

# The Effect of Protective Football Equipment on Alignment of the Injured Cervical Spine Radiographic Analysis in a Cadaveric Model

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The Effect of Protective Football Equipment on Alignment of the Injured Cervical Spine  
Radiographic Analysis in a Cadaveric Model

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**No universally accepted management protocol is available for dealing with the protective equipment worn by a neck-injured football player. The purpose of this cadaveric study was to determine the effects of the helmet and shoulder pads on the alignment of 1) the intact lower cervical spine and 2) the partially destabilized C5-6 motion segment. In Group I cadavers ( N = 15), the lower cervical spine was tested in an intact condition. In Group II ( N = 8), the C5-6 motion segment was tested in both an intact and a partially destabilized condition. Each cadaver was placed supine on a backboard and four lateral cervical radiographs were obtained as follows: no protective equipment, helmet only, helmet and shoulder pads, and shoulder pads only. Results for Group I showed that wearing both helmet and shoulder pads did not result in a significant change in cervical lordosis when compared with the neutral position (i.e., the no-equipment test). Cervical lordosis was significantly decreased in the helmet-only category (mean, 9.6°) and significantly increased in the shoulder pads-only category (mean, 13.6°). In Group II, destabilized specimens under the helmet test situation showed a significant mean increase in C5-6 forward angulation (16.5°), posterior disk space height (3.8 mm), and dorsal element distraction (8.3 mm). Immobilizing the neck-injured football player with only the helmet or only the shoulder pads in place violates the principle of splinting the cervical spine in neutral alignment, according to our findings. We support the concept that removal of the helmet and shoulder pads should be an all-or-none proposition.**

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On-site management of the neck-injured football player differs from that of a typical traumatic cervical spine injury where standard procedure dictates that the patient be positioned supine on a straight backboard with the head and neck secured in neutral alignment using straps and laterally placed sandbags.<sup>[2] [31]</sup> The protective helmet and shoulder pads worn by the athlete complicate the immobilization process and require special consideration. In this regard, there has been considerable debate over the removal of equipment during on-field management. Specifically, the issue of helmet removal has generated considerable controversy. Emergency medical personnel generally follow established local protocol that, in some parts of the United States, requires helmet removal as part of the immobilization and extrication of trauma victims with presumed cervical spine injury.<sup>[8] [18] [19] [30]</sup> One proposed reason for removal of protective head gear is potential hyperflexion of the cervical spine caused by the helmet.<sup>[30]</sup>

Despite the established emergency medical technician protocols, sports medicine professionals almost universally discourage removing the football helmet when cervical spine injury is suspected.<sup>[11] [13] [14] [26] [30] [39] [40]</sup> The primary rationale for leaving the helmet in place is to prevent neurologic injury. Disagreeing with the emergency medical technician claim that helmets cause neck hyperflexion, Feld and Blanc<sup>[14]</sup> and Segan et al.<sup>[30]</sup> assert that the shoulder pads elevate the torso such that the cervical spine remains in a neutral position when the helmet is in place. Further review of the literature reveals

no experimental quantification of the effect of protective football equipment on the alignment of a normal or injured cervical spine.

The purpose of this cadaveric study was to determine the effect of protective football equipment on the alignment of 1) the intact lower cervical spine and 2) the partially destabilized C5-6 motion segment.

## METHODS

Fifteen intact, fresh-frozen human cadavers were used for the experiment. The group consisted of nine men and six women with an age range of 62 to 90 years (average, 75). Cadaveric height averaged 174 cm (range, 160 to 193). All specimens were stored in sealed plastic bags at -20°C and then thawed at room temperature for approximately 12 to 18 hours on the day of testing. The cervical spines were screened for tumor, prior surgery, and preexisting fracture using plain lateral radiographs. Kyphotic deformity of the thoracic spine was also considered an exclusion criterion.

The cadavers were separated into two study populations. Group I included all 15 specimens. In this group, the lower cervical spine was tested in an intact condition. Group II consisted of an eight-member subset of the Group I specimens. Cadavers were selected for Group II based on the paucity of degenerative changes at the C5-6 intervertebral space. The system designed by Gore et al. <sup>[16]</sup> to grade cervical spondylosis on a standard lateral radiograph was used. Specimens with scores of 2 or 3 (i.e., 2, 50% narrowing of the disk space, moderate or severe vertebral body end plate sclerosis, and the presence of moderate or large osteophytes; 3, 75%, narrowing of the disk space, severe vertebral body end plate sclerosis and large osteophytes) were excluded. In this second group, the C5-6 motion segment was tested in both an intact and a two-column, partially destabilized condition.

