Journal of Athletic Training 2000;35(1):65–69

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The Efficacy of the Rapid Form Cervical Vacuum Immobilizer in Cervical Spine Immobilization of the Equipped Football Player

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Objective: To determine the effectiveness of the Rapid Form Cervical Vacuum Immobilizer in controlling the cervical spine movements of a football player wearing shoulder pads and a helmet.

Design and Setting: We used a 1-group, repeated-measures experimental design to radiographically assess cervical spine range of motion with and without the Rapid Form Cervical Vacuum Immobilizer. Two experimental conditions (with and without vacuum splint) were applied to 10 subjects in a repeated-measures design. Each subject was radiographed in cervical forward flexion, extension, and lateral flexion under each experimental condition.

Subjects: Ten healthy male subjects without a history of cervical spine pathology or abnormality volunteered for this study.

Measurements: Cervical forward flexion, extension, and lateral flexion range of motion were compared under both treatment conditions. Joint angles were determined by straight-edge tangential lines drawn on the radiographs along the foramen magnum, inferior ring border of the atlas, and along the inferior tips of the 2nd through 7th vertebral bodies. The total range of motion was determined and compared with the treatment condition by multiple paired *t* tests.

Results: The Cervical Vacuum Immobilizer limited cervical spine range of motion in forward flexion, extension, and lateral flexion. The secondary statistical analysis for the effect size determined that each group had a large effect size, indicating that the power of the experimental or vacuum splint group was high.

Conclusions: We found that the Cervical Vacuum Immobilizer limited cervical spine range of motion in forward flexion, extension, and lateral flexion. The Cervical Vacuum Immobilizer can be easily placed on an injured, fully equipped football player and serves to limit cervical spine range of motion while the athlete is immobilized and transported. Future research should determine how the Cervical Vacuum Immobilizer limits range of motion with the athlete immobilized to the spine board.

Key Words: athletic training, radiography, safety equipment, spinal cord injury

Each year approximately 10000 cases of spinal injury occur in the United States, 10% of those during athletic participation.[1] Recent studies indicate that one half of all spine injuries occur in the cervical region and often result in quadriplegia.[2] In competitive athletics such as football, the cervical spine is subjected to repeated episodes of axial loading, resulting in possible microtrauma or macrotrauma to the cervical spine. Cervical spine injuries in football are rare when compared with the large number of athletes competing annually.[3] Cervical quadriplegia from participation in competitive football during 1977 through 1993 occurred in approximately 9 patients per year,[4–6] although, according to the National Football Head and Neck Injury Registry, there were 32 incidents of serious cervical spine injuries in 1987.[7,8]

Serious cervical spine injury can result from fracture, subluxation, dislocation, or any combination of these to the vertebral body or related spinal structures.[9,10] Neurologic damage occurs in 39% of patients with cervical spine fractures, and, when this injury involves the vertebral body or the posterior vertebra, the chance of associated neurologic damage increases to 70%.[9] The integrity of the spine may be compromised during transportation of the injured athlete, and any unwanted cervical movement may cause paralysis or death.[1,2] Neurologic damage associated with cervical spine injury occurs in 25% of patients during immobilization and transport.[11] Immobilization of an athlete with a suspected cervical injury serves to minimize the risk of further injury before and during transport and treatment.[6,12,13] Typically, a rigid cervical collar will maintain cervical spine stability during transportation,[14–16] although, for a football player wearing a helmet and shoulder pads, a rigid cervical collar may not fit adequately due to the bulkiness of the equipment. Alternative methods of immobilization, such as sand bags and straps, are typically employed in an attempt to limit cervical spine motion while on a spine board.[17,18] Soft cervical collars provide little benefit in restricting motion beyond 5% to 10% of cervical mo-

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tion.[11,19,20] The Rapid Form Cervical Vacuum Immobilizer (Cramer Products Inc, Gardner, KS) was designed to provide greater cervical spine stabilization than soft or rigid orthoses.

The Cervical Vacuum Immobilizer can easily be applied to an athlete wearing a football helmet and shoulder pads. The value of the Cervical Vacuum Immobilizer is in restricting cervical movement before and during spine boarding and transport in order to limit the risk of further damage. The purpose of our study was to measure the effectiveness of the Cervical Vacuum Immobilizer in controlling forward flexion, extension, and lateral movements of the cervical spine in a football player wearing a helmet and shoulder pads.

