficulty (ID) associated with lacrosse helmet facemask removal. Helmets with a lower ID (Brine Triumph and CPX) can be removed more quickly. Certain helmet design characteristics allow for more efficient removal of the helmet facemask. Specifically, helmets with only three screws that do not contain any additional fasteners or other steps to the removal process, can be removed most quickly. Helmet manufacturers need to have research and design teams assess their helmets for safe, easy facemask removal. There does appear to be a speed/accuracy tradeoff that occurs in some helmets during the facemask removal task as the index of difficulty for the helmet increases. This finding is similar to those found in the literature on motor control. Helmets with larger indices of difficulty (Cascade Pro7 and Warrior Venom) took longer to remove the facemasks than the other helmets; however it appeared that the subjects were more careful with their removal, thus creating less movement. Athletic training educational curriculums should include speed/accuracy tradeoff and other basic motor control theories when teaching helmet facemask removal. Knowledge of the speed/accuracy tradeoff can help an athletic trainer be more confident in their skills during the facemask removal process.

When evaluating time of removal and maximum movement angles created, there were no differences between work setting, indicating that level of training and emergency preparedness is similar for all athletic trainers. This research supports the use of an electric screwdriver as a facemask removal tool during the acute management of the cervical spine-injured lacrosse athlete. Athletic trainers need to practice the facemask removal skill and should be familiar with the differences between lacrosse helmets.

Clinical Implications

The current study's results support using the facemask removal procedure in the pre-hospital management of a cervical spine-injured lacrosse athlete since the facemask is able to be removed efficiently (< 3min) while creating a relatively small amount of movement in the cervical spine. The findings also suggest that some helmet designs (higher ID) will take longer to remove their facemasks than those with a less complex design (smaller ID).

Thus, it is critical for athletic trainers to be familiar with the helmets that their lacrosse athletes wear so they can effectively perform a facemask removal, if necessary, on a cervical spine-injured athlete.

Additionally, athletic trainers need to be aware of the speed/accuracy tradeoff present in the facemask removal process given that it requires the athletic trainer to act quickly and accurately to ensure a safe outcome for the patient. Based on the results of this study, and construct of speed/accuracy tradeoff related to index of difficulty, it is recommended that athletic trainers move quickly with helmets with three screws (lower ID) and focus more on accuracy with helmets that have more than 3 screws (higher ID). At a minimum, the findings support facemask removal on a lacrosse helmet using a cordless screwdriver as a viable method for the pre-hospital management of a cervical spine-injured lacrosse athlete since it can occur efficiently while creating minimal amounts of movement.

Recommendations

Based on the design of the Brine Triumph helmet which was consistently rated as easier to remove by the Participant Perception Survey, and the fact that this helmet was most quickly removed during data collection, the following recommendations can be made. When considering helmet designs for use with male lacrosse teams, the facemask should be fastened to the helmet with a maximum of three screws. These screws should be easily accessible; facing outward from below the ear and downward on the forehead.

Screws should fasten to T-nuts that have squared edges to protect against T-nut spinning during the facemask removal process. All helmet hardware should be made of stainless steel to avoid corrosion. Additionally, rivots shall not be used at all in fastening the facemask and throat protector to the helmet, as they make facemask removal with a cordless screwdriver impossible. Helmet manufacturers should investigate the possibility of applying the same quick release technology that is being used on football helmets to help expedite the facemask removal process. Manufacturers and NOCSAE need to standardize lacrosse helmet facemask attachment designs so that athletic trainers and other first responders can easily access an airway of a lacrosse athlete.

All Commission on Accreditation of Athletic Training Education (CAATE) – accredited athletic training education programs should include lacrosse helmet facemask removal in their curriculums since it is a vastly different task from football helmet facemask removal. Additionally, students should be made aware of Fitt's Law of speed/accuracy tradeoff and understand how this can affect the facemask removal process.

All certified athletic trainers must become familiar with the helmets that their team wears so they can be confident in handling on-field emergency situations. They must practice facemask removal prior to the start of each season, or even more frequently so they are competent performing the procedure. Research supports the use of practice for reducing movement times in tasks that are both time and accuracy dependent. In addition to practicing facemask removal, ATCs must routinely inspect helmets to ensure proper fit, make sure that hardware is not corroded, and that chinstraps do not inhibit facemask removal.

Based on the findings of this study, the Cascade CPX or Riddell XR helmets are preferred as they allow for efficient management of cervical spine injuries and easy access to their airway by athletic trainers and other first responders for the lacrosse athlete. These two helmets, because of their design, were removed quickly and with relatively little movement of the head and neck. Similar to the Brine Triumph, these two helmets had a simple three screw attachment of the facemask to the helmet, however they did not have the exterior dial near the occiput which may have been responsible for the additional motion in the Triumph. These recommendations are based solely on efficient facemask removal in the presence of a cervical spine injury or an airway emergency. Recall that the first and foremost reason that an athlete wears a helmet is to protect the head and face from blunt force trauma which may lead to concussions. This study did not produce any data to support nor oppose the use of the Cascade CPX or Riddell XR to protect against concussions.

Limitations

While there were many important findings in this study, one must realize the study's limitations as well. First, the study design can be a limitation as the design only accounted for a "worst case scenario" where a single athletic trainer is performing the pre-hospital management of a lacrosse athlete with a possible cervical spine injury. In many instances, another individual would be able to provide assistance in stabilizing the head and neck of the patient. Also, this study was performed in a controlled lab setting and the facemask removal process was performed on a healthy human model wearing motion analysis markers. In a "real world" emergency, the situation would be of much higher salience and there are numerous items that would not be controlled for (weather, field conditions, fit of the helmet, and condition of the helmet hardware, level of consciousness of the patient and injury pathology).

Additionally, it is important to recognize that the kinematic analysis required building a mechanical model using Visual 3D software. A mechanical model of two rigid segments (head/neck and trunk) was created using the software. Angular data resulted from the collection of all movements that occurred in the head/neck segment in relation to the trunk segment. Specifically, the cervical spine is made up of seven separate vertebrae that may move independently. While the collective movement was useful in making comparisons between the different helmets, it cannot be misinterpreted as actual angles of particular inter-vertebral segments. It should also be noted that the biomechanical model studied the movement of the helmet, not the head. It was assumed that motion of the helmet would result in comparable movement of the head, and those movement changes would affect space around the spinal cord.

Another limitation to this study was the helmets. All of the helmets were provided new from the manufacturers for the study. After the facemask removal process was completed for a subject, the helmets needed to be re-built by the lab assistant. To help ensure equality between trials, all helmet hardware was assessed and replaced if deemed necessary by the lab assistant with identical parts. For example, screw heads that became "stripped" during removal were replaced with a new screw. During the re-building process, the lab assistant used a torque screw driver to ensure that screws had uniform tightness for all trials. Thus, the newly furbished condition of these helmets cannot be considered as consistent with the condition of a helmet that would be used throughout the course of a season given they were not exposed to the environment and suffered no contact that could affect their integrity.

