Lacrosse Equipment and Cervical Spinal Cord Space During Immobilization: Preliminary Analysis

Michael Higgins, PhD, PT, ATC, CSCS*; Ryan T. Tierney, PhD, ATC†; Jeffrey B. Driban, PhD, ATC, CSCS†; Steven Edell, DO‡; Randall Watkins, ATC*

*Department of Kinesiology, Towson University, Towson, MD; †Temple University, Philadelphia, PA; ‡Edell Radiology Associates, Wilmington, DE

Context: Removal of the lacrosse helmet to achieve airway access has been discouraged based only on research in which cervical alignment was examined. No researchers have examined the effect of lacrosse equipment on the cervical space available for the spinal cord (SAC).

Objective: To determine the effect of lacrosse equipment on the cervical SAC and cervical-thoracic angle (CTA) in the immobilized athlete.

Design: Observational study.

Setting: Outpatient imaging center.

Patients or Other Participants: Ten volunteer lacrosse athletes (age = 20.7 ± 1.87 years, height = 180.3 ± 8.3 cm, mass = 91 ± 12.8 kg) with no history of cervical spine injury or disease and no contraindications to magnetic resonance imaging (MRI).

Intervention(s): The lacrosse players were positioned supine on a spine board for all test conditions. An MRI scan was completed for each condition.

Main Outcome Measure(s): The independent variables were condition (no equipment, shoulder pads only [SP], and full gear that included helmet and shoulder pads [FG]), and cervical spine level (C3–C7). The dependent variables were the SAC and CTA. The MRI scans were evaluated midsagittally. The average of 3 measures was used as the criterion variable. The SAC data were analyzed using a 3 × 5 analysis of variance (ANOVA) with repeated measures. The CTA data were analyzed with a 1-way repeated-measures ANOVA.

Results: We found no equipment × level interaction effect ($F_{3.7,72} = 1.34$, $P = .279$) or equipment main effect ($F_{2,18} = 1.20$, $P = .325$) for the SAC (no equipment = 5.04 ± 1.44 mm, SP = 4.69 ± 1.36 mm, FG = 4.62 ± 1.38 mm). The CTA was greater (ie, more extension; critical $P = .0167$) during the SP (32.64° ± 3.9°) condition than during the no-equipment (25.34° ± 2.3°; $t_9 = 7.67$, $P = .001$) or FG (26.81° ± 5.1°; $t_9 = 4.80$, $P = .001$) condition.

Conclusions: Immobilizing healthy lacrosse athletes with shoulder pads and no helmets affected cervical spine alignment but did not affect SAC. Further research is needed to determine and identify appropriate care of the lacrosse athlete with a spine injury.

Key Words: cervical spine position, emergency care, helmet removal

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Key Points

- Immobilizing healthy lacrosse athletes wearing only shoulder pads affected cervical alignment but did not affect space available for the spinal cord.
- Immobilizing the lacrosse athlete in shoulder pads and no helmet may not have detrimental effects on the spinal cord.

The protective helmet and shoulder pads worn by athletes can complicate a thorough medical evaluation and the ability to access an airway.[1–7] The all-or-none principle (ie, keeping both the shoulder pads and helmet on or removing both helmet and shoulder pads) currently guides all equipment-removal decisions to access the airway.[8,9] Clinicians are instructed not to remove the helmet without removing the shoulder pads because of the fear of further compromising the spinal cord.[2,3,5–16] This guideline is based primarily on research[3,4,6,16] with football equipment indicating that immobilizing an athlete without a helmet but with the shoulder pads detrimentally affects cervical spine alignment. Football shoulder pads substantially raise the thoracic region, causing the cervical spine to extend[4,6,11] if the helmet is removed and, therefore, decreasing cervical spinal cord space.[3,7,17,18]

