Neck Strength and Concussion in NCAA Division I Football

By

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ABSTRACT

Purpose: Biomechanical analysis has indicated that concussions will occur secondary to linear and or rotational acceleration-deceleration changes of the head, as well as axial compression to the cervical spine. Researchers have revealed the importance of neck strength in force absorption rates with football players, but have failed to report any definitive relation between weak or untrained musculature and concussion. Through proper neck strengthing regimens, football athletes may train neck muscles to absorb potentially damaging changes in momentum associated with mild traumatic brain injury.

Methods: Twelve division I football athletes from Texas Tech University, who had sustained at least a grade one concussion in the last three years, were compared to twelve matched non-concussed football players based on height, weight, experience, and player position. Subjects' weight charts containing six consecutive weeks of work out routines preceding concussion were analyzed. A normalized volume load (NVL) for each workout on the weight training days preceding concussion was compared between groups and individuals. The NVL data were compared between subjects and across weeks using a 2x6 mixed design ANOVA with repeated measures, and .05 was selected as the level of statistical significance.

Results: No statistically significant relations between the concussed and non-concussed participants ($p>0.05$) were observed. Descriptive statistics for the concussed versus non-concussed group mean $\pm$ SD NVL were: WK1) 15.2$\pm$8.7 vs. 13.0$\pm$9.1; WK2) 18.8$\pm$8.9 vs. 15.9$\pm$6.8; WK3) 15.2$\pm$9.0 vs. 14.8$\pm$5.9; WK4) 15.0$\pm$9.3 vs. 13.6$\pm$7.5; WK5) 16.8$\pm$9.2 vs. 17.9$\pm$8.0; and WK6) 18.1$\pm$9.1 vs. 18.0$\pm$9.1. Week six (WK6) represents the week the concussion occurred. Eight of 12 concussed players were on defense. The concussed group consisted of four defensive backs (DBs), two linebackers, two defensive tackles, one wide receiver, two offensive linemen, and one long snapper. More concussions were observed in upper classmen (i.e., juniors and seniors), as would be expected due to a greater percentage of upper-class first string and starting players.

Conclusion: Comparisons of neck musculature training regimes, rather than actual strength measurements, may not be sufficient to identify a significant relation between training and concussion incidence. Future studies should directly measure neck strength, rather than rely on training records. Consistency in training protocols and comparison of concussion incidence between football programs that implement different training routines (e.g. periodization, isometric isolations, and power enhancing strength) should also be investigated. Future research may also measure cervical neck strength throughout the season as well as after concussion to identify any consistent periods of weakness that may correlate with periods of increased concussion incidence.

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CHAPTER I
INTRODUCTION

1.1. Introductory Comments

Previous concussion research has reported that correlation exists between stronger cervical spinal muscles and a higher force absorption rate of the head during concussive impacts to football players (Conley, Stone, Nimmons, & Dudley, 1997; Hynes & Dickey, 2006; Johnston, McCrory, Mohtadi, & Meeuwisse, 2001; Tierney et al., 2004). Researchers have theorized that football players with greater neck strength will be able to tolerate a greater force resistance from the acceleration to the head, therefore decreasing a football player's chance of experiencing a concussion (Tierney et al., 2004). It is also believed that insufficient muscle strength in the cervical spine could predispose an athlete to concussion because they cannot create the internal muscle force necessary to counter the external force which causes head acceleration (Tierney et al., 2004). Multiple areas of concussion prevention have been researched; however there is an absence of research examining effective training programs for cervical muscles (Leggett et al., 1991). Concussion studies have reviewed many effective ways of preventing concussion through research in helmet material, improvements of return to play guidelines, and improvements of tackling techniques, but have failed to make a relation of cervical strength and concussive impacts (Guskiewicz et al., 2003; Guskiewicz et al., 2004; Pellman, Viano, Tucker, Casson, & Waeckerle, 2003a). To date, there is not a national standard for neck strengthing protocol in collision sports.

Historically, football players have lacked sufficient education regarding neck strength. This is significant as cerebral concussion or mild traumatic brain injury (MTBI) has been cited as the most common type of football head injury affecting one out of every 20 players per season (Maroon, Steele, & Berlin, 1980). In 2005, McCrea et al. estimated 3-8% of the football athletes at the high school and collegiate level sustained a concussion each year they played. The Centers for Disease Control and Prevention (1997) as well as others have estimated that 300,000 sports related traumatic brain injuries occur annually in the United States (Duma et al., 2005; Guskiewicz, Weaver, Padua & Garrett 2000; Guskiewicz et al., 2004). In the 2002- 2003 football seasons, statistics showed that eight percent of all injuries accounted for were due to MTBI's (Duma et al., 2005; McCrea et al., 2003). In the year 2000, on average an athletic trainer cared for seven concussions in one fall football season (Guskiewicz et al., 2000). The large volume of participants in high school and college football constitutes the highest incidences of MTBI's annually in comparison to other sports (Guskiewicz et al., 2000; McCrea et al., 2003). These astounding statistics signify the importance of developing prevention programs for head injuries and should be an important goal of sports medicine staff when addressing concussion protection. The problem lies in the long term influences a concussion has on neurocognitive abilities. Some examples include, disturbances in new learning and memory, reduced attention, and speed of information processing (Johnston, Lassonde, & Ptito, 2001). The damage on the brain caused from a concussion cannot be reversed. Long term brain damage presents multiple issues to researchers interested in studying concussion.

Although prevention of concussion has been researched heavily, few studies have made definitive conclusions to decrease long term damage. The problem lies within the management of the actual concussion itself (Echemendia & Cantu, 2003; Guskiweicz et al., 2004; Hynes & Dickey, 2006; Johnston et al., 2001; Leclerc, Lassonde, Delaney, Lacroix & Johnston., 2001; McCrea et al., 2005; Pellman et al., 2003a; Pellman et al., 2004; Piland, Motl, Ferrara & Peterson, 2003; Tierney et al., 2004). Scientists have determined what anatomically happens in the skull upon a concussive impact, but have failed to reach a universal definition, consistent grading systems, or return to play protocols for concussion. Existing definitions and guidelines come largely from an expert consensus that has limited scientific support (McCrea et al., 2005). With regard to concussion grading scales, there is no consistency as to which grading scale should be used under specific circumstances. This implies that sports medicine professionals must use their own discretion and not follow any specific rule (Echemendia & Cantu, 2003).