### *Testing Procedure*

*Group I (Intact Cervical Spine Specimens).* Each cadaver was placed supine on a standard full-length spineboard. Lateral cervical spine radiographs were obtained with the football gear applied as follows: 1) no protective equipment, 2) helmet only, 3) helmet and shoulder pads, and 4) shoulder pads only. All radiographs were taken by the same certified radiology technician using a stationary grid and a plate focal distance of 40 inches.

The helmet (Riddell-Model WD1, Riddell Helmet Co., Elvria, Ohio) and shoulder pads (Riddell-Warrior II Model) were sized and applied to each cadaver by a certified athletic trainer experienced in this task. A medium shell (head circumference, 6 5/8 to 7 1/8 inches) and a large shell helmet (head circumference, 7 1/4 to 7 3/4 inches) were available along with small (chest size, 34 to 36 inches) and large (chest size, 42 to 44 inches) shoulder pads. The helmet that provided the best fit for each specimen was secured in position with a chin strap. The shoulder pads, sectioned such that only the posterior half was maintained, were applied to the dorsal thorax. This equipment modification was necessary to prevent obstruction of the lower cervical spine on lateral radiographs.

*Group II (Destabilized Motion Segment Specimens).* Each cadaver was first studied in an intact condition before any stabilizing structures were disrupted. Four lateral cervical spine radiographs were obtained under the following test situations: no equipment, helmet only, helmet and shoulder pads, and shoulder pads only. These radiographs, which were taken in the exact manner as for the Group I specimens, served as baseline controls.

The cervical spine was then partially destabilized at the C5-6 intervertebral level to simulate a distractive-flexion stage 3 injury according to the classification of Allen et al. <sup>[1]</sup> The posterior elements of the C-2 through C-7 vertebrae were exposed through a standard midline approach. At the C5-6 level a scalpel was used to section the supraspinous and interspinous ligaments, ligamentum flavum, facet capsules, intertransverse ligaments, posterior longitudinal ligament, and the posterior half of the anulus fibrosus. The anterior longitudinal ligament was left intact and was not stripped off the vertebral bodies. The same experimenter performed all the destabilization procedures.

With the ligaments cut, the neck was then flexed forward until marked distraction was observed in the C5-6 posterior elements. This maneuver was performed to confirm instability and to mimic the clinical situation in which there is plastic deformation of the surrounding posterior

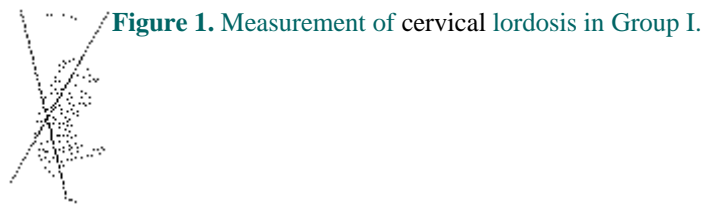
ligamentous and muscular structures. The forced forward flexion also generally resulted in further disruption of the ventral half of the intervertebral disk. To avoid disruption of the anterior longitudinal ligament, no attempt was made to either translate the C-5 vertebral body anteriorly or to jump the inferior facets in front of the superior articular processes. The deep fascia and skin were then reapproximated with a running nylon suture. This model represents a two-column cervical injury with the C5-6 motion segment rendered unstable according to the criteria of White et al. <sup>[41]</sup> <sup>[42]</sup>

Lastly, we rolled the cadaver back into a supine position on the backboard. A second set of four lateral cervical spine radiographs was obtained under identical test situations using the same technique as in the initial baseline set.

### *Radiographic Analysis*

Every radiograph in the study was analyzed independently by two orthopaedic surgeons. For each radiographic parameter studied in Group I (cervical lordosis) and in Group II (C5-6 angular displacement, posterior element distraction, disk space height, and sagittal plane translation), the two independent measurements were averaged. Blind radiographic interpretation was not possible because of the appearance of the protective equipment on the radiographs.

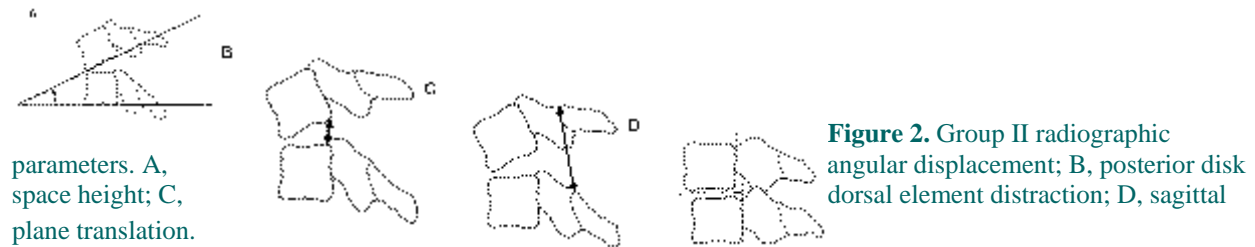
*Group I.* Cervical lordosis was measured by the method of Gore et al. <sup>[16]</sup> as the angle formed by lines projected parallel to the posterior surface of the C-2 and C-6 vertebral bodies (Fig. 1). The sagittal plane alignment of the