Immobilization of the lacrosse athlete with the helmet removed to acquire airway access may not be detrimental for the lacrosse athlete because of the lacrosse shoulder pad design. This is particularly relevant in lacrosse, because extrapolation from available research indicates that lacrosse face mask removal is more difficult than football or ice hockey face mask removal.[19] Lacrosse shoulder pads are much smaller and thinner than football pads and cause minimal elevation of the thorax when the athlete is in the supine position. Some researchers[15] have recommended face mask removal to achieve airway access based on research indicating changes (mean = 4.7°) in upper (occiput to C2) cervical spine alignment when removing the lacrosse helmet only. These findings were limited to viewing only the bony anatomy, did not account for the changes occurring to the spinal cord within the cervical spinal canal, and may not be clinically important because

they occurred in the midranges of cervical motion, where cervical spinal cord size is less affected.[17] Furthermore, no differences were reported between the full-gear and shoulder pads–only conditions in the lower (C2–C7) cervical spine,[15] where most cervical spine injuries occur.[20]

Assessing the space available for the cord (SAC) is most important, because if it can be maintained, there may be a smaller chance of neurologic injury during transportation to an emergency facility. To date, no researchers have reported the effect of lacrosse helmet removal on cervical SAC in the immobilized athlete. Therefore, the purpose of our study was to determine the effect of varied lacrosse equipment conditions on cervical SAC and cervical-thoracic angle (CTA) in the immobilized lacrosse athlete. We hypothesized that immobilization of the lacrosse athlete with the helmet removed would affect cervical spine alignment but would not affect SAC.

METHODS

Research Design

We used a repeated-measures design, with each participant serving as his or her own control. The independent variables were condition (no equipment, shoulder pads only [SP], and full gear that included helmet and shoulder pads [FG]) and cervical spine level (C3–C7). The dependent variables were SAC (mm) and CTA (degrees). The SAC was the difference between the sagittal-cord diameter and corresponding sagittal-canal diameter (Figure 1). The spinal-canal diameter was the narrowest distance from the vertebral body to the spinolaminar line, and the spinal-cord diameter was measured at the appropriate level.[3] The CTA was the intersection of lines drawn parallel to the ventral aspects of C2–C3 and T1–T2 vertebral bodies (Figure 2).

Participants

Ten lacrosse athletes (age = 20.7 ± 1.87 years, height = 180.3 ± 8.3 cm, mass = 91 ± 12.8 kg, chest = 102.6 ± 10.5 cm, head = 57.1 ± 1.8 cm) with no history of cervical spine injury or disease and no contraindications to magnetic resonance imaging (MRI) (eg, claustrophobia, size restriction in the MRI bore, ferromagnetic implantation) volunteered to participate in this study. Participants read and signed a written informed consent form before participating. The Institutional Review Board for Protection of Human Participants at Towson University approved the study.

Procedures

A certified athletic trainer (M.H.) properly fitted each participant with a modified (ie, no metal parts) Riddell Revolution (Riddell, Elyria, OH) lacrosse helmet and Brine Ventilator (Brine, Milford, MA) shoulder pads according to the manufacturers' guidelines. Participants were positioned supine on a spine board for all test conditions (ie, no equipment, SP, FG). In the no-equipment condition, the head was in an "in-line" neutral position, with the lateral canthus of the eye and superior aspect of the ear defining a line perpendicular to the horizon.[3] In the SP and FG conditions, each participant was placed supine on the spine

Figure 1. Measurement of space available for the spinal cord in the following 3 conditions: A, Full gear; B, Shoulder pads only; and C, No equipment.