The lack of agreement in grading scales and even more importantly return to play guidelines, promotes a dangerous environment for athletes participating in collision sports. The problem of return to play has caused serious concern in football personnel since one test cannot solely determine recovery or return to play criteria due to concussion presenting itself in so many ways (Guskiewicz et al., 2004). Traditionally, sports medicine clinicians have relied exclusively on their expertise and subjective observations when following post injury recovery. These clinicians will eventually make a decision on what they ‘feel’ is right (McCrea et al., 2005). Sports medicine officials today believe that return to play guidelines are ‘too conservative,’ choosing to base their assessment on clinical results of individual cases rather than on a general recommendation (Guskiewicz et al., 2004). This introduces a problem in returning an athlete to play too soon after receiving a concussion and risking the athlete’s neurocognitive health. Creating and assessing guidelines has been a popular research topic in the last ten years and will continue to be until an agreement of safe return to play judgments are made (Guskiewicz et al., 2004; McCrea et al., 2005; Echemendia & Cantu, 2003; Johnston, Lassonde, & Ptito, 2001).

Other concerns in concussion research are the execution of prevention techniques such as equipment maintenance, the proper use of preventative equipment, and musculature training. These three concerns have received a credible amount of attention due to increased ability to test concussive forces within not only laboratory settings, but on the field data collection (Pellman et al., 2003a; Pellman, Viano, Tucker & Casson, 2003b; Pellman et al., 2004; Pellman et al., 2006). Equipment research has turned a corner due to recent studies showing that fewer concussions occur with more dynamic football helmets (Collins, Lovell, Iverson, Ide & Maroon, 2006). Although any research study which could decrease a risk of injury in football athletes is highly credible, cervical neck strengthening is still in the shadow of equipment and guideline research.

Previous studies have addressed the direction of impact and the amount of force it takes to create a concussion, but few have identified the relation of neck strength and its relation with head acceleration (Hynes & Dickey, 2006). Research has hypothesized that a stronger neck in a football player will reduce the impairment a concussive collision can cause because of the increased force absorption rate in neck musculature (Conley et al., 1997; Guskiewicz et al., 2006; Tierney et al., 2004). If neck musculature reduces the concussive impact, less force will be transmitted to the brain, therefore decreasing the risk of concussion (Johnston et al., 2001).

1.2. Problem Statement

The aim of this study is to identify the relation between Texas Tech football player's concussion incidence and the cervical musculature strength training regimens over the six weeks leading up to the injury. The research question is: Does greater volume of neck musculature training decrease concussion occurrence in Division I football players? Identifying this relationship will enhance understanding of the role that cervical neck strength plays in concussions in Division I collegiate football. Moreover, individuals working in sports may be able to implement cervical neck strength programs targeted at decreasing concussion rates in Division I football, as based off the research that indicates a prevalent need for isometric, eccentric, as well as concentric strength training (Berg, Berggren, & Tesch, 1994; Kawamori & Haff, 2004; Leggett et al., 1991; Peterson, Rhea, & Alvar, 2004).

1.3. Hypothesis

The non-concussed research group will show a greater normalized volume load on the four way neck routine when compared to the concussed group.

1.4. Assumptions

1) The participants of this study completed the designated neck workout written on their weightlifting sheet and did not skip weight training unless indicated.
2) The participants of this study understand the symptoms of a concussion.

3) The participants of this study reported their concussion symptoms immediately after the injury occurred, and was honest with all the details of the injury including signs and symptoms.
4) The researcher will assume the athlete was honest in answering questions about his head injury.
5) The participants reported any other cervical musculature strengthening attempt on their weight program sheet.
6) The researcher will assume that the normalized volume load is representative of the subjects' neck strength.

1.5. Limitations

The population to be used in this study was limited to Division IA football players at Texas Tech University between the years 2003- 2006. Some athletes were held out of weight lifting periods due to additional injuries sustained in practice, a game, or other. For example, if an athlete sustained an injury that was significant enough to hold them out of weight lifting workouts, their weight chart data showed zero for that period. Incomplete data was not considered for this study. The head strength and conditioning coach's workout plan was used for analysis, and not a computer generated format on all recorded workouts.

1.6. Definition of Terms

Concussion- Clinical syndrome characterized by immediate and transient impairment of neural functions, such as alteration of consciousness, disturbance of vision, and equilibrium due to mechanical forces (Leclerc et al., 2001).

Grading systems- These scales give a guideline to follow in determining the severity of the concussion by looking at specific symptoms. There are over 25 different grading scales in concussion reporting. Four of the most common include, Cantu, Colorado, McGill, and the American Academy of Neurology (Leclerc et al., 2001). The attending Texas Tech football's physician's discretion was used in this study when grading a concussion. Concussion grades were not based off of one of the indicated grading scales.

Grade 1 concussion- No loss of consciousness; transient confusion; concussion symptoms or mental status abnormality resolve in less then fifteen minutes.

Grade 2 concussion- No loss of consciousness; transient confusion; concussion symptoms or mental status abnormally last longer then fifteen minutes.

Grade 3 concussion- Any loss of consciousness, either brief or extended.

Mild traumatic brain injury (*MTBI)*- Another term for concussion

*National Collegiate Athletic Association (*NCAA*)* - the largest governing body in intercollegiate athletics.

National Operating Committee on Standards for Athletic Equipment (NOCSAE) - NOCSAE website provides that the foundation of the organization happened in 1969, and NOCSAE works to improve athletic equipment and reduce athletic injury. Some efforts are placed on the development of test standards for football helmets, baseball/softball batting helmets, baseballs/softballs, lacrosse helmets/face masks and football face masks.

Post Concussive Syndrome- Symptoms such as headache, dizziness, mild mental impairment and fatigue may be present up to a few months or an indefinite period of time following a concussion (Guskiewicz et al., 2004).

Return to Play (*RTP*)- usually associated with return to play protocols for an athlete after a concussion or other injury.

1.7. Significance

Since the brain is the most complex organ in the body and is incapable of regeneration, the importance of protection is critical (Cantu, 1991; Hill, 2006). Cervical neck strength can be one of the easiest and most effective ways to prevent mild traumatic brain injury. By determining the correlation of cervical neck strength and concussion, the safety of every football player can be improved. Universal definition, grading systems, and return to play protocols for concussions have been researched a great deal and will continue to be until universal standards are determined (Echemendia & Cantu, 2003; Leclerc et al., 2001; McCrea et al., 2005; Piland et al., 2003). However, the examination of preventative training techniques is much needed and is the primary aim of this study (Guskiweicz et al., 2004; Johnston et al., 2001; Pellman et al., 2003a; Pellman et al., 2004).

