Cervical Spine Motion in Ice Hockey Players During a Log Roll Technique

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ABSTRACT

Josh R. Beard: Cervical Spine Motion in Ice Hockey Players During a Log Roll Technique (Under the Direction of: Dr. Meredith Petschauer, Dr. Kevin Guskiewicz, Dr. William Prentice, Mr. Jason Mihalik

Objective: Investigate the effect of helmet fit on cervical spine motion during a log roll in ice hockey. Design: Paired samples *t*-tests and within subjects ANOVA's conducted for movement in three planes to determine if a significant difference in cervical spine motion existed under three helmet conditions (1- properly fitted, 2-competition, 3-removed). Setting: Sports Medicine Research Laboratory. Participants: 16 ice hockey players. Measurements: Head and helmet motion relative to the thorax in three planes using the Flock of Birds, reported in deg/sec. Results: No significant difference in helmet to thorax motion and significantly less head to thorax motion for sagittal and transverse planes when condition 3 is compared to 1 and 2. In the frontal plane, condition 2 yielded significantly less motion than 1. Conclusion: More motion occurred in the sagittal and transverse planes during the log roll of an ice hockey player when the helmet remained in place.

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Table of Contents

Chapter I

INTRODUCTION

Cervical spine injuries require certified athletic trainers to exercise skillful management in order to limit the likelihood of secondary injury. Proper management of these injuries has been described in the position statement put out by the NATA interassociation task force (NATAIATF) in 2001 (Kleiner 2001). Due to the difficulty in managing cervical spine injuries in athletic environments, certified athletic trainers must often manage injuries conservatively in order to minimize the risk of further injury until advanced medical imaging and diagnostics can rule out serious injury. It has been well documented in American football that, provided the shoulder pads remain on the injured athlete, inline stabilization can be maintained without removing the helmet (Prinsen, Syrotuik et al. 1995; Gastel, Palumbo et al. 1998; Peris, Donaldson et al. 2002; Kleiner 2001). While this remains relatively uncontested in football, it is inappropriate to extend these findings to all sports that use helmets and shoulder pads such as ice hockey and lacrosse. Ice hockey is a high-speed collision sport shown to have a high incidence of spinal injury. In 1998, 214 cases of fracture or dislocation of the cervical spine in ice hockey players were reported in Canada alone since 1966 (Tator, Carson et al. 1998). Further compounding the significance of the problem, injury rates per 100,000 ice hockey participants is 3 times higher than that observed in American football (Tator, Carson et al. 1998). In North America, the annual incidence of catastrophic cervical spine injuries is 15, 49% of which occurred in young

athletes between 16 and 20 years of age (Tator, 1998, Tator, 2004). The management of cervical spine injuries has an added international impact; Finland and Sweden had 16 total injuries involving spinal cord injury resulting in permanent disability between 1980 and 1996 (Molsa, Tegner et al. 1999). The annual incidence of catastrophic spinal cord injuries is estimated at 20.3 (Laprade, Schnetzler et al. 2000). Once again, while this number may not seem like an enormous problem, it computes to one ice hockey athlete per week that suffers a severe cervical spine injury during the standard ice hockey season worldwide.

From 1990 to 1999 there were 5069 neck injuries that occurred in the United States alone (Delaney and Al-Kashmiri 2005). These injuries ranged from fractures and dislocations to sprains, strains and contusions. During the years of 1996 and 1999 injury rates for the cervical spine per 10,000 participants were six and a half times higher in ice hockey than in American football (Delaney and Al-Kashmiri 2005) Athletes suffering from traumatic neck injury, in the absence of short-term improvement in condition on the field, are often managed conservatively and transported to a medical facility for further testing

Previous studies investigated how the helmet should be handled in American football: none have advocated the removal of the helmet or shoulder pads while performing a cervical spine stabilizing maneuver (Waninger, Richards et al. 2001). However, data to this effect in ice hockey is limited. Studies have shown removing the helmet in ice hockey increases cervical lordosis due to the shoulder pads, echoing similar findings in the football literature (Metz, Kuhn et al. 1998; Laprade, Schnetzler et al. 2000). These studies evaluated still frame radiographs to determine the amount of head and neck movement only after an athlete was secured to a spine board. To date, no study has used three-dimensional motion analysis to investigate cervical spine motion of athletes secured for transport and, perhaps more

importantly, during a log roll technique. Due to the nature of ice hockey at the amateur level, athletes often wear ice hockey helmets that are not securely fitted; they also lack the protective and stabilizing qualities of the cheek padding present in football helmets. Therefore, stabilizing the helmet does not necessarily ensure stabilization of the head and cervical spine in injured ice hockey athletes as it does with American football players. The shoulder pads are also far less rigid and of much lower profile. The NATAIATF states that the helmet should only be removed if:

- After a reasonable period of time, the face mask cannot be removed to gain access to the airway
- The design of the helmet and chin strap is such that even after removal of the face mask, the airway cannot be controlled or ventilation provided
- The helmet and chin straps do not hold the head securely such that immobilization of the helmet does not also immobilize the head
- The helmet prevents immobilization for transport in an appropriate position (Kleiner 2001).

In summary, the research does not support stabilizing the helmet as an effective means of stabilizing the head in ice hockey. Further research is needed in this area if athletic trainers are to provide the best medical care to their athletes with suspected cervical spine injuries.

Problem Statement

Existing differences in protective equipment between ice hockey and football indicate that variations in emergency care protocols should exist. Sufficient evidence-based research to support this claim in the NATA position statement is lacking. This study is designed to

investigate the motion of the cervical spine during a log roll technique in ice hockey players. We will assess this purpose while players are subject to three helmet conditions: properly fitted helmet, competition helmet, and helmet removed. Ideally, this study could make a case for removing the helmet and lead to a longer series of studies that could result in an emergency protocol unique to ice hockey. The purpose of this study was to investigate the effect of helmet fit on cervical spine motion during a log roll technique in ice hockey.

Operational Definitions

Sagittal plane movement: Anterior/Posterior movement; cervical flexion/extension (head nodding movement).

Frontal plane movement: Lateral flexion (ear to shoulder movement).

Transverse plane movement: Rotation of the head

Log roll: Rolling the athlete from a prone position (stomach) to supine (on back).

Competition helmet condition: The helmet regularly worn on the ice while the athlete participates in practice and games

Properly fitted helmet condition: The helmet is fit to the athlete according to the following criteria:

- Helmet rests 1.5" (two finger widths) above the participant's eyebrows
- Chin strap fits tightly under chin and is securely fastened to the helmet
- If the subject holds his head still, the PI should not be able to move the helmet without the skin on the forehead moving with it
- Hair will be wet to account for sweat

Helmet removed condition: The athlete will wear no helmet during this condition.

Delimitations

1. The participants were 18-30 years of age.
2. The helmet was properly fitted according to a list of specifications.
3. The starting position was the same for every subject (prone with head rotated to right side).
4. The log roll was performed the same way by the same team of people each time (Three ATC's).
5. Each participant was participating in competitive ice hockey.

Limitations

1. The possibility of human error is always present such as:
    a. movement of sensor on the mouthpiece
    b. consistently proper fit of the helmet when necessary
2. Testing being done in the lab and not on the ice is not as clinically congruent.

Assumptions

1. The ATC's performing the log roll were competent at the task.
2. Each log roll was consistent.
3. The starting position and ending position was the same for each roll.
4. The sensors accurately represented cervical spine movement.
5. The mouthpiece did not move.

Research Question

1.) Is the helmet to thorax motion in the sagittal, frontal and transverse planes between the properly fitted helmet and the competition helmet significantly different?

2.) Is there a significant difference in cervical spine motion in the sagittal, frontal, and transverse planes during the log roll of an ice hockey player under the following three helmet conditions; properly fitted helmet, competition helmet, helmet removed?

Hypotheses

Null:

H_o 1. There is no significant difference in helmet to thorax motion between the properly fitted helmet and the competition helmet in the sagittal, frontal and transverse planes.

H_o 2a. There is no significant difference in cervical spine movement in the sagittal plane between each of the three different helmet conditions

H_o 2b. There is no significant difference in cervical spine movement in the transverse plane under three different helmet conditions

H_o 2c. There is no significant difference in cervical spine movement in the frontal plane under three different helmet conditions

Alternate:

H_a 1. There will be a significant difference in helmet to thorax motion between the properly fitted helmet and the competition helmet in the sagittal, frontal and transverse planes.

H_a 2a. There will be a significant difference in cervical spine movement in the sagittal plane during a log roll under three different helmet conditions

H_a 2b. There will be a significant difference in cervical spine movement in the transverse plane during a log roll under three different helmet conditions

H_a 2c. There will be a significant difference in cervical spine movement in the frontal plane during a log roll under three different helmet conditions

Research Hypothesis

1. There will be no significant difference in helmet to thorax motion between the properly fitted helmet and the competition helmet in the sagittal, frontal and transverse planes.

2a. There will be a significant difference in cervical spine movement in the frontal, sagittal, and transverse planes when properly fitted helmet is compared to competition helmet.

2b. There will be a significant difference in cervical spine movement in the sagittal, frontal, and transverse planes when helmet removed is compared to competition helmet.

2c. There will be no significant difference in cervical spine movement in the sagittal, frontal, and transverse planes when properly fitted helmet is compared to helmet removed.

Variables

Dependent

1. Sagittal, frontal, and transverse plane head movement relative to thorax

2. Sagittal, frontal, and transverse plane helmet movement relative to thorax

*Movement measured in degrees per second.

Independent

1. Conditions
    a. Properly Fitted Helmet
    b. Competition helmet
    c. Helmet Removed

Chapter II

REVIEW OF LITERATURE

Introduction:

Cervical spine injuries in athletics are events that can quickly turn to catastrophe if handled improperly. Proper pre-hospital care is essential in reducing the odds of paraplegia, quadriplegia and even death that can occur as a result of these injuries. Due to helmet design in American football, adequate stabilization of the head and neck can be maintained without removal of the helmet and shoulder pads (Donaldson, Lauerman et al. 1998; Gastel, Palumbo et al. 1998; Peris, Donaldson et al. 2002; Kleiner 2001). The findings obtained in football-related studies have been extended to the management of cervical spine injuries in other sports such as ice hockey and lacrosse. Although these sports require participants wear shoulder pads and helmets, differences in equipment design may indicate a need for sport-specific considerations in the management of cervical spine injuries.

This chapter will review existing issues in determining proper management guidelines of cervical spine injuries in ice hockey. Frequency and type of cervical spine injuries in ice hockey will be reviewed along with commonly used cervical spine immobilization techniques. Techniques will be presented with the caveat that most of these studies are extensions of findings performed on American football players. Therefore, the purpose of this literature review is to discuss the frequency of cervical spine injuries in ice hockey and to determine whether or not the generalizations taken from football studies accurately establish on ice emergency care.

Mechanism of Injury:

A catastrophic cervical spine injury can be defined as a structural distortion of the cervical spinal column associated with actual or potential damage to the spinal cord (Banerjee, Palumbo et al. 2004).

The most common causes of cervical spine trauma in collision sport athletes are unstable fractures and dislocations (Banerjee, Palumbo et al. 2004). These injuries are considered unstable when there is a resulting loss in the ability of the spine to maintain normal patterns of motion without causing additional damage to the spinal cord or nerve roots. Most frequently, the etiology of cervical spine injuries is an axial load. When this axial force is applied to the crown of an athlete's helmet, the cervical vertebrae are compressed between the head and the mass of the body. This causes the vertebrae to absorb the impact and can result in fracture. What happens to the spine partly depends on what position the neck is in. When the neck is in a neutral position it presents with a lordotic curve that allows forces to dissipate through paravertebral musculature and vertebral ligaments (Banerjee, Palumbo et al. 2004). If the head and neck are positioned in slight flexion at the point of impact, the cervical lordosis is reduced and the force is placed directly on the vertebrae. Studies performed on cadavers have demonstrated that the cervical spine, when loaded in a slightly flexed position, responds in a buckling fashion (Banerjee, Palumbo et al. 2004).

In ice hockey, this injury is most commonly the result of an illegal check from behind that sends the athlete headfirst into the boards that surround the ice (Tator, Edmonds et al. 1991; Tator, Carson et al. 1998; Tator, Provvidenza et al. 2004).

Injury Types:

A number of classification scales are used by medical professionals to describe the severity of an injury. Bailes et al. (1991) classify cervical spine injury as Type I, Type II, or Type III. Type I injuries involve permanent spinal cord injury and result in permanent damage. Type II injuries result in a transient spinal cord injury due to trauma. Individuals with Type II injuries have normal neurological examinations and radiological surveys. In those cases, there is no evidence of vertebral fracture, spinal column instability or intrinsic cord contusion (Bailes, Hadley et al. 1991). These injuries often involve "burners" or "stingers," which is a stretching of the brachial plexus, a large branching of nerves that supply the majority of the upper extremity. Type III injuries demonstrate radiological abnormalities without any neurological deficits. These injuries are cause for cessation of participation in collision sports and usually require surgery. Examples of Type III injuries include unstable fractures or fracture/dislocations, unstable ligamentous injuries, herniated cervical disc and congenital spinal stenosis. Stenosis of the cervical spine is classified by an anteroposterior diameter of the cervical canal of less than 14mm which has been said to predispose athletes to neurological injury (Bailes, Hadley et al. 1991).

The National Center for Catastrophic Sport Injury Research (NCCSIR) classifies injuries as direct, and indirect. Direct injuries result from participating in the skills of a sport (i.e. trauma from a collision, falling while performing a stunt, etc.). Indirect injuries are caused by systemic failure while participating in a sport i.e. cardiovascular conditions, heat illness or dehydration (Boden 2005). Indirect injuries are also subdivided into serious, nonfatal, and fatal. Serious injuries occur when there is a severe injury with no permanent functional deficits. Nonfatal injuries include any injury in which the athlete suffers a

permanent and severe functional disability (Boden 2005). Fatal injuries are those that result in death of the athlete.

Commonly, cervical spinal column damage is classified into two types. The first type is a "flexion teardrop" injury. This occurs after a compressive-flexion injury resulting from an axial force along with a bending movement. Deformation results in a shortening of the anterior column due to compressive failure of the vertebral body and a lengthening of the posterior column due to tensile failure of the spinal ligaments. This is a highly unstable failure and is often associated with spinal cord injury (Banerjee, Palumbo et al. 2004). The compression, or "burst" fracture is another result of an axial load. In a burst fracture, the load applied to the vertebral body is more purely compression without flexion and results in a shortening of the anterior and posterior column. The compression force causes an increase in intradiskal pressure. The rise in pressure causes an extrusion of disk material, which results in displacement of bone fragments in all directions. When this happens, spinal cord compromise very often results (Banerjee, Palumbo et al. 2004).

A secondary injury can be described as an injury that is not the direct result of initial trauma. One example of a secondary injury that can occur in the cervical spine is when an unstable fracture is present. Excessive movement can press the unstable bone fragment into the spinal cord causing damage that was not a problem initially.