Although there were limitations to this study, the findings cannot be discounted. It is critical for athletic trainers to know that facemask removal can be performed efficiently while creating very little motion, validating this procedure to be used when managing a lacrosse athlete with a cervical spine injury. Also, knowing that helmet design significantly affects time of removal can lead to improvements in design from the manufacturers.

Future Research

Future studies need to compare the time and head/neck movement between lacrosse helmet facemask removal and full lacrosse helmet removal. Previous work on football helmets provided support leaving the helmet on and only removing the facemask since it created less segmental cervical spine movement and took less time (Prinsen, Syrotuik, & Reid, 1995). The current study, along with future studies will lead to more competent pre-hospital management of cervical spine-injured lacrosse athletes by athletic trainers and other first responders.

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Appendix A

Recruitment Flyer, Certified Athletic Trainers

Attention:
New York State Certified Athletic Trainers

You are invited to participate in a research study entitled:
"Kinematic Analysis of Head and Neck Movement Associated with Lacrosse Helmet Facemask Removal"

Conducted by: Richard J. Boergers, MS, ATC
PhD candidate in the School of Health and Medical Sciences, Health Sciences Program at Seton Hall University.

The purpose of the study is to assess time and movement created during lacrosse helmet facemask removal.

Your participation would require 30 minutes during a practice orientation session, and 1 hour during the data collection day.

You will be asked to remove the facemasks of five different lacrosse helmets on a human model laying in the supine position using an electric screwdriver. You will be asked to kneel and stabilize the human subject's head with your knees while you complete the removal process.

You must be a BOC certified athletic trainer in good standing to participate in this study

Your participation in this study is completely voluntary.

Your identity will be protected by having a number assigned to your name. All identifying data will be stored in the principal investigator's office in a locked cabinet and will remain confidential.

If you are interested please contact the principal investigator:
Richard J. Boergers, MS, ATC
Phone: 631-632-7164
Email: rboergers@hotmail.com

Seton Hall University
Institutional Review Board

OCT 29 2009

Approval Date

Expiration Date

APR 20 2010

Appendix B

SHU Informed Consent Form – Human Model

SETON HALL UNIVERSITY
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Informed Consent Form – Human Model

Researcher's Affiliation
The research project entitled, "Kinematic Analysis of Head and Neck Movement Associated with Lacrosse Helmet Facemask Removal" is being conducted by Richard J. Boergers, Jr., MS, ATC, who is a doctoral student in the School of Health and Medical Sciences Health Sciences Program, and an assistant professor in Stony Brook University's School of Health Technology and Management.

Purpose
The purpose of the study is to analyze the efficiency of lacrosse helmet facemask removal. Specifically,the researchers want to find out how much time and head/neck movement is caused by the removal process of lacrosse helmet facemasks by certified athletic trainers (ATC) using an electric screwdriver. The subject's participation will take place over two days (one day for the practice session and one day for the data collection). Subjects will be asked to come to a practice session which will allow for facemask removal of the five helmets. It is anticipated that this practice session will take 30 minutes or less. On a different day, subjects will then complete facemask removal of the five different helmets worn by a human model. Time and movement will be recorded during the trial for each of the helmets. It is anticipated that performance of the five trials will take less than 30 minutes.

The human model will wear all of the five different helmets and will be expected to be present for all trials of all subjects which will take approximately 25 hours. It is expected that the human model will need to be present for 10 days over the course of the practice sessions and data collection.

Procedure
The human model will be asked if he has a history of head or neck injury. If the human model has no history of head or neck injury his neck range of motion will be assessed by a certified athletic trainer to determine if he has normal neck range of motion. After normal neck range of motion has been determined, the human model will be properly fitted with the five helmets that will be tested in the study, as well as shoulder pads and tight spandex shorts and shirt.

Expiration Date APR 20 2010

The human model will be required to wear dark tight clothing (spandex) and Brine Core shoulder pads along with the lacrosse helmets during the practice sessions and actual data collection. All helmets will be fitted according to manufacturer's recommendations to assure "best fit". Additionally, the human model will be required to wear standard clear plastic swimming goggles to protect his eyes.

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OCT 29 2009
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School of Health and Medical Sciences
Department of Graduate Programs in Health Sciences
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1856

During the actual data collection, thirteen round plastic retro-reflective markers (17 mm) will be fixed to the human model's clothing using adhesive Velcro. The adhesive Velcro will not come in contact with the human models. To create the segment coordinate system necessary for 3D motion analysis, markers will be placed on the right and left acromion (over the shoulder pads), the right and left iliac crest (over the spandex) and over the right and left ear (over the helmet). To create the local coordinate system necessary for 3D motion analysis, clusters of 3 or more markers will be placed on a hard plastic plate which will be fastened over the anterior aspect of the shoulder pads and fastened in place using adhesive tape.

The human model will be required to lie on the floor of the lab in a relaxed position, being sure to keep his neck muscles relaxed. The subjects participating in the study will be asked to kneel and stabilize the human model's head with their knees while they complete the facemask removal using a cordless screwdriver. If the human model becomes uncomfortable during the facemask removal intervention, he simply needs to state "stop" and the subject will immediately disengage. Additionally, if the subject appears to have poor control during the removal process, the PI will instruct the subject to "stop" and immediately disengage. If the human model would like to discontinue, all trials will be discontinued at this time. If the human model would like to continue, a five minute rest period will be used prior to the start of a new trial. All trials of the actual data collection will be recorded using digital video.

Voluntary Nature
The human model's participation in this study is voluntary. He/she may refuse to participate, or discontinue participating at any time without penalty or loss of benefits in which he/she is entitled.

Confidentiality
The following procedures will be followed in an effort to keep personal information confidential in this study: the human model's identity will be held confidential: i.e. the human model's identity will be coded by a number not his/her name. The linking information is kept separate in a locked file and identifiers will be destroyed when the study is complete. All data will be kept in a locked file cabinet in the office of the principle investigator.

Expiration Date
APR 20 2010

The principle investigator, the members of the research team, faculty advisor, and the Institutional Review Board Committee will be the only people with access to these research records.

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Risks & Discomforts
There is a minimal risk to the human model for participation in this study. It is possible that the screw bit may slip off the screw and injure the human model's face; however, given the location of the screws on the helmets, it is highly unlikely for a subject to have the screwdriver slip and injure the face of the model. Additionally, the human model may feel slight discomfort in his/her low back from lying on the ground during the facemask removal process.