lower cervical spine was considered neutral on the radiograph obtained with no protective equipment in place. This assumption was made because this is the standard position of immobilization for patients with a suspected cervical spine injury. The degree of angulation in this neutral position was used to calculate the change in cervical lordosis caused by the three different football equipment combinations (i.e., helmet only, helmet and shoulder pads, and shoulder pads only). Decreased lordosis (i.e., forward sagittal plane rotation) was assigned a negative value; a positive value indicates increased lordosis.

*Group II.* Angular displacement of the C5-6 motion segment was measured according to the method described by Johnson et al. <sup>[20]</sup> (Fig. 2A). In cases where the lines intersected off the

radiograph, the resultant angle was determined using the method of Cobb.<sup>191</sup> To estimate elongation of the neural axis, posterior disk space height and dorsal element distraction were measured. We defined disk height as the distance separating the posterior inferior lip of the C-5 vertebral body from the posterior superior corner of the C-6 body (Fig. 2B). Distraction of the dorsal elements was determined by measuring the distance



from the most cranial aspect of the C-5 spinolaminar line to the most cranial aspect of the C-6 spinolaminar line (Fig. 2C). Sagittal plane translation of the C-5 vertebra

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was measured according to the technique of Stokes and Frymoyer<sup>1331</sup> (Fig. 2D).

For all four parameters studied, the position of the C5-6 motion segment was considered neutral on the radiograph obtained with no protective equipment. Using the baseline measurement made in this neutral position, the change in each parameter caused by the three other equipment combinations was determined for both the intact and partially destabilized conditions of each cadaver. We then calculated the difference between the intact and partially destabilized condition for each radiographic parameter under all equipment combinations.

### *Statistical Analysis*

For each radiographic parameter studied, the differences in mean values for the four test situations were compared using the general linear models procedure of a one-way analysis of variance. A post hoc multiple comparison test (Duncan's multiple range test) was performed to rank the differences between subgroups. All calculations were made with SAS software (SAS Institute, Cary, North Carolina).

## RESULTS

### *Group I*

Cervical lordosis measured in the neutral position ranged from 3° to 65°. Mean sagittal plane angulation for the no protective equipment test situation was 26.8°, with a standard deviation of 18.2°. Mean measured lordosis (SD, range) for the other three test situations were as follows: 18.8° (17.6°, 2° to 60°) for helmet only, 31.6° (17.9°, 11° to 67°) for helmet and shoulder pads, and 41.7° (17.6°, 18° to 72°) for shoulder pads only.

**Table 1** summarizes the mean angular change in lordosis from neutral position for the three different equipment combinations. We did not include one specimen under the helmet-only situation and two specimens under the shoulder pads-only test situation in the analysis because of suboptimal radiographs. Mean angular change values were not significantly different for the no protective equipment and helmet and shoulder pads categories. A significant decrease in lordosis (i.e., increased forward angulation) was demonstrated for the helmet-only category when

**TABLE 1 -- Change in Cervical Lordosis Caused by Protective Football Equipment in Group I Cadavers (Mean ± SD and Range)**

Test situation	N	Angular change <sup>a</sup> (deg)	P value
Helmet only	14	-9.6 ± 4.7 (4 to -16)	≤0.0001
Helmet and shoulder pads	15	4.8 ± 5.0 (14 to -4)	
Shoulder pads	13	13.6 ± 6.3 (26 to 2)	≤0.0001

<sup>a</sup> Angular change in cervical lordosis with respect to neutral position.

it was compared with the no protective equipment ( $P < 0.0001$ ), helmet and shoulder pads ( $P < 0.0056$ ), and the shoulder pads-only ( $P < 0.0001$ ) categories. A significant increase in lordosis was demonstrated when the shoulder pads only category was compared with the no protective equipment ( $P < 0.0001$ ), helmet-only ( $P < 0.0001$ ), and helmet and shoulder pads ( $P < 0.0001$ ) categories.

### **Group II**

**Table 2** summarizes the mean values for each parameter under the four test situations of the intact C5-6 motion segment. There was no significant difference in any radiographic parameter when the three equipment categories were compared with each other and to the no protective equipment test situation (baseline).