CHAPTER II
LITERATURE REVIEW

2.1. Concussion in American Football

Concussion, or mild traumatic brain injury (MTBI), can deliver damaging neurocognitive effects to the brain in the form of memory, cognitive and functional problems. Because the brain and spinal cord tissues are sensitive to the rate and extent of strain in a collision impact, a sufficient combination of strain and strain rate will result in the bruising of the tissue in the brain, therefore causing dysfunction in neurological recognition (Viano et al., 2005). With all the excitement that comes out of playing collegiate football, there is a risk of serious injury. Due to the study of mild traumatic brain injuries (MBTI) in football continual improvements have resulted in decreasing the likelihood of significant injury. Equipment standards are being raised and athletes are being trained at a higher level, and as a result fewer concussions are being noted (Newman, Beusenberg, Shwechenko, Withnall & Fournier, 2005). Corrections made in hitting techniques and protective equipment have aided in the decrease of head trauma occurrence. This current research is essential because the brain and spinal cord are incapable of regeneration, once injured, the damage is permanent (Cantu, 1991).

Statistics have estimated that nearly 300,000 sports related traumatic brain injuries occur in the United States (Duma et al., 2005; Guskiewicz et al., 2000). This large number does not point out, however, that 497 fatalities resulted from these traumatic brain injuries in just a 54 year period (Cantu & Muller, 2003). Once an athlete sustains a concussion, they are three times more likely to sustain a second one during the same season or continuing through their career (Cantu, 1991; Guskiewicz et al., 2004). Because it is important to address the longevity and future of an athlete, current prevention and treatment of concussions should be held to the highest standard. Although concussion research has improved greatly over the last decade and multiple research studies have aided in greater safety of athletes, systematic research on this topic is still lacking (Collins et al., 1999). This indicates a definite need for intervention and protection of those athletes at risk of concussion.

2.2. Anatomy of a Concussion

The way in which the brain is affected by a concussive impact is unique. The brain is suspended in cerebral spinal fluid and attaches to the sides in the skull by thin fiber dural attachments. As a football players head is struck or strikes an opposing player, the forceful impact jars the head, causing a shift in direction to the brain, therefore tearing or shearing the dural attachments on the inside of the skull bone (Sherwood, 2001). This shift in the brain can cause micro-tearing in brain tissue thus causing neurons to fire at once, flooding the space between cells with chemical neurotransmitters (Hill, 2006). Eventually, the neurons reuptake the chemicals but doing this leads to an imbalance of calcium and potassium. Cells then seek to restore balance which requires a great amount of energy. This stolen energy is what causes the brain to divert from normal functions such as short term memory loss in order to repair the damage (Hill, 2006). If the motion of the head is altered enough after a concussive impact, the motion of the brain lags that of the skull, and the brain distorts (Newman et al., 2005). If this distortion is excessive enough, neurological dysfunction will consequently be observed (Newman et al., 2005).

2.3. Coup versus Contra Coup Concussions

There are two mechanisms in which a concussion can occur, a coup and contra coup. Coup concussions occur when the brain strikes the skull at the site of impact, whereas a contra coup concussion occurs when the brain strikes the skull on the opposite side of impact (Guskiewicz et al., 2004). Contra coup injuries occur once the skull movement is stopped but the movement of the brain continues until it strikes the opposite side of the skull (Guskiewicz et al., 2004). As an athlete starts running and the head is accelerated, the brain will lag toward the trailing surface therefore causing cerebral spinal fluid to “squeeze” (p. 284) and cause maximal shearing forces at the site of impact

(Guskiewicz et al., 2004). It is the shearing of the dural attachments in the brain that presents a concussion. There has been no scientific evidence to suggest that a coup or contra coup injury is more serious then the other and most sports related concussions are classified as a result of a combined coup- contra coup mechanism (Guskiewicz et al., 2004). There are three types of forces we see in concussion injuries, they include compressive, tensile and shear. Tensile and shear forces create the most damage to brain tissues by pulling and stretching the tissue, whereas compressive forces do not tend to create much damage (Guskiewicz et al., 2004).

2.4. Problem Areas

2.4.1. Global definition

Physiologically, scientists have been able to understand what happens to the brain in a concussion; however the greater problem lies in the inability to define the actual concussion itself. The inconsistency of defining a concussion has been a dilemma for the last decade. Many concussion sources report there is no universal agreement on the standard definition of a concussion (Guskiewicz et al., 2003; Leclerc, 2001). This presents a significant quandary for health care professionals as the discrepancy serves to belittle the importance of the study of concussions.

The Congress of Neurological Surgeons in 1966 made an attempt to define concussion by stating that a concussion is a “clinical syndrome characterized by immediate and transient impairment of neural functions, such as alteration of consciousness, disturbance of vision, and equilibrium due to mechanical forces” (Leclerc et al., 2001, p. 630). A more recent definition from the Mild Traumatic Brain Injury Committee of the National Football League constitutes a concussion as “traumatically induced alteration in brain function that is manifested by alteration of awareness or consciousness, including but not limited to loss of consciousness, sensation of being dazed or stunned, sensation of “wooziness” or “fogginess,” seizure, or amnesic period” (Pelman, 2003, p. 797). The difference in concussion definitions across the research points out obvious problems of uniformity in sports medicine professionals.

Although definitions of a concussion may be different, all the signs and symptoms are similar. All concussive symptoms include traumatic amnesia, blurred vision, tinnitus, altered consciousness, light headedness, vertigo, cognitive and memory dysfunction, headache, upset stomach, and photophobia (Leclerc, 2001; Pelman, 2003). While the main problem stems from the commonality of signs and symptoms across different definitions, the lack of uniformity comes from the actual severity of brain injury. Almost always, signs and symptoms are used to grade how severe a concussion is. If there is inconsistency in defining a brain injury according to signs and symptoms, there will also be a contradictory grading scale.

2.4.2. Grading Scales

While an agreement regarding a universal definition of a concussion is important, it is even more critical to determine a universal grading scale. Grading scales for a concussion help to define the severity of the impact to the brain. It is critical to not only determine the severity of the head impact, but to also treat the MTBI based off of the athlete's signs and symptoms. There have been 16-25 grading systems reported for head injuries (Leclerc et al., 2001; Piland et al., 2003). Each one of these grading scales was not validated but represents a differing views from experts rather then consensus of scientific evidence (Johnston, Lassonde, & Ptito, 2001). This lack of harmony creates a huge problem to sports medicine professionals because the multitude of grading systems (Lerlerc et al., 2001).

All grading systems look at issues relative to the importance of loss of consciousness (LOC), post traumatic amnesia (PTA), and post-concussive symptoms (PCS) (Johnston, Lassonde, & Ptito, 2001; Leclerc et al., 2001). Each grading scale divides concussion severity into three grades: mild, moderate, and severe. When following most of the concussion grading systems, any loss of consciousness is considered the most serious type of concussion (Echemendia & Cantu, 2003). Although loss of consciousness is extremely imperative, all grading scales will not only focus on the loss of consciousness, but also evaluate greatly on the presence and duration of any post traumatic amnesia (Johnston, Lassonde, & Ptito, 2001).

