Alternative Techniques to Gain Emergency Airway Access

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A thesis submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Masters of Arts in the Department of Exercise and Sports Science (Athletic Training).

Chapel Hill
2009

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ABSTRACT

JULIANNE D. TOLER: Alternative Techniques to Gain Emergency Airway Access
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The purpose of this study was to determine how head movement and time were affected by three emergency airway access techniques (Revolution IQ™ quick release face mask [IQ], cordless screwdriver [CSD], and pocket mask insertion [PMI]). Eighteen certified athletic trainers (ATCs) and 18 non-certified students (NCSs) performed one trial of each technique. Separate repeated measures ANOVAs were employed for each dependent variable. We observed significant differences ($F_{2,68} = 263.88$; $p < 0.001$) between all three techniques in respect to time with PMI being the quickest followed by IQ and CSD techniques. The PMI technique resulted in significantly less head movement ($F_{2,68} = 9.06$; p=0.001) and maximum head movement ($F_{2,68} = 13.84$; p<0.001) in the frontal plane compared to the IQ and CSD techniques. The PMI technique should be used to gain rapid airway access in a football athlete in respiratory arrest. The face mask of a football athlete that is not in respiratory distress can be carefully removed with a pocket mask ready to perform the PMI technique if necessary.

ACKNOWLEDGEMENTS

A piece of work as large as this one cannot be completed without the diligent work of many people. Throughout this process I was fortunate enough to have support from several individuals. Specific to my research, I owe thanks to Meredith Petschauer for always providing wise words when most needed and Jason Mihalik for keeping me committed to excellence throughout the entire process. My thesis committee: Dr. Kevin Guskiewicz, Saki Oyama, and Doug Halverson were helpful in developing my research into something exceptional. Many of the department's faculty, staff, and my fellow classmates are to thank for thoughtful advice and support throughout this process.

I would like to thank my family; Larry, Marilyn, and Todd Toler, for supporting me in my pursuit of my Master's degree at the University of North Carolina at Chapel Hill. Their cross-country love has been the foundation I needed to succeed so far from home. My loving mentor, Dr. Leon Kugler has been my constant reminder that the things I work so hard to accomplish are not for my own cause, but simply my contribution to a great world created by a great God.

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CHAPTER I

INTRODUCTION

An estimated 1.8 million athletes participate in tackle football every year. The confounding factors of number of participants and the physical nature of the sport has resulted in the highest overall incidence of catastrophic cervical spine injury (Mueller & Cantu, 2007). For medical professionals working in the football setting, handling a suspected cervical spine injured athlete presents the challenging task of preventing secondary injury while accessing the airway. This type of injury is difficult to rule out on the field and the repercussions for mismanagement may be severe. Medical personnel must act conservatively when suspecting cervical trauma. Though relative to other injuries the rate of injury to the cervical spine or spinal cord is low, the true number of instances in which this injury is suspected and managed conservatively is not recorded. Between 1977-2001, 223 football players are known to have sustained cervical spine injuries resulting in incomplete or no neurological recovery (Boden, Tacchetti, Cantu, Knowles, & Mueller, 2006). The ban of spear tackling implemented by the National Collegiate Athletics Association resulted in a significant decrease in the rate of injury after 1976 (Boden et al., 2006; Cantu & Mueller, 2003). Despite this decrease, first responders in the athletic environment must be prepared to gain airways access of any potentially cervical spine injured athlete.

The presence of protective equipment complicates attempts to prepare the injured athlete for transport and acts as a barrier to airway access. Once an athlete has gone into respiratory arrest, time and head movements become the most important factors contributing to secondary injury and eventually cell death. The Inter-Association Task Force for Appropriate Care of the Spine Injured Athlete, reflects the importance of these factors recommending that the helmet should be left in place, while releasing all loop straps, and then fully removing the face mask from the helmet. However, full removal of the face mask can be a very difficult task (Swartz, Norkus, Cappaert, & Decoster, 2005) and is sometimes unacceptably time costly (Swartz, Norkus, Armstrong, & Kleiner, 2003). All techniques are associated with some amount of head movement that may contribute to secondary injury of the spine and the spinal cord it serves to protect. Additional research is necessary to determine which technique minimizes the potential for secondary injury.

Removal of the face mask can be accomplished by either removing the T-bolt that secures the loop strap or by cutting through the loop strap that holds the face mask to the helmet. Various tools have been suggested to be efficient in removing the face mask, but no one method has been determined as a "gold standard" (Swartz et al., 2003). The cordless screwdriver, along with many other tools, has been observed to be an efficient means for removing the T-bolts, but is rendered useless if hardware failure occurs. As the football season progresses, helmets are exposed to weather conditions and playing surfaces which may cause degradation to the carbon or stainless steal T-bolts causing them to fail during removal. In addition, the cordless screwdriver itself may fail due to unknown mechanical properties. Thus, it is suggested that an alternative face mask removal tool be present in case of hardware failure (Decoster, Shirley, & Swartz, 2005; Kleiner et al., 2001; Swartz et al., 2005). Further research is needed to determine the efficiency of these tools under varying circumstances.

Face mask removal has been further complicated by the introduction of the Riddell Revolution T® helmet which has been suggested to decrease the rate of concussion, but also presents medical professionals with a more difficult face mask removal task (Collins, Lovell, Iverson, Ide, & Maroon, 2006). The wide and thick Revolution® lateral strap design was reported to result in significantly greater completion time and higher ratings of perceived exertion during the face mask extraction task in addition to an increase in flexion-extension movement when compared to other loop strap combinations (Copeland, Decoster, Swartz, Gattie, & Gale, 2007). More recently, Riddell released a sequence to the Revolution T® called the Revolution IQ™. The new helmet technology aims to create a helmet design that will allow for more rapid access to the athlete's airway through a Quick Release™ Face Guard System.

An alternative method to face mask removal was first suggested by Ray et al (Ray, 1992) involving the insertion of the pocket mask between the face and face mask in order to bypass the time and head movement associated with removing the face mask. This technique is performed by inserting the pocket mask between the chin and the face mask, gaining an adequate seal with the modified jaw thrust, and performing rescue breathing through the bars of the still-affixed face mask. Later studies conducted observed earlier initiation of rescue breathing with the pocket mask insertion technique as compared to removal with various tools (Ray, Luchies, Bazuin, & Farrell, 1995). Further research is necessary to determine the efficacy of these procedures during attempts to access the airway of an equipped football player.

The purpose of this study was to determine the effect of three airway access techniques (face mask removal of the Riddell Revolution IQ™, face mask removal using a cordless screwdriver, and pocket mask insertion between the chin and face mask) and certification status (certified athletic trainers and non certified students) on time to task completion and head and helmet movement.

Variables

Independent

3 Airway Access Techniques:

1. Face mask removal: Riddell Revolution IQ™ (IQ)
2. Face mask removal: Cordless screwdriver (CSD)
3. Pocket mask insertion technique (PMI)

Certification Status

1. Certified Athletic Trainer (ATC)
2. Non-Certified Student (NCS)

Dependent

1. Time to task completion (seconds)
2. Head movement in each plane (degrees)
    a. Sagittal
    b. Transverse
    c. Frontal
3. Resultant head movement (degrees)
4. Resultant head movement per second (degrees/second)

5. Maximum head movement in each plane (degrees)
6. Helmet movement in each plane (degrees)
    a. Sagittal
    b. Transverse
    c. Frontal
7. Resultant helmet movement (degrees)
8. Resultant helmet movement per second (degrees/second)
9. Maximum helmet movement in each plane (degrees)

Research Questions

RQ_1: Will there be a significant interaction effect between airway access technique and certification status with respect to time to task completion?

Head Movement Variables

RQ_2: Will there be a significant interaction effect between airway access technique and certification status with respect to head movement in each of the three planes?

RQ_3: Will there be a significant interaction effect between airway access technique and certification status with respect to resultant head movement?

RQ_4: Will there be a significant interaction effect between airway access technique and certification status with respect to resultant head movement per second?

RQ_5: Will there be a significant interaction effect between airway access technique and certification status with respect to maximum head movement in each plane?

Helmet Movement Variables

RQ_6: Will there be a significant interaction effect between airway access technique and certification status with respect to helmet movement in any of the three planes?

RQ_7: Will there be a significant interaction effect between airway access technique and certification status with respect to resultant helmet movement?

RQ_8: Will there be a significant interaction effect between airway access technique and certification status with respect to resultant helmet movement per second?

RQ_9: Will there be a significant interaction effect between airway access technique and certification status with respect to maximum helmet movement in each plane?

Hypotheses

Null

H_o1: There will not be a significant interaction effect between airway access technique and certification status with respect to time to task completion.

Head Movement Variables

H_o2: There will not be a significant interaction effect between airway access technique and certification status with respect to head movement in each of the three planes.

H_o3: There will not be a significant interaction effect between airway access technique and certification status with respect to resultant head movement.

H_o4: There will not be a significant interaction effect between airway access technique and certification status with respect to resultant head movement per second.

H_o5: There will not be a significant interaction effect between airway access technique and certification status with respect to maximum head movement in each plane.

Helmet Movement Variables

H_o6: There will not be a significant interaction effect between airway access technique and certification status with respect to helmet movement in any of the three planes.

H_o7: There will not be a significant interaction effect between airway access technique and certification status with respect to resultant helmet movement.

H_o8: There will not be a significant interaction effect between airway access technique and certification status with respect to resultant helmet movement per second.

H_o9: There will not be a significant interaction effect between airway access technique and certification status with respect to maximum helmet movement in each plane.

Alternate

H_1: There will be a significant interaction effect between airway access technique and certification status with respect to time to task completion.

Head Movement Variables

H_2: There will be a significant interaction effect between airway access technique and certification status with respect to head movement in each of the three planes.

H_3: There will be a significant interaction effect between airway access technique and certification status with respect to resultant head movement.

H_4: There will be a significant interaction effect between airway access technique and certification status with respect to resultant head movement per second.

H_5: There will be a significant interaction effect between airway access technique and certification status with respect to maximum head movement in each plane.

Helmet Movement Variables

H_6: There will be a significant interaction effect between airway access technique and certification status with respect to helmet movement in any of the three planes.

H_7: There will be a significant interaction effect between airway access technique and certification status with respect to resultant helmet movement.

H_8: There will be a significant interaction effect between airway access technique and certification status with respect to resultant helmet movement per second.

H_9: There will be a significant interaction effect between airway access technique and certification status with respect to maximum helmet movement in each plane.

