Journal of Athletic Training 2010;45(3):215–221

www.nata.org/jat

Helmet Fit and Cervical Spine Motion in Collegiate Men's Lacrosse Athletes Secured to a Spine Board

Meredith A. Petschauer, PhD, LAT, ATC*; Randy Schmitz, PhD, LAT, ATC†; Diane L. Gill, PhD†

*University of North Carolina, Chapel Hill; †University of North Carolina, Greensboro

Context: Proper management of cervical spine injuries in men's lacrosse players depends in part upon the ability of the helmet to immobilize the head.

Objective: To determine if properly and improperly fitted lacrosse helmets provide adequate stabilization of the head in the spine-boarded athlete.

Design: Crossover study.

Setting: Sports medicine research laboratory.

Patients or Other Participants: Eighteen healthy collegiate men's lacrosse players.

Intervention(s): Participants were asked to move their heads through 3 planes of motion after being secured to a spine board under 3 helmet conditions.

Main Outcome Measure(s): Change in range of motion in the cervical spine was calculated for the sagittal, frontal, and transverse planes for both head-to-thorax and helmet-to-thorax range of motion in all 3 helmet conditions (properly fitted, improperly fitted, and no helmet).

Results: Head-to-thorax range of motion with the properly fitted and improperly fitted helmets was greater than in the no-helmet condition ($P < .0001$). In the sagittal plane, range of motion was greater with the improperly fitted helmet than with the properly fitted helmet. No difference was observed in helmet-to-thorax range of motion between properly and improperly fitted helmet conditions. Head-to-thorax range of motion was greater than helmet-to-thorax range of motion in all 3 planes ($P < .0001$).

Conclusions: Cervical spine motion was minimized the most in the no-helmet condition, indicating that in lacrosse players, unlike football players, the helmet may need to be removed before stabilization.

Key Words: stabilization, emergency management, protective equipment

Key Points

- In all 3 planes (sagittal, frontal, and transverse), range of motion between the head and thorax was greater in both the properly and improperly fitted helmets than in the no-helmet condition.
- Head-to-thorax range of motion in the sagittal plane was greater with the improperly fitted helmet than with the fitted helmet.
- Helmet-to-thorax range of motion did not differ between the properly and improperly fitted helmets for the 3 planes.
- Greater range of motion was available between the head and thorax than between the helmet and thorax, regardless of helmet fit, indicating that the head was moving inside the helmet.

The National Center for Catastrophic Sports Injury Research reported 3 catastrophic spinal cord injuries in collegiate men's lacrosse players from 1982 through 2007, with 1 resulting in permanent paralysis.[1] This incidence is remarkably lower than the numbers commonly seen in football or ice hockey players. However, given the high-velocity collisions that typically occur in lacrosse and the sport's increased popularity, the potential for cervical spine injury exists.[2] Thus, certified athletic trainers may find themselves caring for a lacrosse athlete who has potentially sustained a cervical spine injury.

Given the potential for significant injury in lacrosse players, it is imperative that proper emergency management techniques be identified to prevent secondary injury while care is being provided on the athletic field. To reduce motion of the cervical spine and maximize space for inflammation, immobilization of the cervical spine through neutral alignment of the head and trunk has been recommended as the best position during transport to a medical facility.[3,4]

The Inter-Association Task Force for Appropriate Care of the Spine-Injured Athlete (IATF)[5] advised that in equipment-intensive sports (eg, football, ice hockey, and lacrosse), the helmet and shoulder pads should be left in place when immobilizing the athlete with a possible cervical spine injury. However, it was also recommended that the helmet or protective equipment be removed under certain circumstances: for example, if securing the helmet does not effectively immobilize the head because of either helmet design or fit. Determining if the helmet will stabilize the head presents a dilemma for the certified athletic trainer during on-field management of an athlete with a potential cervical spine injury who is wearing protective equipment. It is important to recognize whether the helmet design and the way in which the athlete wears the helmet allow for adequate spinal stabilization if spine-board immobilization is necessary. Although movement within a properly fitted football, ice hockey, or lacrosse helmet is speculated to be minimal, that claim has not been thoroughly researched.[6] Additionally, the amount of allowable movement considered safe after cervical spine injury has yet to be established.[7] Finally, whether the lacrosse helmet and shoulder pads put the athlete in the most optimal position for immobilization has also been debated.[8] Thus, the purpose of our study was to determine if the Cascade CPX lacrosse helmet (Cascade Lacrosse, Liverpool, NY) provides adequate stabilization of the head and cervical spine in the spine-boarded athlete.