Epidemiology of Cervical Spine Injuries

Injuries to the cervical spine are events that can be attributed to a number of causes. Since 1990 the four leading causes of spinal cord injuries reported to the National Spinal Cord Injury Statistical Center (NSCISC) have been motor vehicle accidents, acts of violence, falls, and sporting events (DeVivo 1997). These causes have been responsible for 35.9%,

29.5%, 20.3%, and 7.3% respectively (DeVivo 1997). Though athletics do not comprise a staggering percentage of the total injuries nationwide compared to other causes, cervical spine injuries in sports can be very costly. Additionally, the mean age of athletes sustaining cervical spine injuries in sports is 24 compared to 30 for motor vehicle accidents, 27 for acts of violence, and 42 for falls (DeVivo 1997). The relatively young age of athletes with sport-related cervical spine injuries can have a significant impact on our health care system. Average initial costs (i.e. those incurred in the year following the injury) for each cervical spine injury is said to be in excess of $295,000. This cost is approximately $62,000 more than that associated with motor vehicle crashes (DeVivo 1997). Health costs in ensuing years remain quite high; averaging in excess of $27,000 per year. It has been estimated that lifetime health care costs associated with sport-related cervical spine injuries may approach $1 million (DeVivo 1997). Therefore the impact of catastrophic cervical spine injuries in sports may be more severe due to the fact that they occur in younger people and they almost always result in tetraplegia. The highest risks in the United States and Canada are in American football and ice hockey, respectively. Although collision sports such as American football have been studied at length due to their high exposure and high participation rates, ice hockey has not been studied sufficiently enough to make conclusions for helmet removal (Banerjee, Palumbo et al. 2004).

American Football

It has been estimated that 1.8 million athletes participate in organized football each year. This includes 1.5 million at the junior and senior high school levels, 75,000 in college, and close to 2000 in professional football (Mueller 2002). With these high participation rates, the potential for catastrophic cervical spine injuries continues to exist.

In 2002, cervical spine injury rates per 100,000 participants were .33 in high school and 1.33 in college football (Banerjee, Palumbo et al. 2004). Over the past 25 years 223 football players have suffered a cervical spinal cord injury that have resulted in very little or no neurological recovery (Cantu and Mueller 2003). That is 8.9 injuries per year in which the victim has permanent impairment of some sort. However, due to equipment standards, teaching fundamentals of the game, and improved health care, injury rates have fallen from a peak of 20 per year during 1971-1975 to 7.2 per year over the last 10 years (Cantu and Mueller 2003). During the last 25 years, the incidence rate per 100,000 participants was .52 in high school, 1.55 in college, and 14 in professional football (Cantu and Mueller 2003; Banerjee, Palumbo et al. 2004)

Ice Hockey

It has been made clear in many studies the annual incidence of hockey related spinal injuries in Canada has increased greatly over the last 20 years (Tator, Edmonds et al. 1991; Tator, Carson et al. 1997; Tator, Carson et al. 1998; Tator, Provvidenza et al. 2004). From 1943 to 1999 there were 271 reported cases of cervical spine injuries in Canada (Tator, Provvidenza et al. 2004). While 271 may not seem like a staggering number, the number per 100,000 participants is three times higher than American football (Tator, Provvidenza et al. 2004).

Between the years of 1980 and 1999 there were, on average, 12.75 cervical spine injuries per year in Canada alone (Tator, Provvidenza et al. 2004). Of all the reported spinal injuries in Canadian ice hockey, 83.5% were to the cervical spine. 245 cases of the 271 provide sufficient documentation to conclude that 75% of the athletes ended up with some form of neurological deficit and approximately one-third of them will be in a wheelchair for

life (Tator, Provvidenza et al. 2004). The majority of the injuries sustained (91%) occurred during supervised games, and they occurred to athletes between the ages of 16 to 20 (Laprade, Schnetzler et al. 2000; Tator, Provvidenza et al. 2004).

Catastrophic cervical spine injuries are not the only spinal injuries that are a problem in the realm of sports medicine. From 1990-1999, 5,069 general cervical spinal injuries were reported in the United States alone. These injuries included contusions, sprains, strains and fractures/dislocations, the majority of which would need to be immobilized on a spine board (Delaney and Al-Kashmiri 2005). In 1996 and 1999 injury rates for the cervical spine in ice hockey were 0.081 and 0.375 per 10,000 participants, respectively. Compare these numbers to 0.077 and 0.057 per 10,000 participants for American football during those same years and it becomes evident that cervical spine injuries are just as prevalent, if not more so in ice hockey.

Ice hockey is also incredibly popular in Europe. Since the 1980's the number of players participating in organized ice hockey has increased from 35,000 to 50,000 per year in Finland, and has been approximately 50,000 in Sweden since the 1980's (Molsa, Tegner et al. 1999). In players from Sweden and Finland there were 16 cervical spine injuries from 1980 until 1996, eight in each country. The data from these injuries follows the same pattern as was reported by Tator; the mean age was 21.2 years, all but one occurred in a supervised game, and all caused permanent neurological damage.
(Molsa, Tegner et al. 1999).

Annual incidence of catastrophic cervical spine injuries in ice hockey in the United States has been calculated to be approximately 9 per year; the global incidence rate has been estimated at approximately 20 per year (Laprade, Schnetzler et al. 2000). The incidence of

20 injuries per year results in an average of one reported cervical spine injury per week worldwide during the standard hockey season (Laprade, Schnetzler et al. 2000). This implies that it is absolutely imperative for emergency personnel and the sports medicine team to have emergency protocols in place to help limit secondary injury when managing these events. Whether the injury is catastrophic or not, if it involves the cervical spine, chances are the athlete is going to be spine boarded. Limiting secondary injury in ice hockey calls for more studies to help establish what the proper emergency care protocol should be.

Management

During acute care of an athlete with a spine injury, it is important to restrict movement of the spinal column to help reduce the chance of secondary injuries. Manual, inline stabilization is the initial step in prehospital management of spine-injured athletes. To do this, it is important to maintain head and neck alignment with the torso to help prevent structural deviations from occurring within the spinal column (Del Rossi and M. Horodyski 2003; Kleiner 2001). Manual stabilization must be replaced with mechanical immobilization for emergency transport. This is done by securing the head, neck, chest and pelvis of the patient to a long, rigid spine board (Del Rossi and M. Horodyski 2003). Maintaining inline stabilization during a transfer technique onto a spine board is not easy. To help achieve this task with minimal movement, there are two common transfer techniques used, the log-roll maneuver and the lift-and-slide technique (Del Rossi and M. Horodyski 2003).

The log-roll has been the most commonly used transfer technique (De Lorenzo and Olson 1996; Del Rossi and M. Horodyski 2003). It has long been popular not only for its minimal personnel and strength requirements, but also its adaptability to handle problems that can arise when athletes are prone (Del Rossi and M. Horodyski 2003). The lift-and-slide

relies on strength and coordination of those performing it and can only be performed on those found in the supine position. However, it has become increasingly popular with sports in which bulky equipment is worn. Since the execution of this technique avoids rolling the injured patient over bulky pads, it has been shown to be more effective at limiting unwanted movement (Del Rossi and M. Horodyski 2003).

According to the NATAIATF, the six person lift (lift and slide) is preferred when used in conjunction with a scoop stretcher (Kleiner 2001). However, if the athlete is found supine a log roll directly onto a spine board may be more practical. Also, in a sport such as ice hockey, using a technique in which the athlete is lifted off of the ice could prove to be hazardous.

Cervical Collars

It has been believed that secondary motion can be limited during the log-roll and the lift-and-slide by using a cervical collar. In a study by Del Rossi et al. done in 2004, the use of cervical collars to limit secondary movement during a log-roll and the lift-and-slide was investigated using cadavers. In this particular study a spinal lesion was created at the C5-C6 vertebral segment. An electromagnetic tracking system was then used to capture the angular motions of flexion-extension, lateral flexion, and axial rotation during each transfer technique. This study yielded no significant interaction between transfer techniques and cervical collars (Del Rossi and T.P. Heffernan 2004). Furthermore, it has been recognized by Kleiner et al. that the application of a cervical collar may not be possible when the helmet and shoulder pads are left in place (Kleiner 2001). In another study, done by Askins et al in 1997, cervical orthoses were shown to be effective in restricting movement when comparing

five different collars. However, this study was done in a clinic, on healthy individuals, and without protective athletic equipment of any kind (Askins and Eismont 1997).

Optimal Positioning

The positioning of the neutral position of the cervical spine is crucial when preventing secondary injury during on field management. According to De Lorenzo et al., optimal position for a patient lying flat on a backboard occurs with a cervical-thoracic angle of 14°, which can be correlated to raising the occiput 2 cm.

It has been documented in a multitude of studies that immobilized, supine football players demonstrate a significant increase in cervical lordosis once their helmet is removed (Prinsen, Syrotuik et al. 1995; Donaldson, Lauerman et al. 1998; Gastel, Palumbo et al. 1998). Current management guidelines of cervical spine injury do not advocate the removal of protective equipment for this reason. It is believed that by stabilizing a properly fitted football helmet, emergency personnel are able to maintain adequate stabilization of the head and cervical spine due to a close fitting design. The NATAIATF maintains that a properly fitting football helmet holds the head and spine in proper alignment as long as the athlete is wearing shoulder pads (Kleiner 2001).

Studies have been done on supine, immobilized ice hockey player to see if the same increase in lordosis is present. In 2000 LaPrade et al investigated whether or not helmet removal caused a significant increase in cervical spine lordosis in ice hockey players. This particular study assessed ten healthy adult male volunteers aged 18-28 years. Each was properly fitted with an ice hockey helmet and shoulder pads and immobilized on a standard spine board. Computerized tomographic scans were then obtained for no equipment, helmet and shoulder pads, and shoulder pads only. The CT scans illustrated a significant increase in

C2 to C7 lordosis when comparing shoulder pads only to the other two conditions. The greatest segmental movement occurred at the C6-C7 level when the shoulder pads only condition was compared to helmet and shoulder pads. LaPrade et al ultimately concluded that ice hockey helmets should not be removed from injured players because it will result in unnecessary motion of the cervical spine (Laprade, Schnetzler et al. 2000).

Metz et al (1998) also found that cervical lordosis without ice hockey equipment was not significantly different than cervical lordosis while wearing an ice hockey helmet and shoulder pads. This study took lateral radiographs of the cervical spine in eight healthy male volunteers. The subjects were immobilized on a spine board while wearing shoulder pads and helmet, shoulder pads only, helmet only, and no equipment. Consistent with other studies, Metz et al (1998) found that subjects wearing shoulder pads averaged 8.9 degrees more lordosis when compared to no equipment and 6.6 degrees more lordosis when compared to the shoulder pads and helmet condition.

This study also investigated neck flexion and extension with helmet and shoulder pads on when secured to the spine board. Interestingly, subjects were able to flex and extend the cervical spine 12.9 degrees while "secured." (Metz, Kuhn et al. 1998)

Waninger et al (2001) also advocates leaving on the helmet and shoulder pads during immobilization and transport of the spine-injured athlete. His study compared total range of head motion for 12 ice hockey, nine football, and nine lacrosse athletes from an NCAA division I program. Athletes were immobilized on a spine board while three motion analysis HiRes cameras tracked movement of the head inside the helmet as the spine board was perturbed 12° along the long axis of the subject to mimic jostling consistent with transport. This study found that total range of head motion for football players was 4.88°, 6.56° for

lacrosse players, and 5.54° for ice hockey players. While the numbers for ice hockey and lacrosse were higher, they were not statistically significant from each other ($p>0.05$) (Waninger, Richards et al. 2001). This study only compared the sports to each other, did not have a no helmet condition for comparison and only analyzed rotation of the head relative to the helmet not the thorax.

Face Mask Removal

The NATAIATF advocates the removal of the face mask during any emergency situation in which a spinal cord injury is suspected. It is recommended that the face mask be removed immediately when the decision to transport the athlete is made, regardless of respiratory status. If a clinician waits until the athlete stops breathing to remove the face mask, valuable time will be lost. (Kleiner 2001).

Helmet Removal

The NATAIATF states that the helmet should only be removed if:

- After a reasonable period of time, the face mask cannot be removed to gain access to the airway
- The design of the helmet and chin strap is such that even after removal of the face mask, the airway cannot be controlled or ventilation provided
- The helmet and chin straps do not hold the head securely such that immobilization of the helmet does not also immobilize the head
- The helmet prevents immobilization for transport in an appropriate position

* If the helmet is removed, the shoulder pads should be removed simultaneously.(Kleiner 2001).

Testing Equipment and Methodology

Equipment used during this study included the Flock of Birds, a three dimensional electromagnetic motion analysis system with a measurement rate of up to 144 measurements per second (Ascension Technology Corporation, 2004). Studies done using this piece of equipment found that this system is capable of measuring the 3-D angles in the neck, and provides negligible interference to the model (Koerhuis, Winters et al. 2003). Another study done by Stokdijk found that the Flock of Birds (FoB) has a low ICC value of .81 which gives it good inter and intraobserver reliability.

Summary

The majority of studies investigating management of cervical spine injuries have advocated that helmets remain on the athlete. Helmets and shoulder pads should only be removed under the four conditions listed by the NATAIATF and if removed, should be done together. These studies investigated volunteers or athletes that were already immobilized in a supine position which is an ideal situation. Complications in the management of cervical spine injuries arise when the athlete is found semi- or fully prone and therefore needs to be log rolled in order to ascertain proper stabilization. An important question that needs to be raised is whether or not ice hockey helmets provide enough stabilization to the head and cervical spine to remain on the athlete during a log roll procedure. If the study by Metz is any indication, the answer is no. Even though they were secured to a spine board, subjects were still able to flex and extend the cervical spine 12.9 degrees with their helmet on.

Chapter III

METHODOLOGY

Participants

A total of 16 ice hockey players (age = 21 ± 2.5 years, height = 181.5 ± 6.0 cm, mass = 80.8 ± 9.0 kg) served as participants for this study. Participants were recruited on a volunteer basis from local club ice hockey teams. Each participant was between 18-30 years of age and actively playing ice hockey within the last year. All participants completed an informed consent form approved by the Institutional Review Board at the University of North Carolina at Chapel Hill prior to participation.

Equipment

Equipment used in this study included an electromagnetic tracking system. In this system, the Flock of Birds hardware (Ascension Technologies, Inc., Burlington, VT) was controlled by MotionMonitor® computer software (Innovative Sports Training Inc., Chicago, IL). The Flock of Birds is a three-dimensional electromagnetic motion analysis system and 144Hz were used to collect all data (Ascension Technology Corporation, 2004). To yield the truest results, the unit was calibrated with a stylus tip prior to every test. For the most reliable results, it was recommended that each measurement be taken three times to ensure accuracy (Meskers, Fraterman et al. 1999; Umberger, Nawoczenski et al. 1999; Koerhuis, Winters et al. 2003).

A rigid orthoplast mouthpiece was created and served as a placement site for the motion sensor of the head (Figure 3-1). This mouthpiece was covered with heat-molded

plastic that was removed and changed between participants. This ensured that each participant had a clean mouthpiece to fit into his mouth for the duration of the testing session.

Figure 3-1:

Four sensors were used for this study. One was placed on the stylus for calibration. A second sensor was placed on the top of the participant's ice hockey helmet. A third sensor was placed on the proximal aspect of the participant's sternum, just below the sternal notch to avoid movement due to breathing. Finally, the fourth sensor was placed on a rigid orthoplast mouthpiece the participant placed in their mouth. All sensors were attached with double-sided tape.

