THE EFFECT OF FOOTBALL SHOULDER PAD REMOVAL TECHNIQUE AND EQUIPMENT REMOVAL TRAINING ON CERVICAL SPINE MOTION, TIME TO TASK COMPLETION, AND PERCEIVED TASK DIFFICULTY

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ABSTRACT

Catherine Shawn Lenhardt: The Effect of Football Shoulder Pad Removal Technique and Equipment Removal Training on Cervical Spine Motion, Time to Task Completion, and Perceived Task Difficulty
(Under the direction of Jason P. Mihalik)

Current recommendations for management of cervical spine injury suggest leaving football equipment in place unless otherwise indicated by the NATA position statement. We investigated the effect of three shoulder pad removal techniques and the effect of reinforced training on cervical spine motion, time, and difficulty. The RipKord shoulder pads were faster than both traditional shoulder pad removal techniques ($P<0.001$) and easier ($P<0.05$) than the flat torso to remove. Less cervical spine range of motion with the flat torso technique was observed in the sagittal and frontal planes ($P<0.05$) during Testing Session II in the reinforced training group. Both traditional shoulder pad removal techniques were faster during Session II [flat ($P=0.001$); elevated ($P<0.001$)]. The RipKord shoulder pads provided a method for removal with superior measure of time and difficulty compared with traditional removal techniques. With reinforced training, cervical spine motion improved with the flat torso technique.

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I dedicate this document to Fred Thompson, a football player who lost his life from an episode of sudden cardiac death. Since his death, my prayer has been that my research would contribute to best practices in the domain of emergency management of catastrophic injury with the hope that well-prepared certified athletic trainers would positively impact lives.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Football athletes are at a high risk for sustaining cervical spine injuries (Mueller & Cantu, 2012). Football produces the highest total number of catastrophic spine injuries of all sports in the United States (Mueller & Cantu, 2012). Currently, the standard of care for a spine injured football athlete is to leave all equipment in place, with the exception of the facemask, while providing rescue care unless one or more of the following conditions are present: 1) access to the airway is not possible or removal of the facemask is unachievable in an appropriate amount of time; 2) the helmet is not properly fit and therefore securing the helmet to the spine board does not result in sufficient immobilization of the head and cervical spine; or 3) leaving the helmet on does not result in neutral alignment of the cervical spine (Swartz et al., 2009). If one of the three aforementioned conditions is present, it is necessary to remove both the helmet and the shoulder pads concurrently (Swartz et al., 2009), as removal of one without the other increases the risk of placing the cervical spine of the athlete in a potentially dangerous extension position (Palumbo, Hulstyn, Fadale, O'Brien, & Shall, 1996). Should full equipment removal be unachievable due to the circumstances of the institution (i.e. too few personnel), but airway access and chest exposure are necessary for attachment of an automated external defibrillator (as in a cardiac event), it is acceptable practice to remove the helmet and fill the void between the occiput and the ground using available padding. With heightened concern for a cervical spine injury, this prevents the cervical spine from assuming a potentially dangerous extension position following helmet removal with the shoulder pads still in place (Swartz et al., 2009).

Traditionally, the flat torso technique has been employed for shoulder pad removal. This method involves 2-4 rescuers, and is accomplished by unfastening the side straps of the shoulder pads, cutting the laces that hold the shoulder pads together anteriorly, and sliding the remaining portion of the shoulder pads over the top of the injured athlete's head (Horodyski et al., 2009; Swartz et al., 2009). If four or more rescuers are available, the elevated torso technique may be employed. The shoulder pads are unfastened in the same manner as the flat torso technique. Shoulder pad removal is achieved after the patient is elevated to 30-40 degrees of trunk flexion, or just enough to allow for unencumbered removal of the shoulder pads while neutral alignment of the head, neck, and torso are maintained (Horodyski et al., 2009; Peris, Donaldson, Towers, Blanc, & Muzzonigro, 2002). One cadaveric study reported the elevated torso technique as a superior method for moderating the amount of induced cervical spine motion during shoulder pad removal when compared with the flat torso technique (Horodyski et al., 2009). However, Dahl et al. note that, while described as a viable option for equipment removal by the National Athletic Trainers' Association position statement, the elevated torso technique (tilt technique as described by the study) results in a greater amount of vertebral displacement between intact and lesioned cervical spines in cadaveric models compared to the log roll and five-person lift techniques (Dahl, Ananthakrishnan, Nicandri, Chapman, & Ching, 2009).

The Riddell™ RipKord technology has recently emerged to address the growing concern of unnecessary patient movement during equipment removal. The Riddell™

RipKord shoulder pads are identical to traditional shoulder pads in nearly all aspects, except for the RipKord itself and its posterior attachment conducive for separation. The RipKord is a guided cable that, when pulled, allows the shoulder pads to separate into right and left halves posteriorly. This allows each side of the shoulder pad to slide out independently from underneath the athlete, provided the anterior attachment is released (Kordecki, Smith, & Hoogenboom, 2011). In one study investigating this new technology, the authors found that removing shoulder pads utilizing the Riddell™ RipKord system resulted in significantly less time to task completion compared to traditional shoulder pads utilizing the flat torso technique. However, the authors found no significant differences in cervical spine motion or in perceived difficulty between the two techniques (Bric, Swartz, S.J., Decoster LC, & J.P, 2013). It is necessary to investigate the Riddell™ RipKord shoulder pad technology as its design yields the potential for a safer method of equipment removal by reducing the risk of iatrogenic pathology to a potentially spine injured athlete. To our knowledge, no investigation had directly compared each of the 3 equipment removal techniques (elevated torso with traditional shoulder pads, flat torso with traditional shoulder pads, and RipKord shoulder pad removal) under a single study design. Furthermore, many institutions complete spine boarding and equipment removal training sessions each year. However, no studies, to our knowledge, had explored the effect of reinforced training on the successful application of these three removal techniques. Thus, further investigation was warranted.

Therefore, the purpose of this study was twofold. The first aim was to compare induced head motion, time to task completion, and perceived difficulty during football equipment removal between the following three techniques: 1) elevated torso with traditional shoulder pads, 2) flat torso with traditional shoulder pads, and 3) Riddell™ RipKord shoulder pad removal. The second aim of the study was to measure the effect of reinforced equipment removal training on induced head motion, time to task completion, and perceived difficulty during football equipment removal.

Variables

Independent variables

1. Testing Session
    a. Session I
    b. Session II
2. Equipment removal technique
    a. Elevated torso with traditional shoulder pads
    b. Flat torso with traditional shoulder pads
    c. Riddell™ RipKord shoulder pad removal
3. Training group
    a. Reinforced training
    b. Control

Dependent variables

1. Head to thorax integrated motion and range of motion in degrees
    a. Sagittal
    b. Frontal
    c. Transverse
2. Time to task completion in seconds
3. Rate of perceived exertion (RPE; perceived difficulty rating)

Research Questions & Hypotheses

Research Question 1: What is the effect of shoulder pad removal technique (elevated torso with traditional shoulder pads, flat torso with traditional shoulder pads, and Riddell™ RipKord shoulder pad removal) on induced head motion, time to task completion, and rate of perceived exertion (RPE)?

Hypothesis 1.1: We hypothesized that the Riddell™ RipKord shoulder pad removal would result in less induced head motion, shorter time to task completion, and a lower RPE than the elevated torso technique with traditional shoulder pads.

Hypothesis 1.2: We hypothesized that the flat torso technique with traditional shoulder pads would result in no differences in induced head motion or RPE, but would take significantly more time to complete than the Riddell™ RipKord shoulder pad removal (Bric et al., 2013).

Hypothesis 1.3: We hypothesized that the elevated torso technique with traditional shoulder pads would result in significantly less induced head motion (Horodyski et al., 2009), but would take significantly more time to complete with a higher RPE than the flat torso technique with traditional shoulder pads.

Research Question 2: What is the interaction between reinforced equipment removal training and control groups on induced head motion, time to task completion, and RPE across the three shoulder pad removal techniques (elevated torso with traditional shoulder pads, flat torso with traditional shoulder pads, and Riddell™ RipKord shoulder pad removal)?

Hypothesis 2: We hypothesized that there would be significantly less induced head motion, time to task completion, and RPE following a reinforced training session during each of the three shoulder pad removal techniques (elevated torso with traditional shoulder pads, flat torso with traditional shoulder pads, and Riddell™ RipKord shoulder pad removal) compared to the control group.

Operational Definitions

Time to task completion: Time to task completion was measured from the initiation of cervical spine stabilization, to the moment the injured patient model was returned to the flat surface (following shoulder pad removal) with the head and neck resting in neutral.

Integrated head motion: Measured as the absolute values normalized to time (seconds) of head-to-thorax motion the head passes through in each plane: sagittal, frontal, transverse.

Range of motion: Measured as the maximum and minimum head-to-thorax motion, or excursion, in each plane: sagittal, frontal, transverse.

Equipment intensive sports: When asked on a demographics survey, equipment intensive sports included football, men's lacrosse, and ice hockey.

Experienced clinicians with equipment intensive sports: Experience with an equipment intensive sport was categorized as greater than or equal to 5 years experience with football, men's lacrosse, or ice hockey at any level of competition.

Assumptions

1. A prone athlete would have already been log rolled to a supine position.
2. There were no contraindications for alignment of the cervical spine during the log roll.
3. The helmet would have already been removed.
4. Cervical spine motion was estimated and measured by induced head to thorax motion.

5. The torso was moved in the same manner for each subject pair during each equipment removal technique.

Delimitations

1. We used one set of Riddell™ RipKord shoulder pads for both the traditional and RipKord removal techniques. No other shoulder pad equipment was used in this study.

Limitations

1. Equipment was fit according to manufacturer guidelines for both traditional shoulder pads and the Riddell™ RipKord shoulder pads. The study design did not account for athlete alterations of the equipment or wear over time.
2. Participant experience with equipment intensive sports and emergent equipment removal varied.
3. Induced head motion was used to make conclusions about cervical spine motion. Motion at the cervical spine was not measured directly.
4. Six injured patient models were utilized for the completion of data collection.
5. Participants were collected as a convenience sample and tested in pairs.

Clinical Significance

Certified athletic trainers must be educated and prepared to initiate football equipment removal in the event they are responsible for providing medical coverage. While not all athletic trainers will work in equipment-intensive sports such as football, it is paramount that those who do are properly trained in football equipment removal techniques. Differentiating between equipment removal techniques in terms of induced cervical spine motion, time to task completion, and RPE will improve the ability of the clinician to select the most appropriate removal technique for their particular setting. We anticipated our study to yield clinically meaningful information, in order to provide clinicians with additional information to support best practices for acute management of suspected cervical spine injuries.

CHAPTER II

REVIEW OF LITERATURE

Head down tackling and catastrophic cervical spine injuries continue to occur in American football despite the advent and implementation of spearing rules. It is necessary that an athlete with a potential cervical spine injury receive the most conservative, immediate, and appropriate care possible so as to avoid further injury. This thesis project sought to compare induced head motion, time to task completion, and perceived difficulty during football equipment removal between elevated torso with traditional shoulder pads, flat torso with traditional shoulder pads, and the new Riddell™ RipKord shoulder pad removal techniques. Additionally, we measured the effect of reinforced training in equipment removal on the aforementioned clinical measures. The purpose of this literature review was to establish the foundational underpinnings of the proposed project, its research questions, and to provide the rationale supporting the study hypotheses.

Epidemiology

Approximately 4.2 million athletes participate in the sport of American football (Mueller & Cantu, 2012). In general, cervical spine injuries are uncommon, but due to the high number of participants in football, it is known for having the highest number of occurrences of catastrophic cervical spine injury as compared to any other sport (Banerjee, Palumbo, & Fadale, 2004b). Additionally, the high number of impacts in football results in a greater opportunity for improper tackling, and subsequently, an elevated risk of cervical spine injury (Bailes, Petschauer, Guskiewicz, & Marano, 2007). In 1976, the National Collegiate Athletic Association implemented a rule in which intentional spearing, or the use of the head as the initial point of contact with the intent of punishing an opponent, was banned from the sport of football (Chao, Pacella, & Torg, 2010; Mueller & Cantu, 2012). This rule was then changed in 2005 to reflect both intentional and unintentional use of head-first contact (Mueller & Cantu, 2012).

Prevention of cervical spine injuries that result from axial loads is dependent on the ability to prevent both intentional and unintentional head-first contact. Instruction in proper tackling techniques for both defense and offense is a key factor as injuries occur on either side of ball possession (Mueller & Cantu, 2012). Head-up tackling, where contact with an opponent is made with the shoulder or the chest, is the safest means of tackling another player in football (Heck, Clarke, Peterson, Torg, & Weis, 2004). It is crucial that this technique be coached and practiced at all positions such that it becomes instinctive to make contact with an opponent with the head held upright (Heck et al., 2004). Additionally, consistent officiating is necessary for penalties to be nondiscriminatory. Every head-down contact should be flagged and awarded a penalty to continue discouragement of head-down tackling for the safety of all participants regardless of intention (Heck et al., 2004).

Annually from 1997 to 2006, there were approximately 7.8 catastrophic cervical spine injuries resulting in incomplete recoveries, and 6 incidences of quadriplegia (Mueller & Cantu, 2010). In 2011, 8 football-related cervical spinal cord injuries were recorded, 7 in 2010, 9 in 2009, and 14 in 2008 (Mueller & Cantu, 2012). In total, from 1977 to the most recent survey of catastrophic spinal injuries in 2011, there have been

324 injuries that have resulted in incomplete recovery, 77.2% of which followed some sort of tackle (Mueller & Cantu, 2012). Of those who suffered a catastrophic injury from tackling specifically, 24.8% followed a head down tackling attempt (Mueller & Cantu, 2012).