METHODS

Participants

A total of 18 collegiate men's lacrosse athletes (age range, 18–22 years; height = 185 ± 6.7 cm, mass = 83.6 ± 7.8 kg) volunteered to participate. All participants had full, pain-free neck range of motion, and none had sustained a cervical spine or neck injury within the past 6 months. Additionally, none had experienced a cervical fracture or dislocation.

Equipment

We collected 3-dimensional kinematic data at 50 Hz using the Motion Star (Ascension Technology Corporation, Burlington, VT) electromagnetic motion analysis system controlled by MotionMonitor software (version 7.24; Innovative Sports Training, Inc, Chicago, IL).

A custom-built rigid Orthoplast (Johnson and Johnson, New Brunswick, NJ) mouthpiece was used as the placement site for a sensor to represent the head. This mouthpiece allowed us to assess movement of the head as each participant bit down on the mouthpiece during testing. The Cascade CPX helmet we used for testing was the same style and brand used by all of the lacrosse players during competition. We chose this helmet because it is a popular brand and model used by several collegiate lacrosse programs. We asked participants to bring the protective equipment (helmet and shoulder pads) they would normally wear during game and practice situations. Participants were then fitted by the principal investigator with a Cascade CPX helmet per the manufacturer's instructions. For immobilization, a rigid spine board (model 35850; Iron Duck, Chicopee, MA) was used. The principal investigator (M.A.P.) secured the participants to the spine board with the Best Strap System (Morrison Medical Corporation, Columbus, OH) for the torso and the Big Blue head immobilizer (Morrison Medical Corporation) for the head. We used a Stifneck cervical collar (Laerdal Medical Corporation, Wappingers Falls, NY) for immobilization when the athlete was not wearing protective equipment.

Protocol

Participants entered the sports medicine research laboratory for testing with their helmet and shoulder pads and read and signed an informed consent form approved by the institutional review board (which also approved the study). Participants were fitted with a Cascade CPX helmet per the manufacturer's guidelines. Each volunteer's usual participation helmet was then assessed using these same guidelines. Participants were fitted with a cervical collar for use during the no-helmet condition, and motion sensors were placed and digitized on the athletes. Each participant was instructed on the cervical range of motion to perform and allowed adequate practice. Participants were immobilized to a spine board, and cervical spine range-of-motion data were collected for the sagittal, frontal, and transverse planes for 3 conditions: a fitted helmet condition, a player-fitted (improperly fitted) condition, and a no-helmet situation in which the participant wore only a cervical collar. The principal investigator was not blinded to the conditions.

Helmet Fitting and Assessment. We fitted the Cascade CPX helmet by placing the manufacturer's padding inside the helmet and adjusting the chin strap by holding the chin cup under the chin and tightening the top straps first and then the bottom, such that all had equal tension. Once the helmet was in place with the chin strap fastened, we performed the following 3 tests to make sure the helmet fit as well as possible: 1) The investigator pushed down on the helmet to make sure that pressure was felt evenly on top of the head. If it was only felt on the sides, the helmet was determined to be too tight. 2) The investigator moved the helmet from side to side and up and down to make sure that the skin on the forehead moved with the helmet. 3) The investigator asked the participant if the fit was "firm but comfortable."

The helmet that the participant actually wore for practice and competition was then evaluated to determine if it fit differently than the properly fitted helmet. If we determined that the padding and chin strap were adjusted in the same way as on the properly fitted helmet, the participant was not eligible for the study because there was no improperly fitted helmet to be used for comparison. If the helmet was not adjusted in the same way as the properly fitted helmet, the participant's helmet was considered to be improperly fitted and he was eligible to be included in the study. We removed the face masks of both helmets before testing.

Motion Sensor Setup. Each participant was fitted with 3 sensors: 1 on the top of the helmet, 1 on the mouthpiece, and 1 on the sternum near the sternal notch. Each participant was asked to bite down on the mouthpiece while he had it in his mouth to make sure the movement of that sensor represented movement of the head.

Using the following landmarks, we digitized each participant while he was sitting in a chair. The head included the bridge of the nose, the middle of the chin, and the occipital protuberance, and the thorax included the spinous process of T8, the xiphoid process, and the spinous process of C7.