Benefits
The benefits of participating in this study are as follows: there is no direct benefit for the human model for participating in this study. He will have increased knowledge on dealing with emergency situations in lacrosse.

Compensation
The human model will receive $10/hr for an anticipated 25 hours ($250) for participating in this research study. Research-related injuries will not be compensated. Any necessary medical treatments as a result of participating in this study will be the sole responsibility of the subject.

Contact Information
If the human model has any questions related to the study, he may call Richard J. Boergers, Jr., MS, ATC/Principle Investigator at 631-632-7164, Genevieve Pinto Zipp, PT EdD /Faculty Advisor at 973-275-2076 or the IRB office at 973-313-6314.

Video Tape Permission
All trials will be videotaped as part of the procedures for the study. The human model's permission is needed for taping. All tapes will be saved in digital format and will be saved on the USB memory stick. The human model's identity will not be recorded and no information that could link him to the trial will be used in the file name. All digital video files will be destroyed three years after completion of the study.

All human models will be given a copy of the signed and dated informed consent form.

Expiration Date
APR 20 2010

Subject ______________________ Date ______________

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OCT 29 2009

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Appendix C

SHU Informed Consent Form – Participants

SETON HALL UNIVERSITY
1856

Informed Consent Form

Researcher's Affiliation

The research project entitled, "Kinematic Analysis of Head and Neck Movement Associated with Lacrosse Helmet Facemask Removal" is being conducted by Richard J. Boergers, Jr., MS, ATC, who is a doctoral student in the School of Health and Medical Sciences Health Sciences Program, and an assistant professor in Stony Brook University's School of Health Technology and Management.

Purpose

The purpose of the study is to analyze the efficiency of lacrosse helmet facemask removal. Specifically, the researchers want to find out how much time and head/neck movement is caused by the removal process of lacrosse helmet facemasks by certified athletic trainers (ATC) using an electric screwdriver. The subject's participation will take place over two days (one day for the practice session and one day for the data collection). Subjects will be asked to come to a practice session which will allow for facemask removal of the five helmets. It is anticipated that this practice session will take 30 minutes or less. On a different day, the subjects will then complete facemask removal of the five different helmets worn by a human model. Time and movement will be recorded during the trial for each of the helmets. It is anticipated that performance of the five trials will take less than 30 minutes.

Procedure

The subject will be asked if he/she has been a certified athletic trainer for one year and if they have worked with men's lacrosse for a minimum of one year. If the subject has at least one year of experience as an athletic trainer working with a men's lacrosse team, he/she will be asked to complete the "Lacrosse Emergency Preparedness Questionnaire". After completing the questionnaire, the subject will have his/her limb lengths measured using a standard cloth tape measure. The height and weight of the subject will also be measured using a standard scale. The subject will then be allowed to familiarize himself/herself with the five helmets. The subject will then perform a practice session removing the helmets from a human model. The human model will wear a properly fitted helmet and will lie in the supine position. The subject will kneel on the ground and use his/her knees to help stabilize the head. The subject will use an electric screwdriver to remove the screws that attach the facemask to the helmet. If the human model becomes uncomfortable during the facemask removal intervention, he simply needs to state "stop" and the subject will immediately disengage. Additionally, if the subject appears to have poor control during the removal process, the PI will instruct the subject to "stop" and immediately disengage. If the human model would like to discontinue, all trials will be discontinued at this time. If the human model would like to continue, a five minute rest period will be used prior to the start of a new trial. No measurements of time or movement will be made at this time. If the subject feels any discomfort at any time, he may quit the study without repercussions.

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The subject will return 1 week later to perform the trials. Reflective markers will be placed on the human model to measure movement. All trials will be videotaped to determine time of the removal process. Subjects will be instructed to remove the facemask from the helmet "as fast and with as little movement as possible". The subject will complete 1 removal trial for each helmet. Each trial will take no longer than 3 minutes. The same procedures for facemask removal in the practice session will be used. The subject will be given a minimum of 2 minutes rest time between trials. If the subject feels any discomfort at any time, he may quit the study without repercussions. If the human model becomes uncomfortable during the facemask removal intervention, he simply needs to state "stop" and the subject will immediately disengage. Additionally, if the subject appears to have poor control during the removal process, the PI will instruct the subject to "stop" and immediately disengage. If the human model would like to discontinue, all trials will be discontinued at this time. If the human model would like to continue, a five minute rest period will be used prior to the start of a new trial.

Instruments
The "Lacrosse Emergency Preparedness Questionnaire" asks brief questions related to a certified athletic trainer's practice for and experience in responding to emergency situations for lacrosse. Questions include, "Have you ever had to spineboard a lacrosse athlete?" Yes/No "If you had to access a downed lacrosse athlete's airway would you a.) remove the entire helmet b.) remove the facemask?"

Voluntary Nature
The subject's participation in this study is voluntary. He/she may refuse to participate, or discontinue participating at any time without penalty or loss of benefits in which he/she is entitled.

Confidentiality
The following procedures will be followed in an effort to keep personal information confidential in this study: the subject's identity will be held confidential: i.e. the subject's identity will be coded by a number not his/her name. The linking information is kept separate in a locked file and identifiers will be destroyed when the study is complete. All data will be kept in a locked file cabinet in the office of the principle investigator.

The principle investigator, the members of the research team, faculty advisor, and the Institutional Review Board Committee will be the only people with access to these research records.

Expiration Date
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Risks & Discomforts
There are no foreseeable risks for participation in this study. The subject may feel slight discomfort in his/her low back and knees while kneeling during the facemask removal process. This discomfort would be similar to discomfort felt while stabilizing an injured athletes head in an emergency situation.

Benefits
The benefits of participating in this study are as follows: the subject may have increased knowledge and practice for dealing with emergency situations in lacrosse. Specifically, he/she will have practice in removing the facemask of five different lacrosse helmets with an electric screwdriver. These practice trials should improve the subject's knowledge and confidence in responding to lacrosse emergencies.

Compensation
The subject will receive $25 for participating in this research study. Research-related injuries will not be compensated. Any necessary medical treatments as a result of participating in this study will be the sole responsibility of the subject.

Contact Information
If the subject has any questions related to the study, he may call Richard J. Boergers, Jr., MS, ATC/Principle Investigator at 631-632-7164, Genevieve Pinto Zipp, PT EdD /Faculty Advisor at 973-275-2076 or the IRB office at 973-313-6314.

Video Tape Permission
All trials will be videotaped as part of the procedures for the study. The subject's permission is needed for taping. All tapes will be saved in digital format and will be saved on the USB memory stick. The subject's identity will be coded by his/her subject number not his/her name and the helmet and trial name. All digital video files will be destroyed three years after completion of the study.