**Table 3** summarizes mean values for each parameter for the partially destabilized C5-6 motion segment under the four test situations. A statistically significant increase in sagittal plane angulation, disk space height, and posterior element distraction were demonstrated when the helmet-only category was compared with no protective equipment ( $P < 0.0048$  for angulation,  $P < 0.0006$  for disk height, and  $P < 0.0053$  for distraction), helmet and shoulder pads ( $P < 0.0004$  for angulation,  $P < 0.0001$  for disk height, and  $P < 0.0006$  for distraction), and shoulder pads-

only ( $P < 0.0007$  for angulation,  $P < 0.0001$  for disk height, and  $P < 0.0002$  for distraction) categories.

Translation did not differ significantly for this set of test situation comparisons. No significant change in any parameter was present when the following test situations were compared: no protective equipment versus helmet and shoulder pads, no protective equipment versus shoulder pads only, and helmet and shoulder pads versus shoulder pads only (Table 3).

Table 4 summarizes the radiographic measurement differences between the intact and partially destabilized condition for each radiographic parameter under all test situations. Compared with the corresponding intact subgroup, the partially destabilized specimens tested with helmets only demonstrated a significant increase in angulation ( $P < 0.0127$ ), disk height ( $P < 0.0011$ ), and dorsal element distraction ( $P < 0.0068$ ). There was no significant change in translation between the intact and partially destabilized groups for the helmet-only category. No significant difference was demonstrated for any parameter between the intact and partially destabilized groups under the three other test situations (i.e., no protective equipment, helmet and shoulder pads, and shoulder pads-only categories).

The difference in radiographic measurements between the intact and partially destabilized condition of the helmet-only test situation differed significantly from the measurement change between the intact and partially destabilized condition of the three other test situations as follows: helmet only versus no protective equipment,  $P < 0.0001$  for angulation,  $P < 0.0004$  for disk height, and  $P < 0.0012$  for distraction; helmet only versus helmet and shoulder pads only,  $P < 0.0001$  for angulation and disk height,  $P < 0.0003$  for distraction; helmet only versus

**TABLE 2 -- Effect of Protective Football Equipment on the Intact C5-6 Motion Segment (  $N = 8$  )**

Test situation	Radiographic parameter <sup>a</sup>			
	Angulation (deg)	Disk height (mm)	Distraction (mm)	Translation (mm)
Neutral	-8.6 ± 8.0	1.6 ± 0.9	14.6 ± 2.6	-1.1 ± 0.6
	(-26 to -3)	(0 to 3)	(10 to 17)	(-2 to 0)
Helmet	-7.4 ± 7.5	1.8 ± 0.9	14.3 ± 3.1	-0.8 ± 0.6
	(-24 to 0)	(0 to 3)	(10 to 18)	(-2 to 0)
Helmet and shoulder pads	-11 ± 7.0	1.1 ± 0.6	12.5 ± 2.5	-1 ± 0.8
	(-25 to -4)	(0 to 2)	(9 to 15)	(-2 to 0)
Shoulder pads	-12.9 ± 6.1	0.5 ± 0.5	11.5 ± 2.4	-1.4 ± 0.9
	(-22 to -3)	(0 to 1)	(8 to 14)	(-2 to 0)

<sup>a</sup> Values expressed as mean ± SD (range).

<b>TABLE 3 -- Effect of Protective Football Equipment on the Partially Destabilized C5-6 Motion Segment</b>				
<b>Test situation</b>	<b>Radiographic parameter <sup>a</sup></b>			
	<b>Angulation (deg)</b>	<b>Disk height (mm)</b>	<b>Distraction (mm)</b>	<b>Translation (mm)</b>
Neutral	-7.3 ± 9.9	2.5 ± 1.2	15.9 ± 3.8	-2.1 ± 1.6
( N = 8)	(-27 to 2)	(0 to 4)	(10 to 20)	(-5 to 0)
Helmet	8.9 ± 14.5	5.5 ± 2.4	22.5 ± 6.7	-2.3 ± 1.6
( N = 8)	(-19 to 28)	(2 to 9)	(12 to 32)	(-4 to 0)
	<i>P</i> < 0.0048	<i>P</i> < 0.0006	<i>P</i> < 0.0053	NS
	-13 ± 7.4	1.4 ± 0.8	13.7 ± 2.4	-2 ± 1.4
Helmet and shoulder pads	(-25 to -3)	(0 to 2)	(10 to 16)	(-5 to -2)
( N = 7)	NS	NS	NS	NS
	-13 ± 6.7	0.8 ± 0.8	12.5 ± 2.1	-1.8 ± 0.8
Shoulder pads	(-24 to -5)	(0 to 2)	(9 to 15)	(-3 to -1)
( N = 6)	NS	NS	NS	NS

<sup>a</sup> Values expressed as mean ± SD (range). *P* values express differences when compared with no protective equipment. NS, no statistical difference.

shoulder pads, *P* < 0.0001 for angulation, disk height, and distraction. [Figure 3](#) demonstrates the alignment change between the intact and partially destabilized condition of a Group II cadaver under the helmet-only test situation.