Protocol

Each participant signed up for an available time slot and reported to the University of North Carolina's Sports Medicine Research Laboratory at the assigned time for one testing session. Each subject was asked to bring his competition helmet for testing. Upon arrival each participant completed an informed consent form. Each participant was then assigned to one of six counterbalanced test orders that included properly fitted helmet, competition helmet, and removed helmet (Figure 3-2).

Figure 3-2: Latin square counterbalanced conditions
PF = Properly fitted; CH = Competition Helmet; HR = Helmet removed

PF, CH, HR	PF, HR, CH	CH, PF, HR
CH, HR, PF	HR, PF, CH	HR, CH, PF

After the consent form was signed and a test order was established, each participant was properly fitted with a new Itech ice hockey helmet according to the following criteria:

- The helmet rests 1.5" (two finger widths) above the participant's eyebrows.
- The chin strap fits tightly under chin and is securely fastened to the helmet.
- If the participant holds his head still, the PI was not able to move the helmet without the skin on the forehead moving with it.
- The participant's hair was wet to account for sweat.

Once the participant had a new helmet that was properly fitted, the competition helmet was examined for fit using the same criteria.

The participant then had the three motion sensors applied with double-sided tape and secured with athletic tape. One sensor was placed on the top of the helmet, the sternum and the mouthpiece. These three sites were chosen due to the minimal movement of the soft tissue surrounding these bony landmarks.

After application of the sensors, the participants were asked to sit in a chair with all of their equipment on and specific bony landmarks were digitized using the movable sensor attached to a wooden stylus. Landmarks for the head included:

Proximal point: chin

Distal point: bridge of the nose

Third point: occipital protuberance

Fourth point: In front and to the left of the model

Origin: (2) chin and occipital protuberance

Landmarks for the thorax included:

Proximal point: T8 and xyphoid process

Distal point: C7 and and sternal notch

Third point: T8

Fourth point: In front and to the left of the model

Origin: (2) C7 and sternal notch

To allow for full motion of the mouthpiece and to minimize any interference of the electromagnetic tracking system, plastic facemasks commonly used in ice hockey were applied to the helmets.

Testing Procedures

For each trial, the participant began lying prone with his head turned to the left and arms along his side. Instructions for the participant were to "bite down firmly on the mouthpiece and lay limp." Every participant began in this position for each roll. Using a total of three certified athletic trainers as rescuers, each participant was log rolled from prone to supine onto a spine board (Ironduck, Chocopee, Ma) in accordance with the NATAIATF's recommendations (Kleiner 2001). The principal investigator acted as rescuer 1 (R1) and immobilized the head and cervical spine. Rescuer 2 (R2) controlled the torso, and the third rescuer (R3) the legs. A fourth investigator was responsible for initiating and terminating the software's data collection process. For the log roll, R2 placed their right hand on the

participant's left shoulder and their left hand on the participant's left greater trochanter. Meanwhile, R3 placed their right hand on the participant's left anterior superior iliac spine, and their left hand on the participant's left shank to help control the legs during the roll. Two rescuers (R2 and R3) kneeled on a spine board that had previously been placed flat on the floor and flush against the participant. On R1's instructions of "prepare to roll, roll" the participant was log rolled towards R2 and R3 onto his back (Kleiner 2001; Swartz, Nowak et al. 2005). The rescuers received a brief practice session before any data collection to ensure the protocol was fully understood. Data collection began after R1 said "prepare to roll" and was terminated when R1 said "stop." This resulted in a period of about a half of a second in which the subject was not moving. This helped to ensure consistency of starting position during data reduction. From start to finish, the log roll lasted between four and six seconds. The log roll procedure was performed three times for each helmet condition. The dependent variables were total degrees of movement between the head and thorax in the sagittal, frontal and transverse planes and degrees of movement between the helmet and thorax for the helmeted conditions. The independent variables were the helmet condition: properly fitted helmet, their competition helmet, and no helmet.

Data Reduction

Data were exported from MotionMonitor software and reduced using a custom C++ program and Microsoft Excel. Motion collected in each plane was reduced separately. For each plane in each trial the C++ program was designed to take the first ten data points collected in the trial and then average them together, representing a baseline value for the starting cervical spine position. The average was then subtracted from every data point in the set. This zeroed the data and gave a standardized starting position of the cervical spine for

each participant. The data was then rectified, making each number positive, and a curve was drawn connecting all the points. The area underneath the curve was calculated using standard integration methods and reported in degrees of total cervical spine motion. This value was then normalized to the time of the log roll allowing us to standardize our values of cervical spine motion across all participants and trials. The normalized values were entered into an Excel spreadsheet in order to compute the ensemble average between the three trials.

Data Analysis

All data were analyzed using SPSS 13.0 statistical software (SPSS Inc., Chicago, IL). Alpha level set *a priori* at .05. In order to answer our first research question, we performed a paired sample T-test for each plane (sagittal, frontal, and transverse). The dependent variable was helmet movement relative to the thorax (measured in degrees/second) and the independent variables were helmet condition (properly fitted and competition helmet).

To answer our second research question, we performed three separate one-way within-participants repeated measures ANOVA comparing head motion relative to the thorax in all three planes (sagittal, frontal and transverse). For each ANOVA, the dependent variable was head movement relative to thorax (measured in deg/sec) and the independent variables were helmet condition (Table 3-1). For each plane of movement, a Bonferroni correction was done to determine where the significant differences were located.

Table 3-1: Research Design

Research Question	Data Source	Statistical Method
Is the helmet to thorax motion in the sagittal, frontal and transverse planes between the properly fitted helmet and the competition helmet significantly different?	IV: Helmet Conditions • Properly fitted helmet • Competition helmet DV: Helmet movement relative to thorax measured in degrees/second	Paired samples t-test

Table 3-2: Research Design

Research Question	Data Source	Statistical Method
Is there a significant difference in cervical spine motion in the sagittal, frontal, and transverse planes during the log roll of an ice hockey player under the following three helmet conditions; properly fitted helmet, competition helmet, helmet removed?	IV: Helmet Conditions • Properly fitted helmet • Competition helmet • Helmet Removed DV: Sagittal, frontal and transverse plane motion measured in degrees/second	One way repeated measures within participants ANOVA with condition being the repeated factor

Chapter IV

RESULTS

This study investigated the influence three different ice hockey helmet conditions had on cervical spine movement during a log roll technique. The conditions investigated were properly fitted helmet, competition helmet, and helmet removed. Total movement of the helmet during a log roll was also examined to determine if it differed from the movement of the head.

A total of 18 ice hockey players served as subjects in this study. Three certified athletic trainers served as rescuers performing the log roll for the duration of the study. Each subject was free of injury and had been active in ice hockey within the last year. Subjects were excluded if they could not provide their own ice hockey helmet.

Data were analyzed using SPSS 13.0. Three separate paired samples t-tests were run to compare the mean range of motion in degrees per second of helmet to thorax movement between the properly fitted helmet and competition helmet conditions in the sagittal, transverse and frontal planes. No significant difference was found between the properly fit helmet and competition helmet condition in the sagittal ($t(15) = 1.153$, $p > .05$), transverse ($t(15) = 1.416$, $p > .05$) or frontal ($t(15) = -0.882$, $p > .05$) planes. This suggests that helmet movement during the log roll remained consistent across conditions. To further investigate the reliability of the log roll, an intraclass correlation coefficient (ICC) was calculated for the helmet removed condition in each plane. Frontal plane ICC (3, 1) was calculated at 0.82 with a corresponding standard error of the measure (SEM) equaling 5.18 deg/sec. Transverse

plane ICC (3,1) had a value of 0.76 with an SEM of 5.50 deg/sec and frontal plane ICC (3,1) was calculated at 0.83 with an SEM of 3.38 deg/sec. Another ICC (3,k) was computed for time and calculated at .90 with an SEM of 29.62 frames/second. At our collection rate of 144 Hz, the SEM is equivalent to .21 seconds.

A one-way repeated measures within participants ANOVA was computed to compare mean cervical spine motion under the three different helmet conditions for each plane of movement. A significant difference was found for sagittal plane movement ($F(2,30) = 7.533$, $p = 0.002$). Bonferroni correction was used to determine the nature of the differences between the helmet conditions (Condition 1- properly fitted, Condition 2-competition helmet, Condition 3-no helmet). The analysis revealed that condition 3 yielded significantly less neck flexion than condition 1 and condition 2. While condition 1 and condition 2 were not found to be significantly different, mean neck flexion was greater for condition 1. A significant difference was also found for transverse plane movement ($F(2,30) = 9.441$, $p = 0.001$). The Bonferroni correction revealed that there was less neck rotation in condition 3 than condition 1 or 2. Also, while condition 1 was not found to be significantly different from condition 2, mean neck rotation was greater for condition 2. Finally, statistical significance was found for frontal plane movement ($F(2,30) = 6.060$ $p = 0.006$). The Bonferroni correction illustrated a significant difference between only condition 1 and 2 with condition 1 experiencing a greater amount of side bending.

Tables

Table 1: Descriptive Statistics (mean ± SD) for sagittal, transverse, and frontal plane head movement (°/sec)

Sagittal Plane		
Helmet Condition	**Mean**	**SD**
Properly Fit	22.695	15.782
Competition	19.156	11.626
Removed	13.803	10.102
Transverse Plane		
Helmet Condition	**Mean**	**SD**
Properly Fit	32.164	7.772
Competition	33.299	7.237
Removed	28.128	7.200
Frontal Plane		
Helmet Condition	**Mean**	**SD**
Properly Fit	17.687	12.033
Competition	10.812	7.002
Removed	14.534	9.867

Table 2: Pairwise Comparisons of head movement (measured in °/sec) under properly fitted helmet (PH), competition helmet (CH), and helmet removed (HR) conditions in all three planes.

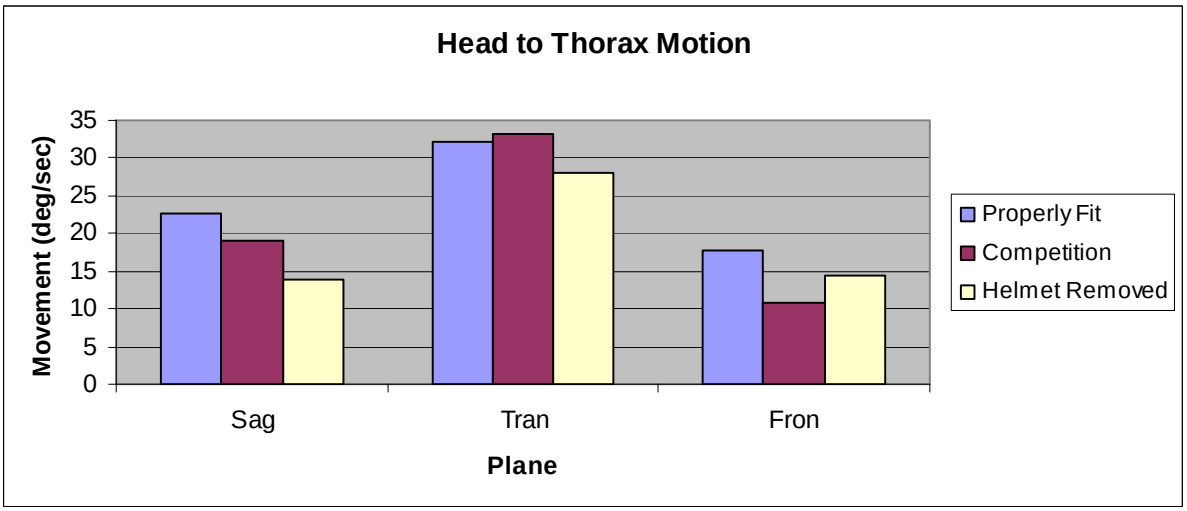

Table 3: Paired-samples *t*-tests comparing helmet movement under properly fitted and competition helmet conditions in all three planes

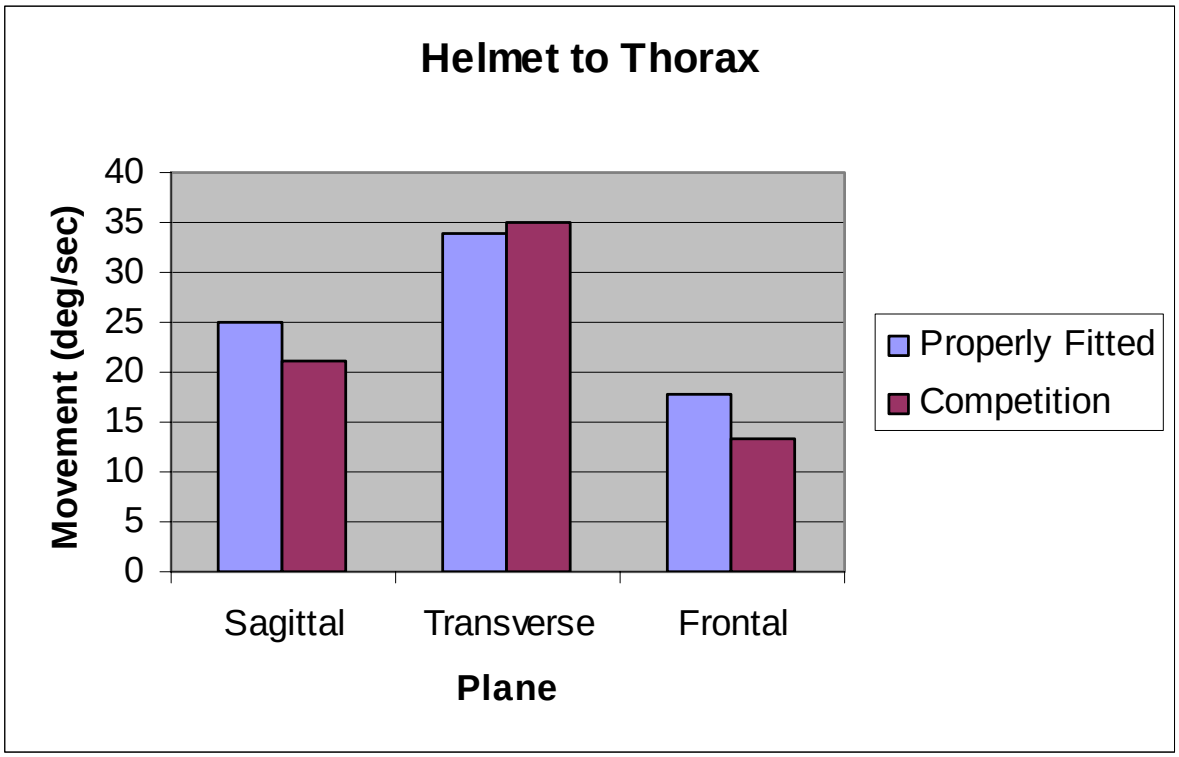

Table 4: Reliability of the log roll for head movement under the HR condition

Plane of Movement	ICC (3,1)	SEM (° / Sec)
Sagittal	0.82	5.18
Transverse	0.76	5.50
Frontal	0.83	3.38

Table 5: Reliability of the log roll time

Outcome Measure	ICC (3,k)	SEM (Seconds)
Duration of the Log Roll	0.90	0.21

Chapter V

DISCUSSION

The primary findings of this study show that regardless of helmet fit, there is significantly more cervical spine motion during the log roll of an ice hockey player when the helmet is not removed. The main differences observed were in the sagittal and transverse planes when the helmet removed condition was compared to the properly fit, and competition helmet conditions. The helmet removed condition yielded significantly less cervical spine motion than either of the others, suggesting that limiting unwanted cervical spine motion during a log roll could best be accomplished by removing the helmet altogether. A lack of significance between conditions 1 and 2 in these two planes illustrate that variations in helmet fit are inconsequential in relation to cervical motion when compared to the helmet removed condition. Interestingly, in the frontal plane, the competition helmet condition resulted in significantly less cervical spine motion than the properly fitted helmet while helmet removed showed no significance. This could be attributed to the procedure for adjusting ice hockey helmets. The outer shells of ice hockey helmets are constructed in two pieces; one anterior and one posterior, allowing them to be adjusted in the sagittal plane. To increase tightness, two screws are loosened on either side which allows the anterior portion to slide over the posterior, thus making the helmet smaller. This results in a focal point of pressure over the frontal bone and occiput when the helmet is properly fitted. Consequently, this will limit the amount of motion available in the sagittal and transverse planes, but allow for motion to still be available in the frontal plane. Under the competition helmet condition,

the poorer fit allows motion to occur over all three planes, which may be a reason why less total range of motion was observed for the frontal plane. While this result was unexpected, it could be argued that the most essential motion to limit is that in the sagittal plane. Studies regarding how much motion will cause further injury are extremely limited, which is why the NATA maintains that any motion is dangerous. It has been stated, however, that cervical flexion and extension create a shearing force between one vertebrae and the adjacent vertebrae, which could result in a narrowing of the spinal canal, thus increasing the risk for spinal cord injury with an increase in sagittal plane motion (Reitman, Mauro et al. 2004). Our data suggest that the properly fitted helmet was superior in limiting sagittal plane movement when compared to the competition helmet, though the finding was not statistically significant it may be clinically significant.