Instruction for the Range-of-Motion Testing. Before data collection, we explained the range of motion each participant was to perform, and he practiced moving in the 3 planes of motion, a single plane at a time. We verbally defined and visually demonstrated flexion, extension, side bending, and rotation. Practice was allowed until we had determined that the athlete could perform each motion of the cervical spine in only 1 plane at a time. This practice helped him understand the desired motion of the cervical spine. Single-plane motion was also assessed during data collection. If the participant did not accomplish this, the trial was performed again.

Securing to the Spine Board. We secured the participant to the spine board 3 times in counterbalanced fashion, 1 time with shoulder pads and the properly fitted lacrosse helmet, 1 time with shoulder pads and the improperly fitted

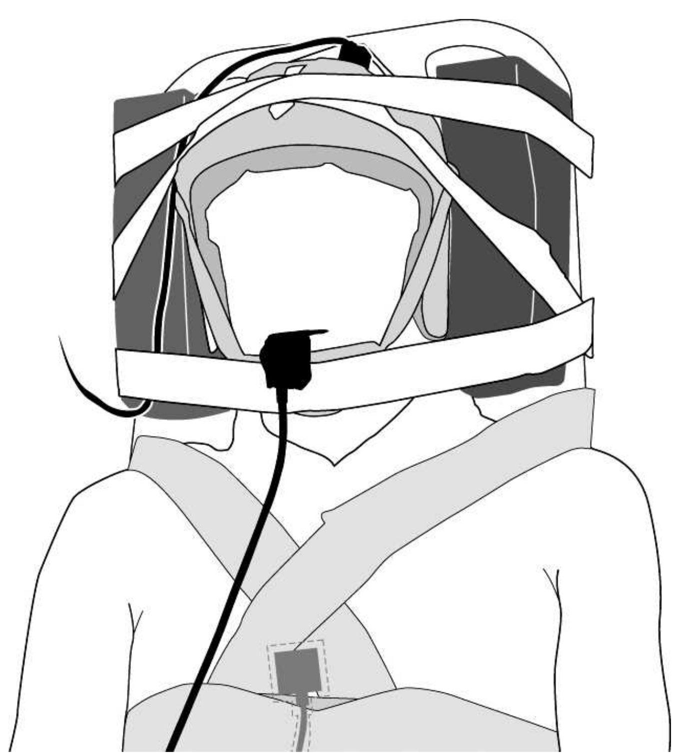

Figure 1. Immobilization with helmet and shoulder pads.

Figure 2. Immobilization without protective equipment.

lacrosse helmet, and 1 time with no protective equipment and a cervical collar. Each time, the participant was in a supine position on the spine board with his head and torso stabilized according to the recommendations of the IATF[5] regarding prehospital care of the spine-injured athlete. This included placing a spider strap around the torso with crossing straps in the front, stabilizing the head or helmet with bolsters on both sides, and applying athletic tape across the head or helmet and the chin. Four strips of tape were oriented in a crossing pattern across the helmet just over the visor, and then 1 piece was placed across the chin strap. The chin strap of the helmet was left in place (Figure 1). When the participant was not wearing protective equipment, he was immobilized on the spine board in a similar fashion (Figure 2).

Data Collection. The orders of testing condition and range of motion were counterbalanced. For each condition, the participant moved into each of the 3 planes of motion according to the previously described instructions. The participant was instructed to ‘‘gently, actively move until you feel the resistance of the helmet or tape and then stop.’’ Each time, the participant returned to a neutral position and was told again to only move until he felt resistance. Each athlete performed movement into each plane 5 times. The procedure was then repeated for each condition.

Data Reduction

Raw kinematic data were low-pass filtered with a fourth-order, zero-lag Butterworth filter with a 10-Hz cutoff frequency. We used an Euler rotation sequence that defined flexion and extension, followed by rotation and side bending.[9] We calculated angles by examining the head sensor position relative to the thorax sensor position and the helmet sensor position relative to the thorax sensor position.

Once the angles were obtained from the sensor positions, the change in range of motion was calculated using the maximum value subtracted from the minimum value. The joint displacements in each of the 3 planes were then averaged across the 5 trials.