Research

RH_1: We hypothesize that there will not be a significant interaction effect between airway access technique and certification status with respect to time to task completion. We hypothesize that there will be a significant main effect for time to task completion between techniques with the PMI technique being significantly quicker than the IQ or CSD techniques.

Head Movement Variables

RH_2: We hypothesize that there will not be a significant interaction effect between airway access technique and certification status with respect to head movement in each of the three planes. We hypothesize that there will be a significant main effect for head movement in all three planes between techniques with the PMI technique resulting in significantly less head movement than the IQ or CSD techniques.

RH_3: We hypothesize that there will not be a significant interaction effect between airway access technique and certification status with respect to resultant head movement. We hypothesize that there will be a significant main effect for resultant head movement between techniques with the PMI technique resulting in significantly less resultant head movement than the IQ or CSD techniques.

RH_4: We hypothesize that there will not be a significant interaction effect between airway access technique and certification status with respect to resultant head movement per second. We hypothesize that there will be a significant main effect for resultant head movement per second between techniques with the PMI technique resulting in significantly less resultant head movement per second than the IQ or CSD techniques.

RH_5: We hypothesize that there will not be a significant interaction effect between airway access technique and certification status with respect to maximum head movement in each plane. We hypothesize that there will be a significant main effect for maximum head movement in all three planes between techniques with the PMI technique resulting in significantly smaller maximal movements than the IQ or CSD techniques.

Helmet Movement Variables

RH_6: We hypothesize that there will not be a significant interaction effect between airway access technique and certification status with respect to helmet movement in each of the three planes. We hypothesize that there will be a significant main effect for helmet movement in all three planes between techniques with the PMI technique resulting in significantly less helmet movement than the IQ or CSD techniques.

RH_7: We hypothesize that there will not be a significant interaction effect between airway access technique and certification status with respect to resultant helmet movement. We hypothesize that there will be a significant main effect for resultant helmet movement between techniques with the PMI technique resulting in significantly less resultant helmet movement than the IQ or CSD techniques.

RH_8: We hypothesize that there will not be a significant interaction effect between airway access technique and certification status with respect to resultant helmet movement per second. We hypothesize that there will be a significant main effect for resultant helmet movement per second between techniques with the PMI technique resulting in significantly less resultant helmet movement per second than the IQ or CSD techniques.

RH_9: We hypothesize that there will not be a significant interaction effect between airway access technique and certification status with respect to maximum helmet movement in each plane. We hypothesize that there will be a significant main effect for maximum helmet movement in all three planes between techniques with the PMI technique resulting in significantly smaller maximal movements than the IQ or CSD techniques.

Operational Definitions

Time to task completion: Time measured in seconds starting when the tool is first picked up and ending when the subject has created an adequate seal with the pocket mask.

Head movement in each plane: Movement of the head in each of the three planes: frontal, transverse, and sagittal.

Helmet movement in each plane: Movement of the helmet in each of the three planes: frontal, transverse, and sagittal.

Resultant head movement: Head movement occurring in all three planes combined with a Pythagorean formula.

Resultant helmet movement: Helmet movement occurring in all three planes combined with a Pythagorean formula.

Resultant head movement per second: Head movement occurring in all three planes combined with a Pythagorean formula divided by the seconds taken to complete the task.

Resultant helmet movement per second: Helmet movement occurring in all three planes combined with a Pythagorean formula divided by the seconds taken to complete the task.

Maximum head movements in each plane: The greatest degree of head movement in each of the three planes: frontal, transverse, and sagittal.

Maximum helmet movements in each plane: The greatest degree of head movement in each of the three planes: frontal, transverse, and sagittal.

Certified Athletic Trainer: Unique health care providers who specialize in the prevention, assessment, treatment and rehabilitation of injuries and illnesses certified by the National Athletic Trainers' Association Board of Certification.

Non-Certified Student: A student currently seeking a bachelor's degree in an accredited Athletic Training Education Program.

Face mask removal: Complete extraction of a football face mask from the helmet in order to access the airway. The face mask is removed by either removing the T-bolt with a screwdriver or cutting the loop strap.

Riddell Revolution IQ™: New helmet design from Riddell with Quick Release™ Face Guard System allowing for removal of lateral straps with a small pointed tool. The two superior straps are regular loop straps.

Pocket mask insertion: Insertion of the pocket mask through the space between the chin and the face mask. Rescue breathing is then initiated with the one-way valve extended through the bars of the face mask concurrent with the modified jaw thrust (Ray et al., 1995).

Assumptions

1. Cervical spine was stabilized equally between tasks.
2. Movement of the head in reference to the thorax accurately represents cervical spine movement.
3. Subjects were not be biased to individual techniques, but extended equal effort to completing each task.

Limitations

1. Study design does not account for equipment failure over time.
2. Subject previous experience with removal and insertion techniques may not be similar.

3. Previous research is limited on the pocket mask insertion technique and face mask removal of the Revolution® helmet.
4. Study design did not account for hand size or grip strength.

Delimitations

1. All subjects were either Certified Athletic Trainers or students from an accredited undergraduate Athletic Training Education Program.
2. All football equipment was fit according to the National Operating Committee on Standards for Athletic Equipment guidelines.
3. All subjects reviewed a standardized protocol on each technique.
4. T-bolts were be replaced after every four trials and tightened to three inch pounds using a torque screwdriver.
5. Subjects were allotted five minutes between tasks to accommodate for fatigue.

Chapter II

REVIEW OF LITERATURE

Introduction

Sport related catastrophic spine injuries present a challenging scenario for medical professionals presented with the task of stabilizing the athlete without causing secondary damage. Medical staff managing injuries of this severity must minimize the potential to worsen the long-term prognosis of neurological damage to the spinal cord. The presence of protective equipment can complicate attempts to prepare the injured athlete for transport, primarily the ability to access the airway if it were to become compromised. Team physicians, Athletic Trainers, and Emergency Medical Technicians must be familiar with various equipment conditions and have proper training in handling such situations.

Removing the helmet of a football player has been suggested to produce an increase in the lordotic curve of the cervical spine and may cause unnecessary movement. Shoulder pad removal has the opposite effect resulting in decreased lorodosis of the cervical spine. Both scenarios place the cervical spine in a non-neutral position and result in extraneous movement (Waninger, 1998). As an alternative the National Athletic Trainer's Association Inter-Association Task Force for the Appropriate Care of the Spine Injured Athletes suggest that the face mask be removed at the first available opportunity to allow quick airway access (Kleiner et al., 2001). Because face mask removal presents the potential for extraneous head movement the task can be difficult and should be practiced regularly. Specific universal guidelines have not been determined regarding the most appropriate technique to accomplish face mask removal in the least amount of time while still limiting head movement.

Epidemiology

An estimated 1.8 million athletes participated in football including all levels of play in the year 2007.The rate of direct fatalities from football in the same year was 0.22 per 100,000 players. Although the rate of injury is lower than other sports, football has the highest overall number of catastrophic cervical spine injuries (Mueller & Cantu, 2007). Boden et al (Boden et al., 2006) reviewed 196 incidences of catastrophic injuries occurring between 1989 and 2002 finding that 76 resulted in quadriplegia. Sixteen of the 196 injuries sustained an injury to the upper cervical region and most occurred following a spear tackling mechanism while the athlete was playing defense. Between 1977-2001, 223 football players suffered cervical spine injuries resulting in no or incomplete neurological recovery. Of the 223 injured players, 183 were high school athletes, 29 were college athletes, 7 were professional athletes, and 4 were sandlot players (Cantu & Mueller, 2003).

The contact nature of football exposes players to potentially harmful forces. Of the 223 cervical spine injuries between 1977 and 2001, 69% occurred during a tackling attempt. Tackling and blocking have been associated with a majority of catastrophic cervical spine injuries (Mueller & Cantu, 2008). Of those injured during tackling 25% were found to have employed incorrect form by tackling with the head down. Spear tackling is defined as intentional use of the helmet in attempt to punish the opponent and is highly associated with cervical spine injury (Cantu & Mueller, 2003). The highest occurrence rate of cervical spine injury existed between 1965 and 1975, when tackling techniques focused on striking the opponent with the head first. The ban of spear tackling by the National Collegiate Athletic Association in 1976 resulted in a significant decrease in the rate of injury. The decreasing trend is also attributed to complete physical screening of players and more strict policies regarding the play of at risk players (Boden et al., 2006; Cantu & Mueller, 2003). In 2004, the National Athletic Trainers' Association released a position statement affirming the ban of head-down tackling regardless of intent. The position statement proposes that injury prevention is best achieved through diligent officiating and proper coaching and instruction (Heck, Clarke, Peterson, Torg, & Weis, 2004).

Despite this decrease, first responders in the football environment are still faced with the challenge of managing a potentially cervical spine injured athlete. On scene evaluation is limited in ruling out cervical spine fracture or dislocation. Due to this inability to gain an on-field diagnosis, several incidences occur when a cervical spine injury is suspected and receives conservative management and hospital transport. Not all incidences result in actual cervical spine fracture, dislocation, or spinal cord injury. Thus, the rate of injury does not reflect the overall number of athletes receiving preventative management to allow rapid airway access in case of airway obstruction due to a possible cervical spine injury.

Normal and Pathological Anatomy

A catastrophic cervical spine injury is defined as structural disruption of the cervical vertebrae resulting in actual or potential damage to the spinal cord (Banerjee, Palumbo, & Fadale, 2004). Medical professionals should have a basic understanding of the cervical anatomy, at minimum, prior to dealing with catastrophic injuries. The cervical spine can be separated into upper and lower regions. The upper region consists of the atlas and axis (C1&C2), which produce 40% of all sagittal plane motion and 60% of all rotational movement. The five remaining vertebrae compose the lower region that accomplish the remaining arc of neck flexion, extension, lateral bending, and rotation. Cervical vertebral bodies and intervertebral discs act primarily to absorb compressive forces during axial loading. Shear forces are resisted by the paraspinal musculature, ligamentous support, and facet articulation. Casing the vertebral bodies, longitudinal ligamentous structures provide additional support to the cervical spine in all planes and during distraction. Facet joint articulations increase joint congruence and aid in joint stability during shear forces and provide resistance against rotations (Banerjee et al., 2004).

The spinal cord traverses from the foramen magnum of the skull, protected by the osseoligamentous structures of the cervical spine. The spinal cord occupies less than half of the spinal canal space of the upper region the spinal cord, but as it descends into the lower region the vertebral foramen narrow and the spinal cord enlarges to occupy 75% of canal space. Midsagittal canal diameters range from 14-23mm and spinal cord compression is predicted at 10 mm diameters (Banerjee et al., 2004). The brain stem resides within the upper cervical region, where it controls respiratory function and circulation to the body. Instability of the spinal column is defined as the inability to maintain its premorbid pattern motions without causing damage to the spinal cord, injury to spinal nerve roots, major deformity, or incapacitating pain (White & Panjabi, 1990).