All subjects will be given a copy of the signed and dated informed consent form.

Expiration Date
APR 20 2010

Subject

Date

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Appendix D

SBU Informed Consent Form - Participants

IRB Approved: 2/22/2010
Expiration Date: 2/21/2011
CORIHS Stony Brook University

STONY BROOK
STATE UNIVERSITY OF NEW YORK

COMMITTEES ON RESEARCH INVOLVING HUMAN SUBJECTS
Established 1971

Project Title: Kinematic Analysis of Head and Neck Movement Associated with Lacrosse Helmet Facemask Removal
Principal Investigator: Richard J. Boergers, MS, ATC

RESEARCH CONSENT FORM

You are being asked to be a volunteer in a research study.

PURPOSE:

The purpose of this study is to determine how much time it takes and how much movement is caused when removing the facemask of a men's lacrosse helmet. Rapid access to an athlete's airway is critical in an emergency situation which requires cardiopulmonary resuscitation (CPR) or rescue breathing. Helmets are made in numerous designs and with numerous materials which may make one more favorable for removal than others. To date, considerable research has been conducted in the removal of football helmet facemasks which has helped in the creation of standard protocols for management of the cervical spine injured athlete. Unfortunately the helmets from the two sports differ greatly and therefore the technique for the removal of the facemasks will be different. Since there has been no research done specifically on lacrosse helmet facemask removal, we will be testing the efficiency of using an electric screwdriver to accomplish this goal. Our research will determine the most time efficient method that also prevents the least cervical spine movement. It is estimated that there will be 24 subjects for this study. To be eligible for the study, each subject must be a certified Athletic Trainer for at least one year. As a result of this research, we will develop a standard protocol for the proper management of cervical spine injuries in men's lacrosse players.

PROCEDURES:

If you decide to be part of this study, your part will involve attending a facemask removal practice session approximately a week prior to actual data collection, and may run for about 1 hour. During the practice session, you will be asked to complete the "Lacrosse Emergency Preparedness Questionnaire". After completing the questionnaire, you will have your limb lengths measured using a standard cloth tape measure. Your height and weight will also be measured using a standard scale. During the day of data collection, you will be required to use a cordless screwdriver, which will be provided for you, to remove the screws which fasten the facemask to the helmet on a model that is lying on their back. You will be asked to kneel on the ground and stabilize the helmet using your knees. Facemask removal should take no longer than 3 minutes per helmet with as little movement of the head as possible. You will complete this procedure for 5 different helmets. The process will be videotaped in conjunction with the motion analysis in order to determine the time it took to remove the facemask.
After completing the procedures for all 5 helmets, you will be asked to complete the "Participant Perception Questionnaire".

RISKS/DISCOMFORTS:

The following risks/discomforts may occur as a result of your participation in this study: You may feel slight discomfort in your knees and/or low back from kneeling for a brief time during the data collection. Your wrist and hand may feel tired while using the electric screwdriver during the study. Frequent rest periods will be encouraged. If you do feel uncomfortable at any time during the study you may drop out without any penalty to you.

BENEFITS:

There may be no foreseeable benefit to you as a result of being in this study.

PAYMENT TO INSTITUTION:

This project is funded, in part, by a grant or contract from the New York State Athletic Trainers' Association to the Research Foundation of Stony Brook University, in support of the Investigators' work on this study.

PAYMENT TO YOU:

You will receive $25 for your participation in the study.

CONFIDENTIALITY:

We will take steps to help make sure that all the information we get about you is kept private. Your name will not be used wherever possible. We will use a code instead. All the study data that we get from you will be kept locked up. The code will be locked up too. If any papers and talks are given about this research, your name will not be used.

We want to make sure that this study is being done correctly and that your rights and welfare are being protected. For this reason, we will share the data we get from you in this study with the study team, the sponsor of the study (and those who work for them), Stony Brook University's Committee on Research Involving Human Subjects, applicable Institutional officials, and certain federal offices. However, if you tell us you are going to hurt yourself, hurt someone else, or if we believe the safety of a child is at risk, we will have to report this.

In a lawsuit, a judge can make us give him the information we collected about you.

COST TO YOU:

You will not have to pay anything to participate in this study.

ALTERNATIVES:

Your alternative is to not participate in the study.

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IN CASE OF INJURY:

If you are injured as a result of being in this study, please contact Mr. Richard Boergers at telephone # 631-444-1645. The services of Stony Brook University Hospital will be open to you in case of such injury. However, you and/or your insurance company will be responsible for payment of any resulting treatment and/or hospitalization'.

SUBJECT RIGHTS:

- Your participation in this study is voluntary. You do not have to be in this study if you don't want to be.
- You have the right to change your mind and leave the study at any time without giving any reason, and without penalty.
- Any new information that may make you change your mind about being in this study will be given to you.
- You will get a copy of this consent form to keep.
- You do not waive any of your legal rights by signing this consent form.

QUESTIONS ABOUT THE STUDY OR YOUR RIGHTS AS A RESEARCH SUBJECT:

- If you have any questions about the study, you may contact Mr. Richard Boergers, MS, ATC at (631) 444-1645.
- If you have questions about your rights as a research subject, you may contact Ms. Judy Matuk, Committee on Research Involving Human Subjects, (631) 632-9036.

If you sign below, it means that you have read (or have had read to you) the information given in this consent form, and you would like to be a volunteer in this study.

____

Subject Name (Printed)

______________________________________ __________________

Subject Signature **Date**

____

Printed Name of Person Obtaining Consent

______________________________________ __________________

Signature of Person Obtaining Consent **Date**

Appendix E

Lacrosse Emergency Preparedness Questionnaire

Subject # ___________

Lacrosse Emergency Preparedness Questionnaire

1. Are you a Certified Athletic Trainer? Yes/No
2. Have you been certified for at least 1 year? Yes/No
3. Have you worked with a men's/boy's lacrosse team for at least 1 season? Yes/No
4. Sex: Male/Female
5. Age: _____
6. Hand dominance: Right/Left
7. How many years have you been a certified athletic trainer? _____
8. At what level of athletics was/is your men's/boy's lacrosse team?
   - High School
   - Club
   - Junior College
   - College D I
   - College D II
   - College D III
   - Professional
9. How many years experience do you have working with each level of men's/boy's lacrosse team?
   - High School _____
   - Club _____
   - Junior College _____
   - College D I _____
   - College D II _____
   - College D III _____
   - Professional _____
10. Have you ever ***practiced*** spineboarding an athlete wearing **football equipment**?
    Yes/No If yes, how many times? _____

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11. What is your most recent experience practicing spineboarding an athlete wearing football equipment?
    - Less than 1 month ago
    - Less than 3 months ago
    - Less than 6 months ago
    - Less than a year ago
    - Longer than a year ago
    - Never