board with the head and neck in an in-line neutral position.[21] The spine board and helmet were modified to contain no metal parts to prevent the creation of "noise" in the MRI scanner. A T1-weighted MRI scan was completed using a Hitachi AIRIS II (Hitachi Ltd, Tokyo, Japan), 0.3 T, with cervical coil for each condition. The MRI scans were assessed midsagittally by a radiologist to determine SAC and CTA. The spinal cord had an intraclass correlation coefficient (ICC) (3,1) (standard error of
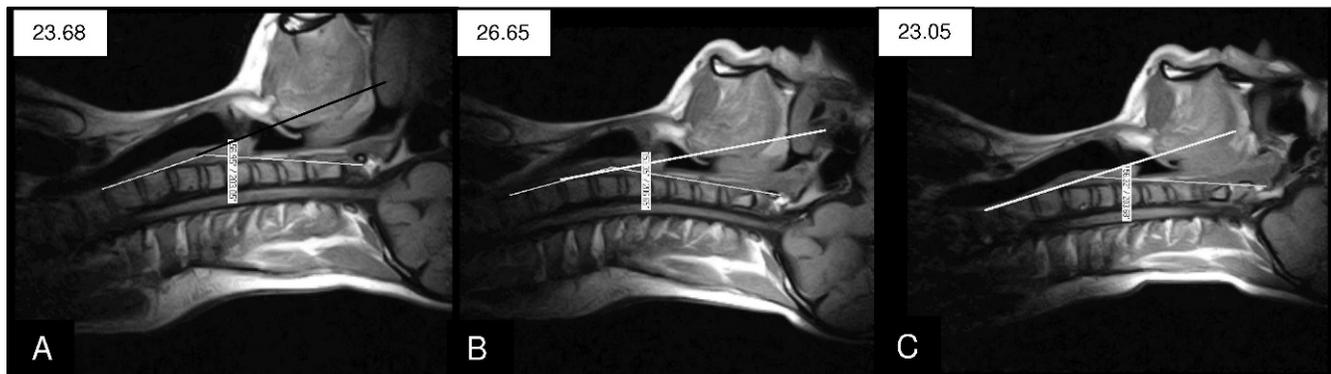
Figure 2. Measurement of cervical-thoracic angle in the following 3 conditions: A, Full gear; B, Shoulder pads only; and C, No equipment.

measurement) of 0.984 (0.059); the vertebral canal, an ICC (3,1) of 0.925 (0.124); and the CTA, an ICC (3,1) of 0.910 (0.935). The radiologist was blinded to the conditions being measured. The average of 3 measures was used as the criterion measure.

Statistical Analysis

We used a 3 (condition) × 5 (cervical level) analysis of variance (ANOVA) with repeated measures on both factors to determine differences in SAC. A 1-way repeated-measures ANOVA was used to assess differences in CTA across the 3 conditions. The Mauchly test of sphericity was used to identify if the data violated this assumption. If findings were significant, we used Greenhouse-Geiser statistical data. Post hoc paired t tests with Bonferroni correction were used when appropriate. The α level was set a priori at .05. Data were analyzed using descriptive and inferential statistics using SPSS (version 15.0; SPSS Inc, Chicago, IL). Power was calculated as part of the statistical analysis of the data.

RESULTS

The SAC and CTA means and SDs are presented in the Table. The ANOVA revealed no condition × cervical level interaction effect ($F_{3.7,72} = 1.34$, $P = .279$) or condition main effect ($F_{2,18} = 1.20$, $P = .325$; $1 - β = 0.229$) for SAC. The 1-way ANOVA revealed a main effect ($F_{2,18} = 21.48$, $P < .001$) for CTA. Post hoc tests (critical $P = .0167$) indicated the CTA was greater (more extension) in the SP than in the no-equipment ($t_9 = 7.67$, $P < .001$) or FG ($t_9 = 4.80$, $P = .001$) conditions. We found no difference in CTA between the no-equipment and FG conditions ($t_9 = 1.10$, $P = .301$; $1 - β = 0.134$).

DISCUSSION

To our knowledge, we are the first to investigate SAC and CTA in the immobilized lacrosse athlete. Our results supported our hypotheses and indicated that immobilizing the lacrosse athlete wearing only shoulder pads affected cervical alignment but did not affect spinal cord space. Because the alignment changes were small and in the midranges of cervical motion, cord size and space remained virtually unchanged. This indicated that immobilizing the lacrosse athlete in shoulder pads and no helmet (if the helmet was removed to access the airway) may not have detrimental effects on the spinal cord when the athlete is immobilized. However, we cannot generalize our findings to an immobilized athlete with an injured, unstable cervical spine.