Although all grading scales look for serious signs and symptoms to classify the severity of a concussion, a consistency of grading scales is still important because it will differentiate the severity for *all* sports medicine professionals to follow. The four most commonly used grading scales include Cantu RC, Colorado Medical Society, American Academy of Neurology (AAN), and McGill grading scales (Piland et al., 2003). Some differences between the scales are that AAN and Colorado guidelines classify a concussion as a grade 3 by any loss of consciousness, whereas the Cantu guidelines argue that a 30 minute post traumatic amnesia period and less than five minutes from a loss of consciousness can be considered a mere grade 2 concussion (Johnston, Lassonde, & Ptito, 2001). The Cantu system, in accordance with AAN and Colorado Medical Society, has been modified to rely more on symptom duration and post traumatic amnesia rather then loss of consciousness being no more the 2 min (Johnston, Lassonde, & Ptito, 2001). Cantu's guidelines promote that an athlete "blacking out" (very brief loss of consciousness) may not be enough to cause the same amount of brain injury that would be presented with 30 minutes or more of post traumatic amnesia (Johnston, Lassonde, & Ptito, 2001). Aside from the grade 2 / grade 3 inconsistencies across the board, multiple problems lie within low grade concussions because it is often that the low grade injuries are missed, because high grade injuries are usually obvious (Johnston, Lassonde, & Ptito, 2001). Due to grade 1 concussions being missed, usually caused by the lack of reported signs and/ or symptoms, or misdiagnosis, grade 1 concussions will not all be graded the same.

Because of the controversy in grading scales, the McGill grading system was developed as a research tool for researchers to emphasize and subdivide lower grade injuries given that they are important and often missed (Johnston, Lassonde, & Ptito, 2001). The McGill guidelines attempted to combine the Cantu, Colorado, and AAN guidelines by stating that grade 2 concussions should include under 30 minute of post traumatic amnesia and under 5 minutes of loss of consciousness. A grade 3 concussion would include such symptoms as post traumatic amnesia lasting over 30 minutes and a loss of consciousness that lasts over 5 minutes using the McGill guideline. Once used as a research tool, the McGill guidelines are in the mist of the never ending concussion guideline selection for sports medicine professionals worldwide.

Although the previously mentioned grading scales have similar signs and symptoms associated with concussion, defining the actually severity based off of a grading scale is what presents the most controversy. Team physicians have to pick one of the 25 grading scales of their choice or create their own grading protocol. One major problem that comes from the lack of a uniform grading scale relates to the university or professional setting where multiple physicians work (Echemendia & Cantu, 2003). This leaves much room for error in properly grading a concussion with the assumption others will know the basis of grading as every symptom will vary from patient to patient.

Guskiewicz et al. (2000) which showed that in 88.9% of all reported concussion cases with football players, grade one concussions were the most common reported. Although research numbers are beneficial in improving safety in athletics, the fact that there can be up to 25 different guidelines for physicians to choose from when grading the athlete's concussion can create a significant amount of confusion. For example what does a grade 1 mean to the physicians reporting concussions? If a physician believes that an athlete has sustained a grade 1 concussion based off the grading scale used and allows the athlete to return to play earlier than they should have, it could be detrimental to that athlete's health. As a result, the need for a universal grading scale continues to be addressed. This information is detrimental, in that it decreases sports medicine personnel ability to diagnose a concussion on a more consistent basis.

2.4.3. Return to Play Guidelines

Following grading scales, sets of guidelines for the return to play decisions (RTP) were developed based on the signs and symptoms an athlete presents (Echemendia & Cantu, 2003). However, due to the inconsistencies of grading scales alone in concussion prevention, return to play protocols are also inconsistent. Deciding when a concussed athlete can safely return to participation after a cerebral concussion is one of the greatest challenges facing athletic trainers and team physicians today. It is first the team physician's decision as to when the athlete is cleared, then followed by the certified athletic trainer. Due to the complexity of the brain only qualified medical professionals should have a say for an athlete to return to play. Making concussion assessment is extremely challenging because of the lack of objective signs or symptoms after injury (Guskiewicz et al., 2000). A premature decision can set up an athlete for long term disability and the potentially negative effects that could accumulate in the future (Leclerc et al., 2001). The importance of the RTP decision can rest on the possible consequences of an untimely decision, and therefore it is essential for team physicians to take all precautions (Echemendia & Cantu, 2003).

McCrea et al. (2005) showed that evidence-based guidelines regarding how long it takes an athlete to recover from a concussion are extremely scarce. Due to the unorganized signs and symptoms behind an actual concussion, no one test can be used solely to determine the recovery time line of return to play decisions in every case (Guskiewicz et al., 2004). The lack of knowledge carries over in deciding when it's safe for an athlete to return after a concussion. Guskiewicz et al. (2000) reported that 30% of all high school and college football players, who sustained concussions, returned to play the same day of injury, while the remaining 70% averaged only four days of rest before returning to participation. Guskiewicz et al. (2000) continued to add that of these 30% of athletes returning on the same day, 14% sustained a subsequent grade II concussion from initial contact. These findings confirm the belief that in some situations, physicians do not follow recommended RTP guidelines or they are not qualified to return an athlete to play, and therefore predispose an athlete to a successive concussion (Guskiewicz et al., 2000). Johnston, Lassonde and Ptito, (2001) stated it well when they said "when it doubt, sit them out" (p. 521). Sports medicine personal should be required to follow the recommended guideline of at least a 15-20 minute clearing period on the sideline immediately after impact, followed by seven days of rest and monitoring of symptoms for those athletes who fail to clear quickly (Guskiewicz et al., 2000).

The problem in concussion management and prevention will continue as long as there is no universal return to play guideline accepted by all sports medicine personnel. Although safe guidelines concerning return to play after a concussion have been published by several authors, they are mostly based on anecdotal clinical evidence rather than scientific research (Echemendia & Cantu, 2003; Guskiewicz et al., 2003; Guskiewicz et al., 2004; Leclerc et al., 2001). Since evidence is not present on this topic, sports medicine clinicians have historically relied on experience and personal observations to track post concussive recovery and guide their decision making about return to play (McCrea et al., 2005).

Inconsistencies in RTP guidelines have caused researchers to turn to baseline testing. Baseline testing prior to activity can be a great reference when later trying to determine the severity of an athlete's concussion. Prior knowledge of the athlete's medical history is necessary before taking baseline concussion tests in order to prevent a false assumption of cognitive abilities. Echemendia and Cantu (2003) pointed out that football players who had incurred two or more concussions often did worse on baseline neuropsychological testing then players who suffered one or less. The sports medicine professional must do a complete medical history in order to prevent biasness towards this cognitive ability. Although these neuropsychological tests may aid in the return to play decision, they in no way diagnose the concussion or determine the time of return to play (Echemendia & Cantu, 2003).