Despite the rule changes, improvements in coaching methods to increase player tackling safety, increased time spent on practicing proper tackling technique, and all other attempts made to eliminate catastrophic spine injuries in football, cervical spine injuries still occur. Consequently, it is vital to assess and improve all associated variables, in our effort to lower the annual number of cervical spine injuries. This includes thorough first responder preparation to ensure optimal initial care of the injured athlete.

Mechanism of Injury

The most common mechanism of injury to the cervical spine is a forceful load to the top of the head along the longitudinal axis of the cervical spine, commonly called axial loading (Bailes et al., 2007; Cantu, Li, Abdulhamid, & Chin, 2013; Chao et al., 2010; Ivancic, 2012). A neutral cervical spine is oriented in a lordotic position such that when the cervical spine is flexed 30 degrees, the vertebrae lose their normal curvature and assume a straight alignment. (Chao et al., 2010). Chao et al. describe this position of the cervical spine stating that the principles of mechanical engineering are the same in the flexed cervical spine as they are with an architectural segmented column such that compression will result in elastic instability, buckling, and ultimately failure (Chao et al., 2010). When the cervical spine is in normal alignment, axial forces are appropriately dissipated to bone, intervertebral discs, and surrounding soft tissue structures. However, when the head is lowered into a flexed position and a load applied to the crown of the helmet, the compressive forces from the rapidly decelerating head and accelerating torso are absorbed primarily by the cervical spine, rather than being properly dispersed to soft tissue (Clark, Ducker, & Cervical Spine Research Society. Editorial Committee., 1998; Heck et al., 2004; Ivancic, 2012). When this load exceeds the amount the cervical spine can bear, soft and hard tissue will fail (Swartz, Floyd, & Cendoma, 2005). This may result in several different independent or concurrent cervical spine injuries. Intervertebral disc deformation occurs, causing the cervical spine to move into a further flexed position (Chao et al., 2010; Torg, Vegso, O'Neill, & Sennett, 1990). If the force is large enough, this forward "buckling" of the cervical spine will continue, leading to fractures and/or dislocations of the cervical vertebrae or herniation of the associated intervertebral discs (Chao et al., 2010; Torg et al., 1990). Unstable fractures with or without a dislocation are the most common cause of catastrophic cervical spine injury in collision sports (Banerjee et al., 2004b). Thus, highlighting the danger head down tackling can impose on an athlete. Cantu et al. note a slightly flexed cervical spine will fail under less than 150 ft lbs of kinetic energy when tested in a controlled environment. A football player in motion is capable of exceeding this kinetic energy threshold by as much as 10 times (Cantu et al., 2013).

In 2012, Ivancic used five cadavers with healthy cervical spines to investigate the effect an impact to the crown of the head has on the cervical spine. The investigator fixed the C5 (fifth cervical vertebra) or C6 vertebra of each cadaver and then positioned the occiput to form a 30 degree angle of the head relative to the cervical spine. This position mimics a head down tackle in football. All five cadavers underwent a single impact with a mass similar to that of a large football player (55.5kg) at a velocity of approximately

4.1 m/s to the crown of the head. The vertebrae experienced high amounts of compressive forces during the 50-60 millisecond time interval as shown on high-speed video. With the neck staying in anatomical flexion limits, the large axial load caused the cervical spine to fail in an “s-shaped curvature”, such that the central cervical vertebrae moved into extension and two milliseconds later the upper cervical vertebrae moved into flexion. Following the impact, Ivancic both visually inspected and used fluoroscopy imaging to inspect the inflicted damage finding fractures of the occiput, first and second cervical vertebrae, and facet joints (Ivancic, 2012).

To summarize, head down tackling places the cervical spine in flexion. This is a vulnerable position for the cervical spine as an axial load to the head and neck in this position may result in catastrophic injury. The abnormal transmission of forces along the longitudinal axis of the cervical spine increases the risk of cervical spine fractures, joint dislocations, disc herniations, and resultant spinal cord/nerve root damage. These phenomena will be later discussed in the literature review.

Pathology

Cervical spine injuries vary in severity, but all potential injuries should be managed in the same manner. It is important, however, to note various cervical spine injuries present differently, and the ability of the clinician to recognize the signs and symptoms of specific injuries allows for appropriate care to be administered. Possible injuries include soft tissue strains, ligamentous sprains, fracture or dislocations of the vertebrae and/or associated intervertebral discs, and complete or incomplete spinal cord injury, which, in a worst case scenario, may lead to death (Ivancic, 2012). Outlined below are examples of cervical spine injuries and associated symptoms that warrant close attention by clinicians.

Soft Tissue Injuries

Soft tissue injuries may occur as a result of many different mechanisms, yet most muscle strains, ligament sprains, or contusions to the cervical spine will not present with neurological symptoms, deformity, or bony pathology (Cantu et al., 2013). Muscle strains are graded on a three-degree scale. First-degree muscle strains involve a stretch with small amounts of damage to the muscle fibers. Primary symptoms of a first degree strain include pain with muscle contraction, pain with palpation, and minimal swelling at the site of injury (Starkey, Brown, Ryan, & Starkey, 2010). Second-degree muscle strains involve more damaged muscle fibers than first-degree strains. Symptoms are similar to first degree strains with the addition of ecchymosis at the site of the injury (Starkey et al., 2010). Third-degree muscle strains involve complete tearing of the muscle fibers resulting in loss of muscle function, weakness, palpable deformity in the muscle fibers, swelling, discoloration, and pain (Starkey et al., 2010). Ligament sprains are also graded on a three-degree scale. First-degree sprains result from a stretch of the fibers with little to no tearing of the ligament. Symptoms of a first degree sprain include local pain, minimal tenderness to palpation, and a small amount of swelling (Starkey et al., 2010). Second-degree sprains result in partial tearing of the ligamentous fibers such that joint laxity may occur when the ligament is stressed during clinical examination. Symptoms of a second-degree sprain include pain and swelling. Loss of proper joint function may also occur (Starkey et al., 2010). A ligament that has lost its integrity completely indicates a third degree sprain. All fibers of the ligament are no longer intact leading to gross joint laxity with an empty end feel upon clinical evaluation. Symptoms of a third-degree sprain include swelling, loss of proper joint function, and ecchymosis at or distal to the site of injury (Starkey et al., 2010). Contusion injuries to soft tissue result from a direct blow. Symptoms include pain, redness, discoloration, and ecchymosis. Bony contusions are extremely painful and result from a direct blow to superficial hard tissue (Starkey et al., 2010). These injuries require treatment and rehabilitation, but can typically be considered far less severe than other potential injuries at the cervical spine. Athletes who suffer contusions may return to play when neck pain with and without palpation has resolved, no symptoms return with and without cervical compression along the longitudinal axis of the spine, and when full range of motion and strength at the cervical spine have returned (Cantu et al., 2013).

The intervertebral discs provide shock absorption and load distribution between the vertebral bodies during weight bearing or loading (Clark et al., 1998). Intervertebral disc herniations can cause damage to the nearby neurological tissue. Disc herniations vary in severity ranging from the least severe, protrusion, to the most, sequestration. Protrusion involves a small amount of the nucleus pulposus encroaching on the annulus fibrosus, but does not exit through the entire annulus fibrosus structure. Sequestration involves the nucleus pulposus material passing completely through an opening in the annulus fibrosus in a pathologic manner. All categories, in some fashion, involve the extrusion of the nucleus pulposus out of its normal containment by the annulus fibrosus. Damage to the annulus fibrosus allows this to occur. The intervertebral disc is the primary structure resisting high load compression (Clark et al., 1998). When the load is low, the disc is malleable, but when the load is high, compression of the nucleus pulposus increases the pressure centrally forcing it against the annulus fibrosus. This distributes the force across the body of the vertebrae and makes the disc rigid and resistant to load. If the integrity of the annulus fibers is compromised, the disc is unable to resist the same compression magnitude and the contents of the disc may herniate. This is often the result of a combination of flexion and lateral bending of the cervical spine. Cervical forward flexion is restrained by the posterior cervical musculature, the ligamentum flavum, interspinous ligaments, and supraspinous ligaments. Extension is limited by anterior cervical musculature and places an increased load on the facet joints of the cervical vertebrae (Clark et al., 1998). The herniation of disc materials can cause compression on the adjacent nerve roots as they exit the spinal cord and ultimately cause radicular symptoms into the cervical region, associated dermatomes, and myotomes of the upper extremity. Symptoms may include pain, spasm, altered sensation, and weakness (Starkey et al., 2010).

Nervous Tissue Injury

Nerve root or brachial plexus injury, often referred to as brachial plexus neuropraxia or burner/stingers, is one of the most commonly occurring injuries in football (Bell, 2007; Rihn et al., 2009). Two mechanisms of head and neck motion can result in neuropraxia symptoms. The first involves a traction injury where the head and one shoulder are forced in opposite directions. This results in elongation of the brachial plexus on the same side as the involved shoulder, and radicular symptoms in the associated upper extremity (Rihn et al., 2009). A compression injury is also common in football and can result in brachial plexus neuropraxia symptoms. This is caused by hyperextension of the head and neck with simultaneous rotation which compresses the nerve roots as they exit the narrowed foraminal canal of the cervical vertebrae (Chao et al., 2010). Symptoms, resulting from a temporary block in nerve conduction to the peripheral nerves, may include pain, weakness, tingling, and other paresthesias. It is common for these symptoms to present unilaterally in the upper extremity (Chao et al., 2010; Rihn et al., 2009). These symptoms usually resolve in a few minutes, but may take up to 24 hours to resolve completely (Rihn et al., 2009).

Spinal cord injury can occur following a variety of mechanisms including hyperflexion, hyperextension, axial loading, or indirectly through other methods (Clark et al., 1998). Injury to the spinal cord can be classified either as complete or incomplete. Complete injury to the spinal cord results in full function loss below the level at which the lesion occurred (Banerjee, Palumbo, & Fadale, 2004a). This may follow a physical injury to the spinal cord itself, but it most commonly follows a hemorrhage or loss of blood supply to the cord permanently blocking the transmission of impulses (Banerjee et al., 2004a). As seen with central cord syndrome, however, not all pathology to the spinal cord results in permanent loss of function. Central cord syndrome is considered a less severe injury than its counterparts, but is the most frequently occurring spinal cord injury (Banerjee et al., 2004a). This syndrome results in incomplete motor loss and weakness affecting the upper and/or lower extremities, yet it may not affect them both equally with larger motor deficits typically noted in the upper extremities (Bailes et al., 2007). Central cord syndrome is most commonly associated with a hyperextension mechanism with no concurrent cervical fracture. A resultant folding of the ligamentum flavum causes temporary compression of the spinal cord and potentially the nearby vascular supply as well (Bailes et al., 2007). Central cord syndrome would be classified as an incomplete spinal cord injury with impermanent effects, but its symptoms and presentation upon initial evaluation would warrant immediate care.

Anterior cord syndrome affects the anterior portion of the spinal cord and the associated blood supply (Bailes et al., 2007). Second to central cord syndrome, anterior cord syndrome is the second most common spinal cord injury (Banerjee et al., 2004a). This syndrome causes complete loss of all motor function and sensation below the level of the spinal cord lesion. Unlike the uneven deficit distribution characteristic of central cord syndrome, anterior cord syndrome is nondiscriminatory affecting all extremities equally (Bailes et al., 2007). This particular injury has been noted following a number of spinal injury mechanisms with no specific primary mechanism (Bailes et al., 2007). Regardless, disruption of the blood supply to the anterior spinal cord via the anterior spinal artery appears to be a large contributing factor (Bailes et al., 2007). Anterior cord syndrome is seen as a complete spinal cord injury with permanent function and sensation damage. Due to the concern for blood supply in anterior cord syndrome, it is important emergency care be initiated immediately to encourage fast and appropriate transportation to a hospital for further assessment.

Other spinal cord syndromes including Brown- Séquard syndrome and posterior cord syndrome result from similar mechanisms and present with similar symptoms as the aforementioned conditions (Bailes et al., 2007). Most spinal cord syndromes present with motor and sensation loss, and can affect the upper extremity, lower extremity, ipsilateral side, contralateral side, and a variety of combinations therein. Many incomplete injuries occur to the spinal cord that do not necessarily fall within each of these defined syndromes, but commonly display loss of function below the level of the lesion and a sensory component that is not always distributed in a predictable fashion (Bailes et al., 2007).

Neuropraxia of the spinal cord can occur following hyperextension, hyperflexion, and even axial compression injuries during football (Rihn et al., 2009) Neuropraxia of the spinal cord is not the same injury as a brachial plexus or nerve root neuropraxia. Neuropraxia of the spinal cord, also known as transient quadriplegia, is characterized by paralysis of motor function, loss of sensation of the extremities depending on the location of the insult to the spinal cord, burning pain, and paresthesias (Bell, 2007; Chao et al., 2010; Rihn et al., 2009). Symptoms typically last between 5 and 15 minutes, but can take up to 48 hours to resolve (Bell, 2007; Chao et al., 2010; Rihn et al., 2009). Similar to brachial plexus neuropraxia, the symptoms arise with fervor, but resolve completely in a relatively short period of time.