## DISCUSSION

Football players are at increased risk of catastrophic neck trauma. From 1977 to 1987, 128 players sustained permanent cervical spinal cord damage.<sup>[7]</sup> An additional 20 to 25 cervical spine injuries occur each year without resulting in permanent neurologic sequelae.<sup>[23]</sup> The relative incidence of neck injuries is low and, as a result, on-site medical staff members are unlikely to have experience managing a cervical spine-injured football player. This creates a high-risk situation where improper handling of a compromised spinal column can lead to a significant neurologic insult or progressive deficit.

Management of the neck-injured football player begins on the field with proper positioning and immobilization of the cervical spine. Immobilization of the neck in neutral position restricts movement of the unstable vertebral column in an effort to prevent damage to the enclosed spinal cord and nerve roots. Flexion or extension posturing of the traumatized neck may result in cord deformation and elongation of the neural axis. Abnormal intervertebral motion, even as little as 1 mm, may cause significant neurologic damage.<sup>[2]</sup> This is especially true in the subaxial cervical spine. In this region, the cord demonstrates an exceptional intolerance of even small amounts of segmental elongation or deformation<sup>[21] [24] [32] [38]</sup> and can lead to further neurologic injury in the athlete in whom the spinal cord and osseoligamentous structures are already compromised.

This potential for the onset or worsening of a neurologic deficit due to improper handling is more than a theoretical concern. Experimental evidence demonstrates both the detrimental effect of continued compression<sup>[15]</sup> and the protective effect of immediate immobilization on the injured spinal cord.<sup>[12]</sup> Clinically, it has been estimated that up to 25% of spinal cord injuries occur after the initial traumatic event either in transport or during the early phase of treatment.<sup>[28]</sup> Although secondary neurologic injury is probably less likely in the relatively controlled setting of an organized football game or practice, the need for proper positioning and immobilization of the injured cervical spine is obvious.

The C5-6 motion segment was selected for study in Group II because the majority of football-related cervical spine injuries involve the vertebrae from C-5 to C-7.<sup>[37]</sup> Secondly, the C6-7 level is usually difficult to visualize on lateral radiographs of the neck because of the overlying shadow of the shoulders.

The choice of the destabilization technique in Group II was based on several factors. From a practical standpoint, the distractive flexion injury was relatively easy to re-create

**TABLE 4 -- Difference in Radiographic Measurements Between Intact and Partially Destabilized C5-6 Motion Segment**

Test situation	Radiographic parameter <sup>a</sup>			
	Angulation (deg)	Disk height (mm)	Distraction (mm)	Translation (mm)
Neutral	1.4 ± 3.7	0.9 ± 1.1	2.5 ± 2.1	-1 ± 1.4
(N = 8)	(-4 to 6)	(0 to 2)	(0 to 6)	(-4 to 0)
Helmet	16.5 ± 8.6	3.8 ± 2.3	8.3 ± 5.4	-1.4 ± 1.8
(N = 8)	(5 to 28)	(1 to 7)	(2 to 15)	(-4 to 2)
	<i>P</i> < 0.0001	<i>P</i> < 0.0004	<i>P</i> < 0.0012	NS
	-1 ± 3.1	0.4 ± 0.8	1.4 ± 1.1	-0.9 ± 1.7

**TABLE 4 -- Difference in Radiographic Measurements Between Intact and Partially Destabilized C5-6 Motion Segment**

Test situation	Radiographic parameter <sup>a</sup>			
	Angulation (deg)	Disk height (mm)	Distraction (mm)	Translation (mm)
Helmet and shoulder pads	(-7 to 2)	(-1 to 1)	(0 to 3)	(-4 to 1)
( N = 7)	NS	NS	NS	NS
	-0.3 ± 1.5	0.3 ± 0.5	0.5 ± 1.2	-0.5 ± 1.0
Shoulder pads	(-2 to 1)	(0 to 1)	(-1 to 2)	(-2 to 1)
( N = 6)	NS	NS	NS	NS

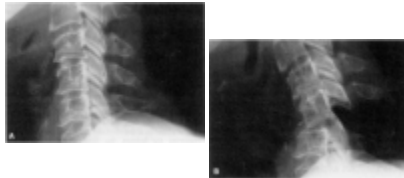
<sup>a</sup> Values expressed as mean ± SD (range). *P* values express difference when compared with no protective equipment. NS, no statistical difference.