12. Have you ever ***practiced*** spineboarding an athlete wearing **lacrosse equipment**? Yes/No If yes, how many times? _____

13. What is your most recent experience practicing spineboarding an athlete wearing football equipment?
    - Less than 1 month ago
    - Less than 3 months ago
    - Less than 6 months ago
    - Less than a year ago
    - Longer than a year ago
    - Never

14. Have you ever ***practiced*** removing the screws of a **football helmet facemask** using an electric screwdriver? Yes/No If yes, how many times? _____

15. What is your most recent experience practicing removing the screws of a **football** helmet facemask using an electric screwdriver?
    - Less than 1 month ago
    - Less than 3 months ago
    - Less than 6 months ago
    - Less than a year ago
    - Longer than a year ago
    - Never

16. Have you ever ***practiced*** removing the screws of a **lacrosse helmet facemask** using an electric screwdriver? Yes/No If yes, how many times? _____

17. What is your most recent experience practicing removing the screws of a **lacrosse** helmet facemask using an electric screwdriver?
    - Less than 1 month ago
    - Less than 3 months ago
    - Less than 6 months ago
    - Less than a year ago
    - Longer than a year ago
    - Never

18. Have you ever ***practiced*** removing a **football helmet facemask** using a cutting tool? Yes/No If yes, how many times? _____

19. What tool did you use?
    - FM extractor
    - Trainers Angel
    - Anvil Pruner
    - PVC cutter
    - Other: ______________________

20. How would you rate efficiency of tool?
    - Very Efficient
    - Efficient
    - Adequate
    - Not efficient

20. Have you ever ***practiced*** removing a **lacrosse helmet facemask** using a cutting tool? Yes/no If yes, how many times? _____

21. What cutting tool did you use?
    - FM extractor
    - Trainers Angel
    - Anvil Pruner
    - PVC cutter
    - Other: ______________________

22. How would you rate efficiency of tool?
    - Very Efficient
    - Efficient
    - Adequate

23. Have you ever ***practiced*** removing a **football helmet** from the head of a player? Yes/No If yes, how many times? _____

24. Have you ever ***practiced*** removing **football shoulder pads** in an emergency situation? Yes/No If yes, how many times? _____

25. Have you ever ***practiced*** removing a **lacrosse helmet** from the head of a player? Yes/No If yes, how many times? _____

26. Have you ever ***practiced*** removing **lacrosse shoulder pads** in an emergency situation? Yes/No If yes, how many times? _____

27. Have you ever spineboarded an athlete wearing **football equipment** in a ***live*** emergency situation? Yes/No If yes, how many times? _____

28. Have you ever spineboarded an athlete wearing **lacrosse equipment** in a ***live*** emergency situation? Yes/No If yes, how many times? _____

29. Have you ever removed the screws of a **football helmet facemask** in a ***live*** emergency situation using an electric screwdriver?
Yes/No If yes, how many times? _____

30. Have you ever removed the screws of a **lacrosse helmet facemask** in a ***live*** emergency situation using an electric screwdriver?
Yes/No If yes, how many times? _____

31. Have you ever removed a **football helmet facemask** in a ***live*** emergency situation using a cutting tool? Yes/no If yes, how many times? _____

32. What cutting tool did you use?
    - FM extractor
    - Trainers Angel
    - Anvil Pruner
    - PVC cutter
    - Other: ____________________

33. How would you rate efficiency of tool?
    - Very Efficient
    - Efficient
    - Adequate
    - Not Efficient

34. Have you ever removed a **lacrosse helmet facemask** in a ***live*** emergency situation using a cutting tool? Yes/No If yes, how many times? _____

35. What cutting tool did you use?
    - FM extractor
    - Trainers Angel
    - Anvil Pruner
    - PVC cutter
    - Other: ____________________

36. How would you rate efficiency of tool?
    - Very Efficient
    - Efficient
    - Adequate
    - Not efficient

37. Have you ever ***removed a football helmet*** from the head of a player in a ***live*** emergency situation? Yes/No If yes, how many times? _____

38. The reason for removal of the football helmet:
    - Recommended procedure at the time
    - Attempts to remove the facemask failed
    - Helmet and chinstrap were poor fit and did not support head
    - Other: ______________________________

39. Have you ever ***removed a lacrosse helmet*** from the head of a player in a ***live*** emergency situation? Yes/No If yes, how many times? _____

40. The reason for removal of the lacrosse helmet:
    - Recommended procedure at the time
    - Attempts to remove the facemask failed
    - Helmet and chinstrap were poor fit and did not support head
    - Other: ______________________________

41. Have you ever **removed football shoulder pads** in a *live* emergency situation? Yes/No If yes, how many times? _____

42. Have you ever **removed lacrosse shoulder pads** in a *live* emergency situation? Yes/No If yes, how many times? _____

43. If a potential catastrophic spine injury emergency situation occurred in a lacrosse athlete, would you feel confident in your emergency procedures? Yes/No

44. How would you manage a potential catastrophic spine injury emergency situation occurring in a lacrosse athlete?
    - Helmet Removal Only
    - Facemask Removal
    - Full equipment removal

45. If you chose Facemask removal in the above question, what tool would you use?
    - Cordless screwdriver
    - FM extractor
    - Trainers Angel
    - Anvil Pruner
    - PVC cutter
    - Other: ____________________

46. Do you always have an electric screwdriver and/or cutting tool (FM Extractor, Trainer's Angel, Anvil pruner) with you when covering lacrosse ***practices***?
    - Yes electric screwdriver always
    - Yes cutting tool always
    - Yes electric screwdriver and cutting tool always
    - No

IRB Approved: 2/22/2010
Expiration Date: 2/21/2011
CORIHS Stony Brook University

47. Do you always have an electric screwdriver and/or cutting tool (FM Extractor, Trainer's Angel, Anvil Pruner) with you when covering lacrosse ***games***?
    - Yes electric screwdriver always
    - Yes cutting tool always
    - Yes electric screwdriver and cutting tool always
    - No

Appendix F

Power Analysis (Effect size and Sample Size)

Effect Size and Sample Size for Time and Head/Neck Movements

Effect Size and Sample Size for Time

	Viking		Triumph		CPRO		XR		CPX	
	Effect Size	Sample Size	Effect Size	Sample Size	Effect Size	Sample Size	Effect Size	Sample Size	Effect Size	Sample Size
Viking			0.66	10	0.61	10	0.70	10	0.68	10
Triumph					0.24	35	0.04	1145	0.09	145
CPRO							0.09	160	0.24	10
XR									0.17	30
CPX										