Return to play is one of the most significant areas in concussion research because it alone can save brain function, alertness, and future complications involving the mind. Research has revealed that athletes with a history of concussion are at an increased risk for sustaining subsequent concussions (Guskiewicz et al., 2004). After an athlete's first concussion, researchers have seen slower recoveries in self reported post concussion signs and symptoms, cognitive dysfunction, and postural instability upon subsequent injuries (Guskiewicz et al., 2004). Athletes with a history of three or more concussions that have reported a slow recovery may be recommended a temporary or permanent disqualification from contact sports (Guskiewicz et al., 2004; Pellman et al., 2003a).

Many of these permanent disabilities could possibly be prevented by more conservative return to play protocols.

Finding a universal definition of concussion, correct grading scales, and return to play protocols are ongoing concerns for sports medicine personal. The lack of universal definitions unavoidably causes controversy for the protection of every athlete involved in potential sport-related collisions. With time, it is hoped that improvements will be made and regulations finalized. Most of the current research regarding concussion management has been shown to be veering away from the classification of concussion and gearing more toward physical prevention strategies. The current prevention strategies currently being identified in concussion prevention include improvements in 1) equipment standards; 2) manipulation of the playing environment, and 3) the athlete's athletic ability and strength (Collins, Lovell, Iverson, Ide & Maroon, 2006; Hill, 2006; Newman et al., 2005).

2.5. Equipment Standards

2.5.1. Helmets

In the early 1950's the single bar face mask was introduced as a part of the football helmet in order to lower fatal injuries caused by head to head contact (Cantu & Muller, 2003). In 1973 the National Operating Committee on Standards for Athletic Equipment (NOSAE) established standards for the impact performance of football helmet (Newman et al., 2005; Pellman et al., 2003b). Since these standards were established, fatalities in football have decreased (Cantu & Muller, 2003; Newman et al., 2005). The main purpose of the helmet is to decrease the acceleration of the head upon impact thereby reducing the extent to which the brain experiences mechanical loading within the skull (Newman et al., 2005).

Football helmets in the past had performed poorly in lateral and oblique impacts to the jaw pad region and rotational accelerations were introduced as an enormous problem predisposing football players to concussion (Pellman et al., 2006). However, a progressive movement in football helmet research has increased the understanding concerning helmet materials and dynamics while decreasing the injury rates in football athletes (Newman et al., 2005). After years of a limited research in concussion to football players, Biokinetics teamed up with Riddell, Inc. to design a new football helmet. Both corporations wanted to create a new helmet by adopting new engineering strategies, based on analysis of on field head impacts (Pellman et al., 2006). The first Revolution helmet emerged in 2002 and was created by Riddell (Pellman et al., 2006). This helmet was made possible through a series of NFL sponsored research projects done by Pellman et al. (2003b) and Viano et al. (2005) over the last five years. The NFL sponsored research projects first looked at the location of impact and the direction of the head when receiving a concussion.

Later studies identify mechanics of the striking player and player being struck in order to determine which athlete was more predisposed to a concussion. Researchers noticed that the striking player has more protection because he lowers his head in order to line up his head, neck, and torso so he can deliver a maximum force to the opposite player (Viano et al., 2005). Whereas, the opposite player, who does not know the impact is coming, did not line up his body properly and did not prepare for the collision. This struck player is off-center; therefore, he resists the whole impact with his head and neck alone. More momentum is transferred from the striking player to the struck player in the collision. The collision mechanics researched by Viano and Pellman (2005) indicated that concussion occurs during the peak load when the highest head accelerations are occurring through struck players.

More recently, Hill (2006) examined the different parts of the brain being affected by concussive impacts and its effects on certain functions in the body. Hill suggested that the type of hit the individual received as well as its location, could possibly predict the type of concussion. For example, by impacting the area of the brain that influences consciousness an individual’s reactions will be dramatically slower or a blow to the temporal lobes may lead to memory difficulty (Hill, 2006).

Duma et al. (2005) conducted a study on 38 members of the Virginia Tech University football. The HIT (head impact telemetry) system was installed into 38 players' Riddell VSR-4 helmets to measure head acceleration and location of impact. The HIT system captured data from sensors embedded in the padding of the helmet by continuously measuring and recording blows to the head. By using six spring mounted accelerometers recording linear and rotational accelerations and impact locations (Duma et al., 2005). The HIT system consisted of six liner accelerometers and two printed circuit boards, one containing a micro controller and another incorporating an RF transceiver. When a player sustained a head impact all six accelerometers were triggered to save the data and send it to a receiver on the sidelines (Falcioni, 2004). The Riddell Incorporated website offers that the HIT system uses a groundbreaking arrangement because it does not replace the skill and judgment of sideline professionals, but rather sharpens and amplifies the skills they already have.

Previous research was conducted by Pellman et al., (2003a) and Pellman et al., (2003b) in which videotapes of significant head impacts and MTBI's of NFL players were analyzed. The key purpose was to determine the biomechanical response of an individual's head to a concussion. Videotapes and laboratory reenactments showed the primary responses of the head when it was hit with a forceful blow. The main cause of concussion in both studies by Pellman et al. (2003a) and (2003b) was the resultant of translational acceleration around the head's center of gravity. The second biomechanical response producing concussion was due to the head rotational acceleration and velocity (Pellman et al., 2003b; Pellman et al., 2006; Viano & Pellman, 2005). This rotational acceleration has been speculated as the key response associated with head injury (Pellman et al., 2003b; Pellman et al., 2004; Viano & Pellman, 2005; Viano et al., 2005).

Pellman et al. (2004) continued research through the National Football League in order to improve concussion prevention. This research introduced the concept of how two accelerations in football player collisions are inextricably coupled by the vector of impact, head- neck anatomic features, and musculoskeletal structures (Pellman et al., 2003b). As mentioned earlier, although concussion exhibits the strongest correlation with translational acceleration, more researchers have agreed that rotational acceleration injury occurrences have a more severe contact to the brain (Pellman et al., 2003b; Pellman et al., 2004; Pellman et al., 2006; Viano et al., 2005; Viano & Pellman, 2005).