Permanent quadriplegia is an irreversible spinal cord injury, which typically occurs following an axial compression mechanism. This particular mechanism, which will be described in detail, may result in a vertebral fracture or dislocation, most commonly in the lower cervical spine, leaving the cervical spine inherently unstable (Banerjee et al., 2004b; Chao et al., 2010). This unstable spine can no longer function as it would normally to protect the now vulnerable cervical spinal cord. The spinal cord then experiences dangerous deformation with permanent functional disruption of the components of the cord that are responsible for impulse transmission (Chao et al., 2010). It is this disruption of nerve impulse capabilities that results in permanent neurological damage including complete loss of sensory and motor function below the level of the injury (Banerjee et al., 2004a).

The severity of the symptoms associated with cervical spinal cord damage is dictated by the injury location. Damage at the C3-C4 level may cause complete paralysis of all four extremities, the abdomen, and the diaphragm as well as sensation loss below the clavicle (Clark et al., 1998). Loss of diaphragmatic control will likely result in respiratory compromise due to its crucial role in breathing (Tortora & Derrickson, 2010). Injury to the C4-C5 spinal cord level will spare function of the trapezius muscle for head extension and shoulder shrugging. However, paralysis of the upper extremities, lower extremities, and the trunk will result. The ability to breathe is still present as diaphragmatic control is spared. Injury to the C5-C6 level will produce diminished function of the distal upper extremities. Only hyperextension at the wrists is preserved, while fine motor movements in the fingers are compromised. Motion into elbow flexion may be weakened and voluntary motion into extension is lost. Pain sensation in the fingers will be absent as well. Injury at the C7-T1 level will result in the ability to flex the fingers into a fist but strength is compromised. Upper extremity extension will be weak and fine motor movements in the fingers will be diminished. Finally, damage below C7 and T1 may spare the upper extremity and trunk depending on the level of the injury. This injury will likely result in lower extremity paralysis with pain sensation compromised in the affected myotome distribution. It is important to note that damage at these levels may affect proximal or distal levels of the spinal cord as a result of hemorrhage and is likely worsened with poor immediate management and immobilization (Clark et al., 1998).

Bony Injuries

Permanent quadriplegia and neurological deficits that occur from participation in football are in large part due to fractures and dislocations (Bailes et al., 2007). Fractures and dislocations can occur at any cervical spine level, any location within each cervical vertebra, or at articulations between the superior and inferior vertebrae. Upper cervical spine fractures and dislocations, however, are rare with the majority of injuries occurring in the lower cervical spine (Banerjee et al., 2004b). These injuries to the cervical vertebra can result in both transient and permanent symptoms (Banerjee et al., 2004a). Chao et al. identified two particular vertebral fractures that both may result from axial loading, the mechanism of injury mentioned previously. The first is a fracture of the anteroinferior corner of the vertebrae that does not result in permanent neurological damage. The second is a fracture in two planes, sagittal and frontal, which typically results in permanent neurological damage. Neurological symptoms from this injury include paralysis and loss of sensation distal to the spinal cord fracture (Chao et al., 2010; Tortora & Derrickson, 2010). It is important to note, however, that cervical spine fractures alone do not necessarily cause spinal cord damage or neurological deficits. Fractures improve the likelihood a bony fragment may lacerate the cord or the resultant swelling may place increasing pressure on the spinal cord producing further damage (Starkey et al., 2010).

Dislocations at the cervical spine are inherently more dangerous to the spinal cord than cervical vertebral fractures. When the cervical spine in flexed and rotated the facet joints become incongruent and a dislocation may result. The normal congruency of the cervical spine is compromised with the pathological vertebra now encroaching the previously adequate spinal canal space. Decreased space for the spinal cord increases the cord pressure and may result in signs and symptoms similar to that of a brachial plexus injury. Unlike brachial plexus neuropraxia, the symptoms of a cervical spine dislocation do not rapidly diminish (Starkey et al., 2010).

Respiratory Compromise

Unmanaged or unsuccessful management of respiratory emergencies may result in the most grievous outcome of cervical spine injury, death. Spinal cord injuries occurring above C5 can result in complete paralysis of the diaphragm and accessory muscles responsible for both inhalation and exhalation (Brown, DiMarco, Hoit, & Garshick, 2006). In the event this vital life function is compromised due to a cervical spinal cord injury, mechanical breathing assistance is necessary to improve the probability of survival. Furthermore, Claxton et al. found injury at or above C4 is an independent predictive factor for death following spinal cord injury (Claxton, Wong, Chung, & Fehlings, 1998). Inherently, death is the most severe potential outcome following cervical spine injury, thus appropriate management is crucial.

Cervical spine injuries occur on a wide severity spectrum from muscle strains and ligament sprains to permanent quadriplegia or death. It is necessary that emergency responders perform a thorough and efficient initial assessment on the field in order to properly handle these conditions. Maintaining life and immobilizing the cervical spine should be revered as the primary responsibility of the responder.

Recommendations for Management

It is imperative clinicians limit the amount of cervical spine motion induced during cervical spine injury management (Bailes et al., 2007). Upon initial evaluation, the first responder is to first conduct a primary survey in which level of consciousness, airway, breathing, and circulation are assessed. The goal of the primary survey is to rule out life threatening injuries (Bailes et al., 2007). The spine injury emergency protocol should be initiated if the athlete is unconscious or their level of consciousness is altered, if they display bilateral neurological deficits or abnormalities, if they express cervical spine or neck pain with or without palpation, or if there is obvious spinal deformity (Swartz et al., 2009). If the patient is conscious and responsive, it is the responsibility of the clinician to question the injured athlete inquiring about numbness, abnormal sensations, and neck pain (Bailes et al., 2007). Should one or more of the aforementioned signs or symptoms be present upon initial evaluation, treatment should include rapid, immediate stabilization of the cervical spine. When the injured athlete is a football player dressed in full equipment, including helmet and shoulder pads, the following protocol should be conducted. The responding clinician should be positioned at the top of the injured athlete's head with their hands placed on either side of the helmet at the level of the mastoid processes (Bell, 2007; Swartz et al., 2009). A firm grip should limit the motion of the helmet and, ideally, the motion that occurs at the head and neck. In the event the injured athlete is prone, the first responder's arms should be in contact with the helmet at the same level as if the athlete were supine, but their arms must be crossed upon initial immobilization of the cervical spine such that they become uncrossed as the injured athlete is log rolled to a supine position (Swartz et al., 2009). Should the head and neck not be in anatomical alignment, the cervical spine can be placed in neutral position for immobilization and securing to the spine board as long as no contraindications for alignment are present. If alignment compromises the airway or the efficacy of the airway, causes increased pain, results in an increase in neurological symptoms, is restricted by or results in increased muscle spasm, is physically difficult for the responder to perform, or if restriction is present upon attempt to align the cervical spine, the head, helmet, and neck should be immobilized in the last position that resulted in none of the aforementioned conditions. No further attempt to align the cervical spine should take place (Swartz et al., 2009).

In terms of equipment removal, the helmet and shoulder pads are to remain in place in the event of a cervical spine injury, while the facemask is removed in order to access the airway. To access the chest should cardiopulmonary resuscitation (CPR) or use of an automated external defibrillator (AED) be indicated, the laces of traditional shoulder pads are to be cut, the side buckles unbuckled, and the shoulder pads splayed anteriorly (Swartz et al., 2009). There are, however, three conditions that warrant removal of football helmet and shoulder pads. If access to the airway is not possible or removal of the facemask is unachievable in an appropriate amount of time, if the helmet is not properly fit and therefore securing of the helmet to the spine board does not result in sufficient immobilization of the head and cervical spine, or if leaving the helmet on does not result in neutral alignment of the cervical spine, both the helmet and the shoulder pads are to be removed (Swartz et al., 2009).

In the event that equipment removal is warranted, both the helmet and the shoulder pads must be removed. This ultimately reduces the risk of iatrogenic pathology or cervical spine compromise (Waninger, 1998). Decoster et al. measured the amount of cervical lordosis imposed on the cervical spine during four conditions including helmet on, helmet off, helmet off and the void filled with towels to the approximate distance the helmet held the head off the ground, and a final measurement of the third condition 20 minutes later. Using x-ray images, the cervical spine angles were measured determining there was a significant increase in cervical lordosis between the first and second condition. Additionally, they concluded there was no significant difference between the full equipment (helmet and shoulder pads on) condition and either condition using the towel to fill the void (Decoster et al., 2012). This suggests removal of the helmet without concomitant removal of the shoulder pads moves the cervical spine out of normal alignment. It is not known how much motion or in what plane may result in further injury to an already cervical spine compromised athlete, but it is generally accepted the least amount of motion induced during injury management, the better.

Similarly, Palumbo et al. studied the effect of equipment, both helmet and shoulder pads, on cervical spine position. Measurements of 15 cadavers were conducted using radiographs to assess the motion induced at the C5-C6 vertebral junction. The four conditions consisted of no equipment, helmet only, helmet and shoulder pads, and shoulder pads only. One image was taken on each cadaver for each condition with an intact cervical spine at the C5-C6 level. Based on these radiographs, the authors concluded that there was no significant change in angle at the vertebral level measured between the no equipment condition and the full equipment condition. They found a significant decrease in the lordotic angle of these vertebrae between the helmet only condition and the other 3 conditions. Lastly, a significant increase in cervical lordosis was noted when the shoulder pads only condition was compared to the no equipment condition and the full equipment condition (Palumbo et al., 1996). A year later, similar claims were made by Swenson et al. who concluded no differences between a no equipment condition and a full equipment condition in sagittal plane angle, yet found a significant increase in cervical lordosis when the helmet only condition was compared to the no equipment condition (Swenson, Lauerman, Blanc, Donaldson, & Fu, 1997). These two studies have contributed to the current recommendation of the National Athletic Trainers' Association (NATA), that when able, responders are to leave both pieces of equipment in place unless otherwise contraindicated as removal of one piece without the other may result unwanted cervical spine motion (Swartz et al., 2009).

In a study of cadavers with induced cervical spine instability, motion at the cervical spine was monitored with fluoroscopy during helmet and shoulder pad removal. The authors concluded that simultaneous removal of the helmet and shoulder pads resulted in less total cervical spine motion than was induced with removal of each piece of equipment separately (Donaldson, Lauerman, Heil, Blanc, & Swenson, 1998). As described in several articles, removal of one piece of equipment without removal of the other places the cervical spine out of neutral alignment (Palumbo et al., 1996; Swenson et al., 1997). Based on the findings of Donaldson et al. removal of equipment, if indicated, is to be done in a simultaneous fashion such that removal of one piece does not result in a delay before removal of the second leaving the cervical spine vulnerable to misalignment or further injury due to the responder's management.

Cervical Spine Injury Research Biomechanics

Head and Helmet Motion

As mentioned, stabilization of the helmet should limit head motion and, therefore, cervical spine motion of the injured athlete. Many studies have made the assumption that the head and properly fitted helmet move as a unit such that head and helmet motion directly correspond to estimations of cervical spine motion (Ray, Luchies, Frens, Hughes,

& Sturmfels, 2002; Swartz, Belmore, Decoster, & Armstrong, 2010; Swartz, Norkus, Cappaert, & Decoster, 2005). Toler et al. measured motion at both the head and helmet during various airway access techniques finding significant differences in head and helmet motion during certain conditions. The authors concluded inconsistent results, however, as the pocket mask insertion technique resulted in smaller differences in head and helmet motion than two other techniques in the study (Toler et al., 2010). This suggests that the head and helmet may move more congruently in certain response scenarios and less congruently in others. There is still a lack of consistent evidence to suggest that stabilization of the helmet does not effectively stabilize the head in other response conditions, such as equipment removal. Discrepancies in head and helmet motion may have resulted from the specific airway access technique, which may not demonstrate a real, on-field scenario. Measurement of head motion is clinically applicable as the first responder is in direct control of the head, not the cervical spine, during management of a cervical spine injured athlete (Swartz et al., 2011).

Helmet Removal

Although the focus of this thesis involves shoulder pad removal, this important step in the field is not possible until the helmet is first removed and, thus, is worthy of discussion. When equipment removal is indicated, the chin strap must be cut or unfastened from the helmet, the jaw pads must be removed or deflated, if the helmet allows for this, all air bladders deflated if applicable, and stabilization of the cervical spine must be assumed anteriorly by a second responder in a supine injured athlete. This allows the initial responder to then take the helmet and remove it from the injured athlete. (Bell, 2007; Swartz et al., 2009). Stabilization of the head by the second responder is accomplished by placing one hand on base of the athlete's occiput and one hand on their mandible using the thumb and index finger (Bell, 2007). The initial responder is then responsible for removal of the helmet by spreading each side of the helmet away from the athlete's head and pulling it superiorly, from the athlete's perspective. Due to helmet design, rotation of the helmet anteriorly, in reference to a supine athlete, may aid removal of this piece of equipment (Bell, 2007; Swartz et al., 2009).