The lack of significance of helmet movement during the log roll is indicative of a consistent log roll. Helmet condition was not expected to have an impact on helmet motion during the log roll because the helmet was being stabilized. We were primarily interested in head motion inside the helmet, but performed these *t*-tests as a reliability measure along with intraclass correlation coefficients.

The intraclass correlation coefficients that were calculated for this study measured the rescuer's ability to consistently perform the log roll with limited motion of the cervical spine. According to our measurements, the team of rescuers performing the log roll was reliable and consistent. Our ICC (3, 1) was calculated only for head movement under the helmet removed condition. However, because our *t*-tests showed no significant findings for helmet movement, it can be inferred that the log roll was consistent across conditions. Our ICC (3,

k) was calculated for time and illustrates that the duration of each log roll was consistent for each subject.

Comparison of this data to previous literature is limited due to a lack of similar reported studies. In a study performed on ice hockey players, it has been reported that the removal of the helmet increases lordosis in the cervical spine if the shoulder pads remain in place (Metz, Kuhn et al. 1998; Laprade, Schnetzler et al. 2000). These studies examined volunteers or athletes that had been previously immobilized in a supine position and no attention was paid to technique of subject immobilization, or to the fit of the helmet. Furthermore, during our study, it was shown that the helmets worn and fitted by the athletes for competition were poorly fitted according to our criteria. An alarming seven of the subjects could completely remove their helmet without unfastening the chinstrap or flipping up the face mask. Theoretically, such a poor helmet fit could result in increased head movement within the helmet.

Although studies have primarily focused on athletes in the supine position, it needs to be recognized that clinically, post injury positions vary. According to Tator et al., the most common cause of cervical spine injuries in ice hockey is a push, or check, from behind causing the athlete to be propelled head first into the boards (Tator, Provvidenza et al. 2004). This mechanism would cause the athlete to fall onto the ice and into the prone position, therefore, requiring a log roll onto a spine board during emergent care.

Equipment Differences

American football has been extensively studied in an attempt to establish a protocol for emergency situations (Cantu and Mueller 2003; Kleiner 2001; Boden 2005). None of these studies advocate the removal of the helmet or shoulder pads unless the situation is life

threatening and an airway needs to be established. Even then, it is well documented that if a spinal injury is suspected, the helmet and shoulder pads should be removed together (Kleiner 2001). More importantly, it has been shown that immobilizing the helmet of a football player will adequately and concurrently stabilize the athlete's head (Kleiner 2001). This can be primarily attributed to a design centered on maximal safety. Football helmets prevent the head from moving inside the helmet by means of a close fitting chinstrap and padding that fits tightly around the head and face.

The stabilization provided by an ice hockey helmet is not comparable to that of a football helmet because the design is centered on protecting against initial impact, not overall stability. Ice hockey helmets are equipped with less padding and cover less of the head. A major contribution to the stability provided by an ice hockey helmet is attributed to a chinstrap that is fastened to both the helmet and the facemask. To remove the face mask, the chinstrap must be cut, which potentially diminishes the helmet's ability to stabilize the head and cervical spine. This raises an important question, in which this study attempted to answer, as to whether ice hockey helmets are able to provide enough stabilization to the head and cervical spine to justify that the helmet remain on the athlete during a log roll procedure.

The NATAIATF attempted to answer this question in a position statement released in 2001. In this statement it is made abundantly clear that during the immobilization of a football athlete, the equipment should remain in place provided an airway does not need to be established. Furthermore, it is reported that while football protective equipment is used as the example, the guidelines can be applied to other collision sports as well (Kleiner 2001). It seems inappropriate to issue a blanket statement supporting this idea for all collision sports, when the only sport providing sufficient research to draw such conclusion is football. The

NATAIATF claims that one of the only instances when it is appropriate to remove the helmet is when the helmet and chin strap do not hold the head securely, such that immobilization of the helmet does not also immobilize the head. In order to determine if the helmet and chin straps are adequately stabilizing the head, studies similar to this one are necessary before broad spectrum statements can be released with implications for numerous sports.

Clinical Application

While information attained from studies by Metz et al. and Laprade et al. suggests that removal of an ice hockey helmet should not be performed during a log roll due to an increase in cervical lordosis, qualified clinicians are taught to fill the void created with a towel roll or bolster (Metz, Kuhn et al. 1998; Laprade, Schnetzler et al. 2000). This bolster can be affixed directly to the spine board prior to events in which a log roll could possibly be utilized. Furthermore, Laprade et al. properly fitted each subject with ice hockey equipment. In reality, youth ice hockey athletes and college ice hockey athletes are not educated on proper fit, nor are they commonly fitted with equipment by trained personnel. Youth athletes wear their helmets comfortably which often does not result in a properly fitted helmet. This poor fit could be attributed to lack of education. For this study, our criteria for helmet fit had to be created because there is not a uniform criterion for ice hockey. Even the equipment manufacturers do not have their own criteria; helmets are sized based solely on circumferential measurement. For these reasons, we felt it was important to test a helmet that was fitted by the athlete because that is what will commonly be seen clinically.

An argument could be raised that values calculated as statistically significant for this study may not be clinically significant. However, studies investigating the degree of motion regarding cervical spine injury are limited. The data from this study indicates that limiting

cervical motion within an ice hockey helmet prior to a log roll may be advantageous in reducing the risk of further spinal injury in these athletes.

Future Research

Further studies need to be conducted on this matter before a change in management can be definitively proposed. Research should concentrate on verifying these findings when log rolling an ice hockey player on the ice, as opposed to within a controlled laboratory setting. In addition, our study focused solely on the log roll, with no regard to movement during the process of immobilization once on the spine board, or during the removal of the helmet. Moreover, since Metz and Laprade have shown that removing the helmet increases lordosis of the cervical spine, it may be useful to investigate the effectiveness of a towel roll or bolster in minimizing excess movement. Also to be addressed is the possibility of stabilizing the helmet and cervical spine simultaneously to minimize movement. For example, if the forearms are used to stabilize the helmet, it may be possible to use the hands to stabilize the cervical spine.

Limitations

There were limitations to this study that warrant discussion. First, our study was conducted in a research laboratory. Ideally such a study should be conducted on the surface of an ice hockey rink where the log roll of an ice hockey athlete would clinically occur. Furthermore, our subjects were uninjured and asked to remain limp for the duration of the roll. Therefore we could not take into account the effects muscle guarding may have had on movement. Also, even though each sensor was attached with double sided tape and secured with athletic tape, it cannot be said definitively that all unwanted motion was eliminated. Finally, the only piece of equipment used that was owned by and sized for the subject was

the competition helmet. One standard set of ice hockey pants and shoulder pads were supplied for all subjects. This could have compromised the appropriate fit on some athletes and therefore may have increased the possibility of excess motion secondary to improper equipment fit.

Summary

As clinicians it is important to bear in mind that variations in sports, such as playing surface and protective equipment, can affect the management of injuries, and therefore claims made for one sport cannot always be applied to another. This study examined the effect of helmet condition on cervical spine movement during a log roll. Both helmet conditions yielded significantly more cervical spine movement when compared to the helmet removed condition in the sagittal and transverse planes, revealing that when an ice hockey helmet is stabilized, the head is not. Because of this finding, we conclude that removal of the helmet from an ice hockey player before performing the log roll technique may be the most effective means to limit extraneous movement at the cervical spine.

Appendix A

INSTITUTIONAL REVIEW BOARD MATERIALS

OFFICE OF HUMAN RESEARCH ETHICS
Institutional Review Board

APPLICATION FOR IRB APPROVAL OF
HUMAN SUBJECTS RESEARCH
Version 30-May-2006

For IRB Use
Behav Biomed Nurs PH
IRB Study #_____
Rec'd_____
Full Expedited Exempt

Part A.1. Contact Information, Agreements, and Signatures

Title of Study: Cervical Spine Motion in Ice Hockey Players During a Log Roll Technique
Date: 01/09/07

Name and degrees of Principal Investigator: Josh R. Beard, BS, LAT, ATC
Department: Exercise and Sport Science Mailing address/CB #: Sports Medicine Research Lab
Fetzer Gymnasium CB 8700
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Chapel Hill NC, 27514
UNC-CH PID: 711622322 Pager: N/A
Phone #: 919-259-0434 Fax #: 919-962-0489 Email Address: jbeard33@email.unc.edu

For trainee-led projects: __ undergraduate X graduate __ postdoc __ resident __ other
Name of faculty advisor: Meredith Petschauer, PhD, ATC
Department: Exercise and Sport Science Mailing address/CB #: Sports Medicine Research Lab
Woollen Gymnasium CB 8605
UNC-CH
Chapel Hill NC, 27514
Phone #: 919-962-1110 Fax #: 919-962-0489 Email Address: mbusby@email.unc.edu

Name, phone number, email address of project manager or coordinator, if any:

List **all other project personnel** including co-investigators, and anyone else who has contact with subjects or identifiable data from subjects:
Kevin Guskiewicz, PhD, ATC Phone #: 919-962-5175
William E. Prentice, PhD, ATC Phone #: 919-962-5174
Jason Mihalik, MS, CAT(C), ATC Phone #: 919-962-7187

Name of funding source or sponsor:
X not funded __ Federal __ State __ industry __ foundation __ UNC-CH
__ other (specify): **Sponsor or award number**:

Include following items with your submission, where applicable.

- Check the relevant items below and include one copy of all checked items 1-11 in the order listed.
- Also include two additional collated sets of copies (sorted in the order listed) for items 1-7.

→ Applications may be returned if these instructions are not followed.

Check	Item	Total No. of Copies
x	1. This application. One copy must have original PI signatures.	3
x	2. Consent and assent forms, fact or information sheets; include phone and verbal consent scripts.	3
□	3. HIPAA authorization addendum to consent form.	3
□	4. All recruitment materials including scripts, flyers and advertising, letters, emails.	3
□	5. Questionnaires, focus group guides, scripts used to guide phone or in-person interviews, etc.	3
□	6. Protocol, grant application or proposal supporting this submission; (e.g., extramural grant application to NIH or foundation, industry protocol, student proposal).	3
□	7. Documentation of reviews from any other committees (e.g., GCRC, Oncology Protocol Review Committee, or local review committees in Academic Affairs).	3
□	8. Addendum for Multi-Site Studies where UNC-CH is the Lead Coordinating Center.	1
□	9. Data use agreements (may be required for use of existing data from third parties).	1
□	10. Documentation of required training in human research ethics for all study personnel.	1
□	11. Investigator Brochure if a drug study.	1

Principal Investigator: I will personally conduct or supervise this research study. I will ensure that this study is performed in compliance with all applicable laws, regulations and University policies regarding human subjects research. I will obtain IRB approval before making any changes or additions to the project. I will notify the IRB of any other changes in the information provided in this application. I will provide progress reports to the IRB at least annually, or as requested. I will report promptly to the IRB all unanticipated problems or serious adverse events involving risk to human subjects. I will follow the IRB approved consent process for all subjects. I will ensure that all collaborators, students and employees assisting in this research study are informed about these obligations. All information given in this form is accurate and complete.

_____ _____

Signature of Principal Investigator Date

Faculty Advisor if PI is a Student or Trainee Investigator: I accept ultimate responsibility for ensuring that this study complies with all the obligations listed above for the PI.

_____ _____

Signature of Faculty Advisor Date

Department or Division Chair, Center Director (or counterpart) of PI: (or Vice-Chair or Chair's designee if Chair is investigator or otherwise unable to review): I certify that this research is appropriate for this Principal Investigator, that the investigators are qualified to conduct the research, and that there are adequate resources (including financial, support and facilities) available. If my unit has a local review committee for pre-IRB review, this requirement has been satisfied. I support this application, and hereby submit it for further review.