According Duma et al. (2005) rotational acceleration- deceleration was the primary mechanism for the most severe diffuse brain injuries. Helmet manufactures have taken advantage of this data in creating a helmet that can absorb more force in oblique patterns. Within the findings from Hill (2006) concussions were addressed to being caused from translational head acceleration from helmet impacts to the facemask, strike by other body regions, and falls to the back of the head. Improvements to the shell of the helmet continue to embark on these trouble areas. For helmet design, research is focusing on streamlining the helmet in order to disperse force more evenly (Pellman et al., 2003b). Research recently completed by Pellman et al. (2006) confirmed concussions occur in impacts on the front, side, and back of the helmet with a combination of linear and rotational acceleration. Impacts to the facemask are more likely to cause rotational acceleration when compared to linear hits which create translational acceleration (Pellman et al., 2003b). Any force above 80g's is considered concussive territory. Current research is working on determining if impacts to different parts of the helmet could create greater G forces then compared to other locations on the helmet (Pellman et al., 2003b; Viano & Pellman, 2005).

It is anticipated that current standards of the NOCSAE will continue to adjust with more clinical evidence of the statistic for an actual concussive force. At the present time, any manufacturer of helmets in high school, collegiate, and professional football must be certified thru the NOCSAE. The NOCSAE conducted an experiment for football helmets in which they tested the resultant translational acceleration measured in a biofidelic head form placed in a helmet (Pellman et al., 2003b). Due to constant improvements in research, each helmet is still tested individually by dropping it onto a stiff flat rubber pad from a height of 1.52m yielding an impact velocity of 5.47 m/s. Several drops were performed, with impact sites around the periphery and crown of the helmet (Pellman et al., 2003b).

Even though the NOCSAE tests every helmet, it must be noted that a helmet which protects the head from a skull fracture does not adequately prevent the rotational and shearing forces that may lead to concussions (Guskiewicz et al., 2004). Although the helmet shell and padding function well in distributing the loads and lowering the risks for more serious brain injuries and cranial fractures, injuries are inevitable. It must also be noted that those players who do receive repeated head injuries, risk a lowered tolerance to concussions, and therefore, must seek out helmets with the greatest protection (Pellman et al., 2003b).

The previous research signifies, theoretically, that concussions occur because the linear and or rotational acceleration/ deceleration change in the head. This sudden change in momentum is what results in tissue damage to the brain. The initial force placed on the head and the damage caused from it is what will define the severity of the concussion. Advances are currently being made through the improvement of protective equipment and mandated changes in hitting mechanics in the football athlete (Cantu & Muller, 2003; Newman et al., 2005). All protective equipment findings are significant to the concussion world in that they provide insight to how helmets can be improved. Armed with the knowledge that mild traumatic brain injuries are being caused by translational and rotational head accelerations, improvements will create a safer playing environment.

2.5.2. Mouth Guards

Mouth guards may be considered an essential protective piece of equipment in preventing possible concussions. However, there has been some controversy on this issue because there is no scientific proof that mouth guards do prevent concussions, but rather the evidence is largely theoretical (Johnston et al., 2001; Winters, 2001). A major reason for the existence of this controversy is that it would unethical for researchers to use human subjects to test concussive theories. As a result most theoretical research is conducted using cadavers or dummies thereby depriving the researchers from obtaining feedback from a living individual.

A major reason for the existence of this controversy is that it would unethical for researchers to use human subjects to test concussive theories. As a result most theoretical research is conducted using cadavers or dummies thereby depriving the researchers from obtaining feedback from a living individual. To understand the benefits of a mouth guard, it is beneficial to recognize the theory behind wearing a mouth guard. When looking at the anatomy of the jaw and head, it has been theorized that concussions are prevented by the separation of the back molars by a mouth piece. The design of a mouth guard aids in creating a separation between the head of the condyle of the mandible and the base of the skull. Wearing an improperly fitted mouthpiece or none at all can increase this space. This space reduction is based on the scientific notion of Newtonian's law of physics which states that an increased separation between two adjacent structures increases time to contact. Therefore, decreasing the amount of contact will decrease the trauma done to the brain (Guskiewicz et al., 2004; Winters, 2001). A posterior separation of the molars by 3 to 4mm relates adequately to the Newtonian laws of physics (Winters, 2001), thus indicating why it is important for an athlete to not only wear a mouthpiece, but a properly fitted mouthpiece.

An *in vitro* study done by Hickey, Morris, Carlson and Seward (1967) looked at a cadaver's head response~~s~~ to a series of impact blows with and without a mouth guard in place. The authors concluded that there was a reduction in the amplitude of the intracranial pressure wave when the mouth protector was in place verses when it was not in place. Bone deformation decreased moderately in the cadaver when a mouth protector was in place (Wisniewski, Guskiewicz, Trope & Sigurdsson, 2004).

When looking at the comparisons of different types of mouth guards, one brand does not statistically stand out or work better. The boil and bite mouth guard compromises 90-95% of all the mouth guards worn by recent athletes (Wisniewski et al., 2004). Wisniewski et al. (2004) looked at football players from 114 Division I football programs in the 2001 football season to determine how custom verses non-custom mouth guards differed in the amount of concussions sustained when wearing either mouth guard. Results indicated that no statistical difference existed in the incidence of cerebral concussions when wearing a custom mouth guard verses a non-custom. However, findings exhibited two benefits from wearing a custom mouth piece. Custom offered more comfort for the athlete and better protection because it was exclusively molded to the teeth. When looking at concussion statistics, the most common mechanism for injury is head to head contact at 64% while a blow to the jaw rates at only 2%. This two percentage rate is assumed to be the result of the use of mouth guards (Wisniewski et al., 2004). This statistic may be the only significant result in supporting wearing a mouth guard in order to prevent concussion.

2.6. Manipulation of Playing Environment

Some environmental factors mentioned in research that have increased a football athletes risk of concussion include position played, the environment played in, and proper hitting technique. All three pieces have an effect on biomechanical considerations in the athletes' risk of injury. Often, it is not the athlete's choice that determines the position or environment played in; therefore the ability to adapt to any situation is critical.

2.6.1. Position

Several studies have addressed the position of the football player as a way to hypothesize the amount of concussions they will receive (Albright, Mcauley, Martin, Crowley & Foster, 1985; Guskiewicz et al., 2003; Hill, 2006; Pellman et al., 2004). Offensive linemen, linebackers, running backs, and defensive backs have been the most frequent to sustain a concussion when compared to their counterparts (Albright et al., 1985; Collins et al., 1999; Guskiewicz et al., 2003; and Pellman et al., 2004). In the study conducted by Guskiewicz et al. (2003) 1000 athlete exposures showed a weak association between position played and the likelihood of a concussion because only three positions showed the highest injury rate compared to the ten playing positions. All ten positions in football related in the most common mechanisms for concussions being colliding with an opponent (37.8%), tackling an opponent (21.4%), being tackled by an opponent (16.8%) and blocking an opponent (14.8%) (Guskiewicz et al., 2003).