Effect Size and Sample Size for Maximal Lateral Flexion Movement

	Viking		Triumph		CPRO		XR		CPX	
	Effect Size	Sample Size	Effect Size	Sample Size	Effect Size	Sample Size	Effect Size	Sample Size	Effect Size	Sample Size
Viking			0.49	15	0.52	10	0.29	20	0.23	45
Triumph					0.01	19180	0.30	25	0.31	15
CPRO							0.33	15	0.35	20
XR									0.05	730
CPX										

Effect Size and Sample Size for Maximal Rotation Movement

	Viking		Triumph		CPRO		XR		CPX	
	Effect Size	Sample Size	Effect Size	Sample Size	Effect Size	Sample Size	Effect Size	Sample Size	Effect Size	Sample Size
Viking			0.31	20	0.29	30	0.28	25	0.25	40
Triumph					0.01	12645	0.01	9580	0.09	200
CPRO							0.09	70	0.07	480
XR									0.03	1850
CPX										

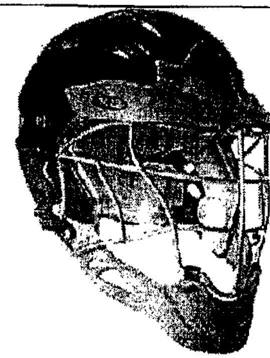
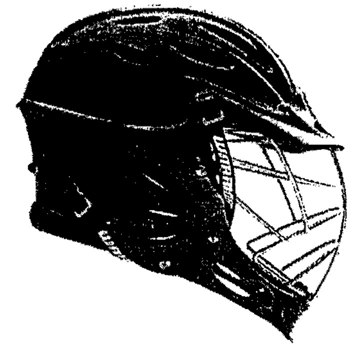
Effect Size and Sample Size for Maximal Flexion/Extension Movement

	Viking		Triumph		CPRO		XR		CPX	
	Effect Size	Sample Size	Effect Size	Sample Size	Effect Size	Sample Size	Effect Size	Sample Size	Effect Size	Sample Size
Viking			0.57	10	0.11	185	0.37	20	0.41	10
Triumph					0.58	10	0.33	15	0.08	265
CPRO							0.33	15	0.38	20
XR									0.16	90
CPX										

Appendix G

Helmet Index of Difficulty

Helmet Index of Difficulty

Helmet Characteristics					
Make/Model	Brine Triumph	Cascade CPX	Cascade Pro7	Riddell XR	Warrior Venom
Unsnap chinstrap	No	No	Yes (2 in back)	No	No
Total # screws	3	3	5	3	7
Type of Screw	Philips slot/combination with truss head	Philips slot/combination with truss head	Philips slot/combination with truss head	Philips slot/combination with truss head	Philips slot/combination with truss head
Screw lengths	All 1.5 cm	All 1.5 cm	1 = 2 cm 2 = 1.5 cm 3 =1 cm (integrated snap)	All 1.5 cm	3 = 1.5 cm 4 = 1 cm
Total Screw length	4.5 cm	4.5 cm	6 cm	4.5 cm	8.5 cm
Insertion description	3 Integrated t-nut	3 t-nut	3 t-nut 2 miniature t-nut	3 t-nut	1 integrated t-nut 2 t-nut 4 miniature t-nut
Additional fasteners	None	None	2 plastic clips at ear	None	None
Orientation of bill screw	Back	Down	Down	Back	Down
Total distance of all screws	44 cm	46 cm	58 cm	46 cm	58 cm
Index of Difficulty (ID)	1.98	2.07	7.48	2.07	4.93

Calculation of ID = (total screw length * total distance of screws / 100) + (1 for each additional step needed)

Appendix H

Participant Perception Questionnaire

Participant Perception Questionnaire
Lacrosse Helmet FM Removal Study

Subject # _____

Rank the order of ease of FM removal for the helmets (1 = easiest to remove, 5 = hardest to remove)

Brine Triumph _____
Cascade CPX _____
Cascade Pro7 _____
Riddell XR _____
Warrior Venom _____

Rank the order of your ability to limit motion during FM removal for the helmets (1 = I could limit motion created the most, 5 = I could limit the motion created the least)

Brine Triumph _____
Cascade CPX _____
Cascade Pro7 _____
Riddell XR _____
Warrior Venom _____

IRB Approved: 2/22/2010
Expiration Date: 2/21/2011
CORIHS Stony Brook University

Appendix I

Seton Hall University (SHU) IRB Approval Letter

OFFICE OF INSTITUTIONAL REVIEW BOARD
SETON HALL UNIVERSITY

October 29, 2009

Richard J. Boergers, MS, ATC
8 Mount Snow Lane
Coram, NY 11727

Dear Mr. Boergers,

The Seton Hall University Institutional Review Board has reviewed the information you have submitted addressing the concerns for your proposal entitled "Kinematic Analysis of Head and Neck Movement Associated with Lacrosse Helmet Facemask Removal". Your research protocol is hereby approved as revised under full review.

Enclosed for your records are the signed Request for Approval form, the stamped original Consent Forms, and Recruitment Flyer. Make copies only of these stamped forms.

The Institutional Review Board approval of your research is valid for a one-year period from the date of this letter. <u>During this time, any changes to the research protocol must be reviewed and approved by the IRB prior to their implementation.</u>

According to federal regulations, continuing review of already approved research is mandated to take place at least 12 months after this initial approval. You will receive communication from the IRB Office for this several months before the anniversary date of your initial approval.

Thank you for your cooperation.

In harmony with federal regulations, none of the investigators or research staff involved in the study took part in the final discussion and the vote.

Sincerely,

Mary F. Ruzicka, Ph.D.

Mary F. Ruzicka, Ph.D.
Professor
Director, Institutional Review Board

cc: Dr. Genevieve Pinto Zipp

Please review Seton Hall University IRB's Policies and Procedures on website (http://www.provost.shu.edu/IRB) for more information. Please note the following requirements:

Adverse Reactions: If any untoward incidents or adverse reactions should develop as a result of this study, you are required to immediately notify in writing the Seton Hall University IRB Director, your sponsor and any federal regulatory institutions which may oversee this research, such as the OHRP or the FDA. If the problem is serious, approval may be withdrawn pending further review by the IRB.

Amendments: If you wish to change any aspect of this study, please communicate your request in writing (with revised copies of the protocol and/or informed consent where applicable and the Amendment Form) to the IRB Director. The new procedures cannot be initiated until you receive IRB approval.

Completion of Study: Please notify Seton Hall University's IRB Director in writing as soon as the research has been completed, along with any results obtained.

Non-Compliance: Any issue of non-compliance to regulations will be reported to Seton Hall University's IRB Director, your sponsor and any federal regulatory institutions which may oversee this research, such as the OHRP or the FDA. If the problem is serious, approval may be withdrawn pending further review by the IRB.