Signature of Department Chair or designee Date

Print Name of Department Chair or designee Department

Part A.2. Summary Checklist

Are the following involved?	Yes	No
A.2.1. Existing data, research records, patient records, and/or human biological specimens?	__	x
A.2.2. Surveys, questionnaires, interviews, or focus groups with subjects?	__	x
A.2.3. Videotaping, audiotaping, filming of subjects (newly collected or existing)?	__	x
A.2.4. Do you plan to enroll subjects from these vulnerable or select populations:		
A.□.□. UNC-CH students or UNC-CH employees?	x	__
A.□.□. Non-English-speaking?	__	x
A.□.□. Decisionally impaired?	__	x
A.□.□. Patients?	__	x
A.□.□. Prisoners, others involuntarily detained or incarcerated, or parolees?	__	x
A.□.□. Pregnant women?	__	x
g. Minors (less than 18 years)? ***If yes***, give age range: to years	__	x
A.2.5. a. Is this a multi-site study (sites outside UNC-CH engaged in the research)?	__	x
A.□.□. Is UNC-CH the sponsor or lead coordinating center?	__	x
If yes, include the ***Addendum for Multi-site Studies where UNC-CH is the Lead Coordinating Center***.		
If yes, will any of these sites be outside the United States?	__	__
If yes, provide contact information for the foreign IRB.		
A.2.6. Will there be a data and safety monitoring committee (DSMB or DSMC)?	__	x
A.2.7. a. Are you collecting sensitive information such as sexual behavior, HIV status, recreational drug use, illegal behaviors, child/physical abuse, immigration status, etc?	__	x
b. Do you plan to obtain a federal Certificate of Confidentiality for this study?	__	x
A.2.8. a. Investigational drugs? (provide **IND #**)	__	x
A.□.□. Approved drugs for "non-FDA-approved" conditions?	__	x
All studies testing substances in humans must provide a letter of acknowledgement from the UNC Health Care Investigational Drug Service (IDS).		
A.2.9. Placebo(s)?	__	x
A.2.10. Investigational devices, instruments, machines, software? (provide **IDE #**)	__	x
A.2.11. Fetal tissue?	__	x
A.2.12. Genetic studies on subjects' specimens?	__	x
A.2.13. Storage of subjects' specimens for future research? ***If yes,*** *see instructions for* ***Consent for Stored Samples***.	—	x
A.2.14. Diagnostic or therapeutic ionizing radiation, or radioactive isotopes, which subjects would not receive otherwise? ***If yes,*** *approval by the* ***UNC-CH Radiation Safety*** ***Committee*** *is required.*	—	x
A.2.15. Recombinant DNA or gene transfer to human subjects? ***If yes,*** *approval by the* ***UNC-CH Institutional Biosafety*** ***Committee*** *is required.*	—	x
A.2.16. Does this study involve UNC-CH cancer patients? ***If yes,*** *submit this application directly to the* ***Oncology Protocol Review Committee***.	—	x
A.2.17. Will subjects be studied in the General Clinical Research Center (GCRC)? ***If yes,*** *obtain the* ***GCRC Addendum*** *from the GCRC and submit complete application (IRB application and Addendum) to the GCRC.*	__	x

Part A.3. Conflict of Interest Questions and Certification

The following questions apply to **all investigators and study staff** engaged in the design, conduct, or reporting results of this project **and/or their immediate family members.** For these purposes, "family" includes the individual's spouse and dependent children. "Spouse" includes a person with whom one lives together in the same residence and with whom one shares responsibility for each other's welfare and shares financial obligations.

A.3.1. Currently or during the term of this research study, does any member of the research team or his/her family member have or expect to have:		
A.□.□. A personal financial interest in or personal financial relationship (including gifts of cash or in-kind) with the sponsor of this study?	__ yes	x no
(b) A personal financial interest in or personal financial relationship (including gifts of cash or in-kind) with an entity that owns or has the right to commercialize a product, process or technology studied in this project?	__ yes	x no
I A board membership of any kind or an executive position (paid or unpaid) with the sponsor of this study or with an entity that owns or has the right to commercialize a product, process or technology studied in this project?	__ yes	x no
A.3.2. Has the University or has a University-related foundation received a cash or in-kind gift from the Sponsor of this study for the use or benefit of any member of the research team?	__ yes	x no
A.3.3. Has the University or has a University-related foundation received a cash or in-kind gift for the use or benefit of any member of the research team from an entity that owns or has the right to commercialize a product, process or technology studied in this project?	__ yes	x no

If the answer to ANY of the questions above is *yes*, the affected research team member(s) must complete and submit to the Office of the University Counsel the form accessible at http://coi.unc.edu. List name(s) of all research team members for whom any answer to the questions above is *yes*:

Certification by Principal Investigator: By submitting this IRB application, I (the PI) certify that the information provided above is true and accurate regarding my own circumstances, that I have inquired of every UNC-Chapel Hill employee or trainee who will be engaged in the design, conduct or reporting of results of this project as to the questions set out above, and that I have instructed any such person who has answered "yes" to any of these questions to complete and submit for approval a Conflict of Interest Evaluation Form. I understand that as Principal Investigator I am obligated to ensure that any potential conflicts of interest that exist in relation to my study are reported as required by University policy.

Signature of Principal Investigator _____ Date _____

<u>Faculty Advisor if PI is a Student or Trainee Investigator</u>: I accept ultimate responsibility for ensuring that the PI complies with the University's conflict of interest policies and procedures.

Signature of Faculty Advisor Date

Part A.4. Questions Common to All Studies

For all questions, if the study involves only secondary data analysis, focus on your proposed design, methods and procedures, and not those of the original study that produced the data you plan to use.

A.4.1. **Brief Summary**. Provide a *brief* non-technical description of the study, which will be used in IRB documentation as a description of the study. Typical summaries are 50-100 words.

Purpose: The purpose of this study is to determine the most appropriate injury management technique for an ice hockey player that has sustained a cervical spine injury. This study will investigate limiting cervical spine movement while log rolling an athlete from a prone (face down) to a supine (face up) position while wearing a properly fitted helmet, a helmet fitted by the subject, a helmet that the participant normally uses when participating in ice hockey and no helmet at all.
Participants: 24 male ice hockey players will serve as subjects in this study. Four certified athletic trainers (ATC) will be used to perform the log roll and control the computer collecting data. A log roll is used during a scenario in which a spinal injury is suspected. During a log roll one person stabilizes the head while two to three others roll the individual onto their back. The ATCs will remain the same throughout the duration of the study.
Procedures (methods): Flexion, extension, rotation and lateral flexion of the cervical spine will be measured with a motion analysis system using electromagnetic sensors.

A.4.2. **Purpose and Rationale**. Provide a summary of the background information, state the research question(s), and tell why the study is needed. If a complete rationale and literature review are in an accompanying grant application or other type of proposal, only provide a brief summary here. If there is no proposal, provide a more extensive rationale and literature review, including references.

Emergency protocols for the management of cervical spine injuries in American football and ice hockey have remained similar due primarily to numerous studies involving American football equipment. However, the obvious differences in protective equipment between ice hockey and football result in a lack of uniformity among sports medicine professionals, suggesting management protocols should be sport-specific. There lacks sufficient literature to support the claim that the helmet should remain on during a log roll procedure in ice hockey. This study will investigate if there is a significant difference in head and neck movement (flexion, extension, lateral flexion and rotation) during a log roll technique in adult ice hockey players under the following conditions: a properly fitted helmet, an athlete-fitted helmet, the helmet that they use during participation, and no helmet. This will be investigated by looking at three-dimensional motion analysis of the head and neck during a log roll to determine if a case should be made for removing the helmet. Ideally, this study will lead to a longer series of studies that could result in an emergency protocol unique to ice hockey.

A.4.3. **Subjects.** *You should describe the subject population even if your study does not involve direct interaction (e.g., existing records).* Specify number, gender, ethnicity, race, and age. Specify

whether subjects are healthy volunteers or patients. If patients, specify any relevant disease or condition and indicate how potential subjects will be identified.

A total of 24 male ice hockey players will serve as subjects for this study. Subjects will be recruited on a volunteer basis from local ice hockey teams. In order to participate in the study, the subjects need to be healthy, currently participating in ice hockey, and be between 18 and 30 years of age.

A.4.4. **Inclusion/exclusion criteria.** List required characteristics of potential subjects, and those that preclude enrollment or involvement of subjects or their data. Justify exclusion of any group, especially by criteria based on gender, ethnicity, race, or age. If pregnant women are excluded, or if women who become pregnant are withdrawn, specific justification must be provided.

Inclusion Criteria: The subjects enrolling in this study must be currently participating on an ice-hockey team and have their own ice hockey protective equipment.

Exclusion Criteria: Subjects will be excluded if they have suffered from a cervical spine or neck injury within the past six months or if they have ever suffered from a cervical fracture or dislocation. Subjects will also be excluded if they cannot provide their own ice hockey protective equipment, including helmet.

A.4.5. **Full description of the study design, methods and procedures.** Describe the research study. Discuss the study design; study procedures; sequential description of what subjects will be asked to do; assignment of subjects to various arms of the study if applicable; doses; frequency and route of administration of medication and other medical treatment if applicable; how data are to be collected (questionnaire, interview, focus group or specific procedure such as physical examination, venipuncture, etc.). Include information on who will collect data, who will conduct procedures or measurements. Indicate the number and duration of contacts with each subject; outcome measurements; and follow-up procedures. If the study involves medical treatment, distinguish standard care procedures from those that are research. If the study is a clinical trial involving patients as subjects and use of placebo control is involved, provide justification for the use of placebo controls.

Procedures

All subjects will complete an informed consent form prior to participation in the study. Each subject will sign up for an available time slot and report to the University of North Carolina's Sports Medicine Research Laboratory (located in the basement of Fetzer Gymnasium—Fetzer 06F) at the assigned time for one testing session. Upon arrival each subject will be randomly assigned to one of 24 counterbalanced test orders. The conditions tested will be as follows:

1. A condition where the *investigators* will properly fit the participant with a new ice hockey helmet and facemask
2. A condition where the *participants* will be asked to properly fit themselves with a new helmet and facemask (provided)
3. A condition where the participants will use the helmet they normally wear while playing ice hockey
4. A condition whereby the participant will be tested without a helmet and facemask

Having 24 test orders will keep each condition counterbalanced.

Helmet fitting and evaluation

Each participant will be given a helmet and asked to wear that helmet as he would wear his helmet on the ice. This will be the "athlete fitted helmet" condition (Condition 2 above). After the

participant has fitted their own helmet, they will be properly fitted with a separate one according to the following criteria:

- Helmet rests 1½" (two finger widths) above the participant's eyebrows
- Chin strap fits tightly under chin and is securely fastened to the helmet
- If the subject holds his head still, the PI should not be able to move the helmet without the skin on the forehead moving with it
- Hair will be wet to account for sweat

The helmet that the participant fitted and the competition helmet will then be evaluated according to the criteria listed above to record differences in the fit.

Motion sensor set up

Three sensors will be placed on each participant in order to capture the motion analysis needed to obtain our outcome measures. One will be secured to the top of the helmet, another will be secured on the mouthpiece and one on the sternum below the sternal notch. The first two were chosen since they represent actual movement of the helmet, and the sensor on the mouthpiece represents the actual movement of the head. The placement of the third sensor close to the sternal notch will help minimize movement of the chest as a result of breathing. All sensors will be applied to the respective sites using double-sided tape and secured with athletic tape.

To orient the axes and digitize the anatomical segments, the subjects will be asked to sit in a chair with their helmet on. To attain the segmental axes the following points on a plane will be digitized. Digitization is a process in which we tell the computer software where body landmarks are in space in order to more accurately build a three-dimensional model of the head and spine in order to measure our outcome measures Digitizing the head is made possible by identifying the location of the bridge of the nose, the middle of the chin, and the occipital protuberance. Digitizing the thorax will include identifying the spinous process of T8, the xyphoid process, and the spinous process of C7. The axis for the head will be the middle of the chin and the occipital protuberance and for the thorax, C7 and the sternal notch are to be used. To allow for full motion of the mouthpiece and to minimize any interference of the electromagnetic tracking system, non-metal facemasks certified for use while playing ice hockey will be used.

The test order of the conditions will be determined randomly using a Latin Square (Figure 1).

Figure 1: Latin square counterbalanced conditions
PF = Properly fitted; CH = Competition Helmet; HR = Helmet removed

PF, CH, HR	PF, HR, CH	CH, PF, HR
CH, HR, PF	HR, PF, CH	HR, CH, PF

For each trial, the subject will start prone with his head turned to the left and arms at his side. Instructions for the participant will be to "bite down firmly on the mouthpiece and lay limp." Every subject will start in this position for each roll. Using a total of 3 certified athletic trainers as rescuers, each subject will be log rolled in accordance with the NATA Pre-hospital Care of the Spine Injured Athlete's recommendations (Kleiner 2001). The principal investigator will act as Rescuer 1 (R1) and be positioned in such a way as to stabilize the cervical spine of the participant. Rescuer 2 (R2) will be controlling the torso, Rescuer 3 (R3) will be controlling the legs and a fourth individual will be stationed at the data collection computer to ensure that all data is appropriately captured. For the log roll, R2 will place their right hand on the subject's left shoulder and their left hand will be placed on the subject's left greater trochanter. R3 will place their right hand on the subject's left anterior superior iliac spine, and their left hand will be placed on the subject's left shank to help control the

legs during the roll. On R1's instructions of "prepare to roll, roll" the subject will be log rolled onto a spineboard in order to simulate on-ice cervical spine injury management procedures (Kleiner 2001; Swartz, Nowak et al. 2005).

The dependent variables will be total degrees of movement in the sagittal, frontal and transverse planes. To determine how much motion takes place the movement of the head relative to the thorax and the helmet relative to the thorax will be evaluated. We will also measure the amount of movement that occurs between the helmet and the head. We can discern the total range of motion from these movements. These motions will be evaluated when the subject has on a properly fitted helmet, an athlete's fitted helmet, their competition helmet, and no helmet to see if one condition has significantly more movement than the others. Each condition will be tested three times.

Equipment used in this study will include an electromagnetic tracking system. This system involves the Flock of Birds hardware (Ascension Technologies, Inc., Burlington, VT) controlled by Motion Monitor® computer software (Innovative Sports Training Inc., Chicago, IL). The Flock of Birds is a three-dimensional (3-D) electromagnetic motion analysis system with a measurement rate of up to 144Hz (Ascension Technology Corporation, 2004). Studies done using this piece of equipment found that this system is capable of measuring the 3-D angles in the neck, and provides negligible interference to the model (Koerhuis, Winters et al. 2003).

A rigid orthoplast mouthpiece will be created and used as a placement site for a motion sensor on the head. Between each subject it will be disinfected with antibacterial soap and soaked in a 10% bleach solution for 10 minutes. It will also be covered with heat-molded plastic that will be removed and changed between subjects. This will ensure that each subject has a clean mouthpiece to fit into his mouth for the duration of the testing session. This will feel no different than the mouthguard an ice hockey player is required to wear while participating in ice hockey.

Participants will be asked to bring in all equipment that they would wear during an ice hockey competition. Skates will not be worn during testing.

A.4.6. **Benefits to subjects and/or society.** Describe any potential for direct benefit to individual subjects, as well as the benefit to society based on scientific knowledge to be gained; these should be clearly distinguished. Consider the nature, magnitude, and likelihood of any direct benefit to subjects. If there is no direct benefit to the individual subject, say so here and in the consent form (if there is a consent form). Do not list monetary payment or other compensation as a benefit.

There is the possibility that participants will not benefit from participating in this study. However, should an athlete's regular helmet not fit properly, the study investigators will ensure that this helmet fits the player as per the manufacturers recommendations before leaving our laboratory. The findings of this study have the potential of improving the on-ice management of cervical spine injuries in youth, adolescent, collegiate, and professional ice hockey; this could affect over 3 million ice hockey players in the United States and Canada.

A.4.7. **Full description of risks and measures to minimize risks.** Include risk of psychosocial harm (e.g., emotional distress, embarrassment, breach of confidentiality), economic harm (e.g., loss of employment or insurability, loss of professional standing or reputation, loss of standing within the community) and legal jeopardy (e.g., disclosure of illegal activity or negligence), as well as known side effects of study medication, if applicable, and risk of pain and physical injury. Describe what will be done to minimize these risks. Describe procedures for follow-up, when necessary, such as when subjects are found to be in need of medical or psychological referral. If there is no direct interaction with subjects, and risk is limited to breach of confidentiality (e.g., for existing data), state this.

Since this study is going to be conducted on healthy individuals the risks are very low. The minimal risk of potentially exacerbating current or previous neck injuries have been eliminating by excluding these subjects from participation.

A.4.8. **Data analysis.** Tell how the qualitative and/or quantitative data will be analyzed. Explain how the sample size is sufficient to achieve the study aims. This might include a formal power calculation or explanation of why a small sample is sufficient (e.g., qualitative research, pilot studies).