Statistical Analyses

The dependent variables were average change in range of motion in the sagittal, frontal, and transverse planes for both head-to-thorax and helmet-to-thorax motion. A 1-way repeated-measures analysis of variance (ANOVA) assessed differences among each of the dependent variables across helmet condition (properly fitted helmet, improperly fitted helmet, no helmet) for head-to-thorax motion. An α level of $P < .05$ was set a priori, and a Tukey honestly significant difference post hoc analysis was conducted to identify specific pairwise differences.

A paired-samples t test was calculated to compare helmet-to-thorax range of motion between properly fitted and improperly fitted helmet conditions for each plane of motion. A 2 (testing condition: properly fitted helmet, improperly fitted helmet) $\times 2$ (motion condition: head-to-thorax motion, helmet-to-thorax motion) repeated-measures ANOVA was performed on each of the average ranges of motion to identify any differences among range-of-motion condition and testing condition as well as the existence of an interaction. We used SPSS (version 14.0; SPSS Inc, Chicago, IL) for all statistical analyses.

RESULTS

Head-to-Thorax Range of Motion

Range of motion between the head and thorax was different among the properly fitted helmet, improperly fitted helmet, and no-helmet conditions, respectively, for

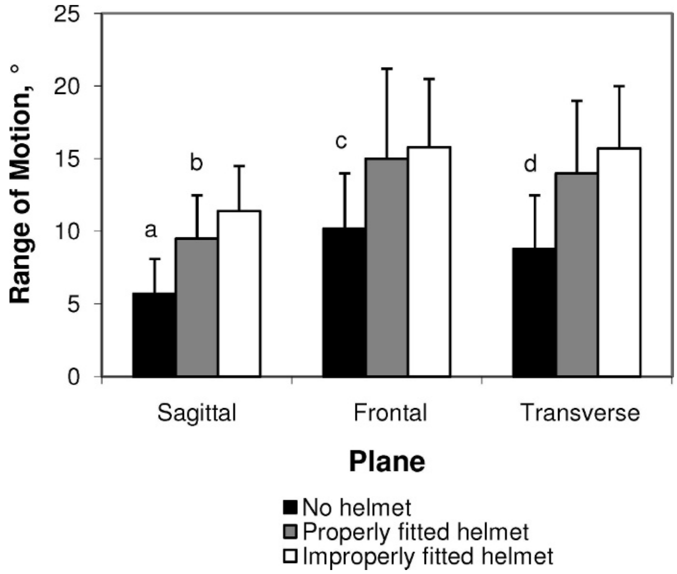

Figure 3. Mean head-to-thorax range of motion for each plane and each condition. [a] Indicates difference between (1) properly fitted and improperly fitted helmets and (2) no helmet: mean differences = 3.7° versus 5.7° and effect sizes = 0.57 and 0.72, respectively. [b] Indicates difference between properly fitted and improperly fitted helmets: mean difference = 1.9°, effect size = 0.30. [c] Indicates difference between (1) both properly and improperly fitted helmets and (2) no helmet: mean differences = 4.8° and 5.6° and effect sizes = 0.42 and 0.55, respectively. [d] Indicates difference between (1) both properly and improperly fitted helmets and (2) no helmet: mean differences = 5.2° and 6.9° and effect sizes = 0.51 and 0.65, respectively.

all 3 planes of motion: sagittal (9.5° ± 3.0°, 11.4° ± 3.1°, 5.7° ± 2.4°; $P < .001$), frontal (15.0° ± 6.2°, 15.8° ± 4.7°, 10.2° ± 3.8°; $P < .001$), and transverse (14.0° ± 5.0°, 15.7° ± 4.3°, 8.8° ± 3.7°; $P < .001$; Figure 3). Tukey post hoc analysis indicated that in all planes, range of motion was greater in both the properly fitted helmet and improperly fitted helmet conditions than in the no-helmet condition. Also, motion in the sagittal plane was greater in the improperly fitted helmet condition than in the properly fitted condition.