The design of lacrosse helmets differs from the designs of football and ice hockey helmets and differs within the sport of lacrosse itself. Researchers have suggested that removing the lacrosse helmet rather than the face mask to achieve airway access is faster and produces less movement in the cervical spine.[19] This is contrary to current emergency equipment-removal guidelines[8,9,11] that are based on research involving football and hockey helmets.[3,4,6,16] Unlike football and hockey helmets, some lacrosse helmet models (eg, Brine, Riddell, Cascade,[a] and Warrior[b]) have small brims that do not allow the face mask to be tilted up after cutting the side clips (not the recommended way to access the airway). In these models, the face mask must be removed by cutting clips on or under the brim and by unscrewing the chin guard that is attached to the helmet by metal screws.[22] Investigators[23,24] have shown that without proper maintenance of the screws attaching the face mask to football helmets, these screws are sometimes rusted and impossible to remove. Other lacrosse helmets have face masks with hidden clips (eg, deBeer/Gait[c]) or chin guards (Cascade, Gait[c]) that must be cut, making the face mask difficult to remove.[22] Because of the apparent difficulties in lacrosse face mask removal,[19] studying unique emergency-

Table. Space Available for the Spinal Cord and Cervical-Thoracic Angle (Mean ± SD)

| Condition | Space Available for the Spinal Cord, mm | | | | | Cervical-Thoracic Angle, ° |
	C3	C4	C5	C6	C7	
No equipment	5.61 ± 2.1	4.59 ± 1.1	4.91 ± 1.3	4.85 ± 1.4	5.23 ± 1.3	25.34 ± 2.6
Shoulder pads only	4.78 ± 1.4	4.50 ± 1.7	4.64 ± 1.3	4.26 ± 0.9	5.29 ± 1.5	32.64 ± 3.6
Full gear	4.94 ± 1.9	4.87 ± 1.1	4.16 ± 0.9	4.62 ± 1.3	4.52 ± 1.7	26.81 ± 5.1

care guidelines for lacrosse athletes seems prudent. Our results indicated that if the helmet must be removed to access the airway, immobilizing the lacrosse athlete in only shoulder pads may be a safe alterative, because when immobilized, the athlete's spinal cord space is not substantially diminished.

Data and research on CTA and SAC in the cervical spine with regard to the immobilized lacrosse athlete are limited. To date, only Sherbondy et al[15] have investigated sagittal-plane CTA in the immobilized lacrosse athlete. The authors reported that the effect of protective lacrosse equipment on sagittal-plane cervical spine alignment was different from the effects reported with football and ice hockey equipment. They reported that immobilizing the lacrosse athlete after helmet removal resulted in 4.7° of cervical flexion (referencing the occiput and C2) and 0.9° of extension (referencing C2 and C7). This is in contrast to the cervical extension found by other researchers[4,6,10,14,16] investigating cervical spine position in immobilized ice hockey and football athletes with shoulder pads and no helmet. In our study, helmet removal resulted in 5.8° more extension in CTA, compared with the FG condition. The difference in study findings may be due to the design of the helmets used. The Riddell lacrosse helmet used in our study is shaped similar to a football helmet, covering more of the occipital region than the Cascade C2 used by Sherbondy et al.[15] In our study, increased extension versus flexion is consistent with the results found in football and ice hockey studies.[4,6,10,11,14,16] The presence of both the helmet and shoulder pads compared with the no-equipment condition caused an increase in cervical spine extension of 1.5°, approximately 3° less than what was previously noted[15] in lacrosse athletes. Although some of our findings of alignment changes were significant, they may not have much clinical importance based on the spinal cord response in the uninjured cervical spine. We caution readers that these comparisons are based on a single helmet-and-shoulder pad combination in both studies.

Changes in head and cervical spine position (eg, extreme flexion or extension) can result in changes in spinal cord cross-sectional area. When the cervical spine moves from full extension to full flexion, the spinal cord changes shape, and the total cross-sectional area decreases.[17,18] This change in cross-sectional area is consistent with the Poisson effect: "any increase in cross-sectional area with a decrease in length, or vice versa, results in the total volume remaining the same."[17(p185)] Most of the cross-sectional area change occurs near the end ranges of motion,[17,18] possibly explaining why an increase in the midranges of cervical motion yielded no change in SAC in our study. This result also indicates that small head and cervical position changes may not adversely influence the spinal cord.