Each football field position needs to take into account the location of the head upon contact with another player. Linebackers and running backs tend to get hit in the facemask and the front of the helmet whereas linemen get hit in a Mohawk like pattern on the top of the head (Hill, 2006). The hits to the facemask and front of the helmet predispose a concussion due to the rotational acceleration around the center of gravity of the head with these types of hits (Pellman et al., 2003b; Pellman et al., 2004; Viano & Pellman, 2005; Viano et al., 2005). Although most studies will lean toward linemen and linebackers being more predisposed to concussion, Pellman et al. (2004) found that quarterbacks, wide receivers, and defensive secondary were more prone to concussive impacts because open field collisions tend to generate more force.

2.6.2. Environment and Location

Some studies have stated there is a higher occurrence to high school football players getting concussions than collegiate and professional (Guskiewicz et al., 2000; Guskiewicz et al., 2003; Hill, 2006; Viano et al., 2005). Viano et al. (2005) reasoned that high school football athletes’ neck musculature and tackling abilities are not as well developed as they are in their older counterparts. Since anatomically the brain matures up to the age of 25, teens and young adults are more susceptible to a more severe concussion (Hill, 2006).

There are also a higher amount of participants in high school football across the nation then in collegiate and professional football combined (Guskiewicz et al., 2000). This increase in participants will automatically amplify the number of concussion occurrences in the younger population, without taking into account physiological differences in brain maturity. The popularity of the sport is what entices most young adults to participate and risk a chance of gaining a concussion.

2.6.3. Proper Hitting Techniques

No matter what position, age, or environment a football athlete plays in, there is a consensus across the research that improper hitting techniques have been an enormous cause of head and neck injuries (Albright et al., 1985; Cantu & Muller, 2003; Muller, Blyth & Cantu, 1989). Data collected before the year 1975 indicated a serious problem with head and neck injuries due to hitting techniques. In 1976 a paradigm shift was made by the NCAA and the National Federation of State High School Associations regarding illegal tackling. This shift considered illegal tackling to include the butt block, face tackle, and spear (Cantu & Muller, 2003; Muller, Blyth & Cantu, 1989). It should be noted that of these illegal tackling actions involve the use of the frontal area, top of the helmet or facemask to make the initial contact (Cantu & Muller, 2003).

The sport of football has seen a tremendous decline in brain injury related fatalities since the rule changes in 1976 (Cantu & Muller, 2003). It still remains an issue of regulating improper hitting techniques in most football programs. Albright et al., (1985) addressed the importance of educating every coach and player on the severity of injury that can come without using proper hitting techniques. The prevalence of acceleration and compression effects to the head and neck is inevitable in football, even with proper hitting techniques. This coherent predisposition to injury brings up the importance of strength preparation in collision sports.

2.6.4. Athletic Ability and Strength

Previous research regarding collision mechanic specified that concussions occur during a peak load when head accelerations are at their highest (Viano & Pellman, 2005). Most often the player who is affected is the one being struck. Because getting hit is unavoidable in football, prior investigations have looked into neck strength as a protector of concussive impacts (Conley, Stone, Nimmons & Dudley, 1997; Hynes & Dickey, 2006; Tierney et al., 2004; Viano & Pellman, 2005). Insufficient muscle strength has the ability to predispose individuals to concussion because they cannot create the internal muscle force necessary to counter the external forces that result in head acceleration (Tierney et al., 2004).

In the past, little research has been conducted in determining the correlation of weak neck musculature with concussive impact (Hynes & Dickey, 2006; Ylinen et al., 2003). To date, there is no national standard of neck strengthing protocols in collision sports (Leggett et al., 1991). The responsibility of neck strengthing in each football athlete is up to the discretion of the strength and conditioning coach. The problem sports medicine personnel face when it comes to the lack of national standards or guidelines regarding neck strengthening is that high neck strength does in fact have a correlation to a decrease in mild traumatic brain injuries, incorrect diagnosis may occur.

When looking at the neck anatomically, several muscles attach to the skull in order to allow flexion, extension, lateral flexion, and rotation of the head-neck segment. The main muscles listed for this purpose have been the levator scapulae, longissimus capitis and cervicis, semispinalis capitis, semispinals cerivicis, trapezius, sternocleiodmastoid, and multifundus (Conley et al., 1997). Research has focused on different training programs in order to maximize force absorption in this neck musculature. By maximizing force absorption upon a concussive impact, less force will be translated to the brain (Viano & Pellman, 2005). Even though there are multiple ways one can prepare their body for collision, the body still has an innate defense mechanism. Right before collision, the body produces a defense mechanism in which the head-spinal column will drop slightly, therefore placing it in the stiffest axis alignment before a collision. This occurs in order for the neck structure to maintain the maximum force possible upon contact (Pintar, Yoganandan, & Voo, 1998).

Training programs for cervical neck musculature help to compliment and improve the body’s natural defense mechanisms. One way to compliment this resistance of force is by increasing the necks muscle cross sectional area (Conley et al., 1997). Hypertrophy in the cervical spine will allow greater absorption rates because of increased size in cross sectional area. Studies have focused on different ways of gaining hypertrophy. Conley et al. (1997) pointed out that isometric actions alone are not enough to gain cervical neck hypertrophy, and therefore resistance training is recommended. According to Kawamori and Haff (2004) optimal muscular power comes from weight training in eccentric and isometric phases, and not just hypertrophy. Full cervical range of motion, hypertrophy, strength, and power may potentially protect an athlete from sustaining the concussive injury (Hynes & Dickey, 2006).

Preparation of stronger cervical muscles starts with isometric and resistance strengthing exercises. It is through these two strengthening regimens that a football player may develop strong neck musculature and thereby reducing potential injury risks (Viano & Pellman, 2005). In the specific application to football, strengthening exercises for neck muscles will give players a far greater tolerance to neck compression during a tackle while maintaining the ability to maintain axial alignment of their cervical spine (Viano & Pellman, 2005).

Since speed and power are important components for competing in football, it is important to note that with stronger necks, more impact force can and will be delivered in tackles without injury (Viano & Pellman, 2005). Biomechanical concepts affirm that the energy from an impacting object will disperse over a greater mass if the object is held rigidly (Whiting & Zernicke, 1998; Winter, 2005). Therefore it is more likely that a football athlete who maintains alignment and has high isometric neck strength will experience less concussive force to the brain (Johnston et al., 2001).