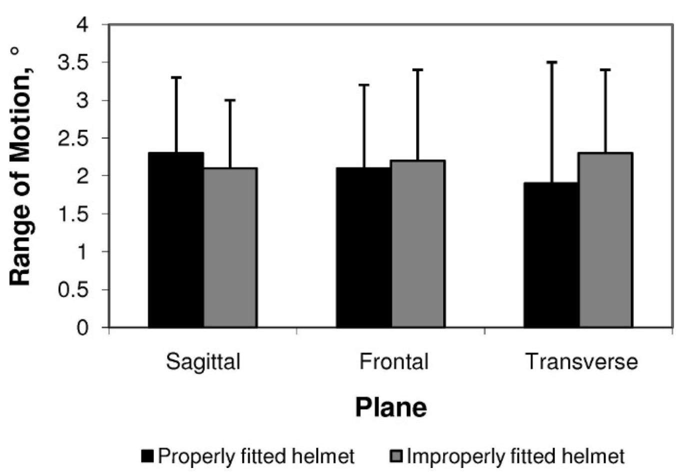

Figure 4. Mean helmet-to-thorax range of motion for both the properly fitted and improperly fitted helmets in the sagittal, frontal, and transverse planes of motion.

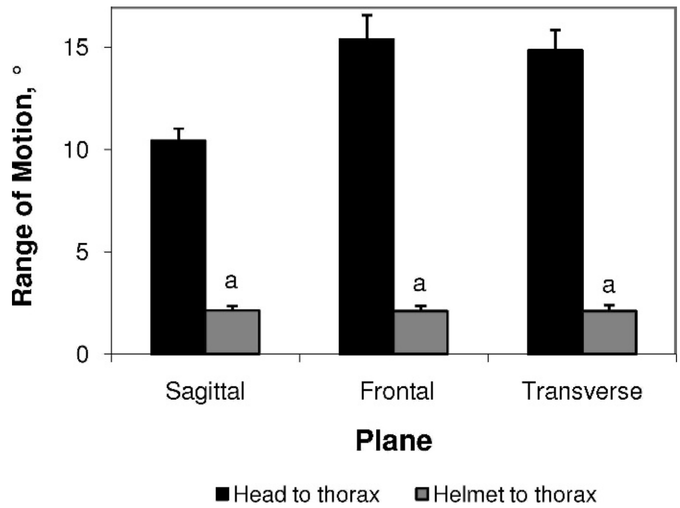

Figure 5. Head-to-thorax and helmet-to-thorax grand means across properly and improperly fitted helmets for all 3 planes of motion. [a] Indicates difference between conditions within planes.

Helmet-to-Thorax Range of Motion

No differences were noted for helmet-to-thorax range of motion between the properly fitted and improperly fitted helmet conditions for each plane of motion ($P > .05$; Figure 4).

A repeated-measures ANOVA using helmet condition (properly fitted, improperly fitted) as one variable and motion condition (head to thorax, helmet to thorax) as the second variable demonstrated a main effect for the motion condition in the sagittal ($F_{1,17} = 279.59$, $P < .001$), frontal ($F_{1,17} = 184.05$, $P < .001$), and transverse ($F_{1,17} = 211.43$, $P < .001$) planes (Figure 5). Greater range of motion was available between the head and thorax compared with the helmet and thorax regardless of helmet fit, indicating that the motion observed between the head and thorax was a result of the head moving inside the helmet, rather than the helmet and the head moving as a single unit.

DISCUSSION

Head-to-Helmet Movement

The most important finding of our study was that participants secured to a spine board and wearing a lacrosse helmet and shoulder pads had more cervical spine motion than those not wearing a helmet and shoulder pads. According to the IATF's[5] prehospital guidelines for care of the cervical spine–injured athlete, the helmet and shoulder pads should be left in place when securing the athlete to the spine board unless the helmet does not sufficiently stabilize the head. The results of our study indicate that the Cascade CPX lacrosse helmet did not fully stabilize the head inside the helmet, regardless of fit. Surprisingly, the kinematic data indicated that the head was most stable when the athlete wore no protective equipment. Thus, an athlete with a suspected cervical spine injury may be at greater risk when the helmet is left in place during spinal stabilization on the field. The IATF[5] did recommend that the equipment can be removed if the helmet does not fit in such a way as to stabilize the head, and our data suggest that this is a common situation in lacrosse players wearing a Cascade

CPX helmet. Because the lack of a proper fit is more the rule than the exception, the recommendations of the IATF,[5] which were based primarily on football, seem to be contradicted.