in a consistent manner because of its purely ligamentous nature. This specific pattern of injury has been confirmed as a useful model in multiple biomechanical studies of cervical instability. <sup>[10]</sup> <sup>[21]</sup> <sup>[34]</sup> Although the compressive-flexion or the vertical-compression injury patterns may have better approximated the most common football-induced injury mechanism of axial load, <sup>[35]</sup> <sup>[36]</sup> the associated vertebral body fractures would have been difficult to accurately reproduce and analyze. Furthermore, it has been demonstrated clinically <sup>[35]</sup> <sup>[36]</sup> and experimentally <sup>[5]</sup> <sup>[17]</sup> <sup>[22]</sup> <sup>[29]</sup> that when maximal vertical compression is reached, the straightened cervical spine often fails when flexed. This failure disrupts the posterior elements under tension and can produce a bilateral facet dislocation (i.e., a distractive-flexion, stage 3 injury).

The living patient with a traumatized cervical spine cannot be represented in a completely adequate fashion by a cadaver. Muscular tone or spasm may provide a splinting effect after acute neck injury in an awake person. Although not accounted for in our model, it is unlikely that paraspinal muscle action can significantly alter cervical alignment. We believe that in the setting of a destabilized spinal column, the cervical muscles cannot be relied on to prevent intersegmental displacement. In fact, the neck muscles in an unconscious athlete may not even be in protective spasm. <sup>[4]</sup> Biomechanical studies <sup>[25]</sup> <sup>[41]</sup> and clinical observations <sup>[27]</sup> support the concept that cervical stability is provided predominantly by the osseoligamentous complex with the musculature playing a relatively minor role.

In addition, there are definite physiologic differences between artificially transecting spinal ligaments in an in vitro experiment and clinical failure of the spine secondary to trauma. In particular, traumatic spinal column injuries are accompanied by plastic deformation of the surrounding ligamentous and muscular structures. We attempted to reproduce this type of soft-tissue deformation in our injury model by forcefully flexing the neck after division of the cervical ligaments and intervertebral disk at the C5-6 level. Second, the destabilization technique did not exactly re-create a true distractive-flexion, stage 3 injury. In a typical traumatic bilateral

facet dislocation, the anterior longitudinal ligament is partially stripped off the anterior surface of the vertebral bodies.<sup>16</sup> Our injury model did not incorporate this component of the pathologic anatomy because, on preliminary testing, it was impossible to consistently strip the ligament without disrupting its substance and without creating a three-column injury.



**Figure 3.** Lateral cervical radiographs of a Group II cadaver under the helmet only test situation. A, intact condition; B, partially destabilized condition.

Adherence of the anterior longitudinal ligament to the vertebral bodies was the probable reason for the lack of forward C-5 translation in the destabilized Group II specimens under the helmet-only test situation. It is likely, therefore, that our model underestimates the magnitude of intersegmental displacement and associated cord deformation caused by helmet-only positioning.

This study analyzed only a single pattern of lower cervical spine injury. All types of mechanisms (compressive flexion, vertical compression, distractive flexion, compressive extension, distractive extension, and lateral flexion), with each causing a spectrum of anatomic damage, can produce significant neck injury in football. The Group II results are only applicable to the distractive-flexion, stage 3 lesion. However, from the Group I data the effect of each equipment combination on the various injury patterns can be extrapolated. For example, positioning a football player with a severe distractive (or compressive) extension-type cervical injury on a backboard with only the shoulder pads applied would likely re-create the extension component of the injurious force and dangerously deform the spinal cord. Likewise, helmet-only positioning would probably be detrimental to the athlete with a compressive flexion or vertical compression pattern of injury.

The plain radiographic technique used in this study provides a measure of intervertebral displacement at only a specific time. It is possible that during the process of removing each piece of equipment, transient displacements occurred in excess of those measured at the final neck resting position. Thus, our methods also may underestimate the magnitude of motion segment displacement caused by the equipment removal process.

Our experimental results indicate that immobilizing the neck-injured football player with only the helmet (or only the shoulder pads) in place violates the principle of splinting the cervical spine in neutral alignment. In Group I, with both pieces of equipment in place, the shoulder pad thickness offsets that of the helmet maintaining neutral neck alignment. If the shoulder pads are removed without removing the helmet, the head translates anteriorly, thereby flexing the cervical spine. In the setting of helmet removal with shoulder pads applied, the elevated thorax allows the head to fall posteriorly, causing cervical extension. The findings in Group II concur with those of Group I and can be explained in the same way. The only difference in results was the lack of C5-

6 hyperextension in Group II under the shoulder pads-only test situation. We thought this discrepancy was due to the experimental injury model. The destabilization procedure created a distractive-flexion type injury that left the anterior longitudinal ligament intact. The checkrein effect of this ligament prevented C5-6 extension in the shoulder pads-only test situation.