Data will be reduced using Motion Monitor data acquisition computer software (Innovative Sports Training Inc., Chicago, IL) along with a custom made program in C++. Euler angles will be used to interpret the data using a rotation order of Y, Z, X. Flexion/Extension will be reported about the Y-axis, rotation around the Z-axis, and lateral bending around the X-axis. A baseline starting position will be calculated from an average of the first 10 data points collected. This average will then be subtracted from each data point collected. All movement data will then be rectified and integrated to obtain a total measure of motion in each plane. The data will be analyzed using SPSS 13.0 statistical software (SPSS Inc., Chicago, IL). Alpha level will be set at .05. The data will be interpreted from a within subjects repeated measures ANOVA for cervical spinal movement. The data analysis will allow us to compare within subjects to help answer the research question of whether there is more cervical spine movement during a log roll under the different equipment conditions. Those conditions being properly fitted helmet, athlete fitted helmet, competition helmet, and helmet removed. To maintain a power of 0.80, it was calculated that 16 subjects would be needed. We have elected to test 24 subjects because it allows for a completely counterbalanced design and will yield higher statistical power.

A.4.9. **Will you collect or receive any of the following identifiers?** Does not apply to consent forms.

__ No _**x**_ Yes *If yes, check all that apply*:

a. _**x**_ Names
b. _**x**_ Telephone numbers
c. __ Any elements of dates (other than year) for dates directly related to an individual, including birth date, admission date, discharge date, date of death. For ages over 89: all elements of dates (including year) indicative of such age, except that such ages and elements may be aggregated into a single category of age 90 and older
d. __ Any geographic subdivisions smaller than a State, including street address, city, county, precinct, zip code and their equivalent geocodes, except for the initial three digits of a zip code
e. __ Fax numbers
f. _**x**_ Electronic mail addresses
g. __ Social security numbers
h. __ Medical record numbers

i. __ Health plan beneficiary numbers
j. __ Account numbers
k. __ Certificate/license numbers
l. __ Vehicle identifiers and serial numbers (VIN), including license plate numbers
m. __ Device identifiers and serial numbers (e.g., implanted medical device)
n. __ Web universal resource locators (URLs)
o. __ Internet protocol (Reitman, Mauro et al.) address numbers
p. __ Biometric identifiers, including finger and voice prints
q. __ Full face photographic images and any comparable images
r. __ Any other unique identifying number, characteristic or code, other than dummy identifiers that are not derived from actual identifiers and for which the re-identification key is maintained by the health care provider and not disclosed to the researcher

A.4.10. **Confidentiality of the data**. Describe procedures for maintaining confidentiality of the data you will collect or will receive. Describe how you will protect the data from access by those not authorized. How will data be transmitted among research personnel? Where relevant, discuss the potential for deductive disclosure (i.e., directly identifying subjects from a combination of indirect IDs).

No subjects will be identified in any report or publication about this study. All subjects will be assigned an identification number (ID) for data collection. This ID number will be matched to the identifiers listed above in an excel document. This will be the only place in which a subject's identifiers and ID number will co-exist. This document will be stored on a separate CD apart from all other data that will be collected. These identifiers will be collected during the screening session for the sole purpose of contacting subjects. Once a subject has completed his testing session, then their identifiers will be deleted from the excel document until all subjects have been tested and the document is destroyed. All information on the data collection form used for testing will be referenced with the subject ID number. At no time will the identifiers above be listed on the same document as data collected during testing. All data will be stored on CD's which will be kept in the Sports Medicine Research Lab. All data analysis will be performed on computers in the Sports Medicine Research Lab where a password is necessary for access to the computers. Only members performing research have access to these computers, therefore identification of any subjects or data is very unlikely. If disclosure is ever required, UNC-CH will take all steps allowable by law to protect the privacy of personal information.

Personal privacy during testing sessions will be maintained through limiting the people within the research lab to current employees of the lab and the testers themselves. The only door to enter the lab is locked with key card access to ensure privacy.

A.4.11. **Data sharing.** With whom will *identifiable* (contains any of the 18 identifiers listed in question A.4.9 above) data be shared outside the immediate research team? For each, explain confidentiality measures. Include data use agreements, if any.

_**x**_ No one
__ Coordinating Center**:**
__ Statisticians**:**
__ Consultants**:**
__ Other researchers**:**
__ Registries**:**
__ Sponsors:

__ External labs for additional testing:
__ Journals:
__ Publicly available dataset:
__ Other:

A.4.12. **Data security for storage and transmission**. Please check all that apply.

For electronic data:

__ Secure network __ Password access __ Encryption
__ Other (describe):
_x_ Portable storage (e.g., laptop computer, flash drive)
Describe how data will be protected for any portable device:

For hardcopy data (including human biological specimens, CDs, tapes, etc.):

__ Data de-identified by research team (stripped of the 18 identifiers listed in question 7 above)
_X_ Locked suite or office
_X_ Locked cabinet
_X_ Data coded by research team with a master list secured and kept separately
__ Other (describe):

A.4.13. **Post-study disposition of identifiable data or human biological materials**. Describe your plans for disposition of data or human biological specimens that are identifiable in any way (directly or via indirect codes) once the study has ended. Describe your plan to destroy identifiers, if you will do so.

Once a subject has completed his testing session, then their identifiers will be deleted from the excel document until all subjects have been tested and the document is destroyed.

Part A.5. The Consent Process and Consent Documentation (including Waivers)

The standard consent process is for all subjects to sign a document containing all the elements of informed consent, as specified in the federal regulations. Some or all of the elements of consent, including signatures, may be altered or waived under certain circumstances.

- If you will obtain consent in any manner, complete **section A.5.1**.
- If you are obtaining consent, but requesting a waiver of the requirement for a signed consent document, complete **section A.5.2**.
- If you are requesting a waiver of any or all of the elements of consent, complete **section A.5.3**.

You may need to complete more than one section. For example, if you are conducting a phone survey with verbal consent, complete sections A.5.1, A.5.2, and possibly A.5.3.

A.5.1. **Describe the process of obtaining informed consent from subjects**. If children will be enrolled as subjects, describe the provisions for obtaining parental permission and assent of the child. If decisionally impaired adults are to be enrolled, describe the provision for obtaining surrogate consent from a legally authorized representative (LAR). If non-English speaking people will be

enrolled, explain how consent in the native language will be obtained. Address both written translation of the consent and the availability of oral interpretation. *After you have completed this part A.5.1, if you are not requesting a waiver of any type, you are done with Part A.5.; proceed to Part B.*

Informed consent will be obtained from all subjects prior to any testing. Subjects will come to the University of North Carolina-Chapel Hill Sports Medicine Research Lab in the Fetzer Gym Building. Before beginning the testing session the subject will be asked to read an informed consent agreement outlining the procedures, protocols and potential risks of the study. This informed consent agreement form will be in accordance with the standards set forth by the Social Behavioral IRB at the University of North Carolina at Chapel Hill. After the subjects sign the consent form, a copy will be given to them, and testing will commence.

A.5.2. **Justification for a waiver of *written* (i.e., signed) consent**. *The default is for subjects to sign a written document that contains all the elements of informed consent.* Under limited circumstances, the requirement for a signed consent form may be waived by the IRB if either of the following is true:

a. The only record linking the subject and the research would be the consent document and the principal risk would be potential harm resulting from a breach of confidentiality (e.g., study involves sensitive data that could be damaging if disclosed). __ yes __ no
Explain.

b. The research presents no more than minimal risk of harm to subjects and involves no procedures for which written consent is normally required outside of the research context (e.g., phone survey). __ yes __ no
Explain.

If you checked "yes" to either, will consent be oral? Will you give out a fact sheet? Use an online consent form, or include information as part of the survey itself, etc?

→ If you have justified a waiver of written (signed) consent (A.5.2), you should complete A.5.3 *only* if your consent process will not include all the other elements of consent.

A.5.3. **Justification for a full or partial waiver of consent.** *The default is for subjects to give informed consent.* A waiver might be requested for research involving only existing data or human biological specimens (see also Part C). More rarely, it might be requested when the research design requires withholding some study details at the outset (e.g., behavioral research involving deception). In limited circumstances, parental permission may be waived. This section should also be completed for a waiver of HIPAA authorization if research involves Protected Health Information (PHI) subject to HIPAA regulation, such as patient records.

__ Requesting **waiver of some elements** (specify; see SOP 28 on the IRB web site):
__ Requesting **waiver of consent entirely**
If you check either of the boxes above, answer items a-f.. To justify a full waiver of the requirement for informed consent, you must be able to answer "yes" (or "not applicable" for question c) to items a-f. **Insert brief explanations that support your answers.**

a. Will the research involve no greater than minimal risk to subjects or to their __ yes __ no

privacy?
Explain.

b. Is it true that the waiver will *not* adversely affect the rights and welfare of subjects? *(Consider the right of privacy and possible risk of breach of confidentiality in light of the information you wish to gather.)* __ yes __ no
Explain.

c. When applicable to your study, do you have plans to provide subjects with pertinent information after their participation is over? *(e.g., Will you provide details withheld during consent, or tell subjects if you found information with direct clinical relevance? This may be an uncommon scenario.)* __ yes __ not applicable
Explain.

d. Would the research be impracticable without the waiver? *(If you checked "yes," explain how the requirement to obtain consent would make the research impracticable, e.g., are most of the subjects lost to follow-up or deceased?).* __ yes __ no
Explain.

e. Is the risk to privacy reasonable in relation to benefits to be gained or the importance of the knowledge to be gained? __ yes __ no
Explain.

If you are accessing patient records for this research, you must also be able to answer "yes" to item f to justify a waiver of HIPAA authorization from the subjects.

f. Would the research be impracticable if you could not record (or use) Protected Health Information (PHI)? *(If you checked "yes," explain how* not *recording or using PHI would make the research impracticable).* __ yes __ no
Explain.

Part B. Questions for Studies that Involve Direct Interaction with Human Subjects

→ *If this does not apply to your study, do not submit this section.*

B.1. **Methods of recruiting.** Describe how and where subjects will be identified and recruited. Indicate who will do the recruiting, and tell how subjects will be contacted. Describe efforts to ensure equal access to participation among women and minorities. Describe how you will protect the privacy of potential subjects during recruitment. *For prospective subjects whose status (e.g., as patient or client), condition, or contact information is not publicly available (e.g., from a phone book or public web site), the initial contact should be made with legitimate knowledge of the subjects' circumstances. Ideally, the individual with such knowledge should seek prospective subjects' permission to release names to the PI for recruitment. Alternatively, the knowledgeable individual could provide information about the study, including contact information for the investigator, so that interested prospective subjects can contact the investigator.* Provide the IRB with a copy of any document or script that will be used to obtain the patients' permission for release of names or to introduce the study. Check with your IRB for further guidance.

Male ice hockey players will be targeted for enrolment in this study. Participants will be recruited primarily from the club ice hockey team at UNC, as well as club ice hockey teams in the greater Raleigh area. One of the study's co-investigator (JPM) is a certified USA Hockey coach with contacts to players within our age range. The principal investigator will approach all potential and interested players. Recruitment will also include an informational email (see Appendix A) in an attempt to recruit ice hockey players who do not play for the club ice hockey team at UNC.

B.2. **Protected Health Information (PHI).** If you need to access Protected Health Information (PHI) to identify potential subjects who will then be contacted, you will need a *limited waiver of HIPAA authorization*. If this applies to your study, please provide the following information.

a. Will the information collected be limited only to that necessary to contact the subjects to ask if they are interested in participating in the study?

b. How will confidentiality/privacy be protected prior to ascertaining desire to participate?

c. When and how will you destroy the contact information if an individual declines participation?

B.3. **Duration of entire study and duration of an individual subject's participation, including follow-up evaluation if applicable.** Include the number of required contacts and approximate duration of each contact.

All subjects will have only one testing session in which all data will be collected and each subject's session should last no more than 90 minutes.

B.4. **Where will the subjects be studied?** Describe locations where subjects will be studied, both on and off the UNC-CH campus.

All subjects will be studied in the Sports Medicine Research Lab located in the basement of Fetzer Gymnasium building on the campus of the University of North Carolina at Chapel Hill

B.5. **Privacy.** Describe procedures that will ensure privacy of the subjects in this study. Examples include the setting for interviews, phone conversations, or physical examinations; communication methods or mailed materials (e.g., mailings should not indicate disease status or focus of study on the envelope).

No subjects will be identified in any report or publication about this study. All subjects will be assigned an identification number (ID) for data collection. All data will be stored on CD's which will be kept in the Sports Medicine Research Lab. All data analysis will be performed on computers in the Sports Medicine Research Lab where a password is necessary for access to the computers. Only members performing research have access to these computers, therefore identification of any subjects or data is very unlikely. If disclosure is ever required, UNC-CH will take all steps allowable by law to protect the privacy of personal information.

Personal privacy during testing sessions will be maintained through limiting the people within the research lab to current employees of the lab and the testers themselves. The only door to enter the lab is locked with key card access to ensure privacy. Patients will be properly draped with a towel during electrode placement to ensure privacy.

B.6. **Inducements for participation.** Describe all inducements to participate, monetary or non-monetary. If monetary, specify the amount and schedule for payments and how this will be prorated if the subject withdraws (or is withdrawn) from the study prior to completing it. For compensation in foreign currency, provide a US$ equivalent. Provide evidence that the amount is not coercive (e.g., describe purchasing power for foreign countries). Include food or refreshments that may be provided.

At this time there are no inducements for participation.

B.7. **Costs to be borne by subjects.** Include child care, travel, parking, clinic fees, diagnostic and laboratory studies, drugs, devices, all professional fees, etc. If there are no costs to subjects other than their time to participate, indicate this.

There will be no cost borne by subjects other than their time.

University of North Carolina-Chapel Hill
Consent to Participate in a Research Study
Adult Participants
Social Behavioral Form

IRB Study #07-0083
Consent Form Version Date: 02/01/07
Title of Study: Cervical Spine Motion in Ice Hockey Players During a Log Roll Technique.
Principal Investigator: Josh R. Beard, BS, ATC, LAT
UNC-Chapel Hill Department: Department of Exercise and Sport Science
UNC-Chapel Hill Phone number: (919) 962-7187
Email Address: jbeard33@email.unc.edu
Co-Investigators: Kevin Guskiewicz, William E. Prentice, Jason P. Mihalik
Faculty Advisors: Meredith Petschauer
Funding Source:

Study Contact telephone number: 919-962-7187
Study Contact email: jbeard33@email.unc.edu

What are some general things you should know about research studies?
You are being asked to take part in a research study. To join the study is voluntary. You may refuse to join, or you may withdraw your consent to be in the study, for any reason, without penalty.

Research studies are designed to obtain new knowledge. This new information may help people in the future. You may not receive any direct benefit from being in the research study. There also may be risks to being in research studies.

Details about this study are discussed below. It is important that you understand this information so that you can make an informed choice about being in this research study. You will be given a copy of this consent form. You should ask the researchers named above, or staff members who may assist them, any questions you have about this study at any time.