Renewal: It is the principal investigator's responsibility to maintain IRB approval. A Continuing Review Form will be mailed to you prior to your initial approval anniversary date. **Note:** No research may be conducted (except to prevent immediate hazards to subjects), no data collected, nor any subjects enrolled after the expiration date.

REQUEST FOR APPROVAL OF RESEARCH, DEMONSTRATION OR RELATED ACTIVITIES INVOLVING HUMAN SUBJECTS

All material must be typed.

PROJECT TITLE: Kinematic Analysis of Head and Neck Movement Associated With Lacrosse Helmet Facemask Removal

CERTIFICATION STATEMENT:

In making **this application,** I(we) certify that I(we) have read and understand the University's policies and procedures governing research, development, and related activities involving human subjects. I (we) shall comply with the letter and spirit of those policies. I(wc) further acknowledge my(our) obligation to (1) obtain written approval of significant deviations from the originally-approved protocol BEFORE making those deviations, and (2) report immediately all adverse effects of the study on the subjects to the Director of the Institutional Review Board, Seton Hall University, South Orange, NJ 07079.

Richard J. Boergers, MS, ATC — 9/14/09
RESEARCHER(S) OR PROJECT DIRECTOR(S) — DATE

**Please print or type out names of all researchers below signature.
Use separate sheet of paper, if necessary.**

My signature indicates that I have reviewed the attached materials and consider them to meet IRB standards.

Genevieve Pinto Zipp, PT, EdD Chair GPHS — 9/14/09
RESEARCHER'S ADVISOR OR DEPARTMENTAL SUPERVISOR — DATE

Please print or type out name below signature

The request for approval submitted by the above researcher(s) was considered by the IRB for Research Involving Human Subjects Research at the Sept 30, 2009 meeting.

The application was approved ✓ not approved ___ by the Committee. Special conditions were _____ were not ✓ set by the IRB. (Any special conditions are described on the reverse side.)

Mary F. Ruzicka, Ph.D — 10/29/09
DIRECTOR,
SETON HALL UNIVERSITY INSTITUTIONAL
REVIEW BOARD FOR HUMAN SUBJECTS RESEARCH — DATE

Appendix J

Stony Brook University (SBU) CORIHS Approval Letter

STONY BROOK
STATE UNIVERSITY OF NEW YORK

Office of the Vice President for Research
Research Compliance

DATE:	February 23, 2010
TO:	Richard Boergers, MS
FROM:	Stony Brook University IRB (CORIHS B)
SUBMISSION TYPE:	Continuing Review/Progress Report
STUDY TITLE:	[83567-5] Kinematic Analysis of Head and Neck Movement Associated with Lacrosse Facemask Removal
CORIHS#:	2008-0051-2
ACTION:	APPROVED
SUBMISSION APPROVAL DATE:	February 22, 2010
PROJECT EXPIRATION DATE:	February 21, 2011
REVIEW TYPE:	Expedited Review
EXPEDITED REVIEW CATEGORY: (IF APPLICABLE)	#7

Thank you for your submission of Continuing Review/Progress Report materials for this research study. Stony Brook University IRB (CORIHS B) (FWA #00000125) has APPROVED your submission.

All research must be conducted in accordance with this approved submission. Any modifications to the study as approved must be reviewed and approved by CORIHS prior to initiation.

Please note:

- Approval includes amendment per PI memo dated 2/2/10.
- When submitting a redacted consent form, block out the name and signature of the study participant and only leave the name, signature and date of the individual who completed the consent process visible.

You are reminded that you must apply for, undergo review, and be granted continued approval for this study before February 21, 2011 in order to be able to conduct your study in an uninterrupted manner. If you do not receive approval before this date, you must cease and desist all research involving human subjects, their tissue and their data until such time as approval is granted.

Where obtaining informed consent/permission/assent is required as a condition of approval, be sure to assess subject capacity in every case, and continue to monitor the subject's willingness to be in the study throughout his/her duration of participation. Only use current CORIHS-stamped forms in the consent process. Each subject must receive a copy of his/her signed consent/permission/assent document.

Unanticipated problems (including serious adverse events) must be reported to this office in accordance with SBU policy at http://www.stonybrook.edu/research/HSG/HSGsec16.html#16.E.

Any complaints or issues of non-compliance must be immediately reported to this office. If you have any questions or comments about this correspondence, please contact:

Office of Research Compliance
Division of Human Subject Protections
Stony Brook University
Stony Brook, NY 11794-3368.
Phone: 631-632-9036
Fax: 631-632-9839
Betsy Baron bbaron@notes.cc.sunysb.edu
Abdool Samad asamad@notes.cc.sunysb.edu
Laura Wessels lwessels@notes.cc.sunysb.edu

Please include your study title and CORIHS # in all correspondence with this office.

Appendix K

Lacrosse Facemask Removal Hints (From US Lacrosse)

US Lacrosse Sports Science and Safety

Lacrosse Helmet Facemask/Chinguard Removal Hints

for

Certified Athletic Trainers

Current lacrosse helmet design calls for a firm fit to the head of the athlete. The days of the lacrosse helmet being allowed to "spin" around the head are gone. A 2006 published study on the effect of removing a lacrosse helmet on the cervical spine alignment concluded that the helmet and shoulder pads of an injured lacrosse athlete should be left in place until they could be removed in a controlled environment (1). This study compliments accepted athletic training protocols for leaving football helmets in place on seriously injured athletes.

While many certified athletic trainers (ATs) are well versed in the removal of a football helmet facemask, the emergence of lacrosse helmets into one's world presents a "horse of another color". Review of current lacrosse helmets and discussions with the helmet manufacturers provides insight into effective methods of removing the facemask/chinguard in case of emergency.

The lacrosse helmet shall be NOCSAE approved and it shall fit properly. It is highly recommended to follow the manufacturer recommendations for helmet fitting. Some general thoughts for helmet fit are:

1. Helmets are generally measured in inches. Charts are available from manufacturers to show the proper size helmet for the athlete's head;
2. The helmet is to sit squarely on the head, with the front of the helmet approximately one finger width above the eyebrows. This way the helmet will protect the forehead;
3. Padding of the helmet shall give firm and uniform pressure about the head. The skin of the forehead should move as the helmet is moved from left to right and from back to front;
4. There shall be a four-point chin-strap. The chin strap shall be tightened so that there is no slack;
5. Properly fitted helmets must take into account the hairstyle of the athlete; if the athlete has a great deal of thick hair and then receives a "buzz" cut the helmet must be refitted.
6. Proper helmet fit does not need to cause the athlete to have headaches.
7. Screws and T-nuts shall be replaced with new ones at the beginning of each season.
8. The facemask shall attach cleanly to the helmet, it shall be replaced if it is bent.