Swartz et al. compared this current recommendation for manual helmet removal to a removal system designed to eject the helmet via inflatable bladders. This system, was designed to be used either in a prophylactic manner or such that it could be inserted between the helmet and the athlete's head when needed if helmet removal was necessary. This tool would be inflated using a handheld device or a specific air-filled cartridge. The inflatable bladder, once inserted if not already, would be filled enough where the helmet would be ejected from the athlete's head. While used primarily in motor sports, this device had not been investigated for use in football helmets. Thirty-five certified athletic trainers completed 2 manual helmet removals and 2 eject system helmet removals and the investigators measured head motion, time to task completion, and difficulty of the tasks. They concluded that there was no significant difference reported in difficulty between the two scenarios. Manual helmet removal was shown to be significantly faster than the time it took for the eject removal system to be completed. Lastly, the eject removal system resulted in significantly larger head movement throughout the procedure (insertion to removal) than the manual helmet removal in all three planes measured: frontal, sagittal, and transverse. Based on this, the authors completed a follow up comparison looking specifically at the time and head motion induced by removal for both techniques with exclusion of the insertion portion of the eject removal system. They reported significantly less overall time and motion in the frontal and transverse planes induced by manual helmet removal. One limitation of this study was that the measurements recorded were of head motion rather than cervical spine motion specifically. However, not only is this is the first study that had measured head motion in 3 planes during helmet removal, it is clinically relevant considering head and helmet motion are what responders are attempting to control during in-line stabilization of a potentially cervical spine injured athlete (Swartz et al., 2011). The investigators note that head motion will result in cervical spine motion. Thus, limiting the amount of head motion during management will also limit the amount of neck motion, which is the goal of all cervical spine management (Swartz et al., 2011).

Shoulder Pad Removal

Removal of the helmet is to be completed in conjunction with shoulder pad removal. If necessary, padding can be utilized as suggested by Decoster et al. to prevent the head and neck from moving into extension (Bell, 2007; Decoster, Swartz, Cappaert, & Hootman, 2010; Swartz et al., 2009). Once the helmet is removed, the initial responder takes over inline stabilization of the head by holding the head and neck in neutral while the second responder begins shoulder pad removal. To initiate shoulder pad removal, the responder must cut and splay the jersey, cut the anterior laces and unbuckle or cut the lateral straps of the shoulder pads. From here, one of two techniques can be used to complete shoulder pad removal.

Two techniques are noted in the literature as acceptable methods for removal of traditional, lace-up shoulder pads: elevated torso and flat torso. The elevated torso technique is an accepted protocol for shoulder pad removal according to the NATA (Peris et al., 2002). This removal technique involves 4 rescuers and a supine athlete with a suspected cervical spine injury. To remove the shoulder pads, the above steps are taken and then the torso of the athlete is elevated approximately 30-40 degrees so the shoulder pads can be slid out from underneath the athlete (Horodyski et al., 2009; Peris et al., 2002). The second technique, flat torso, involves a team of 2-4 rescuers. The initial steps for removal must take place including cutting the necessary attachments. The anterior portion of the apparatus is then splayed such that it clears the head and can be slid out from under the athlete cerebrally from the perspective of the injured athlete (Horodyski et al., 2009; Swartz et al., 2009).

Horodyski et al. compared the elevated torso technique to the flat torso technique using cadavers with and without induced cervical spine injury. Cadavers with initially intact cervical spines received each of the two shoulder pad removal techniques, flat torso and elevated torso, and then underwent each shoulder pad removal technique again following an experimentally induced cervical spine injury. They found that in the cadavers with the induced cervical spine instability, the elevated torso shoulder pad removal technique resulted in significantly less overall cervical spine motion when compared to the flat torso technique (Horodyski et al., 2009). It is reasonably prudent to assume a fracture or dislocation, in any athlete that presents with symptoms that would elicit inline stabilization and initiation of the spine injury emergency protocol. Additionally, Peris et al. viewed the cervical spine from baseline (a supine athlete in full equipment) through the elevated torso helmet and shoulder pad removal technique with the use of continuous fluoroscopy. They found no change in disc height, vertebral translation, or space available for the spinal cord through the duration of the protocol. Most importantly, no significant change was seen in the normal lordotic posture of the cervical spine from initial position to the elevated position (Peris et al., 2002). On the contrary, Dahl et al. note, while described as a viable option for equipment removal by the National Athletic Trainers' Association position statement, the elevated torso technique (tilt technique as described by the study) results in a greater amount of vertebral displacement between intact and lesioned cervical spines in cadaveric models compared to the log roll and five-person lift techniques (Dahl et al., 2009). The contradictions in the literature concerning the viability of the elevated torso technique in reducing cervical spine motion warrants further investigation.

During initial management of a cervical spine injured athlete, the primary goals of the responder are to maintain the life of the injured athlete if vital signs are compromised and provide proper management of the cervical spine. It is imperative the emergency responders make equipment removal decisions, when indicated, that provide the athlete with the best care, and in the case of cervical spine injury, the least amount of cervical spine motion.

Experience & Training

Experience

There is evidence to suggest there is no difference in experience with emergency response protocols. Toler et al. investigated airway access techniques on football athletes using certified athletic trainers (3.75 ± 3.95 years certified, 2.67 ± 3.18 seasons working football) and non-certified athletic training students (2.5 ± 1.36 semesters in the program, 0.92 ± 0.73 seasons working football). They found across all analyses of head and helmet motion there were no differences in clinical measure between the groups. This is to say that both certified athletic trainers and non-certified students induced approximately the same amount of head motion suggesting that experience, as defined by certification status, makes no difference in effectiveness of care (Toler et al., 2010).

Del Rossi et al. measured induced cervical spine motion during the log roll and lift and slide spine boarding techniques. The participants included certified athletic trainers, non-certified athletic training students, and emergency medical technicians. The subjects were randomly assigned into groups to complete each condition and all subjects watched the same video presentation prior to the familiarization period. During the familiarization period, all subjects completed both techniques on all 5 cadavers being used for the study. The study results showed no differences in cervical spine motion between the two techniques regardless of injury status as the cadavers were initially measured with healthy cervical spines and then received experimentally induced cervical spine instability at C5-C6. Although experience was not directly measured in this study, it is relevant as they used non-certified students as subjects (Del Rossi et al., 2004).

Toler et al., in a study of emergency airway access, analyzed the effect of experience on a multitude of clinical measures. The authors concluded that neither time nor head motion was significantly affected by certification status. Certification status was defined as certified athletic trainer or non-certified athletic training student (Toler et al., 2010).

It is our understanding that no studies at this time have measured differences in experience with football equipment removal.

Training & Retention

To our knowledge, no training retention effects have been investigated with regard to football equipment removal. In the aforementioned study of airway access techniques by Toler et al., significant improvements were reported in the amount of time to task completion and induced cervical spine motion from one trial to a second within participants. The authors did not find differences between participants, but rather performance improved from one trial to the next regardless of airway access technique being used for that trial (Toler et al., 2010). Another study investigated cardiopulmonary resuscitation (CPR) skill retention. The authors found skill deterioration in multiple medical professionals as early as two weeks following their initial training session in CPR (Moser & Coleman, 1992). This skill deterioration may be problematic in an emergency scenario depending on how distant the event is from the first responder's last CPR training. Furthermore, deterioration in lifesaving skills, such as CPR, could potentially determine the survival of the patient. In light of this studied skill deterioration, we investigated the effect of training retention in football equipment removal in terms of induced head motion, time to task completion, and perceived difficulty. Improvements in these clinical measures following reinforced training, or a deterioration in skills for those that do not receive reinforced training, may influence the notion of more frequent training sessions for emergency responding staff. Not only is it necessary to improve the clinical skills of clinicians completing equipment removal, but it is important skill retention take place to ensure emergency responders are prepared to deliver the optimal care to a potentially cervical spine injured athlete when necessary.

Methodological Considerations

The Riddell™ RipKord shoulder pads present an alternative method for equipment removal. Removal of these new shoulder pads requires 2-3 rescuers, unlike the flat and elevated torso techniques which each require 2-4 (Horodyski et al., 2009; Kordecki et al., 2011). These shoulder pads are manufactured such that, to remove them, the rescuer must cut the anterior laces and zip tie, and then pull the anteriorly fastened RipKord. Removal of the RipKord results in posterior separation of the shoulder pads into right and left halves. The shoulder pads can then be slid out from either side of the supine athlete with no need for elevation (Kordecki et al., 2011).

Bric et al. compared use of the Riddell™ RipKord shoulder pads to the flat torso shoulder pad removal technique on cervical spine motion, time to task completion, and perceived difficulty of the task. They found shoulder pad removal utilizing the Riddell™ RipKord shoulder pads resulted in a significantly shorter amount of time to task completion when compared with the flat torso technique. However, the authors found no differences between the two methods of shoulder pad removal in cervical spine motion (measured in the frontal, sagittal, and transverse planes). Lastly, no differences were reported in the perceived difficulty between the two tasks (Bric et al., 2013). To our knowledge, there has been no comparison of the new Riddell™ RipKord shoulder pad technology to the elevated torso technique. It is necessary to investigate the induced cervical spine motion, time to task completion, and perceived difficulty between these two techniques to make appropriate future recommendations for clinical practice.

Measurement of Cervical Spine Motion

Head motion has been measured using a variety of measurement tools. Many studies have used optoelectric motion capture systems with high-speed cameras and active reflective markers to measure the head motion induced during various emergency protocols (Swartz et al., 2010; Swartz et al., 2011; Swartz, Nowak, Shirley, & Decoster, 2005). Others have utilized electromagnetic motion capture systems to measure head and helmet motion, as well as cervical spine motion (Del Rossi et al., 2004; James, Riemann, Munkasy, & Joyner, 2004; Mihalik, Beard, Petschauer, Prentice, & Guskiewicz, 2008; Toler et al., 2010).

A pilot study conducted by Morphett et al. examined passive cervical spine motion using an electromagnetic tracking system. Study subjects were fixed with one electromagnetic sensor atop a plastic helmet. Head motion was measured via the sensor relative to the fixed electromagnetic transmitter. Full range of motion was measured from anatomical neutral in all three planes (sagittal, frontal, and transverse) using the electromagnetic tracking system. Two sets of measurements were taken, one by an experienced clinician and one set by an inexperienced clinician. They concluded that the electromagnetic motion capture system is an accurate measurement instrument for the objective evaluation of passive cervical spine motion. This system was shown to have high intraexaminer reliability regardless of experience operating the equipment with intercorrelation coefficient (ICC) values of 0.97, 0.94, and 0.96 for rotation, lateral flexion, and flexion/extension, respectively. Interexaminer reliability was shown to be fair to high with ICC values of 0.94, 0.80, and 0.78 for rotation, lateral flexion, and flexion/extension, respectively. (Morphett, Crawford, & Lee, 2003). Intrainstrument reliability values for the electromagnetic tracking system were shown to be good to high with ICC values of 0.94, 0.89, and 0.90 for rotation, lateral flexion, and flexion/extension, respectively (Morphett et al., 2003).

An electromagnetic motion capture system, MotionStar (Ascension, Inc., Burlington, VT), was used to measure head motion relative to a fixed thorax during football shoulder pad removal from a supine model. The absolute value of head motion was measured to achieve resultant head motion in all planes. A Simpson integration was used to calculate the absolute value of movement in all 3 planes (Toler et al., 2010).

All equipment was fit according to manufacturer guidelines and a 9-volt trigger was used to time each trial. When depressed by the primary investigator, the signal to the trigger exceeded 9 volts (9V) and spike in the data marked the time stamp at that moment. The trigger was activated at the initiation of the trial (onset of cervical spine stabilization) and at the end of the trial with the injured patient model lying in neutral.

Perceived difficulty, RPE, was measured using a modified Borg CR 10 scale. This scale has been used frequently in the relevant literature and has been chosen for future comparisons to other equipment removal protocols (Copeland, Decoster, Swartz, Gattie, & Gale, 2007; Swartz et al., 2010; Swartz et al., 2011; Swartz, Norkus, et al., 2005).

CHAPTER III

METHODOLOGY

Participants

Thirty-two participants were recruited (12 males, 20 females, age = 28.25 ± 7.75 years, height = 172.89 ± 10.04 cm, weight = 80.95 ± 18.66 kg, years certified as an athletic trainer = 6.02 ± 7.48 years, experience with equipment intensive sports = 3.35 ± 4.69 years, last training in equipment removal = 3.95 ± 4.80 years) for this experimental prospective repeated measures study. All participants were certified athletic trainers or eligible to take the Board of Certification examination. Participants were excluded if they were younger than age 18, had any current upper extremity injury, a neuromuscular disorder, or reported any bias toward the study, study participants, or equipment removal techniques. Each participant was required to read and sign an informed consent approved by our institution detailing the purpose of the study prior to participation. The participants then completed a demographic questionnaire and were allowed to ask questions regarding their participation in the study.

Instrumentation

Injured Patient Model

A research assistant served as the injured patient model. A total of six male injured patient models were used throughout the entirety of the study (age = 20.83 ± 1.72 years, height = 186.09 ± 7.47 cm, weight = 92.50 ± 9.50 kg). The model was fit with shoulder pads according to the manufacturer's guidelines. The same Riddell™ RipKord shoulder pads were used for all trials and techniques. For the elevated and flat torso removal techniques, the participants were asked to disregard the RipKord mechanism and manage the scenario as though the athlete were wearing traditional shoulder pads. The same certified athletic trainer verified shoulder pad fit prior to all trials.

Research Assistants

Two research assistants (RA_1 and RA_2) were employed to assist in the equipment removal techniques when necessary. For all trials, RA_1 removed a wood head block (described below) once the participant at the head verbally confirmed readiness. This initiated the trial. Specific roles of the RAs are described in each technique below.