## CONCLUSIONS AND RECOMMENDATIONS

Immobilizing the cervical spine of a football player must account for the effect of each piece of equipment on the relative position of the head and torso. We recommend that the neck-injured player without evidence of cardiorespiratory compromise should be immobilized on the field with both helmet and shoulder pads in place. If access to the face becomes necessary to maintain the airway or initiate rescue breathing, only the face mask should be removed. These recommendations agree with those found in the majority of the sports medicine literature on this topic. <sup>[11] [13] [14] [26] [30] [39] [40]</sup>

Equipment removal becomes a crucial issue when a football player with a potential cervical spine injury goes into cardiac arrest, necessitating cardiopulmonary resuscitation. For this rare clinical scenario, Segan et al. <sup>[30]</sup> advise leaving the protective gear in place. In their study, after face mask removal, they were able to provide sufficient respiration and adequate chest compressions on cardiopulmonary resuscitation mannequins equipped with helmets and shoulder pads. Although Segan et al. maintained the cervical spine in neutral alignment, there is no documentation of the efficacy of this resuscitation technique on human subjects. Vegso and coworkers <sup>[39] [40]</sup> advocate removing the face mask and shoulder pads while leaving the helmet in place. Despite providing full access for resuscitative efforts, this helmet-only positioning has the potential to hyperflex the injured cervical column. Other authors do not offer specific guidelines regarding the shoulder pads. <sup>[2] [3] [8]</sup>

We support the concept that removing the helmet and shoulder pads is an all-or-none proposition. <sup>[13] [14]</sup> In the critically injured player requiring cardiopulmonary resuscitation, both pieces of protective gear should be removed. This provides unobstructed access to the airway and thorax for resuscitation while maintaining neutral alignment of the cervical spine. The proper technique for removal of football equipment has been described in detail by Patel and Rund <sup>[26]</sup> and Feld. <sup>[13]</sup> This protocol is also recommended for removing equipment from any neck-injured football player who arrives at the emergency department with helmet and shoulder pads in place.

## REFERENCES

1. Allen BL Jr, Ferguson RL, Lehmann TR, et al: A mechanistic classification of closed, indirect fractures and dislocations of the lower cervical spine. *Spine* 7: 1-27, 1982
2. American Academy of Orthopaedic Surgeons, Committee on Allied Health: *Emergency Care and Transportation of the Sick and Injured*. Fifth edition. Chicago, American Academy of Orthopaedic Surgeons, 1987
3. American College of Surgeons, Committee on Trauma: Techniques of helmet removal from injured patients. *Bull Am Coll Surgeons* 65: 19-21, 1980
4. Anderson C: Neck injuries--backboard, bench or return to play. *Physician Sportsmed* 21: 23-34, 1993

5. Bauze RJ, Ardran GM: Experimental production of forward dislocation in the human cervical spine. *J Bone Joint Surg 60B*: 239-245, 1978
  6. Bucholz RW: Lower cervical spine injuries, in Browner BD, Jupiter JB, Levime AM, et al (eds): *Skeletal Trauma*. Philadelphia, WB Saunders Co, 1992, p 719
  7. Cantu RC, Mueller FO: Catastrophic spine injuries in football (1977-1989). *J Spinal Disord 3*: 227-231, 1990
  8. Caroline NL: *Emergency Medical Treatment. A Text for EMT-As and EMT-Intermediates*. Third edition. Boston, Little, Brown and Co, 1991, pp 285-288
  9. Cobb JR: Outline for the study of scoliosis. *Instr Course Lect 5*: 261-275, 1948
  10. Coe JD, Warden KE, Sutterlin CE III, et al: Biomechanical evaluation of cervical spine stabilization methods in a human cadaveric model. *Spine 14*: 1122-1131, 1989
- 