The integrity of the spinal cord quickly becomes compromised when space-occupying lesions decrease the spinal canal space. All disruptions to the cervical spine do not result in space occupying lesions, but injury creates the potential for disruption of the canal and the ultimately endangers the integrity of the spinal cord.

Mechanism of Injury

Blows that occur during football impose forces at the cervical spine that can cause structural deformities to the dynamic and inert tissues. A compressive force by which the cervical spine is axially loaded most often causes the spinal cord injuries that occur in football. As the helmeted athlete strikes another player with the crown of the head the forward momentum of the body compresses the cervical spine between the decelerated head. Force is dissipated from the crown of the head through the vertebral column until tissue failure occurs. A slightly flexed position that occurs when lowering the head, like during spear tackling, eliminates the normal lordotic curve of the cervical vertebral column placing it in a straight line, inhibiting the surrounding musculature from assisting in force absorption (Bailes, Petschauer, Guskiewicz, & Marano, 2007). The vertebrae respond to significant axial loads and compression by buckling under the pressure. Seventy-nine percent of cases resulting in spinal cord damage were associated with fracture or dislocation of the cervical spine (Cantu & Mueller, 2003). The posterior stabilizing ligaments dissipate force until failure occurs, allowing the anterior movement of the vertebrae and crushing of the vertebral body (Banerjee et al., 2004). Another study reported that 8.2% of cervical spine injuries occurred at C1 or C2, where the brain stem resides (Boden et al., 2006).

Management

Excessive movement occurring at the spine as a result of medical intervention may lead to secondary injury, as the vertebral column potentially encroaches on the spinal cord. Evaluation must be performed in a manner that limits excessive movement while assessing the athlete's level of consciousness, airway, breathing, and circulation to rule out immediate life threatening conditions. The presence of any life threatening conditions warrants immediate activation of the emergency action plan and contact with the Emergency Medical Services. Manual inline stabilization of the head, neck, and shoulders should be performed during evaluation. After a primary assessment has been completed a quick neurological screening should be performed recognizing painful dyesthesias, parasthesias, neck pain, and weakness. Major neurological deficits usually present as the inability to move one or more limbs, gross weakness, numbness, and/or pain with palpation to the cervical region. An athlete that is unconscious or has signs and symptoms associated with a cervical spine injury is assumed to have an unstable cervical fracture until proven otherwise by further testing and diagnosis (Bailes et al., 2007; Kleiner et al., 2001; Kleiner, 1998, 2003)

Medical staff caring for an athlete with a potential cervical spine injury must consider the potential for vertebral fragments to encroach on the spinal cord at the level of the brain stem where breathing and circulation are controlled and the potential for permanent neurological damage. In case of respiratory arrest the modified jaw thrust maneuver must be performed to restore an adequate airway while considering the implications on the movement of the cervical spine. The modified jaw-thrust maneuver attempts to open the airway while creating minimal movement of the head and cervical spine and avoids complications with football equipment. This technique aids in avoiding complications with football equipment by adapting arm positioning to allow access to the mandibular angles and aids better control over head movement. If this technique does not open the airway an oral airway or endotracheal intubation may be required (Kleiner et al., 2001). Once an airway is established supplemental oxygen can be supplied through a CPR pocket mask or bag valve mask (Waninger, 2004) Protective face masks worn on football helmets prevent rapid access of medical professionals to a compromised airway. Thus, consideration must be paid to the removal of this equipment in the attempts to maintain adequate stabilization (Kleiner et al., 2001).

Helmet Removal

Accessing the airway is particularly complicated by the presence of the helmet and face mask blocking access to the mouth and nose. In the past there have been discrepancies between Emergency Medical Technician and sports medicine protocols regarding removal of the football helmet of a potentially spine injured athlete. Motorcycle helmets, which are more commonly run across by Emergency Medical Technicians, do not usually have retractable or removable face masks, are not fit snuggly to the head, and are not usually worn with shoulder pads. Therefore, these helmets are routinely removed prior to transportation (Kleiner et al., 2001). This design contrasts that of a football helmet prompting athletic trainers to implement protocols excluding helmet removal as a primary mean for accessing the airway.

Several studies have examined the orientation of the cervical spine under various football equipment combinations. Radiographic studies show that the cervical spine stays in neutral alignment under conditions with no equipment or both helmet and shoulder pads on, but removal of either the helmet or shoulder pads resulted in a change in cervical lorodosis. Thus, all studies suggest that the helmet and shoulder pads should be left in place to maintain neutral alignment (Gastel, Palumbo, Hulstyn, Fadale, & Lucas, 1998; Palumbo, Hulstyn, Fadale, O'Brien, & Shall, 1996; Swenson, Lauerman, Blanc, Donaldson, & Fu, 1997). No published studies support the removal of a football helmet, nor suggested a threat of increased morbidity due to leaving the helmet in place (Waninger, 2004).

The National Athletic Trainers' Association formed the Inter-association Task Force for Appropriate care of the Spine-injured Athlete with the objective to form guidelines regarding proper pre-hospital management of a physically active person with a suspected cervical spine injury. Groups including physicians, certified athletic trainers, and emergency medical services, recognized the recommendations put forth in the position statement. In regards to helmet removal, the Inter-Association Task Force suggested that the helmet only be removed under specific circumstances. These circumstances include performing helmet removal only if after a reasonable period of time the face mask cannot be removed, if helmet or chin strap design interfere with attempts to ventilate or inhibit attempts to immobilize the helmet, and if the helmet prevents immobilization during transport. With the helmet remaining in position the face mask acts as a barrier between medical staff and maintaining an airway. Thus, it has been suggested that the face mask be removed at the first available opportunity (Kleiner et al., 2001). Although inline stabilization attempts to limit extraneous movements occurring at the cervical spine, removal of the face mask may result in excess movement.

Football Equipment Design

Although improvements in football equipment design reduce the occurrence of injury, new designs can complicate management efforts. Because a variety of equipment combinations are possible, medical staff must be prepared to manage various circumstances. A traditional helmet is equipped with four loop straps encasing the bars of the face mask held secure by a T-bolt and T-nut combination. Two lateral and two superior attachments secure the face mask to the helmet. Swartz et al (Swartz et al., 2005) studied the effects of various helmet and loop strap combinations on time of removal, rating of perceived exertion, and head movement when using a cordless screwdriver, face mask extractor, and the trainers' angel. Studies such as this one provide valuable information to medical professionals in regards to both football equipment and appropriate tools used to remove the face mask.

Another recent variation in equipment design that has grown in popularity is the Riddell Revolution T® helmet. This design secures two lateral bars of the face mask with a thick plastic bridge affixed with a central T-bolt. Although the Revolution is suggested to absorb shock better than traditional helmets decreasing the rate of concussion the thick and wide straps present an additional challenge when accessing the airway (Collins et al., 2006). Face mask removal of the Riddell Revolution T® helmet was reported to result in significantly greater task completion time, higher ratings of perceived exertion during task, and an increase in flexion-extension movement when compared to other loop strap combinations (Copeland et al., 2007; Prinsen, Syrotuik, & Reid, 1995; Swartz et al., 2005). Although this helmet design is growing in popularity medical professionals have limited means by which to manage the bulky lateral straps.

More recently, Riddell released a newer version of the Revolution T® helmet called the Revolution IQ™. The new helmet technology aims to create a helmet design that will allow for more rapid access to the cervical spine injured athlete's airway through a Quick Release™ Face Guard System. The lateral attachments are equipped with a spring loaded T-bolt mechanism triggered by inserting a fine-point tool into the depressed center of the head of the nut. Once triggered, the T-bolt is released and the lateral strap is freed from the helmet. The superior attachments are outfitted with standard loop straps that must be removed by either cutting the loop strap or T-bolt removal with a screwdriver to free the face mask. The efficiency of similar quick release designs has been observed to result in significantly less time and head movement compared to cutting tools. This design fastens a loop strap with a quick release nut and bolt system which is triggered by a quarter turn with a flat head screwdriver (Jenkins, Valovich, Arnold, & Gansneder, 2002). This new technology provides a reasonable alternative to traditional face mask removal tools. However, further research is necessary to determine how these helmet designs compare to other airway access techniques.

Face Mask Removal

When the helmet is left in place the face mask must be removed to allow access to the athletes airway. Removal of the facemask can be accomplished by either removing the both the superior and lateral T-bolts or by cutting through the loop strap that encases the face mask holding it to the helmet (Swartz et al., 2003). Several tools have been suggested to be efficient in completing this task, but no true "gold standard" has been determined (Kleiner et al., 2001). Further research is needed to determine the efficiency of these tools under varying circumstances.

A common tool used is the cordless screwdriver, which removes the T-bolt from the T-nut, which is imbedded in the helmet. The use of the cordless screwdriver has been suggested to decrease removal time and movement when compared to tools such as the Trainers' Angel and Face Mask Extractor. Tools used to remove rather than cut the loop strap have been observed to be more efficient in terms of time and head movement (Decoster et al., 2005; Jenkins et al., 2002). However, removal with a screwdriver is dependant on the condition of the hardware and failure of the T-bolt and T-nut may render the screwdriver ineffective. Additional complications include failure of the cordless screwdriver. Therefore, it is suggested that a second tool be available in case of hardware failure (Copeland et al., 2007; Decoster et al., 2005).

Several cutting tools have been suggested to be efficient in cutting through the loop straps allowing the face mask to be removed. The face mask extractor and the trainers' angel are both tools specifically designed for cutting through the loop straps of a football helmet. Among cutting tools, the face mask extractor has been observed to allow the quickest airway access and was the highest rank in terms of efficiency by clinicians (Swartz et al., 2003). The trainers' angel was reported to cause significantly more head movement when compared to an anvil pruner and manual screwdriver (Knox & Kleiner, 1997). Other purposed cutting tools include but are not limited to the PVC pipe cutters, wire cutters, bolt cutters, EMT scissors, and utility knives (Waninger, 2004). These cutting tools are viable options in case of hardware failure. Medical professionals should become familiar with their use prepared to use them if necessary.