Riddell™ RipKord Shoulder Pads

The Riddell™ RipKord shoulder pads (Figure 4.1), designed in 2011, represent a novel removal technique utilizing a stiff guided cable laced through the shoulder pads connecting right and left sides posteriorly. On the right side of the shoulder pads there are two posteriorly fastened loop-tabs that insert through two slits on the back of the left half of the shoulder pads. The RipKord runs through the loops, thus securing both sides together. After the anterior laces are cut, the attachment (zip tie) of the RipKord is cut, and the RipKord pulled. Two rescuers are then able to slide each side of the shoulder pads laterally from underneath the injured athlete (Kordecki et al., 2011).

Modified Borg CR10 Rating of Perceived Exertion

A modified Borg CR10 scale was administered to each participant following the completion of each technique for evaluation of RPE. This scale was used to draw conclusions about the perceived difficulty of each removal technique. Each participant individually and privately completed separate RPE scales by circling the number that they believed best described their perception of the level of difficulty for each removal technique (taking into consideration their position at the head and the torso). This scale has been used frequently in the relevant literature and was chosen to allow for future comparisons to other equipment removal protocols (Copeland et al., 2007; Swartz et al., 2010; Swartz et al., 2011; Swartz, Norkus, et al., 2005). The RPE scale ranged from 0 to 10 with 0 defined as no difficulty at all and 10 defining the task as impossible (Swartz et al., 2005).

Three-Dimensional Motion Analysis System

Data were collected using an electromagnetic motion capture system, (Motion Star, Ascension, Inc., Burlington, VT), and controlled by Motion Monitor Software (Innovative Sports Training, Chicago, IL). Using an electromagnetic field, the system captured 3-dimensional movement of the head-to-thorax body segment (Del Rossi et al., 2004; James et al., 2004; Toler et al., 2010). This motion capture system had a static accuracy orientation measure of 0.5 degrees in a five-foot range and measured six degrees of freedom from the sensors within the electromagnetic field (Ascension Motion Star, Burlington VT). One electromagnetic sensor was placed on the forehead of the injured patient model to measure head motion. A second sensor was placed on the proximal manubrium of the sternum. This sensor was used as a reference for head-to-thorax motion, which was used to interpret cervical spine motion (Walmsley, Kimber, & Culham, 1996). Sensor placement was chosen based on their proximity to the fixed transmitter, limited soft tissue underlying the skin, low likelihood breathing would influence the markers, and convenience for equipment removal. Once all sensors were in place, the head and thorax segments were digitized with the motion capture system and the axes oriented. The injured patient model, marked with sensors, sat upright in the electromagnetic field. Using a stylus, the head segment was digitized using the bridge of the nose, the center of the chin, and the occipital protuberance. In the same way, the thorax segment was digitized using the spinous process of T8, the xiphoid process of the sternum, and the spinous process of C7 (Toler et al., 2010). This digitization was done to establish an approximate joint center location for the head-to-thorax body segment.

Procedures

Participants were randomly selected into pairs and then randomized to removal technique order. Additionally, the starting position (head or torso) for each rescuer within the team unit was also randomized (4 trials of each): 1) elevated torso with traditional shoulder pads; 2) flat torso with traditional shoulder pads; and 3) Riddell™ RipKord shoulder pad removal. Each participant completed 2 of the pair's 4 trials positioned at the head, and the other 2 trials positioned at the injured patient model's torso. This order was randomized.

Orientation

The injured patient model was positioned supine, on a large piece of field turf to simulate equipment removal on a football field, with the model's head on a 12" long wood 2"x4" block. This block recreated the approximate height from the floor the head would be resting had the helmet still been in place (3.8 cm). The injured patient model was instructed to be completely relaxed with eyes closed (Figure 4.1). The supine position with helmet removed was based on the tenet that a prone patient would have undergone a prone log roll and helmet removal would have occurred prior to shoulder pad removal. Each participant pair underwent training in all 3 equipment removal techniques at both the head and torso positions. They were guided through a detailed practice session, using a simulation manikin fitted with shoulder pads, where mistakes were corrected and participants were permitted to practice until proficiency the shoulder pad removal techniques was achieved. Participants achieved proficiency when they were able to verbally confirm they were comfortable and displayed competency in completion of each removal technique positioned at both the head and at the torso. The participants' hand placement when taking over stabilization of the head was left to the discretion of the participant. There was, however, very little variability in the method of stabilization chosen by the participants. The majority of participants stabilized the head at the level of the mastoid processes of the IPM's bilateral temporal bones.

Testing Session I

All trials in Testing Session I were used to address the first aim of the study. Following the orientation session, participants completed the actual testing procedures. Prior to recording each removal technique, the primary investigator read a standardized scenario with generalized instructions for the equipment removal technique to be employed. These instructions explained the task was to be completed in the shortest amount of time while attempting to induce the least amount of head and neck motion as possible. Removal of the simulated helmet block by the research assistant positioned at the left shoulder of the injured patient model (RA_1), and verbal confirmation of "ready" were given to the primary investigator, who initiated the trial by depressing a 9V trigger synced with the motion capture system.

A failed trial was considered one in which the subjects took more than two minutes to remove the shoulder pads, shoulder pad equipment failure, tool failure (shears, 9-volt trigger, etc.), or other unexpected reasons. Pilot testing revealed two minutes to be an acceptable time to deem a failed trial as equipment removal could be completed with ample time to spare under two minutes. Two sets of participant trials in Testing Session I were excluded from the study, and not replaced, due to failure of the trigger to mark the start and end of the trials. Following completion of all 4 trials of a given technique, both participants completed a modified Borg CR10 perceived difficulty scale. The procedures for each shoulder pad removal technique were completed as follows (Table 4.1):

Elevated torso with traditional shoulder pads (Figure 4.3). The elevated torso with traditional shoulder pads technique was completed such that the participant at the head maintained the head and cervical spine in a neutral position. RA_1 then removed the wood head block after the participant at the head signaled readiness. The primary investigator depressed the 9V trigger to mark the initiation of the trial. The participant at the torso then began removal of the shoulder pads by cutting the anterior laces and unbuckling the side straps of the shoulder pads. The participant at the torso then took over inline stabilization. Once the participant at the torso had control of the head, he/she and two research assistants (RA_1 and RA_2 positioned at the right and left shoulder of the injured patient model, respectively) simultaneously elevated the torso of the injured patient model 30-40 degrees, or enough for the participant at the head to remove the shoulder pads from beneath the injured patient model. The participant at the torso, when ready, provided the signal to RA_1 and RA_2 to initiate elevation and lowering of the injured patient model. Following shoulder pad removal, the injured patient model was then lowered down until his head and torso were both in contact with the ground in a neutral position (Horodyski et al., 2009; Peris et al., 2002). The 9V trigger was used to mark the initiation of the trial after removal of the simulated helmet block and the end of the trial. The end of the trial was triggered at the moment the injured patient model was resting in a supine neutral position. This condition was repeated four times with each participant completing two trials at the head position and two trials at the torso position in random order.

Flat torso with traditional shoulder pads (Figure 4.4). The flat torso with traditional shoulder pads technique was completed such that the participant at the head maintained the head and cervical spine in a neutral position. RA_1 then removed the wood head block after the participant at the head signaled readiness. The primary investigator depressed the 9V trigger to mark the initiation of the trial. The participant at the torso then began removal of the shoulder pads by cutting the anterior laces and unbuckling the side straps of the shoulder pads. The participant at the torso then took over inline stabilization of the injured patient model's head. The participant at the head then splayed the anterior portion of the shoulder pads over top of the injured patient model's head and slid the remaining portion out from underneath model cerebrally. During removal of the shoulder pads, the head and torso were allowed to lower to the flat surface (Horodyski et al., 2009). The 9V trigger was used to mark the initiation of the trial after removal of the wood head block and the end of the trial. The end of the trial was triggered at the moment the injured patient model was resting in a supine neutral position. This condition was repeated four times with each participant completing two trials at the head position and two trials at the torso position in random order.

Riddell™ RipKord shoulder pad removal (Figure 4.5). The Riddell™ RipKord shoulder pad removal technique was completed such that the participant at the head maintained the head and cervical spine in a neutral position. RA_1 then removed the wood head block after the participant at the head signaled readiness. The primary investigator depressed the 9V trigger to mark the initiation of the trial. The participant at the torso then began removal of the shoulder pads by cutting the anterior laces and the anteriorly fastened zip tie that holds the RipKord in place. The participant at the torso then pulled the RipKord device, which allowed for posterior separation of the shoulder pads. The participant at the torso and RA_1 then slid each side (right and left) laterally out from underneath the torso and down each arm of the injured patient model (Kordecki et al., 2011). During equipment removal, the injured patient model was placed with both the head and torso in contact with the flat surface in a neutral position. The 9V trigger was used to mark the initiation of the trial after removal of the wood head block and the end of the trial. The end of the trial was triggered at the moment the injured patient model was resting in a supine neutral position. This condition was repeated four times with each participant completing two trials at the head position and two trials at the torso position in random order.

Following completion of all 12 trials (4 for each shoulder pad removal technique), the primary investigator debriefed both participants. The participants were provided with contact information for the primary investigator in the event questions arose at a later date regarding their participation in this study. The participant pair then scheduled a second testing session approximately 4 weeks following their initial data collection session. They were instructed not to perform any form of football equipment removal training between the end of Testing Session I and the beginning of Testing Session II.

Testing Session II

In order to address our second aim, each participant pair was randomly assigned without replacement to one of two groups: reinforced training group or control group. Each participant pair in the control group completed the same equipment removal trials as in Testing Session I with repeated verbal instructions, but no further training or practice period. Each participant pair in the reinforced training group completed the procedures employed for Testing Session I a second time including the verbal instruction, removal training, and a practice period. All trials for Testing Session II were completed approximately 4 weeks (29.19 ± 2.58 days) after completion of Testing Session I in 1 of 6 counterbalanced orders for equipment removal technique and position at the head or torso. Following the completion of Testing Session II, the primary investigator debriefed each participant one last time to address any questions they had regarding their participation in this study.

Data Reduction

Kinematic data were sampled at 144 Hz. Orthogonal axes were defined in the order of YZX where positive Y indicated motion into cervical flexion, positive Z indicated left cervical rotation, and positive X indicated right cervical lateral flexion (James et al., 2004; Toler et al., 2010). Head to thorax motion that occurred in each plane was captured using Motion Monitor (Innovative Sports Training; Chicago, IL) and imported into a custom Matlab (The MathWorks, Inc.) program for subsequent reduction.

A trigger was used to define the beginning and end of each trial which served as our measure of time to task completion. To account for any difference in starting position, the average of the first 10 data points in each trial was subtracted from all the data points in that given trial. In order to obtain the total amount of motion in a given plane, the data were computed using a Simpson's integration. The data were normalized to time in order to take into account any variation in the total amount of time needed to complete the trials. We also calculated the range of motion for each trial by subtracting the minimum value in each trial from the maximum. For each participant pairing the mean was calculated from the four individual trials for each technique during each session.

We computed the RPE difference between both team participants across all techniques and sessions, and tested these differences against a null value of zero by employing a one-sample t-test. No statistically significant departure from zero was observed ($t_{95} = 0.89$; $P = 0.378$); thus, we computed the mean of both participants' RPE as our outcome measure for these analyses.

Statistical Analyses

Our first research question was analyzed using separate one-way repeated measures analyses of variance (ANOVA) across our three equipment removal techniques (elevated torso—traditional pads; flat torso—traditional pads; and Riddell™ RipKord shoulder pad removal) for each dependent variable of interest (sagittal, frontal, and transverse head-to-thorax integrated motion and range of motion; time to task completion; and RPE). We employed Mauchly's Test of Sphericity on our analyses and, when significant, we employed a Greenhouse-Geisser correction. To address Research Question 2, separate 2 (training group assignment) x 2 (testing session) mixed model ANOVAs were implemented for each dependent variable of interest. All statistical analyses were completed using SPSS Version 19 (SPSS Inc., Chicago, IL). An a priori alpha level of 0.05 was set for statistical significance. Tukey post hoc testing was employed to explore all statistically significant omnibus ANOVA interactions and main effects.

CHAPTER IV

MANUSCRIPT

Introduction

Football athletes are at a high risk for sustaining cervical spine injuries (Mueller & Cantu, 2012). Football produces the highest total number of catastrophic spine injuries of all sports in the United States (Mueller & Cantu, 2012). Currently, the standard of care for a spine injured football athlete is to leave all equipment in place, with the exception of the facemask, while providing rescue care unless one or more of the following conditions are present: 1) access to the airway is not possible or removal of the facemask is unachievable in an appropriate amount of time; 2) the helmet is not properly fit and therefore securing the helmet to the spine board does not result in sufficient immobilization of the head and cervical spine; or 3) leaving the helmet on does not result in neutral alignment of the cervical spine (Swartz et al., 2009). If one of the three aforementioned conditions is present, it is necessary to remove both the helmet and the shoulder pads concurrently (Swartz et al., 2009), as removal of one without the other increases the risk of placing the cervical spine of the athlete in a potentially dangerous extension position (Palumbo et al., 1996). Should full equipment removal be unachievable due to the circumstances of the institution (i.e. too few personnel), but airway access and chest exposure are necessary for attachment of an automated external defibrillator (as in a cardiac event), it is acceptable practice to remove the helmet and fill the void between the occiput and the ground using available padding. With heightened concern for a cervical spine injury, this prevents the cervical spine from assuming a potentially dangerous extension position following helmet removal with the shoulder pads still in place (Swartz et al., 2009).