Our results disagree with those of Waninger et al,[6] who concluded that the lacrosse helmet did sufficiently stabilize the head during cervical spine immobilization. They compared football, ice hockey, and lacrosse helmets and found no difference in participants' head ranges of motion while wearing the equipment. However, these authors assessed only passive rotational movement when the athlete was jostled, which does not indicate the total available range of motion, and they did not compare this measure with a no-helmet condition. The active range of motion included in our study is important in that it represents the worst possible scenario. Although an individual is unlikely to use his full range of available motion after sustaining a cervical spine injury, a combative patient or motion resulting from transport can be very unpredictable. Therefore, if the patient can actively move, the stabilization procedure is not truly providing immobilization and does not help to prevent secondary injury. Additionally, Waninger et al[6] did not evaluate flexion-extension, which is potentially the most damaging range of motion in the cervical spine–injured patient.[7,10,11] Hence, given the design differences between their investigation and ours, it is not surprising that our findings differ.

Helmet-to-Thorax Motion

Our findings indicate that a helmet can effectively be secured to a spine board. The motion of the stabilized helmet that occurred (helmet to thorax) was very small (1.9°–2.3°) in comparison with the range of motion available at the head (head to thorax: 5.7°–15.8°). Thus, the measured head motion included a minimal contribution from the motion of the helmet; most of the motion was that of the head inside the helmet. Additionally, the motion of the helmet relative to the thorax was not different among helmet conditions, which indicated that the helmet was stabilized similarly between fit conditions. As a result, we can conclude that stabilization of the helmet was adequate and that the difficulty lies in the ability to stabilize the head inside the helmet.

Helmet Fitting

All the lacrosse players in our study were currently participating with helmets that were not fitted according to the manufacturer's instructions, so none were eliminated because of a properly fitting helmet during the helmet screening. All participants wore the chin strap too loose (18/18) and 14 of the 18 required additional occipital padding to fit the helmet properly.

The addition of the padding and correctly fitting the chin strap likely resulted in the difference between the properly and improperly fitted conditions in the sagittal plane. The manner by which these helmets are fitted allows for padding to be placed on the posterior aspect of the head, just inferior to the occiput. This padding could prevent some flexion and extension but would not affect the additional planes of motion. Hence, properly fitting the helmet may offer better stabilization when trying to limit flexion and extension.

Given that in the other 2 planes, the fit of the helmet did not reduce the available range of motion, properly fitting the helmet may not be enough to provide satisfactory stabilization. Although fitting the helmet properly reduced some motion, less available range of motion was exhibited in all 3 planes when the helmet and shoulder pads were removed. This indicates that removing the helmet may be the best treatment plan until a helmet that properly stabilizes the head can be designed. Peris et al[12] and Prinsen et al[13] investigated motion that occurs during helmet and shoulder pad removal. Peris et al[12] noted that when the IATF[5] guidelines were followed, no significant motion occurred when removing the helmet and shoulder pads. They[12] concluded that the IATF guidelines were effective in limiting motion. Prinsen et al,[13] however, indicated that removing the helmet from the head did create significant angular displacement of the cervical spine in hockey and football players and, therefore, recommended that the helmet stay on the head for transport.[13] We did not study the motion generated by removing the helmet, but we continue to believe that if the head is not stabilized inside the helmet, the helmet should be removed. Finally, we speculate that if the helmet does not fit properly, it may not be as difficult to remove and, thus, would not create much in the way of movement. Further research is needed in this area.

The face mask of a lacrosse helmet may also affect the fit of the helmet by bringing the temporal portion of the helmet in toward the head. If the current guidelines generated by the IATF[5] are followed (ie, removal of the face mask), the fit of the helmet is potentially disturbed, which then affects its ability to limit movement of the cervical spine during spine boarding. A helmet that fits properly with the face mask in place may not fit as well when the face mask is removed.

Finally, it is necessary to educate the lacrosse community as to the importance of wearing a properly fitted helmet. However, this is a challenging task. The culture among lacrosse players is to wear the helmet fitting loosely. Coaches, younger players, and parents must be educated regarding the importance of a properly fitted helmet. Although this process will take time, as it did in football, we hope that the lacrosse community will require players to wear their helmets with the safest fit.