Copeland et al. (Copeland et al., 2007) observed a 100% success rate with a combined tool technique allowing the clinician to use a back up Face Mask Extractor in case of failure of the cordless screwdriver or T-bolt. Due to the variety of equipment variations a combination of tools may be necessary. Medical staff must be familiar with the equipment type and helmet condition of the teams with which they work in order to develop the appropriate cervical spine injury management protocol.

Pocket Mask Insertion

The pocket mask insertion (PMI) technique was first suggested by Richard Ray as an alternative to face mask removal, following a pilot study where he observed that an airway could be established on a cardiopulmonary resuscitation mannequin outfitted in full football gear by inserting the pocket mask between the face mask and the chin (Ray, 1992). This approach requires only one task of placing the pocket mask appropriately over the mouth, where as face mask removal or retraction requires at least four (right and left T-bolt removal, face mask repositioning, and pocket mask placement). Later research was conducted to analyze the PMI technique measuring time and extraneous head movement when compared to traditional face mask retraction using the Trainer's Angel, manual screwdriver, and power screwdriver. Rotation of the face mask after use of the trainer's angel introduced significantly more head movement in all planes and peak displacements (Ray et al., 1995). Subsequent research was performed to compare the time and head movement associated with three airway preparation techniques; PMI between the chin and face mask, pocket mask insertion through the face mask eye-hole, and face mask rotation using a manual screwdriver. Both PMI techniques were observed to take significantly less time to access the airway than face mask rotation. They observed that PMI allowed quicker initiation of rescue breathing by 18 seconds compared to face mask retraction using the cordless screwdriver. This period of time could potentially allow for three additional cycles of rescue breathing if needed. In addition, insertion of the pocket mask through the face mask eye-hole caused significantly less head movement compared to the other two techniques. Based on their research, they suggested that when handling a non-breathing athlete with a suspected cervical spine injury medical professionals should first log roll or re-position the athlete if necessary and then prepare the airway by using the modified jaw thrust. If the athlete does not resume respiration determine which portal to insert the pocket mask, perform insertion technique, and begin rescue breathing or cardiopulmonary resuscitation (Ray, Luchies, Frens, Hughes, & Sturmfels, 2002). In both studies completed by Ray et al they compared the PMI technique to trials in which the face mask was retracted rather than fully removed. This method goes against that suggested by the National Athletic Trainers' Association position statement and may have influenced the results (Kleiner et al., 2001). Thus, it is necessary that head movements occurring during the PMI technique be compared to face mask removal efforts. Although not commonly used on-field, the pocket mask insertion technique offers a reasonable alternative to face mask removal and may decrease the time and head movement associated with more traditional airway access methods. As often occurs in these situations, a cervical spine injury is suspected but breathing has not ceased. The use of this technique would allow medical professionals to leave the face mask and helmet in place while still allowing for rapid airway access if the athlete ceased breathing.

Measurement of Head Movement

Cervical spine range of motion has been measured using a variety of techniques. Handheld goniometry and radiographic measurement were used in early studies, but have since been replaced by more precise measurement tools such as three-dimensional motion analysis systems with electromagnetic tracking devices. Although previous studies investigating airway access techniques by measuring head movement are limited, some have measured movement with the helmeted head of a football model placed on a forceplate (Jenkins et al., 2002; Knox & Kleiner, 1997). Other instrumentations include opteoelectric motion analysis systems, that require a large aluminum boom that attaches to the helmet only (Ray et al., 1995; Ray et al., 2002). More recently head movement has been measured using an EVa Hi-Res three-dimensional (3D) kinematic motion capture system which records the 3D movement of retro-reflective markers placed on long rods extending from the helmet (Swartz et al., 2003; Swartz et al., 2005). All previous research designs assume that movement of the helmet accurately represents movement of the head. Although fitting standards are suggested to limit movement of the head within the helmet, tissue compliance and the presence of hair may cause inequality between helmet and head movement.

One method of measuring neck mobility involves electromagnetic sensors that are placed on the head and sternum to track relative motion. A stylus is used to designate bony landmarks in three-dimensional planes to track multiplane movements. Morphett et al. (Morphett, Crawford, & Lee, 2003) conducted a study with the objective to determine the efficacy of measuring passive cervical range of motion using an electromagnetic tracking system. They suggested that the electromagnetic tracking system had high intraexaminer (rotation ICC=0.94, lateral flexion ICC=0.80, flexion-extension ICC=0.78) and fair-to-high interexaminer reliability in all three planes (rotation ICC=0.96, lateral flexion ICC=0.95, flexion-extension ICC=0.96). A similar research study observed the

“Flock of Birds” electromagnetic tracking system as a reliable and sufficiently precise instrument for tracking active and passive neck motion with a maximum measurement error of 2.5°. Therefore, the use of electromagnetic tracking is an accurate instrument and efficient method for measuring both active and passive head movement. This instrument also allows for tracking of the movement of the head relative to the thorax as well as the helmet relative to the thorax.

CHAPTER III

METHODOLOGY

The purpose of this study was to determine the effect of three airway access techniques (face mask removal of the Riddell Revolution IQ™, face mask removal using a cordless screwdriver, and pocket mask insertion between the chin and face mask) and certification status (certified athletic trainers and non certified students) on time to task completion and head and helmet movement. The dependant variables were time to task completion, head movement in each plane, resultant head movement, resultant head movement per second, maximum head movement in each plane, helmet movement in each plane, resultant helmet movement, resultant helmet movement per second, and maximum helmet movement in each plane. The independent variable consisted of airway access technique, with three levels representing face mask removal of the Revolution IQ™ (IQ), face mask removal using the cordless screwdriver (CSD), and the pocket mask insertion technique (PMI). The second independent variable consisted of certification status, with two levels representing Certified Athletic Trainers (ATC) and Non-Certified Students (NCS).

Subjects

A total of 36 subjects were recruited to participate in this study; 18 subjects were clinically active ATCs (3.75±3.95 years certified, 2.67±3.18 seasons working football) and 18 NCSs (2.5±1.36 semesters in program, 0.92±0.73 seasons working football) currently enrolled in an accredited undergraduate athletic training education program. Based on data previously collected in a similar study performed at the University of North Carolina at Chapel Hill, we expected to observe an effect size between groups of 0.488. Using this effect size in conjunction with our a priori alpha level (0.05) and proposed statistical model (ANOVA), we required 13 subjects in each group to attain a statistical power of 0.80. Since the proposed methodology differs slightly from that of previous work in this area (Petschauer, 2006), and to account for even counterbalancing in our study, we conservatively proposed a total sample of 18 subjects in each group. Subjects were excluded if they reported any upper extremity injury, neuromuscular disorders, or any bias towards a particular airway access technique. All subjects signed an informed consent form approved by the University of North Carolina at Chapel Hill Institutional Review Board.

Equipment

A single football model (victim) was used for every subject and for every trial. The football model (age=21 years; height=185.42 cm; mass=99.79 kg) wore shoulder pads and one of the two available helmets fit according to the manufacturers instructions by a Division I football equipment manager. The model wore a Riddell Revolution IQ™ during IQ trials and a Riddell Revolution T® for the CSD. Both helmets were used interchangeably for the PMI trials, depending on the sequencing used for a given participant. A four-point chinstrap was worn during all trials to further secure the helmet. Due to the interference to our electromagnetic motion analysis system, the standard metal facemask was replaced by a custom-made aluminum facemask that was identical in both size and shape of the original metallic facemask. At the time the study was performed, polycarbonate or plastic facemasks for the Revolution helmet were not commercially available. The model was supine on artificial turf to simulate the position and location that the task would normally be performed. In-line stabilization for 50% (18 trials) of the trials was maintained by one of two ATCs; an undergraduate research assistant maintained inline stabilization for the remaining trials. Preliminary pilot work demonstrated there were no observable differences in the three individuals' ability to maintain inline stabilization.

Data were captured using the Motion Monitor (Innovative Sports Training Inc Chicago, Ill) electromagnetic motion analysis system. The device tracks the movement of sensors placed on body segments in reference to anatomical landmarks on the body. A sensor placed on the crown of the helmet tracked helmet movement. A sensor placed on the right temple tracked head movement. A third sensor was located just below the sternal notch to limit movement occurring during normal breathing. These locations were chosen due to their orientation with the fixed transmitter, distance from potential disruptions due to equipment movement, and minimal presence of underlying soft tissue. Helmet and head movement were calculated relative to a sensor placed on the proximal sternum representing the thorax.

Prior to testing, we were concerned that the cordless screwdriver would disrupt the electromagnetic field creating noise within our data. To test this we ran trials under three conditions as follows: five trials as the football model lay at rest with the sensors affixed as previously described, five trials introducing the cordless screwdriver near each superior and lateral strap with a standard-sized bit, and five trials with the cordless screwdriver introduced near the t-bolts of the superior and lateral straps. We performed separate repeated measures ANOVA for each plane of movement for head and helmet movement. No significant differences were found for any of the statistical analyses between the long bit and resting conditions suggesting that data collected at rest were similar to that collected with the cordless screwdriver near the sensors. The longer bit was attached to the cordless screwdriver to ensure that no error occurred due to the cordless screwdriver.

Following sensor placement, the football model sat upright on the ground while anatomical landmarks were identified to the motion analysis system through a digitization process to recognize the head and thorax segments and orient the axes. Digitization points for the head included the bridge of the nose, middle of the chin, and the occipital protuberance. The thorax was digitized by identifying the spinous process of T8, xiphoid process, and spinous process of the C7.

Protocol

Upon arrival to the Neuromuscular Research Laboratory, all subjects were informed of the study purpose and allowed to ask the investigators any questions they may have had in regards to their participation. They were then asked to read and sign an informed consent form and complete a questionnaire regarding exclusion/inclusion criteria, previous airway access training, and athletic training experience (Appendix A). After providing consent to participate, each subject was then assigned to one of six counterbalanced testing orders that include IQ, CSD, and PMI (Appendix B).