Our findings cannot provide evidence of the quantity or quality of cervical motion occurring during lacrosse helmet removal.[11,12,19] Most of the research in this area has been performed using football or hockey equipment. Previous cadaver research[11] using fluoroscopy demonstrated that flexion occurs during football helmet removal in uninjured (5.5°) and unstable (9.3°) cervical spines. Significant findings[25] of alterations in the position of adjacent cervical vertebrae have been noted during helmet removal, cervical collar application, and head rest using fluoroscopy in participants wearing hockey and football equipment. Researchers[11,12,25] have also noted that helmet removal resulted in increased cervical traction, which may be harmful in the unstable cervical spine. In research involving human controls, investigators[12] noted no changes in the angulation, disc height, or SAC in the uninjured cervical spine with helmet removal when following the National Athletic Trainers' Association protocol for helmet removal.

Recommendations for prehospital care of the athlete with a spine injury have been developed and are largely based on the research involving the football athlete, but they apply to all sports.[9] The general recommendation is to leave all equipment on when taking care of an athlete with a suspected spine injury, but equipment can be removed (1) if the face mask cannot be removed quickly enough to allow airway access; (2) if the helmet, chin strap, or chin guard does not allow for adequate airway control or ventilation even after the face mask has been removed; (3) if the head is not held securely within the helmet, such that immobilization of the helmet does not secure the head; and (4) if the helmet prevents immobilization for transport in a certain position.[9]

With regard to the third criterion for equipment removal, researchers have found that the cervical spine was better stabilized in the immobilized lacrosse athlete with the helmet removed because the athlete could move his or her head inside the lacrosse helmet. Total sagittal-plane movement (flexion-extension) of the cervical spine in an immobilized athlete was found[26] to increase in the properly (9.5°) and improperly (11.4°) fitted helmet condition compared with the no-helmet condition (5.7°). Helmets have been improved to protect the head from injury over the past decades, but these improvements have potentially made securing an athlete properly to a spine board more difficult.[27]

According to investigators,[9,12] the helmet and shoulder pads can be removed safely by following the prescribed guidelines that allow the helmet to be removed with minimal cervical flexion or extension. How much motion is deleterious in a potentially injured cervical spine is unknown, yet the chance of small changes in cervical spine position while the patient is immobilized may move clinicians away from efficient airway access methods in the lacrosse athlete. The rationale for removing all protective equipment is to prevent further neurologic injury by keeping the spine in a neutral position and by not moving the unstable cervical spine into excessive extension.[4,6–12,14–16] This may be prudent in football, as research[4,6,14,16] has indicated approximately a 10° increase in cervical extension when immobilizing the athlete without the helmet. Because of equipment structure, helmet removal to achieve airway access in lacrosse may be an option, as the small amount of cervical spine alignment change exhibited by immobilized participants in our study did not affect cervical SAC.

Limitations

Although our results indicated that spinal cord space was not diminished in immobilized healthy participants, they cannot be applied to athletes immobilized with injured, unstable cervical spines. We investigated SAC and CTA in the sagittal plane only; we did not make

volume or coronal-plane measurements. We did not investigate the motion that occurred during helmet removal. We do not know if lacrosse helmet removal would cause harmful cervical spine motion or SAC changes in healthy or injured athletes. We only used 1 type of helmet and shoulder pads for this study for consistency among participants. Numerous other types of lacrosse helmets and shoulder pads and combinations thereof may change head and thorax position and result in different SAC and CTA measures, as was seen when comparing our study and the study of Sherbondy et al.[15] The results of these studies only pertain to the equipment used in the studies and should not be applied to all the combinations of lacrosse equipment available on the market today.

CONCLUSIONS

The goal of sports medicine professionals is to manage prehospital emergency situations so that no iatrogenic injury occurs to the athlete. We recommend that if the face mask can be removed without difficulty to access the airway, then the helmet and shoulder pads should be left on to transport an athlete. Our results indicated that when removing the face mask is difficult or impossible, immobilizing the athlete with the helmet removed only causes small changes in CTA, which minimally affect the cervical SAC. Although more research is needed, our findings may be used to help create unique guidelines for appropriate emergency care for the lacrosse athlete.

ACKNOWLEDGMENTS

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Address correspondence to Michael Higgins, PhD, PT, ATC, CSCS, Department of Kinesiology, Towson University, 8000 York Road, Towson, MD 21252. Address e-mail to mhiggins@towson.edu.