Traditionally, the flat torso technique has been employed for shoulder pad removal. This method involves 2-4 rescuers, and is accomplished by unfastening the side straps of the shoulder pads, cutting the laces that hold the shoulder pads together anteriorly, and sliding the remaining portion of the shoulder pads over the top of the injured athlete's head (Horodyski et al., 2009; Swartz et al., 2009). If four or more rescuers are available, the elevated torso technique may be employed. The shoulder pads are unfastened in the same manner as the flat torso technique. Shoulder pad removal is achieved after the patient is elevated to 30-40 degrees of trunk flexion, or just enough to allow for unencumbered removal of the shoulder pads while neutral alignment of the head, neck, and torso are maintained (Horodyski et al., 2009; Peris et al., 2002). One cadaveric study reported the elevated torso technique as a superior method for moderating the amount of induced cervical spine motion during shoulder pad removal when compared with the flat torso technique (Horodyski et al., 2009).However, Dahl et al. note that, while described as a viable option for equipment removal by the National Athletic Trainers' Association position statement, the elevated torso technique (tilt technique as described by the study) results in a greater amount of vertebral displacement between intact and lesioned cervical spines in cadaveric models compared to the log roll and five-person lift techniques (Dahl et al., 2009).

The Riddell™ RipKord technology has recently emerged to address the growing concern of unnecessary patient movement during equipment removal. The Riddell™

RipKord shoulder pads are identical to traditional shoulder pads in nearly all aspects, except for the RipKord itself and its posterior attachment conducive for separation. The RipKord is a guided cable that, when pulled, allows the shoulder pads to separate into right and left halves posteriorly. This allows each side of the shoulder pad to slide out independently from underneath the athlete, provided the anterior attachment is released (Kordecki et al., 2011). In one study investigating this new technology, the authors found that removing shoulder pads utilizing the Riddell™ RipKord system resulted in significantly less time to task completion compared to traditional shoulder pads utilizing the flat torso technique. However, the authors found no significant differences in cervical spine motion or in perceived difficulty between the two techniques (Bric et al., 2013). It is necessary to investigate the Riddell™ RipKord shoulder pad technology as its design yields the potential for providing a safer method of equipment removal by reducing the risk of iatrogenic pathology to a potentially spine injured athlete. To our knowledge, no investigation has directly compared each of the 3 equipment removal techniques (elevated torso with traditional shoulder pads, flat torso with traditional shoulder pads, and RipKord shoulder pad removal) under a single study design. Furthermore, many institutions complete spine boarding and equipment removal training sessions each year. However, no studies, to our knowledge, had explored the effect of reinforced training on the successful application of these three removal techniques. Thus, further investigation was warranted.

Therefore, the purpose of this study was twofold. The first aim was to compare induced head motion, time to task completion, and perceived difficulty during football equipment removal between the following three techniques: 1) elevated torso with traditional shoulder pads, 2) flat torso with traditional shoulder pads, and 3) Riddell™ RipKord shoulder pad removal. The second aim of the study was to measure the effect of reinforced equipment removal training on induced head motion, time to task completion, and perceived difficulty during football equipment removal.

Methodology

Participants

Thirty-two participants were recruited (12 males, 20 females, age = 28.25 ± 7.75 years, height = 172.89 ± 10.04 cm, weight = 80.95 ± 18.66 kg, years certified as an athletic trainer = 6.02 ± 7.48 years, experience with equipment intensive sports = 3.35 ± 4.69 years, last training in equipment removal = 3.95 ± 4.80 years) for this experimental prospective repeated measures study. All participants were certified athletic trainers or eligible to take the Board of Certification examination. Participants were excluded if they were younger than age 18, had any current upper extremity injury, a neuromuscular disorder, or reported any bias toward the study, study participants, or equipment removal techniques. Each participant was required to read and sign an informed consent approved by our institution detailing the purpose of the study prior to participation. The participants then completed a demographic questionnaire and were allowed to ask questions regarding their participation in the study.

Instrumentation

Injured Patient Model

A research assistant served as the injured patient model. A total of six male injured patient models were used throughout the entirety of the study (age = 20.83 ± 1.72 years, height = 186.09 ± 7.47 cm, weight = 92.50 ± 9.50 kg). The model was fit with shoulder pads according to the manufacturer's guidelines. The same Riddell™ RipKord shoulder pads were used for all trials and techniques. For the elevated and flat torso removal techniques, the participants were asked to disregard the RipKord mechanism and manage the scenario as though the athlete were wearing traditional shoulder pads. The same certified athletic trainer verified shoulder pad fit prior to all trials.

Research Assistants

Two research assistants (RA_1 and RA_2) were employed to assist in the equipment removal techniques when necessary. For all trials, RA_1 removed a wood head block (described below) once the participant at the head verbally confirmed readiness. This initiated the trial. Specific roles of the RAs are described in each technique below.

Riddell™ RipKord Shoulder Pads

The Riddell™ RipKord shoulder pads (Figure 4.1), designed in 2011, represent a novel removal technique utilizing a stiff guided cable laced through the shoulder pads connecting right and left sides posteriorly. On the right side of the shoulder pads there are two posteriorly fastened loop-tabs that insert through two slits on the back of the left half of the shoulder pads. The RipKord runs through the loops, thus securing both sides together. After the anterior laces are cut, the attachment (zip tie) of the RipKord is cut, and the RipKord pulled. Two rescuers are then able to slide each side of the shoulder pads laterally from underneath the injured athlete (Kordecki et al., 2011).

Modified Borg CR10 Rating of Perceived Exertion

A modified Borg CR10 scale was administered to each participant following the completion of each technique for evaluation of RPE. This scale was used to draw conclusions about the perceived difficulty of each removal technique. Each participant individually and privately completed separate RPE scales by circling the number that they believed best described their perception of the level of difficulty for each removal technique (taking into consideration their position at the head and the torso). This scale has been used frequently in the relevant literature and was chosen to allow for future comparisons to other equipment removal protocols (Copeland et al., 2007; Swartz et al., 2010; Swartz et al., 2011; Swartz, Norkus, et al., 2005). The RPE scale ranged from 0 to 10 with 0 defined as no difficulty at all and 10 defining the task as impossible (Swartz et al., 2005).

Three-Dimensional Motion Analysis System

Data were collected using an electromagnetic motion capture system, (Motion Star, Ascension, Inc., Burlington, VT), and controlled by Motion Monitor Software (Innovative Sports Training, Chicago, IL). Using an electromagnetic field, the system captured 3-dimensional movement of the head-to-thorax body segment (Del Rossi et al., 2004; James et al., 2004; Toler et al., 2010). This motion capture system had a static accuracy orientation measure of 0.5 degrees in a five-foot range and measured six degrees of freedom from the sensors within the electromagnetic field (Ascension Motion Star, Burlington VT). One electromagnetic sensor was placed on the forehead of the injured patient model to measure head motion. A second sensor was placed on the proximal manubrium of the sternum. This sensor was used as a reference for head-to-thorax motion, which was used to interpret cervical spine motion (Walmsley et al., 1996). Sensor placement was chosen based on their proximity to the fixed transmitter, limited soft tissue underlying the skin, low likelihood breathing would influence the markers, and convenience for equipment removal. Once all sensors were in place, the head and thorax segments were digitized with the motion capture system and the axes oriented. The injured patient model, marked with sensors, sat upright in the electromagnetic field. Using a stylus, the head segment was digitized using the bridge of the nose, the center of the chin, and the occipital protuberance. In the same way, the thorax segment was digitized using the spinous process of T8, the xiphoid process of the sternum, and the spinous process of C7 (Toler et al., 2010). This digitization was done to establish an approximate joint center location for the head-to-thorax body segment.

Procedures

Participants were randomly selected into pairs and then randomized to removal technique order. Additionally, the starting position (head or torso) for each rescuer within the team unit was also randomized (4 trials of each): 1) elevated torso with traditional shoulder pads; 2) flat torso with traditional shoulder pads; and 3) Riddell™ RipKord shoulder pad removal. Each participant completed 2 of the pair's 4 trials positioned at the head, and the other 2 trials positioned at the injured patient model's torso. This order was randomized.

Orientation

The injured patient model was positioned supine, on a large piece of field turf to simulate equipment removal on a football field, with the model's head on a 12" long wood 2"x4" block. This block recreated the approximate height from the floor the head would be resting had the helmet still been in place (3.8 cm). The injured patient model was instructed to be completely relaxed with eyes closed (Figure 4.1). The supine position with helmet removed was based on the tenet that a prone patient would have undergone a prone log roll and helmet removal would have occurred prior to shoulder pad removal. Each participant pair underwent training in all 3 equipment removal techniques at both the head and torso positions. They were guided through a detailed practice session, using a simulation manikin fitted with shoulder pads, where mistakes were corrected and participants were permitted to practice until proficiency the shoulder pad removal techniques was achieved. Participants achieved proficiency when they were able to verbally confirm they were comfortable and displayed competency in completion of each removal technique positioned at both the head and at the torso. The participants' hand placement when taking over stabilization of the head was left to the discretion of the participant. There was, however, very little variability in the method of stabilization chosen by the participants. The majority of participants stabilized the head at the level of the mastoid processes of the IPM's bilateral temporal bones.

Testing Session I

All trials in Testing Session I were used to address the first aim of the study. Following the orientation session, participants completed the actual testing procedures. Prior to recording each removal technique, the primary investigator read a standardized scenario with generalized instructions for the equipment removal technique to be employed. These instructions explained the task was to be completed in the shortest amount of time while attempting to induce the least amount of head and neck motion as possible. Removal of the simulated helmet block by the research assistant positioned at the left shoulder of the injured patient model (RA_1), and verbal confirmation of "ready" were given to the primary investigator, who initiated the trial by depressing a 9V trigger synced with the motion capture system.

A failed trial was considered one in which the subjects took more than two minutes to remove the shoulder pads, shoulder pad equipment failure, tool failure (shears, 9-volt trigger, etc.), or other unexpected reasons. Pilot testing revealed two minutes to be an acceptable time to deem a failed trial as equipment removal could be completed with ample time to spare under two minutes. Two sets of participant trials in Testing Session I were excluded from the study, and not replaced, due to failure of the trigger to mark the start and end of the trials. Following completion of all 4 trials of a given technique, both participants completed a modified Borg CR10 perceived difficulty scale. The procedures for each shoulder pad removal technique were completed as follows (Table 4.1):

Elevated torso with traditional shoulder pads (Figure 4.3). The elevated torso with traditional shoulder pads technique was completed such that the participant at the head maintained the head and cervical spine in a neutral position. RA_1 then removed the wood head block after the participant at the head signaled readiness. The primary investigator depressed the 9V trigger to mark the initiation of the trial. The participant at the torso then began removal of the shoulder pads by cutting the anterior laces and unbuckling the side straps of the shoulder pads. The participant at the torso then took over inline stabilization. Once the participant at the torso had control of the head, he/she and two research assistants (RA_1 and RA_2 positioned at the right and left shoulder of the injured patient model, respectively) simultaneously elevated the torso of the injured patient model 30-40 degrees, or enough for the participant at the head to remove the shoulder pads from beneath the injured patient model. The participant at the torso, when ready, provided the signal to RA_1 and RA_2 to initiate elevation and lowering of the injured patient model. Following shoulder pad removal, the injured patient model was then lowered down until his head and torso were both in contact with the ground in a neutral position (Horodyski et al., 2009; Peris et al., 2002). The 9V trigger was used to mark the initiation of the trial after removal of the simulated helmet block and the end of the trial. The end of the trial was triggered at the moment the injured patient model was resting in a supine neutral position. This condition was repeated four times with each participant completing two trials at the head position and two trials at the torso position in random order.

Flat torso with traditional shoulder pads (Figure 4.4). The flat torso with traditional shoulder pads technique was completed such that the participant at the head maintained the head and cervical spine in a neutral position. RA_1 then removed the wood head block after the participant at the head signaled readiness. The primary investigator depressed the 9V trigger to mark the initiation of the trial. The participant at the torso then began removal of the shoulder pads by cutting the anterior laces and unbuckling the side straps of the shoulder pads. The participant at the torso then took over inline stabilization of the injured patient model's head. The participant at the head then splayed the anterior portion of the shoulder pads over top of the injured patient model's head and slid the remaining portion out from underneath model cerebrally. During removal of the shoulder pads, the head and torso were allowed to lower to the flat surface (Horodyski et al., 2009). The 9V trigger was used to mark the initiation of the trial after removal of the wood head block and the end of the trial. The end of the trial was triggered at the moment the injured patient model was resting in a supine neutral position. This condition was repeated four times with each participant completing two trials at the head position and two trials at the torso position in random order.

Riddell™ RipKord shoulder pad removal (Figure 4.5). The Riddell™ RipKord shoulder pad removal technique was completed such that the participant at the head maintained the head and cervical spine in a neutral position. RA_1 then removed the wood head block after the participant at the head signaled readiness. The primary investigator depressed the 9V trigger to mark the initiation of the trial. The participant at the torso then began removal of the shoulder pads by cutting the anterior laces and the anteriorly fastened zip tie that holds the RipKord in place. The participant at the torso then pulled the RipKord device, which allowed for posterior separation of the shoulder pads. The participant at the torso and RA_1 then slid each side (right and left) laterally out from underneath the torso and down each arm of the injured patient model (Kordecki et al., 2011). During equipment removal, the injured patient model was placed with both the head and torso in contact with the flat surface in a neutral position. The 9V trigger was used to mark the initiation of the trial after removal of the wood head block and the end of the trial. The end of the trial was triggered at the moment the injured patient model was resting in a supine neutral position. This condition was repeated four times with each participant completing two trials at the head position and two trials at the torso position in random order.