Subjects were then informed of the first technique in their chosen test order and instructed with a brief automated video demonstration of the technique. All videos instructed the subject to attempt to complete the technique in the least amount of time possible while creating as minimal head movement as possible. Following their instruction, subjects were allowed as much time as desired to practice the technique and ask questions. Mistakes noticed during the practice period were corrected with verbal instruction by the primary investigator. Subjects were then asked to prepare to complete their first technique. The subjects were instructed to tell the investigator when they were ready and began the technique after being verbally cued by the investigator. Concurrent to the subjects' performance of the task, inline stabilization of the cervical spine was performed to replicate a realistic on-field scenario in the laboratory. All subjects knelt by the head of the football model and tools were placed to the side of hand dominance. All subjects used a Ryobi® 4V Lithium-ion cordless screwdriver during tasks that required T-bolt removal and a standard Laerdal pocket mask during all tasks. Timing of each trial began when the tool was first picked up and was ended when an adequate seal of the pocket mask was made over the mouth. An adequate seal was determined by the primary investigator observing the closure of space between the face and pocket mask and noting the deformation of the skin around the pocket mask. A trial was categorized as a failed attempt under four circumstances: 1) exceeding the three-minute maximum allotted time, 2) helmet equipment failure, 3) tool failure (screw and T-nut spinning or screw head stripped), and 4) or other (failure to complete task due to other reasons)(Swartz, Decoster, Raskow, & Hernandez, 2008). As a result, we had to repeat seven total trials over the course of the study. Following each technique, subjects were allotted a five-minute break to account for fatigue. During this time, subjects viewed the instructional video of their next counterbalanced technique until all three techniques were completed. Screws were replaced after every trial and tightened to three inch-pounds using a torque gage on the cordless screwdriver (Ray et al., 2002). The cordless screwdriver was set to seven inch-pounds prior to screw removal.

For the IQ airway access technique, subjects were instructed that the helmet had a quick-release mechanism of the lateral mask straps prior to removal of the Revolution IQ™ face mask. They were provided with a tool specifically designed to fit into a small indention in the center of this mechanism. Subjects were trained to insert the tool's tip into the quick release mechanism causing the T-bolt to release and allow removal of the lateral straps. Instruction then detailed that the superior loop straps must be removed with the cordless screwdriver by orienting the Phillip's head perpendicular with the T-bolt head. By pressing down on the activation trigger while the screwdriver was in reverse mode the T-bolt was turned counter-clockwise direction, releasing it and the loop strap from the helmet. Subjects were then trained to remove the face mask by pulling it upward away from the helmet with both hands. The task was considered complete when the face mask had been placed on the ground and the subject had positioned the pocket mask over the mouth and nose of the football model creating a seal with the modified jaw thrust maneuver.

For the CSD condition, subjects were instructed to begin removal of the face mask using the cordless screwdriver by orienting the Phillip's head perpendicular with the T-bolt head. By pressing down on the activation trigger while the screwdriver was in reverse mode the T-bolt was turned counter-clockwise direction and release the loop strap from the helmet. Subjects were trained to remove the face mask by pulling it upward away from the helmet with both hands once the T-bolts were removed from both lateral and both superior loop straps. The task was considered complete when the face mask had been placed on the ground and the subject had placed the pocket mask over the mouth and nose creating a seal with the modified jaw thrust maneuver.

For the PMI condition, subjects were instructed to perform the pocket mask insertion technique by first sliding a collapsed pocket mask between the chin and the lowest part of the face mask. Instruction then detailed that the pocket mask should be expanded to extend the one-way valve through the bars of the face mask. The task was considered complete when the pocket mask had been placed over the mouth and nose creating a seal with the modified jaw thrust maneuver (Ray et al., 1995).

Following completion of all three tasks, subjects were allowed to take a personal copy of the informed consent form and were given the primary investigator's contact information in case they had further questions regarding their participation.

Data Reduction

Kinematic data were sampled at a rate of 100 Hz with a low pass, zero lag, butterworth filter of 10 Hz. Euler angles were used to calculate the movement of the head and helmet relative to the thorax. Orthogonal planes were defined in the order of flexion-extension (Y-axis), right and left rotation (Z-axis), and right and left lateral flexion (X-axis) (James, Riemann, Munkasy, & Joyner, 2004). Positive motions were flexion, left rotation, and right lateral flexion; negative motions were extension, right rotation, and left lateral flexion. The average of the first ten frames was subtracted from all data points to baseline the starting position of all trials across subjects.

The time to task completion variable was calculated by determining the number of frames recorded between a "start" and "stop" event trigger, divided by the data collection frequency (100 Hz) to represent total time to task completion (seconds). Resultant head movement and resultant helmet movement in each plane were computed using Simpson's method of integration in a custom Matlab program. This integration calculated the absolute value of movement, and sums the area under the curve to determine resultant movement for each plane. The movements in each plane were combined using a Pythagorean approach, yielding a composite value for the overall resultant movement of the head and helmet during each task. Resultant head movement per second and resultant helmet movement per second were calculated using resultant head movement and resultant helmet movement divided by time in seconds of the same trial. Maximum head movement and maximum helmet movement in each plane were calculated by rectifying the data and finding the maximum value for each plane.

Statistical Analyses

In order to address our research questions, we employed separate 3x2 repeated measures ANOVAs for each of our dependent variables using SPSS (version 16.0 for Macintosh, SPSS Inc, Chicago, IL). Each analysis allowed us to study the interaction effect between airway access technique (IQ, CSD, PMI) and certification status (ATC, NCS), in addition to evaluating their respective main effects. An a priori alpha level of 0.05 was used as our statistical cutoff value to determine whether significant findings existed. In the event of significant findings, a Tukey post hoc test was employed to determine where any significant differences existed.

CHAPTER IV

RESULTS

Time

We performed a 3x2 repeated measures ANOVA to identify whether there was an interaction between airway access technique and certification status with regards to the time required to complete the three techniques. We noted a significant main effect for airway access technique ($F_{2,68} = 263.88$; $p < 0.001$). It took ATC and NCS participants significantly less time to complete the PMI technique compared to the IQ and CSD techniques. Further, accessing the airway in the IQ condition occurred in significantly less time than what we observed with the CSD condition. We did not observe a significant interaction ($F_{2,68} = 1.00$; $p = 0.374$), suggesting that time to complete a particular airway access technique was not influenced by certification status. There were no significant differences in time to task completion between ATC and NCS participants ($F_{1,34} = .36$; $p = 0.555$). All results pertaining to this analysis are displayed in Table 4.1.

Head Movement in Each Plane

To address head movement in each plane (sagittal, transverse, frontal) we performed three 3x2 repeated measures ANOVAs to determine if there was an interaction between airway access technique and certification status. We identified a significant main effect for head movement in the frontal plane between airway access techniques ($F_{2,68} = 9.06$; p=0.001). Both groups caused significantly less head movement in the frontal plane during the PMI technique compared to both the IQ and CSD techniques. No interaction effect was identified for head movement in any of the three planes (Sagittal: $F_{2,68} = 0.93$; $p = 0.401$; Transverse: $F_{2,68} = 1.51$; $p = 0.229$; Frontal: $F_{2,68} = 0.19$; $p = 0.802$) suggesting that the significance found in airway access technique is not influenced by certification status. There were no significant group main effects in head movement in any of the three planes between ATC and NCS participants (Sagittal: $F_{1.34} = 0.88$; $p = 0.354$; Transverse: $F_{1.34}= 0.40$; $p = 0.351$; Frontal: $F_{1.34}= 0.2$; $p = 0.642$). All results pertaining to this analysis are displayed in Table 4.2.

Resultant Head Movement

We performed a 3x2 repeated measures ANOVA to identify whether there was an interaction between airway access technique and certification status with regards to the resultant head movement. No interaction effect was identified ($F_{2,68} = 0.09$; $p = 0.899$) suggesting that certification status did not influence resultant head movement for any of the airway access techniques. We found no significant main effect for airway access techniques in regards to resultant head movement ($F_{2,68} = 0.97$; $p = 0.380$). There were no significant differences in resultant head movement between ATC and NCS participants ($F_{1,34} = 1.02$; $p = 0.321$). All results pertaining to this analysis are displayed in Table 4.3.

Resultant Head Movement Per Second

A 3x2 repeated measures ANOVA was used compare interactions between airway access technique and certification status with regards to resultant head movement per second. We noted a significant main effect for airway access technique ($F_{2,68} = 49.83$; $p < 0.001$). Greater resultant head movement per second occurred during the PMI technique compared to the IQ and CSD techniques. Further, subjects created significantly greater resultant head movement per second during the IQ technique than what we observed with the CSD technique. No interaction effect was observed for resultant head movement per second ($F_{2,68} = 0.34$; $p = 0.615$) suggesting that certification status did not influence resultant head movement per second for any of the airway access techniques. There were no significant differences ($F_{1,34} = 0.87$; $p = 0.359$) in resultant head movement per second between ATC and NCS participants. All results pertaining to this analysis are displayed in Table 4.4.

Maximum Head Movement in Each Plane

To address maximum head movement occurring in each plane we ran three 3x2 repeated measures ANOVAs to identify whether there was an interaction between airway access technique and certification status. We identified a significant main effect for maximum head movement in the frontal plane between airway access techniques ($F_{2,68} = 13.84$; $p<0.001$). Both ATC and NCS participants caused significantly less maximal head movements in the frontal plane during the PMI technique. No interaction effects were revealed in any of the three planes (Sagittal- $F_{2,68} = 0.13$; $p = 0.879$, Transverse- $F_{2,68} = 0.31$; $p = 0.732$, Frontal- $F_{2,68} = 1.14$; $p = 0.32$) suggesting that certification status did not effect maximum head movement in any of the airway access techniques. There were no significant differences (Sagittal- $F_{1,34} = 0.14$; $p = 0.709$, Transverse- $F_{1,34} = 0.39$; $p = 0.538$, Frontal- $F_{1,34} = 0.38$; $p = 0.54$) in maximum head movement in any of the three planes between ATC and NCS participants. All results pertaining to this analysis are displayed in Table 4.5.

Helmet Movement in Each Plane

To address helmet movement occurring in each plane we ran three 3x2 repeated measures ANOVAs to identify whether there was an interaction between airway access technique and certification status in each plane. We identified a significant main effect for airway access technique in helmet movement in the sagittal plane ($F_{2,68} = 4.68$; p=0.012). Both groups caused significantly less helmet movement in the sagittal plane during the CSD technique compared to the PMI technique. No interaction effect was identified for helmet movement in any of the three planes (Sagittal: $F_{2,68} = 0.98$; $p = 0.381$; Transverse: $F_{2,68} = 0.37$; $p = 0.681$; Frontal: $F_{2,68} = 1.44$; $p = 0.244$) suggesting that certification status did not influence helmet movement in any of the three planes. We found no significant differences (Sagittal: $F_{1,34} = 0.33$; $p = 0.568$; Transverse: $F_{1,34} = 1.05$; $p = 0.313$; Frontal: $F_{1,34} = 0.02$; $p = 0.900$) in helmet movement in any of the three planes between ATC and NCS participants. All results pertaining to this analysis are displayed in Table 4.6.