11. Denegar CR, Saliba E: On the field management of the potentially cervical spine injured football player. *Athl Train 24*: 108-111, 1989
12. Ducker TB, Salzman M, Daniell HB: Experimental spinal cord trauma. III. Therapeutic effect of immobilization and pharmacologic agents. *Surg Neurol 10*: 71-76, 1978
13. Feld F: Management of the critically injured football player. *J Athl Train 28*: 206-212, 1993
14. Feld F, Blanc R: Immobilizing the spine-injured football player. *J Emerg Med Serv 12*: 38-40, 1987
15. Gooding MR, Wilson CB, Hoff JT: Experimental cervical myelopathy--Effects of ischemia and compression on the canine spinal cord. *J Neurosurg 43*: 9-17, 1975
16. Gore DR, Sepic SB, Gardner GM: Roentgenographic findings of the cervical spine in asymptomatic people. *Spine 11*: 521-524, 1986
17. Gosch HH, Gooding E, Schneider RC: An experimental study of cervical spine and cord injuries. *J Trauma 12*: 570-576, 1972
18. Grant H, Murray R, Bergeron D: *Brady Emergency Care*. Fifth edition. Englewood Cliffs, NJ, Prentice Hall, 1990, pp 306-307
19. Haffen BQ, Karren KJ: *Prehospital Emergency Care and Crisis Intervention*. Fourth edition. Englewood Cliffs, NJ, Prentice Hall, 1992, pp 285-288
20. Johnson RM, Hart DL, Simmons EF, et al: Cervical orthoses--A study comparing their effectiveness in restricting cervical motion in normal subjects. *J Bone Joint Surg 59A*: 332-339, 1977
21. McLain RF, Aretakis A, Moseley TA, et al: Sub-axial cervical dissociation: Anatomic and biomechanical principles of stabilization. *Spine 19*: 653-659, 1994

22. Mertz HJ, Hodgson VR, Thomas LM, et al: An assessment of compressive neck loads under injury-producing conditions. *Physician Sportsmed* 6(11): 95-106, 1978
23. Mueller FO, Blyth CS, Cantu RC: Catastrophic spine injuries in football. *Physician Sportsmed* 17(10): 51-53, 1989
24. Owen JH, Naito M, Bridwell KH: Relationship among level of distraction, evoked potentials, spinal cord ischemia and integrity, and clinical status in animals. *Spine* 15: 852-857, 1990
25. Panjabi MM, White AA, Johnson RM: Cervical spine mechanics as a function of transection of components. *J Biomech* 8: 327-336, 1975
26. Patel MN, Rund DA: Emergency removal of football helmets. *Physician Sportsmed* 22(9): 57-59, 1994
27. Perry J, Nickel VL: Total cervical-spine fusion for neck paralysis. *J Bone Joint Surg* 41A: 37-60, 1959
28. Podolsky S, Baraff LJ, Simon RR, et al: Efficacy of cervical spine immobilization methods. *J Trauma* 23: 461-465, 1983
29. Sances AJ Jr, Myklebust JB, Maiman DJ, et al: The biomechanics of spinal injuries. *Crit Rev Biomed Eng* 11: 1-76, 1984
30. Segan RD, Cassidy C, Bentkowski J: A discussion of the issue of football helmet removal in suspected cervical spine injuries. *J Athl Train* 28: 294-305, 1993
31. Soderstrom CA, Brumback RJ: Early care of the patient with cervical spine injury. *Orthop Clin North Am* 17: 3-13, 1986
32. Stern WE, Rand RW: Birth injuries to the spinal cord. *Am J Obstet Gynecol* 78: 498-512, 1959
33. Stokes IAF, Frymoyer JW: Segmental motion and instability. *Spine* 12: 688-691, 1987
34. Sutterlin CE II, McAfee PC, Warden KE, et al: A biomechanical evaluation of cervical spine stabilization methods in a bovine model. *Spine* 13: 795-802, 1988
35. Torg JS, Vegso JJ, O'Neill MJ, et al: The epidemiologic, pathologic, biomechanical, and cinematographic analysis of football-induced cervical spine trauma. *Am J Sports Med* 18: 50-57, 1990
36. Torg JS, Vegso JJ, Sennet B, et al: The National Football Head and Neck Registry--14-year report on cervical quadriplegia, 1971 through 1984. *JAMA* 254: 3439-3443, 1985
37. Torg JS, Wiesel SW, Rothman RH: Diagnosis and management of cervical spine injuries, in Torg JS (ed): *Athletic Injuries to the Head, Neck and Face*. Philadelphia, Lea & Febiger, 1982, pp 181-209
38. Towbin A: Spinal cord and brainstem injury at birth. *Arch Pathol* 77: 620-632, 1964
39. Vegso JJ, Bryant MH, Torg JS: Field evaluation of head and neck injuries, in Torg JS (ed): *Athletic Injuries to the Head, Neck and Face*. Philadelphia, Lea & Febiger, 1982, pp 39-52
40. Vegso JJ, Lehman RC: Field evaluation and management of head and neck injuries. *Clin Sports Med* 6: 1-15, 1987

41. White AA III, Johnson RM, Panjabi MM, et al: Biomechanical analysis of clinical stability in the cervical spine. *Clin Orthop* 109: 85-96, 1975
42. White AA, Southwick WO, Panjabi MM: Clinical instability in the lower cervical spine--A review of past and current concepts. *Spine* 1: 15-27, 1976