METHODS

Subjects and Design

Ten male subjects (age = 26.3 ± 2.26 years, ht = 179.32 ± 6.48 cm, wt = 84.46 ± 8.26 kg) with previous competitive football experience and without a history of cervical spine pathology or abnormality volunteered for this study. Each subject received information regarding the risks and benefits of the investigation and gave written consent to participate. All subjects completed demographic and medical history forms before the actual data collection. All procedures were approved by the Oklahoma State University Institutional Review Board.

This study involved a 1-group, repeated-measures experimental research design, with the subjects acting as their own controls. Each subject was tested under 2 experimental conditions: with and without the Cervical Vacuum Immobilizer. The repeated-measures design included a set of radiographs taken in forward flexion, extension, and lateral flexion, with the football helmet and shoulder pads in place. The treatment was the addition of the Cervical Vacuum Immobilizer. Each subject served as his own control, with the dependent variable being the cervical spine range of motion. The independent variable was the degree of cervical immobilization provided by the vacuum splint.

Procedures

The subjects reported to a licensed medical facility at a predetermined date and time. Each subject wore an Air2 football helmet (Schutt Products, Litchfield, IL) and a pair of Douglas Model 56Z football shoulder pads (Douglas Equipment, Houston, TX), properly fitted to the subject by the principal investigator using techniques described by the manufacturer. The face mask was removed to allow each subject full movement of the cervical spine. In addition, the face mask could interfere with the radiographic image of the cervical spine. Each subject sat in a chair with the chest strapped to the chair, isolating cervical movement from thoracic movement. Lead shielding protected the pelvic region from radiation exposure. To visualize the entire cervical spine, lateral radiographic images were taken using low-radiation Kodak TML/RA film (Eastman-Kodak, Rochester, NY) with a Picker Model GX550 radiograph (Picker Health Care Products, Cleveland, OH) following identical parameters for each subject. A certified x-ray technician took all radiographs, with the principal investigator present at all filming. The total dosage for all radiographs was within 0.18 to 1.0 rad, an acceptable range as determined by the University Institutional Review Board.

Injuries involving a possible spine injury are best splinted using a spine board.[1,6,11,12,15] The injured athlete should be secured to a spine board while lying in a neutral position with the cervical spine stabilized.[6,11,13–16] To adequately evaluate cervical spine range of motion, the subjects were placed in a sitting position to allow full cervical forward flexion, extension, and lateral flexion without impedance by the face mask or spine board. A subject secured to a spine board would be limited in his ability to extend the cervical spine beyond the neutral position.

Order of cervical spine movements and experimental conditions (with and without Cervical Vacuum Immobilizer) was selected for each subject. The subject flexed his neck forward as far as possible without moving his back away from the chair. A lateral view radiograph was taken of the subject's neck in this position. Each subject extended his neck as far back as possible without arching his back from the chair. Another lateral radiograph was taken of the subject's neck in this position. The subject placed his head into maximal lateral flexion (left or right position randomly chosen by the investigator). The subject held an occlusal radiopaque marker in his teeth as an anterior-posterior radiograph was taken in this position.

The first set of x-ray films examined normal range of motion of each subject with football helmet and shoulder pads in place. Subsequent radiographs were taken with the Cervical Vacuum Immobilizer around the neck and helmet of the subject, secured according to the manufacturer's specifications, with an additional VELCRO (Velcro USA Inc, Manchester, NH) strap provided by the manufacturer. The air within the vacuum splint was removed according to the manufacturer's guidelines. The subjects repeated the motions as described earlier, and radiographs were taken in each of the 3 positions (Figure 1). Confidentiality was maintained during testing, with each subject's assigned code number placed on the radiographs instead of the subject's name. The x-ray technician retained the only copy of the key, which identified each subject and his code number.

Johnson et al[20] developed the method for determining cervical spine forward flexion, extension, and lateral flexion range of motion used in this investigation. We drew straight-edge tangential lines on the radiographs at the base of the skull along the foramen magnum and the inferior border of the ring of the atlas and along the inferior edges of the C2-C7 vertebral bodies, extended until each line intersected with the line below it. The measured angles of these intersections determined forward flexion or extension of each individual vertebra. Lines that intersected anteriorly to the vertebra were forward flexion angles, whereas lines intersecting posteriorly identified extension angles. The sum of all the measured angles determined the degrees of total cervical forward flexion or extension.