Resultant Helmet Movement

We performed a repeated measures ANOVA to compare interactions between airway access technique and certification status with regards to the resultant helmet movement. No interaction effect was identified ($F_{2,68} =0.85$; $p =0.430$) suggesting that certification status did not influence resultant helmet movement for any of the airway access techniques. We found no significant main effect for airway access technique in regards to resultant helmet movement ($F_{2,68} =2.38$; $p =0.100$). There were no significant differences in resultant helmet movement between ATC and NCS participants ($F_{1,34}$ =0.47; $p =0.500$). All results pertaining to this analysis are displayed in Table 4.7.

Resultant Helmet Movement Per Second

A repeated measures ANOVA was used to identify whether there was an interaction between airway access technique and certification status with regards to the resultant helmet movement per second. We noted a significant main effect for airway access technique ($F_{2,68} = 72.99$; $p < 0.001$). ATC and NCS participants caused more helmet movement per second during the PMI technique compared to the IQ and CSD techniques. Further, the IQ technique caused significantly greater helmet movement per second than what we observed with the CSD technique. No interaction effect was identified for resultant helmet movement per second ($F_{2,68} = 1.08$; $p = 0.316$) suggesting that certification status did not influence resultant helmet movement per second for any of the airway access techniques. There were no significant differences ($F_{1,34} = 1.09$; $p = 0.306$) in resultant helmet movement per second between ATC and NCS participants. All results pertaining to this analysis are displayed in Table 4.8.

Maximum Helmet Movement in Each Plan

To address maximum helmet movement occurring in each plane we ran three 3x2 ANOVAs to identify whether there was an interaction between airway access technique and certification status. We identified a significant main effect for airway access technique in the maximum helmet movement in the sagittal plane ($F_{2,68} = 6.32$; $p= 0.003$). Both ATC and NCS participants caused significantly smaller maximal helmet movements in the sagittal plane during the CSD technique. Further, the both groups created significantly greater helmet movement in the sagittal plane during the IQ technique compared to the CSD technique. No interaction effects were revealed in any of the three planes (Sagittal: $F_{2,68} = 0.08$; $p = 0.894$; Transverse: $F_{2,68} = 2.02$; $p = 0.140$; Frontal: $F_{2,68}$

$=1.88$; $p = 0.159$) suggesting that certification status did not effect maximum helmet movement in any of the airway access techniques. There were no significant differences (Sagittal: $F_{1,34} = 0.16$; $p = 0.689$; Transverse: $F_{1,34} = 2.61$; $p = 0.116$; Frontal: $F_{1,34} = 0.04$; $p = 0.838$) in maximal helmet movement in any of the three planes between ATC and NCS participants. All results pertaining to this analysis are displayed in Table 4.9.

Table 4.1. Descriptive and statistical results for time to task completion

Variable	Revolution IQ		Cordless Screwdriver		Pocket Mask Insertion		Group*Condition Interaction		Group Effect		Condition Effect	
	Mean	SD	Mean	SD	Mean	SD	$F_{2,68}$	*P*	$F_{1,34}$	*P*	$F_{2,68}$	*P*
Time (sec)												
ATC	49.90	11.95	66.31	15.31	20.11	7.13						
NCS	50.84	14.55	71.66	15.50	19.61	4.60	1.00	0.374	0.36	0.555	263.88	<0.001[a,b,c]
Overall	50.37	13.13	68.98	15.42	19.86	5.92						

[a] Denotes a significant difference between the Revolution IQ and Cordless Screwdriver

[b] Denotes a significant difference between the Revolution IQ and Pocket Mask Insertion techniques

[c] Denotes a significant difference between the Cordless Screwdriver and Pocket Mask Insertion techniques

Table 4.2. Descriptive and statistical results for head movement in each plane

Variable	Revolution IQ		Cordless Screwdriver		Pocket Mask Insertion		Group*Condition Interaction		Group Effect		Condition Effect	
	Mean	SD	Mean	SD	Mean	SD	$F_{2,68}$	P	$F_{1,34}$	P	$F_{2,68}$	P
Sagittal(deg)												
ATC	1.06	0.67	1.03	0.51	1.06	0.44						
NCS	1.36	0.92	0.95	0.44	1.19	0.53	0.93	0.401	0.88	0.354	1.26	0.289
Overall	1.21	0.81	0.99	0.47	1.12	0.48						
Transverse (deg)												
ATC	0.63	0.46	0.48	0.15	0.48	0.30						
NCS	0.64	0.34	0.64	0.34	0.54	0.36	1.51	0.229	0.40	0.531	0.44	0.648
Overall	0.58	0.36	0.56	0.27	0.51	0.32						
Frontal(deg)												
ATC	0.68	0.35	0.76	0.52	0.38	0.26						
NCS	0.66	0.56	0.83	0.44	0.45	0.27	0.19	0.802	0.22	0.642	9.06	0.001[a,b]
Overall	0.67	0.46	0.79	0.47	0.42	0.26						

[a] Denotes a significance difference between the Revolution IQ and Pocket Mask Insertion techniques

[b] Denotes a significance difference between the Cordless Screwdriver and Pocket Mask Insertion techniques

Table 4.3. Descriptive and statistical results for resultant head movement

Variable	Revolution IQ		Cordless Screwdriver		Pocket Mask Insertion		Group*Condition Interaction		Group Effect		Condition Effect	
	Mean	SD	Mean	SD	Mean	SD	$F_{2,68}$	*P*	$F_{1,34}$	*P*	$F_{2,68}$	*P*
(deg)												
ATC	1.48	0.76	1.43	0.59	1.27	0.49						
NCS	1.66	1.00	1.49	0.50	1.44	0.57	0.09	0.899	1.02	0.321	0.97	0.380
Overall	1.57	0.88	1.46	0.54	1.35	0.53						

4.4. Descriptive and statistical results for resultant head movement per second

Variable	Revolution IQ		Cordless Screwdriver		Pocket Mask Insertion		Group*Condition Interaction		Group Effect		Condition Effect	
	Mean	SD	Mean	SD	Mean	SD	$F_{2,68}$	*P*	$F_{1,34}$	*P*	$F_{2,68}$	*P*
(deg/sec)												
ATC	0.030	0.013	0.022	0.006	0.068	0.036						
NCS	0.032	0.013	0.022	0.011	0.078	0.039	0.34	0.615	0.87	0.359	49.83	<0.001[a,b,c]
Overall	0.031	0.013	0.022	0.009	0.073	0.037						

[a] Denotes a significant difference between the Revolution IQ and Cordless Screwdriver

[b] Denotes a significant difference between the Revolution IQ and Pocket Mask Insertion techniques

[c] Denotes a significant difference between the Cordless Screwdriver and Pocket Mask Insertion techniques

Table 4.5. Descriptive and statistical results for maximum head movement in each plane

Variable	Revolution IQ		Cordless Screwdriver		Pocket Mask Insertion		Group*Condition Interaction		Group Effect		Condition Effect	
	Mean	SD	Mean	SD	Mean	SD	$F_{2,68}$	*P*	$F_{1,34}$	*P*	$F_{2,68}$	*P*
Sagittal (deg)												
ATC	4.43	3.30	3.93	1.68	3.65	1.97						
NCS	4.24	1.74	3.54	1.51	3.68	1.59	0.13	0.879	0.14	0.709	1.50	0.231
Overall	4.34	2.60	3.74	1.59	3.67	1.76						
Transverse(deg)												
ATC	2.40	1.62	2.41	2.06	2.08	1.79						
NCS	2.48	1.41	2.22	0.89	1.62	0.93	0.31	0.732	0.39	0.538	1.64	0.203
Overall	2.44	1.50	2.32	1.57	1.85	1.43						
Frontal (deg)												
ATC	3.01	1.87	2.63	1.26	1.61	1.10						
NCS	2.85	1.50	3.30	1.05	1.61	0.80	1.14	0.32	0.38	0.54	13.84	<0.001[a,b]
Overall	2.93	1.67	2.96	1.19	1.61	0.94						

[a] Denotes a significant difference between the Revolution IQ and Pocket Mask Insertion techniques

[b] Denotes a significant difference between the Cordless Screwdriver and Pocket Mask Insertion techniques

Table 4.6. Descriptive and statistical results for helmet movement in each plane

Variable	Revolution IQ		Cordless Screwdriver		Pocket Mask Insertion		Group*Condition Interaction		Group Effect		Condition Effect	
	Mean	SD	Mean	SD	Mean	SD	$F_{2,68}$	*P*	$F_{1,34}$	*P*	$F_{2,68}$	*P*
Sagittal (deg)												
ATC	0.94	0.55	0.83	0.38	0.99	0.36						
NCS	1.08	0.54	0.46	0.15	0.45	0.31	0.98	0.381	0.33	0.568	4.68	0.012[a]
Overall	1.01	0.54	0.78	0.33	1.05	0.41						
Transverse (deg)												
ATC	0.44	0.36	0.39	0.21	0.34	0.24						
NCS	0.46	0.25	0.44	0.15	0.45	0.38	0.37	0.681	1.05	0.313	0.60	0.552
Overall	0.45	0.30	0.41	0.18	0.39	0.27						
Frontal (deg)												
ATC	0.51	0.31	0.47	0.28	0.33	0.19						
NCS	0.41	0.21	0.47	0.22	0.41	0.24	1.44	0.244	0.02	0.900	2.37	0.101
Overall	0.46	0.27	0.47	0.25	0.37	0.22						

[a] Denotes a significant difference between the Cordless Screwdriver and Pocket Mask Insertion techniques

Table 4.7. Descriptive and statistical results for resultant helmet movement

Variable	Revolution IQ		Cordless Screwdriver		Pocket Mask Insertion		Group*Condition Interaction		Group Effect		Condition Effect	
	Mean	SD	Mean	SD	Mean	SD	$F_{2,68}$	*P*	$F_{1,34}$	*P*	$F_{2,68}$	*P*
(deg)												
ATC	1.19	0.66	1.07	0.43	1.12	0.41						
NCS	1.29	0.52	1.00	0.28	1.31	0.51	0.85	0.430	0.47	0.500	2.38	0.100
Overall	1.24	0.59	1.04	0.36	1.21	0.46						

Table 4.8. Descriptive and statistical results for resultant helmet movement per second

Variable	Revolution IQ		Cordless Screwdriver		Pocket Mask Insertion		Group*Condition Interaction		Group Effect		Condition Effect	
	Mean	SD	Mean	SD	Mean	SD	$F_{2,68}$	*P*	$F_{1,34}$	*P*	$F_{2,68}$	*P*
(deg/sec)												
ATC	0.024	0.011	0.016	0.004	0.060	0.027						
NCS	0.026	0.093	0.015	0.005	0.071	0.035	1.09	0.316	1.08	0.306	72.99	<0.001[a,b,c]
Overall	0.025	0.010	0.015	0.005	0.067	0.032						