Following completion of all 12 trials (4 for each shoulder pad removal technique), the primary investigator debriefed both participants. The participants were provided with contact information for the primary investigator in the event questions arose at a later date regarding their participation in this study. The participant pair then scheduled a second testing session approximately 4 weeks following their initial data collection session. They were instructed not to perform any form of football equipment removal training between the end of Testing Session I and the beginning of Testing Session II.

Testing Session II

In order to address our second aim, each participant pair was randomly assigned without replacement to one of two groups: reinforced training group or control group. Each participant pair in the control group completed the same equipment removal trials as in Testing Session I with repeated verbal instructions, but no further training or practice period. Each participant pair in the reinforced training group completed the procedures employed for Testing Session I a second time including the verbal instruction, removal training, and a practice period. All trials for Testing Session II were completed approximately 4 weeks (29.19 ± 2.58 days) after completion of Testing Session I in 1 of 6 counterbalanced orders for equipment removal technique and position at the head or torso. Following the completion of Testing Session II, the primary investigator debriefed each participant one last time to address any questions they had regarding their participation in this study.

Data Reduction

Kinematic data were sampled at 144 Hz. Orthogonal axes were defined in the order of YZX where positive Y indicated motion into cervical flexion, positive Z indicated left cervical rotation, and positive X indicated right cervical lateral flexion (James et al., 2004; Toler et al., 2010). Head to thorax motion that occurred in each plane was captured using Motion Monitor (Innovative Sports Training; Chicago, IL) and imported into a custom Matlab (The MathWorks, Inc.) program for subsequent reduction.

A trigger was used to define the beginning and end of each trial which served as our measure of time to task completion. To account for any difference in starting position, the average of the first 10 data points in each trial was subtracted from all the data points in that given trial. In order to obtain the total amount of motion in a given plane, the data were computed using a Simpson's integration. The data were normalized to time in order to take into account any variation in the total amount of time needed to complete the trials. We also calculated the range of motion for each trial by subtracting the minimum value in each trial from the maximum. For each participant pairing the mean was calculated from the four individual trials for each technique during each session.

We computed the RPE difference between both team participants across all techniques and sessions, and tested these differences against a null value of zero by employing a one-sample t-test. No statistically significant departure from zero was observed ($t_{95} = 0.89$; $P = 0.378$); thus, we computed the mean of both participants' RPE as our outcome measure for these analyses.

Statistical Analyses

Our first research question was analyzed using separate one-way repeated measures analyses of variance (ANOVA) across our three equipment removal techniques (elevated torso—traditional pads; flat torso—traditional pads; and Riddell™ RipKord shoulder pad removal) for each dependent variable of interest (sagittal, frontal, and transverse head-to-thorax integrated motion and range of motion; time to task completion; and RPE). We employed Mauchly's Test of Sphericity on our analyses and, when significant, we employed a Greenhouse-Geisser correction. To address Research Question 2, separate 2 (training group assignment) x 2 (testing session) mixed model

ANOVAs were implemented for each dependent variable of interest. All statistical analyses were completed using SPSS Version 19 (SPSS Inc., Chicago, IL). An a priori alpha level of 0.05 was set for statistical significance. Tukey post hoc testing was employed to explore all statistically significant omnibus ANOVA interactions and main effects.

Results

Two participant pairs were excluded from motion and time analyses due to trigger failure. Since the RPE ratings were not influenced by the trigger employed for our motion data capture, they were included in our analyses explaining the discrepancy in degrees of freedom for the results presented below.

Effect of Shoulder Pad Removal Technique

A main effect of time across shoulder pad removal technique was identified ($F_{2,26} = 44.89$, $P < 0.001$). Less time was required to perform the Riddell™ RipKord shoulder pad removal technique compared to the flat torso with traditional shoulder pads ($P < 0.001$) and the elevated torso with traditional shoulder pads ($P < 0.001$). We observed a main effect of RPE ($F_{2,30} = 3.41$, $P = 0.046$), such that the Riddell™ RipKord shoulder pad removal technique had lower difficulty ratings compared to the flat torso with traditional shoulder pads removal technique ($P < 0.05$). All other analyses were not statistically significant ($P > 0.05$). All descriptive (means and standard deviations) and statistical data for Aim 1 are provided in Table 4.2.

Interaction Between Training Groups and Testing Sessions

A significant interaction of testing session and training group was observed with the flat torso with traditional shoulder pads removal technique in range of motion in the sagittal plane ($F_{1,12} = 11.75$, $P = 0.005$) and the frontal plane ($F_{1,12} = 5.47$, $P = 0.038$). Specifically, the reinforcement group saw improvements in limiting range of motion in both planes ($P < 0.05$). Our participants were able to complete the flat ($F_{1,12} = 19.03$, $P = 0.001$) and elevated ($F_{1,12} = 25.71$, $P < 0.001$) torso with traditional shoulder pads removal technique faster during Testing Session II compared to Testing Session I. No other interaction or main effects were statistically significant ($P > 0.05$). All descriptive (means and standard deviations) and statistical data are provided in Table 4.3.

Discussion

Removing RipKord shoulder pads is faster and easier compared to traditional shoulder pads under the conditions we studied. Improvements were observed in the reinforced training group with respect to cervical spine range of motion in the sagittal and frontal planes with the flat torso with traditional shoulder pads removal technique. Repeating the testing (Session II) resulted in improvements in time for both traditional (elevated and flat) shoulder pad removal techniques.

Effect of Shoulder Pad Removal Technique

A significantly shorter time to task completion of Riddell™ RipKord shoulder pad removal is consistent with the findings of Bric et al. and our hypotheses when comparing the RipKord shoulder pads to the flat torso removal technique with traditional shoulder pads (Bric et al., 2013). The implication of this finding is that the RipKord shoulder pad removal technique results in earlier access to the chest and therefore initiation of CPR and administration of an AED in the case of a cardiac event. The RipKord removal technique is unique in that it does not require the rescuers to switch between cervical spine stabilization. In other words, the certified athletic trainer immobilizing the cervical spine at the initiation of the removal technique remains the same throughout the process, eliminating the time it takes to complete the cervical spine transfer. A lack of required cervical spine stabilization transfer likely resulted in this technique being faster to complete compared to both flat and elevated traditional shoulder pad removal techniques, as well as easier than the flat torso removal technique. These findings are consistent with our hypotheses. Ultimately, shorter time for removal allows athletic trainers to more quickly provide lifesaving care to injured athletes. Another potential influencing factor of time to task completion was the unbuckling of the side straps. In an emergency scenario, it is likely that these straps would be cut rather than unbuckled. It is unlikely, however, that this would cause a significant difference in time to removal than the times observed in this study. Lastly, the Riddell™ RipKord shoulder pad removal technique received a lower overall difficulty score compared to the flat torso technique due to a number of likely factors. In particular, this technique is set apart from the others with the RipKord being a stiff guided cable that, when pulled, easily slides out from under the injured patient and splits the back of the shoulder pads in two easily removable pieces. This creates a simple and easy-to-understand removal technique; thereby, reducing the number of steps athletic trainers have to remember to properly complete the technique. This technique, while easier to perform than that of the flat torso technique, requires the responding clinicians to have an intricate understanding of the mechanism by which the guided RipKord cable is removed. Institutions should consider more widespread use of the RipKord shoulder pads as shortened time and increased ease of removal may expedite administration of necessary and appropriate care.

Differences in the three removal techniques exist outside of the clinical measures used for this study. The number of rescuers required for each technique, for example, varied. The flat torso with traditional shoulder pads requires at least 2 rescuers, the Riddell™ RipKord shoulder pad removal requires at least 3 rescuers, and the elevated torso with traditional shoulder pads requires at least 4 rescuers. While the manufacturer recommends 3 rescuers remove the RipKord shoulder pads, it would be worth exploring the extent of cervical spine motion elicited when only two rescuers—as might be seen at less competitive athletic events—attempt to remove these novel shoulder pads. In this scenario, we anticipate one rescuer would stabilize the cervical spine while the other would remove one side of the shoulder pads at a time. The problem, however, would be the transitional step when one half of the shoulder pads would be removed and the other still in place. This could place the trunk of the injured patient into non-neutral alignment and therefore alter the neutrality of the cervical spine. Further research should be performed to address differences in motion at the cervical spine when the RipKord technique is performed by various numbers of rescuers. Depending on the competitive level at which football is being played, there may be a limited number of trained responders available. This may dictate the use of one particular technique over another based solely on the ability of the primary responder to administer life-saving care. In light of the finding that the RipKord shoulder pads are a superior method for shoulder pad removal in terms of time, it is important institutions employing use of these shoulder pads have adequate staff or train additional personnel (if at a high school or small budget institutions) on equipment removal to ensure the technique is performed correctly.

Interaction Between Groups and Testing Sessions

Four weeks following an initial training/practice session in shoulder pad removal, certified athletic trainers were able to remove traditional shoulder pads using both the elevated torso and flat torso techniques faster regardless of further training. In addition, and consistent with our hypotheses, a second training session in equipment removal improved clinicians' moderation of cervical spine range of motion for the flat torso removal technique in both the sagittal and frontal planes. More frequent practice may decrease the risk of secondary injury by improving clinical measures such as cervical spine motion. In a spine injury scenario, it is unknown how much motion will cause further injury; however, it is generally accepted that limiting motion minimizes the possibility of secondary complications associated with the primary cervical spine injury. Although we observed improvements completing these removal techniques 4 weeks apart with further training, it is likely certified athletic trainers' football shoulder pad removal skills would decay if not practiced for longer periods of time (e.g. annual training/rehearsals). This skill decay may result in improper management of a cervical spine injured athlete and may cause further unnecessary injury. Decreases in cervical spine motion following two training sessions 4 weeks apart may impact best practices suggesting it is important to practice these techniques monthly to see skill improvement. However, no studies to our knowledge, have investigated these clinical measures across 1 year (customary time between spine boarding/equipment removal practice sessions). Based on these findings, for football teams that utilize traditional shoulder pads, sports medicine teams should consider monthly training sessions and practice. There appears to be an exposure-related retention during this 4-week window. Repeat training and removal rehearsal may help to improve performance by the sports medicine team. Future studies should explore how long this test-retest improvement is still notable in non-training groups to elucidate the minimum interval for rehearsal/training. The same training effects were not observed in the elevated torso or the RipKord removal techniques during Testing Session II. We did not observe any significant skill decay with these removal techniques. This is advantageous to institutions with large sports medicine teams since it is often logistically challenging to schedule monthly rehearsals in these settings. Institutions widely using the RipKord shoulder pads may need to rehearse this technique less frequently to stay within an acceptable level of competence. Long term practice and training effects need to be investigated to make conclusions about the improvements seen with training sessions at different time points and the effect on cervical spine motion, time, and difficulty.

Because no differences were seen between groups in Testing Session II, it is possible there is a limit to the time and skill improvement that can be made with practice of any skill. It is possible that our modest sample size may have mitigated significant findings related to training group differences. However, our sample size was consistent with others published in this domain. Further investigation on training effects should be completed to determine the necessary number of practice sessions throughout the year and the aggregate improvement of clinician skills.

Limitations

Six different injured patient models were used throughout the entirety of this investigation. While the number of models may be perceived as a limitation, the study design with randomized trial order, participant placement order, and group assignment accounted for this. The nature of the staged scenario for equipment removal provides a limitation to this study. Performing this study in a controlled laboratory environment offered several key advantages to ensuring experimental control. However, several environmental factors could not be accounted for as we studied an injured patient model who was not sweaty, performed the tasks on artificial turf that may behave differently in adverse weather conditions, and did not have to contend with the indirect pressures associated with spectator crowds observing the performances of the athletic trainers under the types of scenarios we studied. A future study should investigate the influence a sweaty injured patient model has on the same clinical measures during these three equipment removal techniques. We chose to allow each clinician to select the cervical spine stabilization method that they believed would result in the most effective stabilization of the cervical spine during the tested scenarios. It was assumed that clinicians would choose, based on their positioning, the specific scenario, and what allowed them to most effectively stabilize when managing a cervical spine injured athlete. Anecdotally, there was very little variability in the stabilization techniques chosen by the participants. Most chose to place their hands at the level of the mastoid processes of the bilateral temporal bones of the IPM. Future studies should investigate cervical spine stabilization hand positions when completing the same equipment removal techniques. The scenario used in this study reflected shoulder pad removal only and did not take into account any clinical measures during helmet removal. It was assumed that helmet removal would cause the same amount of cervical spine motion for each trial and each removal technique. In order to look solely at the effects of the shoulder pad removal techniques, we utilized a wood head block to simulate the height the head and neck would be following helmet removal. Lastly, we recorded our participants' perceived difficulty after they completed 4 trials (2 at the head and 2 at the torso) for each removal technique. Participants may have unknowingly biased this measure of perceived difficulty to reflect that of the last trial they completed.

Conclusions

The Riddell™ RipKord shoulder pads may provide a superior method for removal in terms of time for removal and difficulty of the task. Institutions that support football programs should consider use of Riddell™ RipKord shoulder pads for their superiority of removal method over traditional shoulder pads in relevant clinical measures. The novelty of these shoulder pads has proven effective in both their time for removal and difficulty. For institutions primarily using traditional shoulder pads, there should be consideration of more frequent equipment removal practice sessions as improvement in time were observed with traditional shoulder pad removal techniques. These recommendations for consideration highlight contributions to the improvement of emergency management of a cervical spine injured athlete by certified athletic trainers.