ATs should review all helmets and be prepared with knowledge of how to deal with their own team helmets as well as those of opponents.

Removing the Facemask/Chinguard of the Lacrosse Helmet

The chinguard of the lacrosse helmet attaches to the facemask. For clear access to the athlete's face and neck it is necessary to remove both the facemask and chinguard.

Tools.

There are two types of tools appropriate for the facemask/chinguard removal: a power screwdriver and a cutting tool. The AT will find cutting tools to be specific to the helmet. Common cutting tools are the: FMXtractor, the Trainer's Angel, anvil pruner, modified pruning shears and other cutting tools the AT personally prefers. Specific types of tools will be designated for specific helmets in the following information.

The primary tool the AT will find helpful is the power screwdriver. Screws on the lacrosse helmet are a "combo" screw which means that a flathead or Phillips head screwdriver will work. There is no recommendation on the specific brand of power screwdriver. Suggestions for the power screwdriver include:

A. One with a light to allow better viewing of the mechanical action;

B. 2 charged batteries at all times;

C. Charging the batteries daily;

D. Practice with the torque of the screwdriver to prevent accidental damage to the screw and/or T-bolt.

Screws/Clips.

Helmets have between 3 to 5 specific screws to be removed and/or clips to be cut. Screws may be stainless steel, covered brass or anodized screws. They are similar in mechanism to football screws in that the screw attaches to a T-bolt. Many of the screws attaching the clip to the chinguard also attach the chinguard to the helmet. In this case the screw must be removed leaving cutting the connecting clip useless. Lacrosse helmet clips are smaller and may be thinner than football clips, making them easier to cut.

Specific Helmet Facemask/Chinguard Removal Hints.

The information following regards the current helmets for 2008. However, these hints may be applicable to multiple helmets from the same manufacturer. It is highly recommended that the AT not only have some responsibility in the fitting of the lacrosse helmet, but that the AT and his/her staff practice removal of the facemask/chinguard prior to the season. Practice only benefits the AT and the injured athlete with quick and efficient removal of the items allowing effective assessment of the athlete. Problems of removal can be identified and strategies developed to eliminate or compensate for them.

The chinstrap should remain snug and attached at all four (4) points on the helmet.

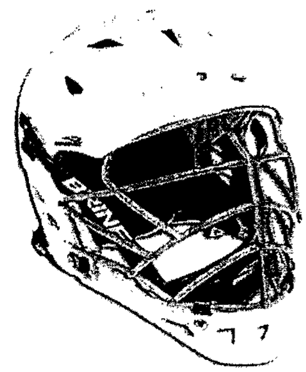
The following lacrosse helmets are shown in alphabetical order by manufacturer.

Brine Triad:

1. Use a screwdriver to remove the screws on either side of the chinguard (red area in this photo)- may need angle or extender on the screwdriver;
2. Remove the top center screw on the visor (may remove the other 2 side screws on the visor to remove entire visor);
3. Facemask/chinguard will remove as one unit.

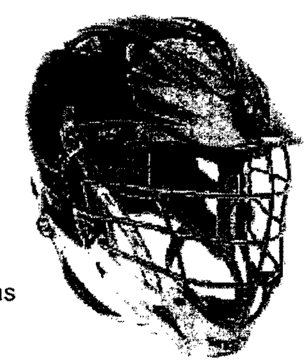
Brine Triumph:

1. Use a screwdriver to remove the screws on either side of the facemask; the screw must be removed entirely to allow the will separation from the helmet;
2. Use a screwdriver to remove the screw at the visor;
3. The facemask/chinguard unit should come away as a single unit.

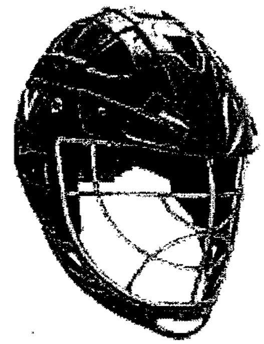


Cascade CPX, CLH2, PRO7, CS, etc:

1. Remove 2 side screws with screwdriver or clip with cutting tool;
2. Remove top screw at visor with screwdriver, one may be able to cut clip under visor;
3. Cut chinguard at back vent on both side with cutting tool;
4. After cutting the chinguard the facemask/chinguard should come off as a unit.

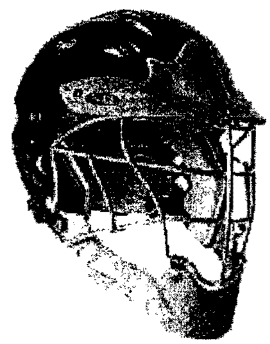


DeBeer Identity (Gait):



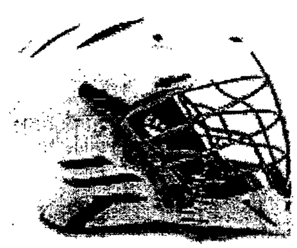
1. Screws are brass with a rust resistant coating; T-square bolts are nickel plated;
2. Remove the 2 top screws on the visor (upper orange);
3. Under the orange visor piece, remove this screw;
4. With cutting tool (Trainer's Angel not likely to work here), cut the chinguard first layer (orange on this helmet) on each side back as far as you can. The plastic is a medium density polyethylene which is relatively easy to cut. It is necessary to cut the first layer of the chinguard as there is a recessed screw which is impossible to access. NOTE: Future runs of the helmet will show the screw to be accessible outside the chinguard.
5. Removing the lower (orange) plastic piece will allow the entire facemask/chinguard to come off as a unit. There is still some secondary chinguard plastic (dark blue) that may or may not need to be trimmed based on the AT's preference.

Onyx Riddell (formerly Shamrock Lacrosse):



1. Screws are stainless steel;
2. Use a power screwdriver to remove the 2 side screws; the entire screw must be removed to allow separation of the chinguard;
3. Use a power screwdriver remove the screw at the visor;
4. The entire facemask/chinguard should come off as a unit.

Warrior Viking:



1. Use a screwdriver to remove the 2 screws on each side; the bottom screw must be removed entirely to allow the chinguard to release;
2. Use a screwdriver to remove the screw at the middle of the visor
3. The facemask/chinguard will remove as one unit.

References:

1. Sherbondy, P, Hertel, J and Sebastianelli, W, "The Effect of Protective Equipment on Cervical Spine Alignment in Collegiate Lacrosse Players," The American Journal of Sports Medicine, May 2006, 34:1675-1679.

If you have questions regarding the information presented in this document, please contact: Nancy Burke, ATC, US Lacrosse Sports Science and Safety Committee, at 703.629.2038 or ncbatc@verizon.net.

US Lacrosse
Sports Science and Safety
February 2008