What is the purpose of this study?
Emergency protocols for the management of cervical spine injuries in American football and ice hockey have remained similar due primarily to numerous studies involving American football equipment. However, the differences in protective equipment between ice hockey and football suggest that management protocols should be different. There lacks sufficient literature to support the claim that the helmet should remain on during a log roll procedure in ice hockey. This study will investigate if there is a significant difference in head and neck movement (flexion, extension, lateral flexion and rotation) during a log roll technique in an college ice hockey player under the following conditions; a properly fitted helmet, an athlete fitted helmet, competition helmet and no helmet. This will be investigated by looking at a three-dimensional motion analysis of the head and neck during a log roll to try and make a case for removing the helmet. This study is an important first step towards establishing an emergency protocol unique to ice hockey.

Are there any reasons you should not be in this study?
You should not be in this study if any of the following criteria apply to you:

- You have suffered a cervical spine or neck injury within the last six months
- You have ever suffered from a cervical fracture or dislocation
- You do not have your own ice hockey protective equipment

How many people will take part in this study?
If you decide to be in this study, you will be one of approximately 24 people in this research study.

How long will your part in this study last?
Your participation in this study will involve a one time testing session that will last no more than 90 minutes.

What will happen if you take part in the study?
You will be randomly assigned to one of 24 counterbalanced testing orders. Each person in this study will be put through the same testing procedures with only the order of conditions being altered. The conditions that will be tested are as follows:

- Properly fitted helmet
- Athlete fitted helmet
- Competition helmet
- Helmet removed

You will be supplied with two RBK 8K ice hockey helmets for the duration of the testing session. One of them will be properly fitted to you by the principal investigator. You will be asked to fit the other one to yourself as you deem appropriate.

After the helmets have been fitted and labeled, you will be asked to sit in a chair with your equipment on. An electromagnetic sensor will be placed on your sternum (chest), on top of each helmet, and on a rigid mouthpiece that you will be provided with. Your head and neck will then be digitized using a computer program. Digitization is a process where we tell our computer system where landmarks necessary for our calculations are located. We will identify landmarks such as the bridge of your nose, your chin, the back of your head (occipital protuberance), your sternal notch (at the top of your breastbone), xyphoid process (bottom of your breastbone), the spinous process of C7 (a point located in the back of your lower neck), and the spinous process of T8 (a landmark located between the lower portion of your shoulder blades). Once the digitization process is complete you will be asked to lie on your stomach with your head turned to the left. From that position three certified athletic trainers will perform a log roll technique on you, meaning that you will be rolled from your stomach onto your back. This technique is used in emergency situations in which a person needs to be secured to a spine board. The roll will be repeated three times per condition, a total of 12.

What are the possible benefits from being in this study?
Research is designed to benefit society by gaining new knowledge. The potential benefits of this study lie not with you as an individual, but with ice hockey players as a whole. This

study could act as a springboard for more studies of its kind. As more studies are conducted, there is a greater chance of an emergency care protocol that is specific to ice hockey being implemented. If this can happen, then the standard of care that ice hockey athletes receive in the event of a potentially catastrophic neck injury will increase dramatically.

What are the possible risks or discomforts involved from being in this study?
This study is very low risk, however there is a risk of aggravating existing injuries. Therefore, you are being asked to not participate if you have any of the following conditions:

- You have suffered a cervical spine or neck injury within the last six months
- You have ever suffered from a cervical fracture or dislocation

No penalty will be incurred if you decide to not participate or if you withdraw yourself from testing during the study. Please do not feel pressured to participate, or continue with the study if at any point you feel uncomfortable.

There may be uncommon or previously unknown risks. You should report any problems to the researcher.

How will your privacy be protected?
No subjects will be identified in any report or publication about this study. All subjects will be identified as a number throughout data collection. All data storage and analysis will be on computers the sports medicine research lab where a password is necessary for access to the computers. Only members performing research have access to the lab and use of its computers. Although every effort will be made to keep research records private, there may be times when federal or state law requires the disclosure of such records, including personal information. This is very unlikely, but if disclosure is ever required, The University of North Carolina at Chapel Hill will take all steps allowable by law to protect the privacy of personal information. In some cases, your information in this research study could be reviewed by representatives of the University, research sponsors, or government agencies for purposes such as quality control or safety.

What will happen if you are injured by this research?
All research involves a chance that something bad might happen to you. This may include the risk of personal injury. In spite of all safety measures, you might develop a reaction or injury from being in this study. If such problems occur, the researchers will help you get medical care, but any costs for the medical care will be billed to you and/or your insurance company. The University of North Carolina at Chapel Hill has not set aside funds to pay you for any such reactions or injuries, or for the related medical care. However, by signing this form, you do not give up any of your legal rights.

Will you receive anything for being in this study?
You will not receive anything for taking part in this study.

Will it cost you anything to be in this study?

Your costs will include your time and transportation to the University of North Carolina at Chapel Hill Sports Medicine Research Laboratory for your testing session.

What if you are a UNC student?
You may choose not to be in the study or to stop being in the study before it is over at any time. This will not affect your class standing or grades at UNC-Chapel Hill. You will not be offered or receive any special consideration if you take part in this research.

What if you are a UNC employee?
Taking part in this research is not a part of your University duties, and refusing will not affect your job. You will not be offered or receive any special job-related consideration if you take part in this research.

What if you have questions about this study?
You have the right to ask, and have answered, any questions you may have about this research. If you have questions, or concerns, you should contact the researchers listed on the first page of this form.

What if you have questions about your rights as a research participant?
All research on human volunteers is reviewed by a committee that works to protect your rights and welfare. If you have questions or concerns about your rights as a research subject you may contact, anonymously if you wish, the Institutional Review Board at 919-966-3113 or by email to IRB_subjects@unc.edu.

- -

Participant's Agreement:

I have read the information provided above. I have asked all the questions I have at this time. I voluntarily agree to participate in this research study.

_____ _____
Signature of Research Participant Date

_____
Printed Name of Research Participant

_____ _____
Signature of Person Obtaining Consent Date

_____
Printed Name of Person Obtaining Consent

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Appendix A

MANUSCRIPT

INTRODUCTION

Cervical spine injuries require certified athletic trainers to exercise skillful management in order to limit the likelihood of secondary injury. Proper management of these injuries has been described in the position statement put out by the National Athletic Trainers' Association's Inter-Association Task Force (NATAIATF) in 2001.[3] Due to the difficulty in managing cervical spine injuries in athletic environments, certified athletic trainers must often manage injuries conservatively in order to minimize the risk of further injury until advanced medical imaging and diagnostics can rule out serious injury. It has been well documented in American football that, provided the shoulder pads remain on the injured athlete, inline stabilization can be maintained without removing the helmet.[2, 3, 8, 9] While this remains relatively uncontested in football, it is inappropriate to extend these findings to all sports that use helmets and shoulder pads. Ice hockey is a high-speed collision sport shown to have a high incidence of spinal injury. In North America, the annual incidence of catastrophic cervical spine injuries is 15, 49% of which occurred in young athletes between 16 and 20 years of age.[12] Annually, the incidence of catastrophic cervical spine injuries is estimated at 20.3.[5] This equates to one ice hockey athlete per week that suffers a severe cervical spine injury during the standard ice hockey season. However, the majority of cervical spine injuries are not catastrophic.

From 1990 to 1999 there were 5069 neck injuries that occurred in the United States alone .[1] These injuries ranged from fractures and dislocations to sprains, strains and contusions. During the years of 1996 and 1999 injury rates for the cervical spine per 10,000

participants were six and a half times higher in ice hockey than in American football.[1] Athletes suffering from traumatic neck injury, in the absence of short-term improvement in condition on the field, are often managed conservatively and transported to a medical facility for further testing.

Previous studies investigated how the helmet should be handled in American football: none have advocated the removal of the helmet or shoulder pads while performing a cervical spine stabilizing maneuver.[15] However, data to this effect in ice hockey is limited. Studies have shown removing the helmet in ice hockey increases cervical lordosis due to the shoulder pads, echoing similar findings in the football literature.[5, 7] These studies evaluated still frame radiographs to determine the amount of head and neck movement only after an athlete was secured to a spine board. To date, no study has used three-dimensional motion analysis to investigate cervical spine motion of athletes secured for transport and, perhaps more importantly, during a log roll technique. Due to the nature of ice hockey at the amateur level, athletes often wear ice hockey helmets that are not securely fitted; they also lack the protective and stabilizing qualities of the cheek padding present in football helmets. Therefore, stabilizing the helmet does not necessarily ensure stabilization of the head and cervical spine in injured ice hockey athletes as it does with American football players. According to the NATA, the helmet should be removed if the helmet and chin straps do not hold the head securely such that immobilization of the helmet does not also immobilize the head[3].

In summary, the research does not support stabilizing the helmet as an effective means of stabilizing the head in ice hockey. Further research is needed in this area if athletic

trainers are to provide the best medical care to their athletes with suspected cervical spine injuries.

This study was designed to investigate the motion of the cervical spine during a log roll technique in ice hockey players. We assessed this purpose while players were subjected to three helmet conditions: properly fitted helmet, competition helmet, and helmet removed. Ideally, this study could make a case for removing the helmet and lead to a longer series of studies that could result in an emergency protocol unique to ice hockey. The purpose of this study was to investigate the effect of helmet fit on cervical spine motion during a log roll technique in ice hockey.

METHODS

Participants

A total of 16 ice hockey players (age = 21 ± 2.5 years, height = 181.5 ± 6.0 cm, mass = 80.8 ± 9.0 kg) volunteered from local ice hockey clubs to participate. Each participant was between 18-30 years of age and actively playing ice hockey within the last year. All participants completed an informed consent form approved by the Institutional Review Board at the University of North Carolina at Chapel Hill prior to participation.

Equipment

Equipment used in this study included the Flock of Birds hardware (Ascension Technologies, Inc., Burlington, VT) controlled by MotionMonitor® computer software (Innovative Sports Training Inc., Chicago, IL). The Flock of Birds is a three-dimensional electromagnetic motion analysis system that was set to 144Hz to collect all data (Ascension Technology Corporation, 2004). To yield the truest results, the unit was calibrated with a

stylus tip prior to every test. For the most reliable results, it was recommended that each measurement be taken three times to ensure accuracy.[4, 6, 14]

A rigid orthoplast mouthpiece was created and served as a placement site for the motion sensor of the head. This mouthpiece was covered with heat-molded plastic that was removed and changed between participants to ensure that each participant had a clean mouthpiece.

Four sensors were used, one placed on the stylus for calibration, a second placed on the top of the participant's ice hockey helmet, a third placed on the proximal aspect of the participant's sternum, just below the sternal notch and the fourth placed on a rigid orthoplast mouthpiece.

Protocol

Each participant came to the Sports Medicine Research Laboratory at the University of North Carolina for one testing session. He was asked to bring his competition helmet for testing and was assigned to one of six counterbalanced test orders that included properly fitted helmet, competition helmet, and removed helmet (Figure 3-1).

Figure 3-1: Latin square counterbalanced conditions
PF = Properly fitted; CH = Competition Helmet; HR = Helmet removed

PF, CH, HR	PF, HR, CH	CH, PF, HR
CH, HR, PF	HR, PF, CH	HR, CH, PF

Each participant was then properly fitted with a new Itech ice hockey helmet according to the following criteria:

- The helmet rests 1.5" (two finger widths) above the participant's eyebrows.
- The chin strap fits tightly under chin and is securely fastened to the helmet.

- If the participant holds his head still, the PI was not able to move the helmet without the skin on the forehead moving with it.
- The participant's hair was wet to account for sweat.

Once the participant had a new helmet that was properly fitted, the competition helmet was examined for fit using the same criteria.

The sensors were then applied, secured with athletic tape, and digitized using the following landmarks: chin, bridge of the nose, and occipital protuberance for the head and T8, xyphoid process, C7, and sternal notch for the thorax.

Testing Procedures

For each trial, the participant began lying prone with his head turned to the left and arms along his side. Instructions for the participant were to "bite down firmly on the mouthpiece and lay limp." Every participant began in this position for each roll. Using a total of three certified athletic trainers as rescuers, each participant was log rolled from prone to supine onto a spine board (Ironduck, Chocopee, Ma) in accordance with the NATAIATF's recommendations.[3] The principal investigator acted as rescuer 1 (R1) and immobilized the head and cervical spine. Rescuer 2 (R2) controlled the torso, and the third rescuer (R3) the legs. For the log roll, R2 placed their right hand on the participant's left shoulder and their left hand on the participant's left greater trochanter. Meanwhile, R3 placed their right hand on the participant's left anterior superior iliac spine, and their left hand on the participant's left shank to help control the legs during the roll. The two assistant rescuers (R2 and R3) kneeled on a spine board that had previously been placed flat on the floor and flush against the participant. On R1's instructions of "prepare to roll, roll" the participant was log rolled towards R2 and R3 onto his back.[3, 11] The rescuers received a brief practice session before

any data collection to ensure the protocol was fully understood. Data collection began after R1 said "prepare to roll" and was terminated when R1 said "stop." From start to finish, the log roll lasted between four and six seconds. The log roll procedure was performed three times for each helmet condition.

Data Reduction

Data were exported from MotionMonitor software and reduced using a custom C++ program and Microsoft Excel. Motion collected in each plane was reduced separately. For each plane in each trial the first ten data points collected in the trial were averaged representing a baseline value for the starting cervical spine position. This average was then subtracted from every data point in the set to give a standard starting position of the cervical spine for each participant. The data were then rectified, integrated using Simpson'method and normalized to time. The normalized values were entered into an Excel spreadsheet to compute the ensemble average between the three trials.

Data Analysis

All data were analyzed using SPSS 13.0 statistical software (SPSS Inc., Chicago, IL). Alpha level set *a priori* at .05. To determine if the helmet to thorax motion between the properly fitted helmet and the competition helmet was significantly different, we performed a paired sample T-test for each plane (sagittal, frontal, and transverse). The dependent variable was helmet movement relative to the thorax (measured in degrees/second) and the independent variables were helmet condition (properly fitted and competition helmet).

To determine if there was a significant difference in cervical spine motion during the log roll of an ice hockey player under the following three helmet conditions; properly fitted helmet, competition helmet, helmet removed, we performed three separate one-way within-

participants repeated measures ANOVA comparing head motion relative to the thorax in all three planes (sagittal, frontal and transverse). For each ANOVA, the dependent variable was head movement relative to thorax (measured in deg/sec) and the independent variables were helmet condition. For each plane of movement, a Bonferroni correction was done to determine where the significant differences were located.

To further investigate the reliability of the log roll, an intraclass correlation coefficient (ICC (3, 1)) was calculated for the helmet removed condition in each plane. Another ICC (3,k) was computed for time to determine the consistency of the roll duration.

RESULTS

There was no significant difference was found between the properly fit helmet and competition helmet condition in the sagittal ($t(15) = 1.153$, $p > .05$), transverse ($t(15) = 1.416$, $p > .05$) or frontal ($t(15) = -0.882$, $p > .05$) planes. This suggests that helmet movement during the log roll remained consistent across conditions. Also, frontal plane ICC (3, 1) was calculated at 0.82 with a corresponding standard error of the measure (SEM) equaling 5.18 deg/sec. Transverse plane ICC (3,1) had a value of 0.76 with an SEM of 5.50 deg/sec and frontal plane ICC (3,1) was calculated at 0.83 with an SEM of 3.38 deg/sec. Another ICC (3,k) was computed for time and calculated at .90 with an SEM of 29.62 frames/second. At our collection rate of 144 Hz, the SEM is equivalent to .21 seconds.