Cervical Collar

A cervical collar was not part of this investigation in the helmeted athlete conditions because one could not be used on every player. Because the lacrosse helmet protrudes posteriorly, a player with a short neck or head structure that positions the helmet lower on his head cannot be properly fitted with a cervical collar. Waninger et al[6] indicated that it was very difficult to properly apply a cervical collar to a participant wearing football, ice hockey, or lacrosse equipment. However, in some cases, it may be possible, given the individual's anatomy and helmet fit, to apply a cervical collar. Podolsky et al[14] and James et al[9] demonstrated reductions in all ranges of motion when using a rigid cervical collar. Podolsky et al[14] reported reductions of 11° in flexion, 11° in extension, 3° in lateral bending, and 26° in rotation when comparing a Philadelphia collar with no immobilization. Similarly, James et al[9] noted a 28° reduction in total angular displacement with a StifNeck collar compared with a softer vacuum immobilizer. Therefore, if a cervical collar can be applied, its use is indicated.[4,9,14]

Shoulder Pads

During the no-helmet condition, participants were not wearing shoulder pads. Sherbondy et al[8] indicated that the lacrosse helmet and shoulder pads put the neck in an extended position rather than neutral position, but they did not recommend removal of the shoulder pads and helmet together because of the potential motion that could occur with this process.[8] They also did not recommend removal of the helmet because the shoulder pads–only condition was not optimal, leaving the athletes in a relatively flexed position.[8] The position of the head without the shoulder pads depends on the type of shoulder pads worn. Whether the shoulder pads and helmet should be removed together or the helmet should be removed and padding placed under the head to maintain good alignment were not questions addressed in our study. Additionally, the type of shoulder pads used varies considerably among players, making a generalized recommendation difficult. However, the recommendation stands that if the helmet does not fit properly, it should be removed. More research is clearly needed on both men's lacrosse and other types of equipment.

Clinical Significance

The amount of cervical motion required for secondary injury to occur is unknown, but the current line of thinking is that range of motion should be limited as much as possible.[7] When we try to speculate as to how much motion is too much, difficulty arises because of the normal biomechanics of the spine when flexing and extending. According to Swartz et al,[15(p157)] "a vertebra may experience its greatest flexion and extension before the cervical column itself is fully flexed or extended." Additionally, not all the vertebrae are moving in the same direction at the same time: for example, during flexion, C6 and C7 are actually extending at times, and the available space for the spinal cord varies.[15] Tierney et al[10] indicated that sagittal column space was greatest when the occiput was in a neutral position, compared with lifting it 2 cm and 4 cm. This lifting would, in theory, generate flexion. If a generalization about what happens to this space is possible, we could speculate that as flexion continued or as the occiput was raised, the space would decrease. However, according to De Lorenzo et al,[3] the largest spinal-cord space occurred with 2 cm of occiput elevation; this space was smallest at C6 and greater at all levels from C2 to T1. Thus, as the spine flexes, the space changes are not predictable and vary among individuals. The spinal cord folds and unfolds in response to tension and compression.[10] This change in sagittal diameter of the spinal cord means that even if the sagittal column space were predictable, the diameter of the cord is not.[10] Therefore, given the changes and instability that could result from injury, it is difficult to draw any conclusions about the type or amount of motion that is potentially damaging.

The available cervical spine ranges of motion during spine-board immobilization as determined by our investigation could be significant in the cervical spine–injured men's lacrosse player. Given that the goal of immobilization is to reduce the risk of secondary injury to the cervical spine, it may be necessary to remove the helmet. Because there is so much we still do not know about how to manage a lacrosse player on the field with a suspected cervical spine injury, we recommend that clinicians use caution when determining a protocol for treatment of cervical spine injury in men's lacrosse players.

We recognize that this was an isolated sample of players and only 1 type of lacrosse helmet was tested. Thus, it is difficult to generalize our findings to the entire population of lacrosse players. We also realize that we did not remove the helmet and, hence, do not know how much motion would occur if the helmet was removed. One limitation of our study is that we did not control for the effort participants used. Additionally, the principal investigator was not blinded to the participant's helmet condition, which is a potential source of bias. However, because of the repeated-measures design of the study, we do not believe either of these limitations affected the results. What is very clear is that more research needs to be conducted on lacrosse equipment to further assist in educating certified athletic trainers and emergency medical personal on how to most effectively reduce the chance of secondary injury in the spine-injured athlete. Furthermore, our results indicate that clear guidelines should be established for athletes wearing equipment in different sports.