[a] Denotes a significant difference between the Revolution IQ and Cordless Screwdriver

[b] Denotes a significant difference between the Revolution IQ and Pocket Mask Insertion techniques

[c] Denotes a significant difference between the Cordless Screwdriver and Pocket Mask Insertion techniques

Table 4.9. Descriptive and statistical results for maximum helmet movement in each plane

Variable	Revolution IQ		Cordless Screwdriver		Pocket Mask Insertion		Group*Condition Interaction		Group Effect		Condition Effect	
	Mean	SD	Mean	SD	Mean	SD	$F_{2,68}$	P	$F_{1,34}$	P	$F_{2,68}$	P
Sagittal (deg)												
ATC	3.43	2.31	2.72	1.02	3.43	1.59						
NCS	3.24	1.02	2.49	0.90	3.39	1.11	0.08	0.894	0.16	0.689	6.32	0.003[a,b]
Overall	3.34	1.76	2.60	0.96	3.41	1.35						
Transverse (deg)												
ATC	1.32	0.69	1.10	0.51	1.05	0.49						
NCS	1.30	0.51	1.57	0.56	1.30	0.76	2.02	0.140	2.61	0.116	1.06	0.353
Overall	1.31	0.60	1.34	0.58	1.18	0.65						
Frontal (deg)												
ATC	1.77	0.97	1.36	0.75	1.37	0.97						
NCS	1.38	0.82	1.72	0.89	1.52	1.04	1.88	0.159	0.04	0.838	0.23	0.79
Overall	1.58	0.91	1.54	0.83	1.44	0.99						

[a] Denotes a significant difference between the Revolution IQ and Cordless Screwdriver

[b] Denotes a significant difference between the Cordless Screwdriver and Pocket Mask Insertion technique

Table 4.10. Ordered results for each dependent variable

Variable	Revolution IQ	Cordless Screwdriver	Pocket Mask Insertion	
Time	2	3	1	**A,B,C**
Head movement: Sagittal	3	1	2	
Head movement: Transverse	3	2	1	
Head movement: Frontal	2	3	1	**b,c**
Total head movement:	3	2	1	
Total head movement per second:	2	1	3	**a,b,c**
Maximum head movement: Sagittal	3	2	1	
Maximum head movement: Transverse	3	2	1	
Maximum head movement: Frontal	2	3	1	**a,b,c**
Helmet movement: Sagittal	2	1	3	**c**
Head movement: Transverse	3	2	1	
Helmet movement: Frontal	2	3	1	
Total helmet movement:	3	1	2	
Total helmet movement per second:	2	1	3	**a,b,c**
Maximum helmet movement: Sagittal	2	1	3	
Maximum helmet movement: Transverse	2	3	1	
Maximum helmet movement: Frontal	3	2	1	**a,c**

Ranked means: 1=smallest, 2= intermediate, 3= largest

a. denotes a significant difference between IQ and CSD

b. denotes a significant difference between IQ and PMI

c. denotes a significant difference between CSD and PMI

CHAPTER V

DISCUSSION

We observed significant main effects for time to task completion with the PMI technique being significantly faster than both the IQ and CSD techniques. In addition, the IQ technique was significantly faster than the CSD technique. During the PMI technique, significantly less head movement and maximum head movement occurred in the frontal plane compared to the IQ and CSD techniques. We observed that significantly more resultant head movement per second occurred during the PMI technique compared to both the IQ and CSD techniques. Significantly greater resultant head movement per second occurred during the IQ technique compared to the CSD technique. No interaction effects existed for any statistical analyses suggesting that both the ATCs and NCS groups created the same amount of head-to-thorax and helmet-to-thorax movement. For eleven of seventeen of our dependent variables the PMI technique had the smallest mean indicating that less time, head movement, or helmet movement occurred. In four of those eleven dependent variables the PMI technique resulted in significantly less time, head movement, or helmet movement than at least one of the other techniques.

Time

All three airway access techniques differed in time to task completion, with participants achieving access to the airway quicker in the PMI condition (19.86 ± 5.92 sec), followed by IQ (50.37 ± 13.13 sec), and CSD (68.98 ± 15.42 sec). These findings suggest that the PMI technique is significantly quicker than both the IQ and CSD techniques by 30.51 and 50.12 seconds, respectively. Although differences between techniques may seem minimal, the 30.51-second difference between the PMI and the IQ techniques could allow for six cycles of rescue breathing. Additionally, initiation of the PMI technique compared to the CSD technique would allow for 10 cycles of rescue breathing to be completed. This technique allows the medical professional to bypass the lengthy task of removing the face mask. In an injured football player that has gone into respiratory arrest, this additional time could decrease the length of time that the brain and body go without supplemental oxygen. However, this technique may not stand alone in its ability to prepare an athlete for transport and hospital care. In agreement with the NATA position statement, we maintain that the face mask be removed prior to transport (Kleiner et al., 2001). This task prepares the athlete for radiographic examination upon arrival at the hospital. In the on field scenario, where a cervical spine injury is suspected and the football player has gone into respiratory arrest, the PMI technique is an appropriate approach to establish an airway prior to face mask removal. Additionally, more time and caution may be available when handling an athlete that is breathing with a suspected cervical spine injury during face mask removal with the pocket mask ready to perform the PMI technique if respiratory arrest occurs. Further research is necessary to determine if face mask removal can be performed following the PMI technique and during rescue breathing. Our findings are similar to those of Ray et al suggesting that PMI technique allows for earlier initiation of rescue breathing (Ray et al., 1995; Ray et al., 2002). In their most recent study, they found that pocket mask insertion through the open space in the face mask over the eyes introduced less sagittal plane movement compared to insertion through the space between the chin and the face mask (Ray et al., 2002). We chose to instruct our subjects on inserting the pocket mask through the space between the chin and face mask because of the increasing use of eye shields and various face mask designs that place bars over the eyes.

These findings also suggest that the quick release face mask may be superior to the cordless screwdriver when considering time taken to gain airway access. The 19.61-second difference between the IQ and CSD conditions could allow for the completion of just less than four cycles of rescue breathing. Previous research regarding the quick release mechanism observed that removal of the face mask had lower failure rates, quicker or similar times to removal, and similar ratings of perceived exertion than traditional airway access techniques (Swartz et al., 2005). Therefore, the quick release design allows for more rapid access to the airway than the traditional removal of the facemask using the cordless screwdriver. Currently, this quick release design is not widely used among all levels of play for football, but further development and promotion of this type of helmet could change the current standards for face mask removal. Development of similar helmet designs should be promoted in order to continue to decrease the amount of time necessary to access the airway of a suspected cervical spine injured athlete. However, further research is necessary to determine how these quick release mechanisms hold up following exposure to weather, temperature, and contact with playing surfaces.

Head Movement and Technique

One of our purposes was to determine the amount of head movement that occurred during each technique. Even small extraneous movements that occur during emergency airway access techniques present additional threat to the potentially injured spinal cord. Therefore techniques that minimize head movement should be used to reduce the chance of secondary injury during pre-hospital care. We observed that significantly less head movement and maximal head movement occurred in the frontal plane during the PMI technique as compared to the IQ and CSD techniques (table 4.2 & 4.5). It is possible that because the PMI technique primarily introduces force to the head along the sagittal plane it is less likely that frontal and transverse plane movements would be observed. As the pocket mask is inserted between the chin and the face mask, the head is most likely to move into extension as the force is introduced to the face mask, chin and nose in and upward direction. This contrasts with forces applied during the IQ and CSD techniques where pressure is applied to the superior helmet along the sagittal plane and to the lateral straps along both the transverse and frontal plane. These two techniques require pressure to be applied to the lateral helmet and are more likely to result in rotation and side bending. The IQ and CSD techniques likely resulted in significantly greater frontal plane movement because the two techniques required subjects to apply force to the lateral helmet.

Since the amount of head movement in our study is similar between the IQ and CSD techniques, the important variable then becomes the time to task completion. Thus, the use of quick release mechanisms should be considered in the football setting accompanied with proper training on removal of the face mask. Future helmet designs should incorporate quick release mechanisms for the superior loop straps in addition to the lateral straps.

Resultant Head Movement and Head Movement Velocity

The resultant head movement variable provides a composite of movement regardless of plane. Because no one plane of movement has been suggested as detrimental during airway access techniques, it seems appropriate to collapse movement across all planes into one mean. However, this analysis revealed no significant differences between techniques. This contrasts with head movement in each plane where we observed that the PMI resulted in significantly less frontal plane movement than the CSD or IQ techniques. By combining movements across planes, the variable became less sensitive to differences. Future research should continue to express head movement by separate planes to ensure that true differences are revealed.

Because we expected to see the PMI technique take less time than the other two techniques we chose to use a variable that would allow us to see how much movement was occurring per unit of time (velocity) during each technique. Significant differences existed between all three techniques, most notably the PMI technique created the most head movement per second. Because similar resultant head movements occurred between techniques the differences in movement velocities are attributed to the differences in time to task completion. The PMI technique resulted in the greatest movement velocities because the period of time over which it was performed was so short. In the past, research has focused on time and head movement as separate entities during airway access techniques, but little is known about the effects of movement velocity on the injured cervical spine (Ray et al., 2002; Swartz et al., 2003; Swartz et al., 2005). Although velocity of movement may be detrimental or beneficial during emergency management of the cervical spine, not enough research has been done on the normal mechanics and pathomechanics of the cervical spine to determine if this significant finding is relevant in an on-field scenario. We suggest that future studies use time, head movement in each plane, and maximum head movement in each plane to best determine the efficiency of emergency airway access techniques.

Certification Status

Across all analyses, no significant difference existed between Certified Athletic Trainers and Non-Certified Students. These findings suggest that both groups introduced similar amounts of movement to the head and helmet over similar periods of time over each technique. It is possible that because most ATCs and NCSs did not have previous experience with the IQ and PMI techniques they were similar in experience at the time of participation. All subjects were required to watch an instructional video on the technique directly before completing the task and were allowed as much practice time as desired. This form of education on each technique seemed to have been effective in familiarizing the subjects with the techniques and objectives. Our findings are similar to those of previous research in regards to time to task completion, suggesting that there is no differences in time between certified and non-certified groups when performing face mask removal techniques (Swartz et al., 2008). Contrary to our results, Knox and Kleiner observed that student Athletic Trainers created significantly less head movement than certified Athletic Trainers (Knox & Kleiner, 1997). It is possible that differences between groups could have influenced confidence during the performance of the airway access techniques. For example, a staff football ATC may have been more comfortable learning new techniques than an undergraduate student. In contrast the same ATC may be less comfortable learning new techniques because they are unfamiliar, while a student is accustomed to learning new techniques. Despite certification status, it is possible that subjects had more previous experience with face mask removal using the cordless screwdriver. In our study, subjects performed the technique directly following watching the instructional video and a practice period. This method did not allow us to determine how groups retained the information over time. Future research should explore how practicing these techniques effects retention and performance of airway access techniques.