Anterior-posterior radiographs measured lateral flexion of the radiopaque marker held by the subject's teeth extended to intersect with a line drawn on the radiograph along the superior margin of the transverse processes of T1. The angle of these 2 lines reflected the lateral flexion attained by each subject.

Statistical Analysis

Descriptive statistics detailed each subject's forward flexion, extension, and lateral flexion individually, with and without the vacuum splint. The total recorded degrees of cervical forward flexion, extension, and lateral flexion determined total cervical spine range of motion for each subject. A comparison between each subject's total range of motion without the vacuum splint

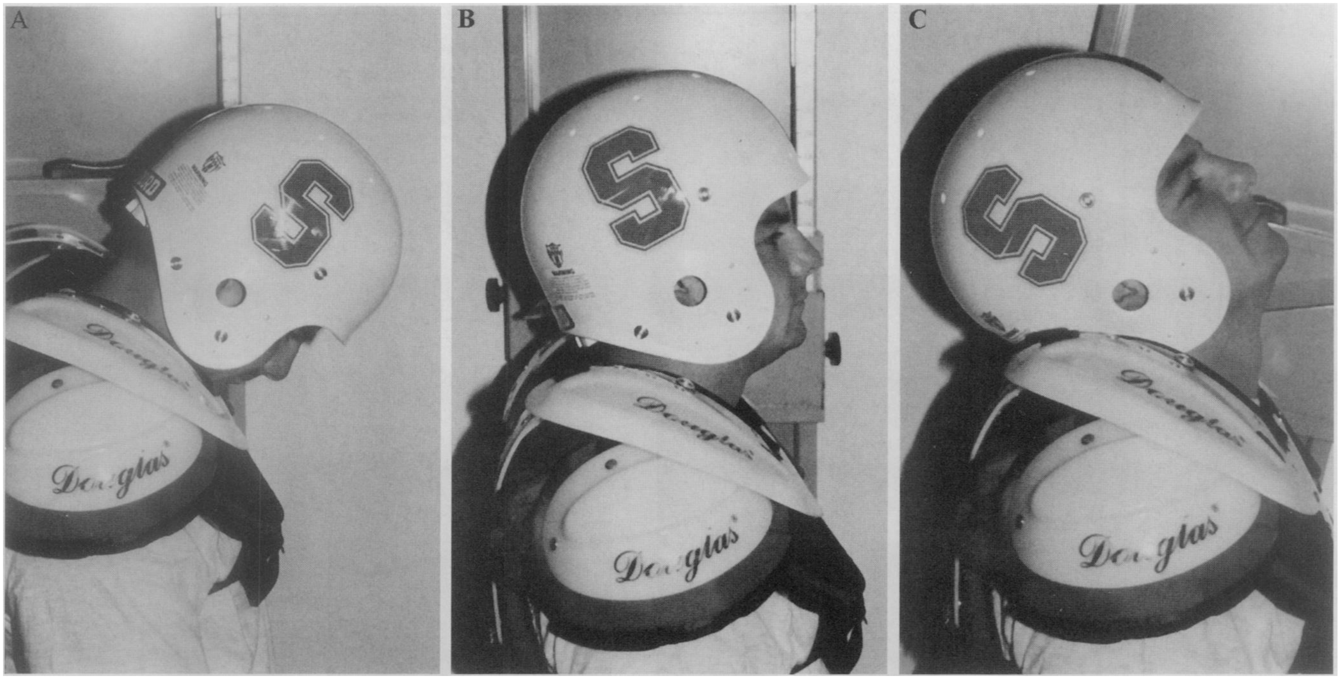

Figure 1. Cervical spine motion with football helmet and shoulder pads in place. A, cervical forward flexion; B, normal anatomical position; C, cervical extension.

and total range of motion with the vacuum splint was accomplished using a paired t test. The α level for all tests was set at 0.05. We used additional statistical analysis to evaluate between-test reliability and to determine the effect size for the inferential power of the sample size.[21] The between-test reliability determines the relationship between the control and experimental variables. The effect size allows inference by determining the practical importance unaffected by the number of the participants in the study.