A one-way repeated measures within participants ANOVA was computed to compare mean cervical spine motion under the three different helmet conditions for each plane of movement. A significant difference was found for sagittal plane movement ($F(2,30) = 7.533$, $p = 0.002$). Bonferroni correction revealed that the helmet removed condtition yielded significantly less neck flexion than properly fit and competition helmet. While the properly

fit and competition helmet conditions were not found to be significantly different, mean neck flexion was greater when the helmet was properly fit. A significant difference was also found for transverse plane movement ($F(2,30) = 9.441$, $p = 0.001$). The Bonferroni correction revealed that there was less neck rotation with helmet removed than properly fit or competition helmet. Also, while a properly fitted helmet was not found to be significantly different from the competition helmet, mean neck rotation was greater with a competition helmet. Finally, statistical significance was found for frontal plane movement ($F(2,30) = 6.060$ $p = 0.006$). The Bonferroni correction illustrated a significant difference between only the properly fit and competition conditions with the properly fit condition experiencing a greater amount of side bending.

Table 1: Descriptive Statistics (mean ± SD) for sagittal, transverse, and frontal plane head movement (°/sec)

Sagittal Plane		
Helmet Condition	**Mean**	**SD**
Properly Fit	22.695	15.782
Competition	19.156	11.626
Removed	13.803	10.102
Transverse Plane		
Helmet Condition	**Mean**	**SD**
Properly Fit	32.164	7.772
Competition	33.299	7.237
Removed	28.128	7.200
Frontal Plane		
Helmet Condition	**Mean**	**SD**
Properly Fit	17.687	12.033
Competition	10.812	7.002
Removed	14.534	9.867

Table 2: Pairwise Comparisons of head movement (measured in °/sec) under properly fitted helmet (PH), competition helmet (CH), and helmet removed (HR) conditions in all three planes.

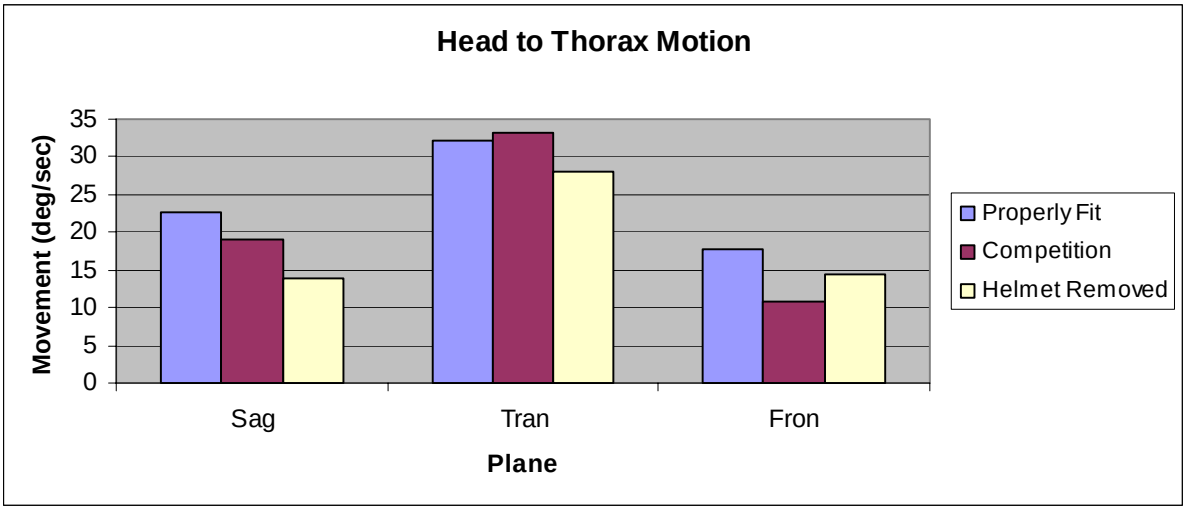

Table 3: Paired-samples *t*-tests comparing helmet movement under properly fitted and competition helmet conditions in all three planes

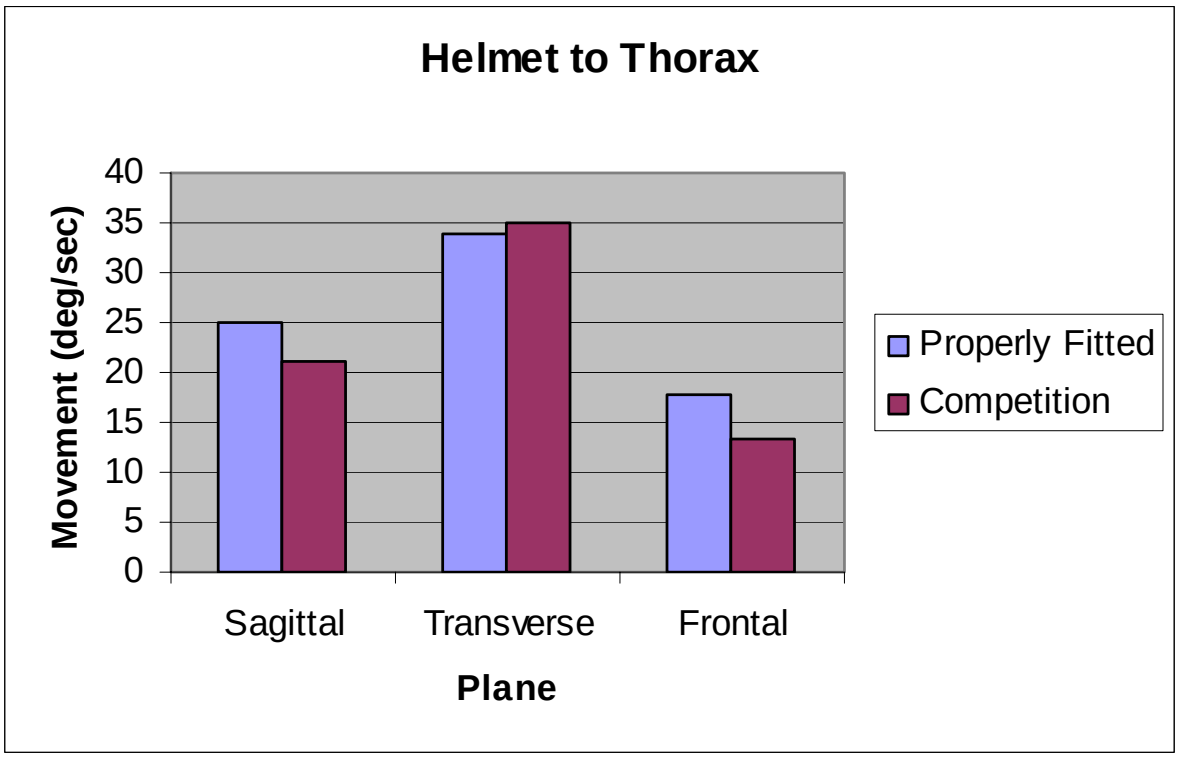

Table 4: Reliability of the log roll for head movement under the HR condition

Plane of Movement	ICC (3,1)	SEM (° / Sec)
Sagittal	0.82	5.18
Transverse	0.76	5.50
Frontal	0.83	3.38

Table 5: Reliability of the log roll time

Outcome Measure	ICC (3,k)	SEM (Seconds)
Duration of the Log Roll	0.90	0.21

DISCUSSION

The primary findings of this study show that regardless of helmet fit, there is significantly more cervical spine motion during the log roll of an ice hockey player when the helmet is not removed. The main differences observed were in the sagittal and transverse planes when the helmet removed condition was compared to the properly fit, and competition helmet conditions. The helmet removed condition yielded significantly less cervical spine motion than either of the others, suggesting that limiting unwanted cervical spine motion during a log roll could best be accomplished by removing the helmet altogether. A lack of significance between the properly fit and competition helmet conditions in these two planes illustrates that variations in helmet fit are inconsequential in relation to cervical motion when compared to the helmet removed condition. Interestingly, in the frontal plane, the competition helmet condition resulted in significantly less cervical spine motion than the properly fitted helmet while helmet removed showed no significance. This could be attributed to the procedure for adjusting ice hockey helmets. The outer shells of ice hockey helmets are constructed in two pieces; one anterior and one posterior, allowing them to be adjusted in the sagittal plane. To increase tightness, two screws are loosened on either side which allows the anterior portion to slide over the posterior, thus making the helmet smaller. This results in a focal point of pressure over the frontal bone and occiput when the helmet is properly fitted. Consequently, this will limit the amount of motion available in the sagittal and transverse planes, but still allow for motion to be available in the frontal plane. Under the competition helmet condition, the poorer fit allows motion to occur over all three planes, which may be a reason why less total range of motion was observed for the frontal plane. While this result was unexpected, it could be argued that the most essential motion to limit is

that in the sagittal plane. Studies regarding how much motion will cause further injury are extremely limited, which is why the NATA maintains that any motion is dangerous. It has been stated, however, that cervical flexion and extension create a shearing force between one vertebrae and the adjacent vertebrae, which could result in a narrowing of the spinal canal, thus increasing the risk for spinal cord injury with an increase in sagittal plane motion.[10] Our data suggests that the properly fitted helmet was superior in limiting sagittal plane movement when compared to the competition helmet, though the finding was not statistically significant.

The lack of significance of helmet movement during the log roll is indicative of a consistent log roll. Helmet condition was not expected to have an impact on helmet motion during the log roll because the helmet was being stabilized. We were primarily interested in head motion inside the helmet, but performed these *t*-tests as a reliability measure along with intraclass correlation coefficients.

The intraclass correlation coefficients that were calculated for this study measured the rescuer's ability to consistently perform the log roll with limited motion of the cervical spine. According to our measurements, the team of rescuers performing the log roll was reliable and consistent. Our ICC (3, 1) was calculated only for head movement under the helmet removed condition. However, because our *t*-tests showed no significant findings for helmet movement, it can be inferred that the log roll was consistent across conditions. Our ICC (3, k) was calculated for time and illustrates that the duration of each log roll was consistent for each subject.

Comparison of this data to previous literature is limited due to a lack of similar reported studies. In a study performed on ice hockey players, it has been reported that the

removal of the helmet increases lordosis in the cervical spine if the shoulder pads remain in place.[5, 7] These studies examined volunteers or athletes that had been previously immobilized in a supine position and no attention was paid to technique of subject immobilization, or to the fit of the helmet. Furthermore, during our study, it was shown that the helmets worn and fitted by the athletes for competition were poorly fitted according to our criteria. An alarming seven of the subjects could completely remove their helmet without unfastening the chinstrap or flipping up the face mask. Theoretically, such a poor helmet fit could result in increased head movement within the helmet.

Although studies have primarily focused on athletes in the supine position, it needs to be recognized that clinically, post injury positions vary. According to Tator et al., the most common cause of cervical spine injuries in ice hockey is a push, or check, from behind causing the athlete to be propelled head first into the boards.[13] This mechanism would cause the athlete to fall onto the ice and into the prone position, therefore, requiring a log roll onto a spine board during emergent care.

Equipment Differences

The stabilization provided by an ice hockey helmet is not comparable to that of a football helmet because the design is centered on protecting against initial impact, not overall stability. Ice hockey helmets are equipped with less padding and cover less of the head. A major contribution to the stability provided by an ice hockey helmet is attributed to a chinstrap that is fastened to both the helmet and the facemask. To remove the face mask, the chinstrap must be cut, which potentially diminishes the helmet's ability to stabilize the head and cervical spine. This raises an important question, in which this study attempted to

answer, as to whether ice hockey helmets are able to provide enough stabilization to the head and cervical spine to justify that the helmet remain on the athlete during a log roll procedure. The NATAIATF attempted to answer this question in a position statement released in 2001. In this statement it is made abundantly clear that during the immobilization of a football athlete, the equipment should remain in place provided an airway does not need to be established. Furthermore, it is reported that while football protective equipment is used as the example, the guidelines can be applied to other collision sports as well.[3] It seems inappropriate to issue a blanket statement supporting this idea for all collision sports, when the only sport providing sufficient research to draw such conclusion is football. The NATAIATF claims that one of the only instances when it is appropriate to remove the helmet is when the helmet and chin strap do not hold the head securely, such that immobilization of the helmet does not also immobilize the head. In order to determine if the helmet and chin straps are adequately stabilizing the head, studies similar to this one are necessary before broad spectrum statements can be released with implications for numerous sports.

Clinical Application

In reality, youth ice hockey athletes and college ice hockey athletes are not educated on proper fit, nor are they commonly fitted with equipment by trained personnel. Youth athletes wear their helmets comfortably which often does not result in a properly fitted helmet.

For this study, our criteria for helmet fit had to be created because there is not a uniform criterion for ice hockey. Even the equipment manufacturers do not have their own criteria; helmets are sized based solely on circumferential measurement. For these reasons,

we felt it was important to test a helmet that was fitted by the athlete because that is what will commonly be seen clinically.

An argument could be raised that values calculated as statistically significant for this study may not be clinically significant. However, studies investigating the degree of motion regarding cervical spine injury are limited. The data from this study indicates that limiting cervical motion within an ice hockey helmet prior to a log roll may be advantageous in reducing the risk of further spinal injury in these athletes.

Future Research

Further studies need to be conducted on this matter before a change in management can be definitively proposed. Research should concentrate on verifying these findings when log rolling an ice hockey player on the ice, as opposed to within a controlled laboratory setting. In addition, our study focused solely on the log roll, with no regard to movement during the process of immobilization once on the spine board, or during the removal of the helmet. Moreover, since Metz and Laprade have shown that removing the helmet increases lordosis of the cervical spine, it may be useful to investigate the effectiveness of a towel roll or bolster in minimizing excess movement. Also to be addressed is the possibility of stabilizing the helmet and cervical spine simultaneously to minimize movement. For example, if the forearms are used to stabilize the helmet, it may be possible to use the hands to stabilize the cervical spine.

Limitations

There were limitations to this study that warrant discussion. First, our study was conducted in a research laboratory. Ideally such a study should be conducted on the surface of an ice hockey rink where the log roll of an ice hockey athlete would clinically occur.

Furthermore, our subjects were uninjured and asked to remain limp for the duration of the roll. Therefore we could not take into account the effects muscle guarding may have had on movement. Also, even though each sensor was attached with double sided tape and secured with athletic tape, it cannot be said definitively that all unwanted motion was eliminated. Finally, the only piece of equipment used that was owned by and sized for the subject was the competition helmet. One standard set of ice hockey pants and shoulder pads were supplied for all subjects. This could have compromised the appropriate fit on some athletes and therefore may have increased the possibility of excess motion secondary to improper equipment fit.

Summary

As clinicians it is important to bear in mind that variations in sports, such as playing surface and protective equipment, can affect the management of injuries, and therefore claims made for one sport cannot always be applied to another. This study examined the effect of helmet condition on cervical spine movement during a log roll. Both helmet conditions yielded significantly more cervical spine movement when compared to the helmet removed condition in the sagittal and transverse planes, revealing that when an ice hockey helmet is stabilized, the head is not. Because of this finding, we conclude that removal of the helmet from an ice hockey player before performing the log roll technique may be the most effective means to limit extraneous movement at the cervical spine.

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