Table 4.1. Methodology of removal techniques

	Flat Torso Traditional	Elevated Torso Traditional	Riddell™ RipKord
Research Assistants	1. IPM 2. RA_1: L shoulder 3. RA_2: N/A	1. IPM 2. RA_1: L shoulder 3. RA_2: R shoulder	1. IPM 2. RA_1: L shoulder 3. RA_2: N/A
Procedures	1. PH inline stabilization 2. RA_1 remove bolster 3. PT cut laces, unbuckle straps 4. PT take over inline 5. PH slide SP over top of IPM head and from underneath 6. IPM allowed to rest in supine neutral position	1. PH inline stabilization 2. RA_1 remove bolster 3. PT cut laces, unbuckle straps 4. PT take over inline, control elevation timing 5. RA_1 and RA_2 assist in elevation of torso 6. PH removes SP 7. IPM returned to supine neutral position	1. PH inline stabilization 2. RA_1 remove bolster 3. PT cut laces/zip tie, pull RipKord 4. PT and RA_1 remove both sides of SP 5. IPM allowed to rest in supine neutral position

IPM: Injured Patient Model, RA: Research Assistant, PH: Participant at the Head, PT: Participant at the torso, SP: Shoulder Pads.

Table 4.2. Means (standard deviations) and statistical results for sagittal, frontal, and transverse plane range of motion in degrees, time for task completion in seconds, and task difficulty (ratings of perceived exertion) across shoulder pad removal techniques (traditional flat torso, traditional elevated torso, and RipKord) performed during the first testing session.

Variable	**Flat Torso**	**Elevated Torso**	**RipKord**	***ES***	***F***	***P***
Average plane motion, º						
Sagittal	2.70 (2.47)	4.71 (5.76)	2.64 (1.79)	0.18	2.80	0.101
Frontal	2.42 (2.51)	4.83 (6.98)	2.59 (3.97)	0.14	2.09	0.145
Transverse	2.17 (1.32)	3.56 (4.18)	2.55 (3.41)	0.09	1.33	0.274
Range of motion, º						
Sagittal	8.88 (5.02)	22.03 (28.07)	8.10 (7.56)	0.20	3.23	0.089
Frontal	8.12 (5.48)	17.80 (22.98)	9.31 (13.89)	0.19	2.86	0.075
Transverse	6.91 (3.90)	12.66 (10.70)	8.85 (11.09)	0.18	2.99	0.068
Time, sec	38.37 (7.90)	41.17 (5.22)	28.51 (7.05)	0.775	44.89	<0.001†
RPE	2.50 (1.60)	2.11 (1.24)	1.45 (0.96)	0.185	3.41	0.046‡

Table abbreviations: ES—Effect Size calculated as partial η^2; ROM—Range of motion; RPE—Rate of perceived exertion.
F statistics all based on (2,26) degrees of freedom, except RPE (2,30).
† Shortest time to completion observed during RipKord removal technique compared to both flat and elevated torso.
‡ Lower difficulty rating observed during RipKord removal technique compared to flat torso.

Table 4.3. Means (standard deviations) for sagittal, frontal, and transverse plane range of motion in degrees, time for task completion in seconds, and task difficulty (ratings of perceived exertion). Statistical results (Effect Sizes; *F* ratios; *P* values) for each technique (traditional flat torso, traditional elevated torso, and RipKord) are provided for the session by group interaction effect, and main effects for session and group.

Variable	Session I Reinforced	Session I Control	Session II Reinforced	Session II Control	Interaction[a]		Session[b]		Training Group[c]	
					F	***P***	***F***	***P***	*F*	*P*
Average plane motion, °										
Sagittal										
Flat Torso	3.62 (3.26)	1.77 (0.79)	2.14 (1.21)	3.02 (2.33)	3.51	0.086	0.03	0.877	0.31	0.589
Elevated Torso	5.61 (7.46)	3.81 (3.79)	2.26 (1.63)	4.40 (2.74)	1.86	0.198	0.91	0.358	0.01	0.932
RipKord	2.40 (1.53)	2.88 (2.11)	2.03 (1.54)	3.45 (3.64)	1.06	0.323	0.50	0.826	0.63	0.438
Frontal										
Flat Torso	3.26 (3.39)	1.67 (0.92)	1.81 (0.56)	3.32 (4.68)	2.45	0.144	0.02	0.879	<0.01	0.990
Elevated Torso	5.79 (8.52)	3.87 (5.55)	2.47 (1.65)	3.22 (3.15)	0.83	0.381	1.83	0.201	0.06	0.819
RipKord	1.84 (1.39)	3.35 (5.55)	1.35 (0.66)	6.60 (11.65)	2.33	0.153	1.27	0.282	1.08	0.319
Transverse ROM, °										
Flat Torso	1.95 (0.98)	2.38 (1.64)	2.18 (0.95)	3.12 (3.33)	0.12	0.737	0.43	0.522	0.81	0.386
Elevated Torso	2.48 (1.13)	4.64 (5.81)	2.42 (1.60)	3.28 (2.31)	0.72	0.414	0.86	0.373	0.92	0.357
RipKord	1.74 (1.37)	3.36 (4.67)	1.64 (1.34)	3.22 (3.10)	<0.01	0.970	0.05	0.820	1.14	0.306
Range of motion, °										
Sagittal										
Flat Torso	11.12 (6.26)	6.63 (1.90)	6.47 (3.65)	9.77 (4.17)	11.75	0.005[d]	0.45	0.517	0.09	0.770
Elevated Torso	32.34 (35.85)	11.73 (13.23)	10.01 (6.30)	16.73 (12.54)	3.72	0.078	1.50	0.245	0.71	0.417
RipKord	6.95 (4.32)	9.25 (10.11)	6.43 (4.38)	12.61 (15.00)	1.58	0.232	0.85	0.375	0.76	0.401
Frontal										
Flat Torso	10.07 (6.42)	6.18 (3.87)	6.34 (3.16)	9.23 (8.34)	5.47	0.038[d]	0.05	0.820	0.03	0.859
Elevated Torso	21.24 (25.54)	14.35 (21.54)	10.12 (10.90)	11.23 (10.03)	0.68	0.427	2.14	0.169	0.12	0.739
RipKord	6.70 (6.92)	11.92 (18.81)	5.71 (3.33)	14.66 (19.22)	0.76	0.399	0.17	0.691	0.98	0.342
Transverse										
Flat Torso	7.28 (4.57)	6.55 (3.43)	7.59 (4.29)	9.54 (6.42)	0.62	0.446	0.94	0.352	0.10	0.758
Elevated Torso	9.34 (5.03)	15.98 (14.04)	11.00 (9.45)	9.14 (4.24)	2.07	0.176	0.77	0.398	0.39	0.546
RipKord	8.15 (9.53)	9.56 (13.21)	9.20 (8.25)	11.06 (10.19)	0.01	0.940	0.18	0.676	0.12	0.735
Time, sec										
Flat Torso	33.80 (4.17)	42.93 (8.32)	30.64 (3.50)	34.27 (8.58)	4.13	0.065	19.03	0.001[e]	3.88	0.072
Elevated Torso	39.71 (3.68)	42.62 (6.36)	30.27 (2.56)	37.19 (10.80)	1.86	0.198	25.71	<0.001[e]	2.30	0.155
RipKord	25.81 (4.45)	31.22 (8.41)	23.21 (2.83)	28.62 (6.13)	<0.01	0.998	4.37	0.060	3.59	0.082

RPE										
Flat Torso	3.06 (1.93)	1.79 (0.62)	2.06 (1.23)	1.71 (0.98)	2.63	0.127	3.50	0.082	1.75	0.207
Elevated Torso	2.14 (1.35)	2.07 (1.18)	2.00 (1.56)	2.18 (1.07)	0.24	0.634	0.04	0.951	0.01	0.930
RipKord	1.28 (0.92)	1.68 (1.04)	0.67 (0.38)	1.68 (1.50)	2.65	0.126	2.65	0.126	2.28	0.153

Table abbreviations: ES—Effect Size; ROM—Range of motion; RPE—Rating of perceived exertion.

All F statistics (1,12) degrees of freedom, except RPE (1,14).

[a] Interaction effect of testing session and training group.

[b] Session main effect compared Session I to Session II across both groups (collapsed means for Reinforced training and control groups)

[c] Training group main effect compared Reinforced training group to Control group, across both test sessions (collapsed means for Session I and Session II)

[d] Denotes a significant improvement from Testing Session I to Testing Session I in the reinforced training group.

[e] Denotes an improvement during Session II (decreased time) compared to Session I

Figure 4.1. Shoulder pad views and block to simulate height of helmet. A. Anterior view; B. Posterior view; C. RipKord removed; D. Wood head block

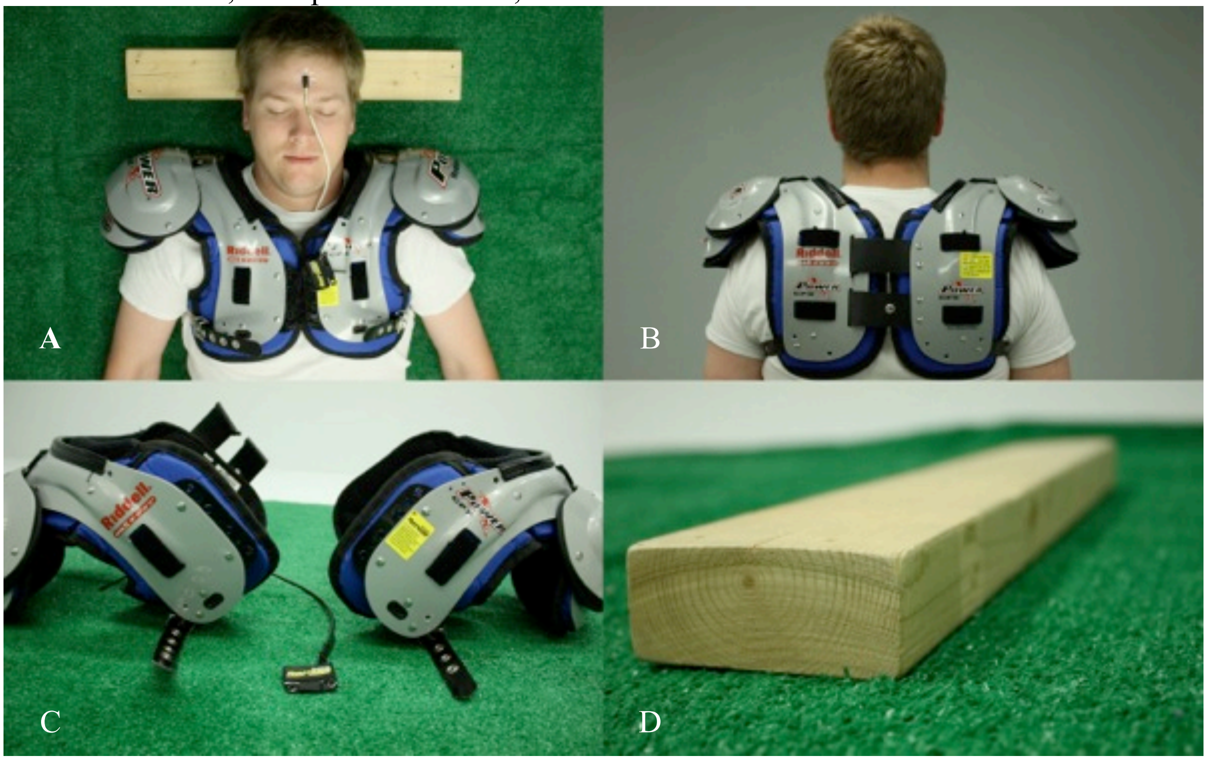
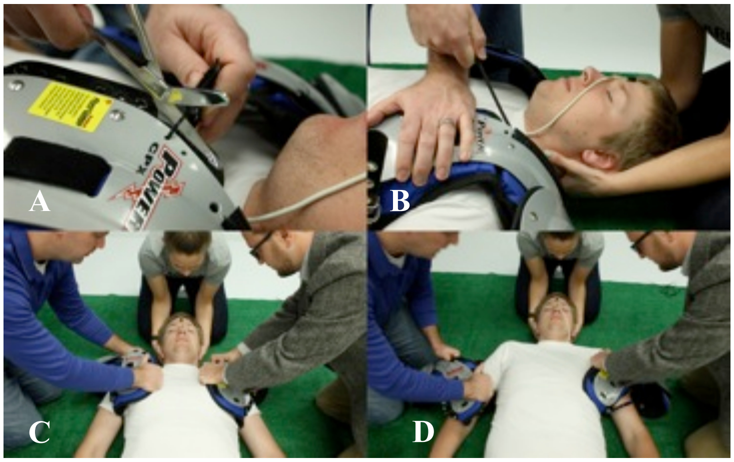


Figure 4.2. Starting position for each removal technique following removal of the wood head block.

Figure 4.3. Elevated torso removal technique. A. Switch inline stabilization; B. Elevate torso and remove shoulder pads.

Figure 4.4. Flat torso removal technique

Figure 4.5. RipKord removal technique. A. Cutting the zip tie; B. Pull the RipKord; C. Take both sides of the shoulder pads; D. Simultaneously slide each side from underneath the injured athlete.



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