RESULTS

Each subject's total cervical spine range of motion without the vacuum splint was compared with his total range of motion with the vacuum splint. Cervical spine forward flexion range of motion ($t_9 = -4.73$, $P < .001$), extension range of motion ($t_9 = -12.22$, $P < .001$), and lateral flexion range of motion ($t_9 = -8.61$, $P < .001$) were all significantly different (Figure 2).

We performed a statistical analysis using a reliability analysis scale (α) to determine the between-test reliability for cervical spine range of motion. The correlations among the cervical spine range-of-motion variables revealed a strong relationship between the control and experimental groups. The cervical spine forward flexion range of motion with the vacuum splint was correlated with the range of motion without the use of the vacuum splint, $r = 0.7254$, sharing 52.6% of the variance. The cervical spine extension range of motion with the vacuum splint was correlated with the range of motion without the use of the vacuum splint, $r = 0.8970$, sharing 80.4% of the variance. The cervical spine lateral flexion range of motion with the vacuum splint was correlated with the range of motion without the use of the vacuum splint, $r = 0.8262$, sharing 68.3% of the variance. In general, the measurements taken with the vacuum splint had a strong relationship with the range of motion without the use of the vacuum splint, supporting strong between-test reliability for the measurements of both groups.

We performed additional statistical analysis for the effect size to determine the inferential power of the sample size. The effect sizes for the forward flexion, extension, and lateral flexion groups were 1.89, 2.13, and 2.00, respectively. All 3 effect sizes were considered large in inferential power of the sample size.[21] The fact that all groups had a large effect size indicates that the power of the experimental or vacuum splint group was high.

DISCUSSION

Catastrophic cervical spine injuries are rare in all levels of competitive football.[3,18] However, the certified athletic trainer and emergency medical personnel must be prepared for such an occurrence. Extra care needs to be taken in transporting victims, such as football players wearing bulky equipment. Traditional rigid cervical collars do not fit properly on a football player with the helmet and shoulder pads in place.[17] To date, no research exists on the Cervical Vacuum Immobilizer and its efficacy in providing stability to the cervical spine of an equipped football player.

The purpose of our study was to determine the effectiveness of the Cervical Vacuum Immobilizer in controlling cervical spine movements of a football player wearing a helmet and shoulder pads. Each subject's range of motion was measured radiographically under both treatment conditions. Use of the Cervical Vacuum Immobilizer significantly decreased cervical spine forward flexion, extension, and lateral flexion range of motion in the equipped football player.

Patel and Rund[22] described the emergency medical technicians' guidelines for the management of motorcycle crash victims wearing helmets. These technicians typically remove the helmet before transport because the solid face guard may restrict access to the victim's airway. In addition, helmet removal allows for further assessment of the head and neutral alignment of the cervical spine during transport.[23] These same