Helmet Movement and Helmet Fitting

In the past, most research has assumed that the head and properly fitted helmet move together and have used the measurement of helmet movement to depict what is occurring at the head to make assumptions regarding the cervical spine (Jenkins et al., 2002; Knox & Kleiner, 1997; Ray et al., 1995; Ray et al., 2002; Swartz et al., 2003; Swartz et al., 2005). Our findings suggest that the head and helmet often move separately of each other. The PMI technique resulted in significantly greater helmet movement and maximum head movement as compared to the CSD technique. This contrasts with our findings for total and maximal movements of the head in the sagittal plane where no significant differences were identified. Greater frontal plane movements occurred at the head during the IQ and CSD techniques while greater sagittal plane movement occurred at the helmet during the PMI technique. Subject contact with the face mask during the PMI technique may have caused additional movement at the helmet in the sagittal plane without effecting the head. The helmet may be more prone to move in the sagittal plane because of its shape and fit to the head. Although fitting standards are suggested to limit movement of the head within the helmet, tissue compliance and the presence of hair may explain the inequalities we observed between helmet and head movement. Forces applied during airway access techniques may result in head movement in one plane while the helmet simultaneously moves in another plane or not at all. In a previous study by Ray et al, the PMI technique resulted in greater sagittal plane helmet movement than a CSD technique and another PMI technique where the pocket mask was inserted through the open space of the face mask over the eyes (Ray et al., 2002). It is possible that during the CSD and PMI techniques the head did not move in equal proportion to the helmet resulting in differences. This disparity between findings suggests that the head and helmet do not move together under all circumstances even when the helmet is properly fitted. In terms of secondary injury, movement of the head more closely represents movement occurring at the cervical spine than the helmet. During in-line stabilization, the arms of the medical professional control movement through contact with the helmet. Movement of the helmet is more easily controlled than movement of the head within the helmet. Therefore, future research should make efforts to measure movements of the head rather than generalizing movements of the helmet as one segment. Measurement of movements of the helmet should only be used to supplement dependent measures of head movement.

Limitations

Because we used three people to stabilize the head, it is possible that different stabilizers introduced different amounts of movement. However, during stabilization every effort was made to consistently limit movement of the head. As part of each technique each subject applied the modified jaw thrust to establish an adequate seal of the pocket mask while simultaneously opening the airway. This action may have created more homogeneity in maximum head and helmet variables by causing similar peak movements. If the modified jaw thrust contributed the maximal movement in each technique then this would have been across all techniques and subjects reducing the chances that we measured the effects of the airway access technique. In addition, our measurement of head movement assumes that segmental cervical spine movement is directly related to movement of the head. Therefore, it is possible that the actual movements at each cervical level could not be accurately represented by measurement of head movement.

Our study design does not account for equipment failure over time. Because the Revolution IQ™ helmet was a new design at the acquisition of this study we were unable to account for how this quick release system would perform after a season of use. Past research suggests that equipment exposed during a season of play may be more vulnerable to hardware failure (Decoster et al., 2005). Future research should focus on new helmet designs following exposure to playing surfaces, impacts, and weather. Face mask removal techniques are a required proficiency of undergraduate athletic training education programs and as a result our subjects may have had more previous experience with the CSD technique. It is possible that subjects performed this technique quicker and with less head movement than they may have after learning it for the first time as most subjects did with the IQ and PMI techniques. Another factor that may have affected performance during the techniques is the variance in hand size and grip strength among subjects and their effects on control of the screwdriver or pocket mask. It is possible that subjects with smaller hand size or less grip strength may have had more difficulty during the techniques. We chose not to control for these factors because medical professionals with varying hand size and grip strength may encounter a potential cervical spine injury in football.

Future Research

The associated risk of secondary injury as it relates to management of the cervical spine in equipped sports is still largely unknown. How much motion is too much at the cervical spine remains unclear. Until research determines an allowance of time and movement every effort should be made to identify techniques that minimize these variables. Future research is needed to determine if the rescue breathing can be initiated following the PMI technique and during face mask removal. This would allow for rapid access to the airway and proper preparation for transport. Future research should establish how the Revolution IQ and other quick release face mask systems perform following a season or multiple season of use.

Conclusions

When managing an athlete in respiratory arrest with a suspected cervical spine injury, the PMI technique may be the most efficient means to gain an immediate airway followed by face mask removal. The face mask removal technique then depends on the type of helmet worn by the injured athlete. The quick release mechanism of the Revolution IQ™ allows for quicker access to the airway compared to removal using the CSD or cutting tools without introducing any additional head movement. Therefore, it is suggested that medical professionals support advances in this type of helmet design to be better prepared in cases of emergency airway access. Familiarity with emergency action plans as they relate to emergency airway access is a vital part of preventing secondary injury in cases of cervical spine trauma.

APPENDIX A

SID#:___

University of North Carolina

Department of Exercise and Sports Science

Research Questionnaire

What is your NATABOC certification status? *(Circle one)*

Certified *(Answer questions under subheading a)*

Non-certified *(Answer questions under subheading b)*

a. Certified:
   i. How many years have you been certified? ___
   ii. Are you currently working in a clinical setting? Y N
   iii. Have you worked previously in the football setting? Y N
      1. If so, how many seasons? ____
      2. With which football levels have you worked? *(Circle one)*
         a. Professional
         b. Collegiate
         c. High School
         d. Other
b. Non-Certified:
   i. Are you currently enrolled in an accredited Athletic Training Education Program? Y N
   ii. How many semesters have you completed following your acceptance into an accredited Athletic Training Education Program? _____________
   iii. Have you worked previously in the football setting? Y N
      1. If so, how many seasons? ____
      2. With which football levels have you worked? *(Circle one)*
         a. Professional
         b. Collegiate
         c. High School
         d. Other

2. Which hand would you choose to write with? *(Circle one)*
   Right Left Either
3. Do you have any significant bias toward a particular airway access technique that may inhibit your ability to extend equal effort during each task that you will be asked to complete? Y N
   If so, which technique?____
4. Do you have any current or previous upper extremity injuries or conditions that would affect your participation in this study? Y N
   a. If so, explain____
   ____
5. Do you have any current or previous upper extremity neuromuscular disorders that would affect your participation in this study? Y N
   a. If so, explain____
   ____

APPENDIX B

Latin Square Counterbalanced Condition Assignments

IQ= Revolution IQ, CSD= Cordless Screwdriver, PMI= Pocket Mask Insertion

IQ, CSD, PMI	IQ, PMI, CSD	CSD, PMI, IQ
CSD, IQ, PMI	PMI, IQ, CSD	PMI, CSD, IQ

APPENDIX C

Research Design Table

RQ	Description	Data Source	Comparison	Method
1	Will there be a significant interaction effect between airway access technique and certification status with respect to time to task completion?	Resultant time to task completion	IV: *Technique (T)* IQ vs. CSD vs. PMI *Cert. status (CS)* ATC vs. NCS DV: *Time*	One 3x2 Repeated Measures ANOVA (TxCS interaction, and main effects)
2	Will there be a significant interaction effect between airway access technique and certification status with respect to head movement in each of the three planes?	Head movement in each plane	IV: *Technique* IQ vs. CSD vs. PMI *Cert. status* ATC vs. NCS DV: *Head movement* • *Sagittal* • *Transverse* • *Frontal*	Three separate 3x2 Repeated Measures ANOVA (TxCS interaction, and main effects)

3	Will there be a significant interaction effect between airway access technique and certification status with respect to resultant head movement?	Resultant head movement	IV: *Technique* IQ vs. CSD vs. PMI *Cert. status* ATC vs. NCS DV: *Resultant head movement*	One 3x2 Repeated Measures ANOVA (TxCS interaction, and main effects)
4	Will there be a significant interaction effect between airway access technique and certification status with respect to resultant head movement per second?	Resultant head movement per second	IV: *Technique* IQ vs. CSD vs. PMI *Cert. status* ATC vs NCS DV: *Resultant head movement/sec*	One 3x2 Repeated Measures ANOVA (TxCS interaction, and main effects)
5	Will there be a significant interaction effect between airway access technique and certification status with respect to maximum head movement in each plane?	Maximum head movement in each plane	IV: *Technique* IQ vs. CSD vs. PMI *Cert. status* ATC vs NCS DV: *Maximum Head Movement* • *Sagittal* • *Transverse* • *Frontal*	Three separate 3x2 Repeated Measures ANOVA (TxCS interaction, and main effects)
6	Will there be a significant interaction effect between airway access technique and certification status with respect to helmet movement in any of the three planes?	Helmet movement in each plane	IV: *Technique* IQ vs. CSD vs. PMI *Cert. status* ATC vs. NCS DV: *Helmet Movement* • *Sagittal* • *Transverse* • *Frontal*	Three separate 3x2 Repeated Measures ANOVA (TxCS interaction, and main effects)

7	Will there be a significant interaction effect between airway access technique and certification status with respect to resultant helmet movement?	Resultant helmet movement	IV: *Technique* IQ vs. CSD vs. PMI *Cert. status* ATC vs. NCS DV: *Resultant helmet movement*	One 3x2 Repeated Measures ANOVA (TxCS interaction, and main effects)
8	Will there be a significant interaction effect between airway access technique and certification status with respect to resultant helmet movement per second?	Resultant helmet movement/ sec	IV: *Technique* IQ vs. CSD vs. PMI *Cert. status* ATC vs. NCS DV: *Resultant helmet Movement/sec*	One 3x2 Repeated Measures ANOVA (TxCS interaction, and main effects)
9	Will there be a significant interaction effect between airway access technique and certification status with respect to maximum helmet movement in each plane?	Maximum helmet movement in each plane	IV: *Technique* IQ vs. CSD vs. PMI *Cert. status* ATC vs NCS DV: *Maximum Helmet Movement* • *Sagittal* • *Transverse* • *Frontal*	Three Separate 3x2 Repeated Measures ANOVA (TxCS interaction, and main effects)

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