The purpose of our study was to evaluate the ability of the Cascade CPX men's lacrosse helmet to properly stabilize the head inside the helmet when the helmet was properly fitted and improperly fitted. We found that the helmet did not effectively stabilize the head in either condition. It is important to recognize that men's lacrosse helmets and shoulder pads are not the same as those pieces of equipment in football and ice hockey and, therefore, we should not necessarily treat them the same way when an athlete has a possible cervical spine injury. As illustrated by our study, the helmet did an insufficient job of stabilizing the head; if the goal during immobilization on a spine board is to stabilize the head, that goal is not accomplished by leaving the lacrosse helmet in place. Although fitting the helmet properly offers some benefit when trying to limit sagittal-plane motion, the helmets of the participants in our study were not properly fitted. Thus, if a helmet was designed to help stabilize the head during these situations, players need to be educated as to the importance of both properly fitting their helmets and wearing them properly at all times. We encourage coaches, parents, and athletes to follow the fitting instructions for each helmet.

ACKNOWLEDGMENTS

We thank David H. Perrin, PhD, ATC, FACSM, and Kathleen Williams, PhD, University of North Carolina, Greensboro, and Kevin M. Guskiewicz, PhD, ATC, FNATA, FACSM, University of North Carolina, Chapel Hill, for their assistance with the study and Joe Patrizzi for the artwork.

REFERENCES

1. Mueller FO, Cantu RC. National Center for Catastrophic Sports Injury Research. Twenty-fifth annual report. http://www.unc.edu/depts/nccsi/AllSport.pdf. Accessed January 8, 2010.

2. Proctor MR, Cantu RC. Head and neck injuries in young athletes. *Clin Sports Med*. 2000;19(4):693–715.
3. De Lorenzo RA, Olson JE, Boska M, et al. Optimal positioning for cervical immobilization. *Ann Emerg Med*. 1996;28(3):301–308.
4. Cervical spine immobilization before admission to the hospital. *Neurosurgery*. 2002;50(3 suppl):S7–S17.
5. Kleiner DM, Almquist JL, Bailes J, et al. *Prehospital Care of the Spine-Injured Athlete: A Document From the Inter-Association Task Force for Appropriate Care of the Spine-Injured Athlete*. Dallas, TX: National Athletic Trainers' Association; 2001.
6. Waninger KN, Richards JG, Pan WT, Shay AR, Shindle MK. An evaluation of head movement in backboard-immobilized helmeted football, lacrosse, and ice hockey players. *Clin J Sport Med*. 2001;11(2):82–86.
7. Del Rossi G, Horodyski M, Powers ME. A comparison of spine-board transfer techniques and the effect of training on performance. *J Athl Train*. 2003;38(3):204–208.
8. Sherbondy PS, Hertel JN, Sebastianelli WJ. The effect of protective equipment on cervical spine alignment in collegiate lacrosse players. *Am J Sports Med*. 2006;34(10):1675–1679.
9. James CY, Riemann BL, Munkasy BA, Joyner AB. Comparison of cervical spine motion during application among 4 rigid immobilization collars. *J Athl Train*. 2004;39(2):138–145.
10. Tierney RT, Mattacola CG, Sitler MR, Maldjian C. Head position and football equipment influence cervical spinal-cord space during immobilization. *J Athl Train*. 2002;37(2):185–189.
11. Torg JS, Vegso JJ, O'Neill MJ, Sennett B. The epidemiologic, pathologic, biomechanical, and cinematographic analysis of football-induced cervical spine trauma. *Am J Sports Med*. 1990;18(1):50–57.
12. Peris MD, Donaldson WF III, Towers J, Blanc R, Muzzonigro TS. Helmet and shoulder pad removal in suspected cervical spine injury: human control model. *Spine*. 2002;27(9):995–999.
13. Prinsen RK, Syrotuik DG, Reid DC. Position of the cervical vertebrae during helmet removal and cervical collar application in football and hockey. *Clin J Sport Med*. 1995;5(3):155–161.
14. Podolsky S, Baraff LJ, Simon RR, Hoffman JR, Larmon B, Ablon W. Efficacy of cervical spine immobilization methods. *J Trauma*. 1983;23(6):461–465.
15. Swartz EE, Floyd RT, Cendoma M. Cervical spine functional anatomy and biomechanics of injury due to compressive loading. *J Athl Train*. 2005;40(3):155–161.

Address correspondence to Meredith A. Petschauer, PhD, LAT, ATC, University of North Carolina, Chapel Hill, CB#8700, Fetzer Gym, Chapel Hill, NC 27599-8700. Address e-mail to mbusby@email.unc.edu.