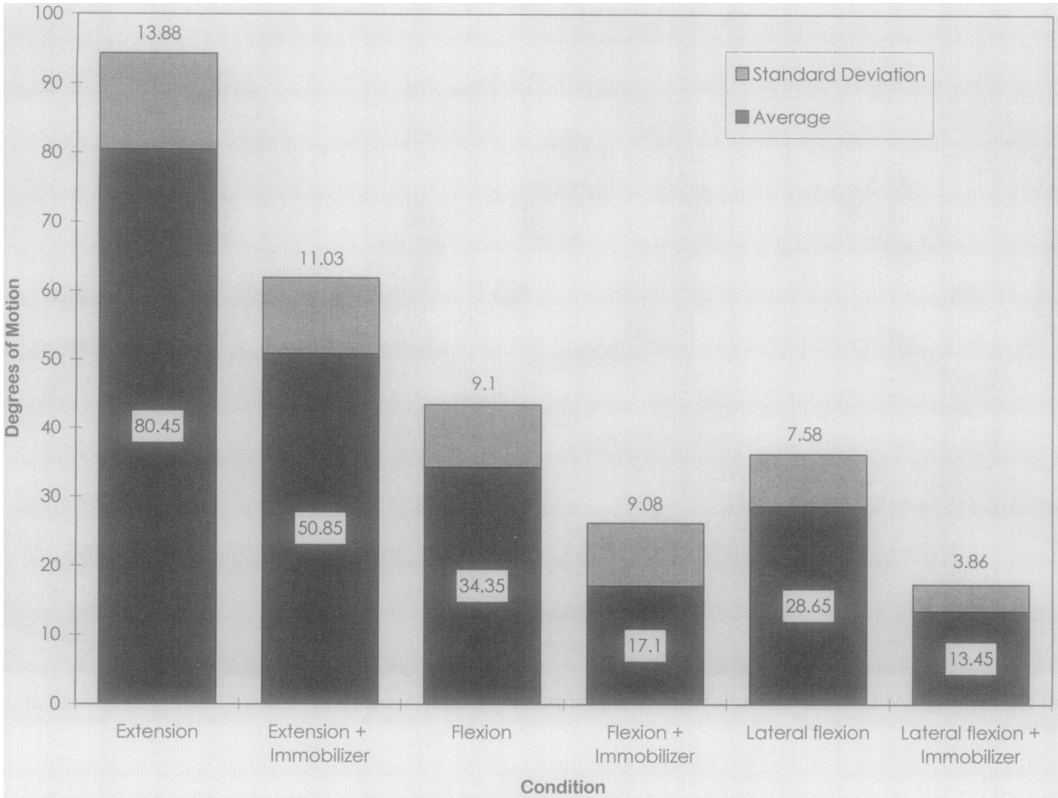

Figure 2. Cervical spine range of motion with and without the Cervical Vacuum Immobilizer.

principles, however, may not pertain to football helmets. Football helmets fit more tightly than motorcycle helmets and are typically fitted to the player by a qualified equipment manager. While the athlete is supine, the helmet raises the head, and the shoulder pads raise the shoulders, placing the cervical spine in a neutral position.[6,15] Removal of the football helmet before transport involves unnecessary movement of the head and cervical spine, risking the possibility of further injury.[22,24] Removal of the helmet alone allows the head to fall back, hyperextending the neck.[6,15,25,26]

Feld and Blanc[26] indicated that victims of traffic accidents who are wearing motorcycle helmets are subject to facial injuries and skull fractures. Football players are not typically subjected to such forces, and the incidence of significant facial soft tissue injuries, depressed skull fractures, or other types of trauma is negligible.[26] The face mask on a football helmet allows visualization of the face and provides access to the airway. The ears are visible through the ear holes, and the cervical spine can be palpated with the helmet still in place.[1,6,24]

It is essential that the cervical spine be stabilized before transport to a medical facility. Rigid cervical collars provide significant immobilization in most victims, but, as already noted, these types of rigid collars will not fit adequately on the equipped football player. Traditional methods of cervical spine immobilization for football players include sandbags next to the head and strapping the helmet to the spine board with tape.[10,12] The Cervical Vacuum Immobilizer is flexible before deflation and is easily placed around the cervical region of the equipped football player. One advantage of the Cervical Vacuum Immobilizer lies in its ability to fit on different body somatotypes. Removal of air from the Cervical Vacuum Immobilizer provides a rigid support, limiting cervical spine range of motion of the equipped football player, as evident from our results.

CONCLUSIONS

This study demonstrated that the Cervical Vacuum Immobilizer limited cervical spine range of motion in forward flexion, extension, and lateral flexion of the equipped football player. Potentially, the Cervical Vacuum Immobilizer placed on a fully equipped injured football player may limit cervical spine range of motion while the athlete is immobilized and during transport. Our study investigated cervical spine range of motion of the equipped football player with the face mask removed, allowing x-ray films of the cervical spine in full motion without impedance of movement. Immobilization of the cervical spine is enhanced when the face mask is in place.[15,24] Potentially, the use of the Cervical Vacuum Immobilizer on the equipped football player with the face mask in place may further limit cervical spine range of motion.

We acknowledge our results were found in 10 healthy subjects with no history of cervical spine pathology or abnormality. Further research is needed to investigate how the Cervical Vacuum Immobilizer limits cervical spine rotation and its effectiveness when the athlete is immobilized on the spine board. In addition, this study should be replicated on other athletes to determine the cervical spine range of motion limited by the Cervical Vacuum Immobilizer with and without athletic equipment.

ACKNOWLEDGMENTS

We thank Martin Trieb, MD, Kathleen Butruce, RT, and Tona Palmer, ATC, for their assistance in collecting these data. We also thank Cramer Products, Inc (Gardner, KS) for their support of this study.

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