Multiple cervical spine muscle tests have shown that the extensors are much stronger then the flexors of the neck (Gabriel, Matsumoto, Davis, Currier & An, 2004; Seng & Lam, 2002; Seng, Peter, & Lam, 2002). This can be explained by differences in head and neck positions, muscle length-tension relationships, and neck positions with respect to motion axis (Seng, Peter, & Lam, 2002). The avoidance of neck injury and concussion can come from maintaining an aligned neck and torso while an athlete is preparing to tackle (Viano & Pellman, 2005). Overall, training the musculature in the neck, teaching proper hitting technique, and equipping athletes with the safest gear, will ideally reduce the greatest amount of concussive collisions.

2.7. Summary

Every year mild traumatic brain injuries are seen in high school, college, and professional football teams across the nation. Much research has been done on this injury due to the severity and future complications which it addresses. A universal definition, grading systems, and return to play protocol are all areas of continued research in concussion management. Some newer areas focus on prevention strategies through enhancing equipment standards, changing the environment, and increasing athletic ability and skill.

Research has concluded that concussion occurs because of liner and or rotational acceleration-deceleration changes in the head, as well as axial compression to the cervical spine. A sudden change in momentum caused from the listed forces is what results in tissue damage (Guskiewicz et al., 2004). Anatomical and physiological research of head injury has improved dramatically as concussion has been defined as an almost ~~a~~ preventable risk. Future research may focus on prevention strategies such as equipment changes, hitting techniques, and increasing athletic ability and skill.

CHAPTER III
METHODS

3.1. Participants

Twenty four Texas Tech Football players, ranging in age from 19 to 22 years, served as subjects. The concussion group of participants, consisting of 12 football players, had the following characteristics, mean and standard deviation in parentheses: age, 20.9 (1.0) years; height, 1.890 (0.061) meters; body mass, 109.8 (17.8) kilograms. The on- concussion group of participants, consisted of 12 football players each matched with their concussed counterpart, had the following characteristics, mean and standard deviations in parentheses: age, 20.3 (0.9) years; height, 1.880 (0.078) meters; body mass, 105.3 (15.9) kilograms.

All concussion participants reported symptoms of a head injury shortly after football practice or game to a general physician. Each injured athlete was held out of contact for at least seven days due to the head injury. No subject received a concussion in the year prior to the injury date; therefore post concussive syndrome was not a factor. Each subject's head injury was medically noted with the date and time of occurrence. The grade of concussion sustained was between mild (grade 1) and moderate (grade 2), and was diagnosed at the discretion of the physician. The concussion evaluation as performed by the physician(s) varied greatly between the twelve concussed subjects. Therefore, concussion grade and return to play timelines were not used as variables for statistical comparisons.

Player identity was kept highly confidential as each athlete was assigned a reference number (concussed 1-12, non-concussed 1C-12C). This reference number is not traceable to any name or identity. All records used in this study were not for public viewing. Information taken from personal records by the athletic trainers included: height, weight, player position, eligibility, and concussion date. The weight training programs retained by the strength and conditioning staff included sets, repetitions, and weights lifted by each athlete on their neck every day, for the six weeks preceding the concussion. The subjects used in this study had no physical involvement in the data collection process. All methods utilized in the collection of these data were approved by Texas Tech University Institutional Review Board (IRB) for human subjects testing.

3.2. Procedure

Each concussed subject was individually matched with a non-concussed player by season, height, weight, and player position. Data were obtained from logged player weight charts, and comparisons were made between concussed and non-concussed groups across the six weeks preceding the concussion date. Non-concussed participants were matched to concussed participants in the same season the concussion was received.

Subjects were physically active and on a regimental professional weight training program prior to and during this study. Weekly workout routine logs for each player consisted of four days per week, all of which were held in the football training facility. All Texas Tech football players were required to perform neck strengthing exercises each week. On each lifting day, players received volume load assignments (weight, repetitions, and sets) from the strength and conditioning staff. Neck exercises were performed using a four way neck machine and consisted of flexion, extension, and left to right lateral flexion. Each player's workout was recorded each week over the course of the season. Records were filed and stored in the football strength and conditioning facility, and were utilized to obtain neck strength training data for all subjects.

Dates of injury occurrence of concussion participants were retrieved from athletic medical files maintained by athletic trainers. The date of injury was used as a baseline, and weight charts from the six weeks preceding the injury were pulled. A normalized volume load statistic (NVL) was calculated for each subject. The statistic was calculated as follows, (weight lifted (kg) x reps x sets / body mass (kg)), and was compared between groups and across the six weeks preceding concussion incidence. A 2x6 ANOVA table with repeated measures was used to compare the statistical means between the two groups. The athlete's information of date of injury, height, body mass, position, and eligibility were examined and displayed in pie graphs.

CHAPTER IV
RESULTS

The twelve concussed (1-12) and twelve non-concussed (1-12C) Texas Tech football players used for this study were on active roster. Each concussed player was matched to a non-concussed player by height, weight, eligibility, playing status, and position (see tables 4.1 and 4.2). Illustrative statistics of all twenty four subjects include age, mean= 20.6 (1.0) years, height, mean= 1.886 (.074) meters, and body mass, mean= 107.6 (16.6) kg.

NVL values were not statistically significant between the groups. The NVL statistics across the six weeks for the two groups are presented in Table 4.3. Descriptive statistics (means and standard deviations) of the NVL groups are distinguished by concussed and non-concussed participants as well as averaged across groups in table 4.4. Comparison of concussed and non-concussed NVLs over the six week period can be seen in figures 4.1 through 4.12.

Out of the twelve concussed players, 66% (n=8) were on defense and 33% (n=4) were on offense (see figure 4.13). Seventy five percent of the sample's concussions occurred in fall football seasons, while the other twenty five percent occurred in the 2006 spring football season. Of the four players on offense who sustained a concussion, one was a wide receiver, two were offensive linemen, and one was a long snapper. Of the eight players on defense, two were linebackers, four were defensive backs, and two were defensive tackles (see figure 4.14). Four of the concussed were seniors, four were juniors, three were sophomores, and one was a freshman (see figure 4.15). Within the fall season 58% of the concussions happened in the months of September and October.

4.1. Format of Data Analysis

SPSS for windows (Version 12.0) was used for the statistical analyses in this study. Correlation analysis was used to examine the relationship between concussed and non-concussed groups during weeks 1-6 of activity (see figure 4.16). A 2x6 analysis of variance (ANOVA) with post hoc analysis was used to determine the statistical significance of the NVL between concussed and non-concussed participants from weeks one to six. The groups were: (1) concussed and (2) non-concussed with six levels representing weeks. A repeated measures design with the last factor on weeks was used for the ANOVA. A within subjects design was run with assumed sphericity. Mauchly's test for sphericity was .002 between concussed and non-concussed groups. Statistical analysis revealed no significant differences between concussed and non-concussed groups NVL's across the six weeks [$F (5, 110) = 1.735$, $p=.132$] or between weeks [$F (1, 6) < 1.00$, $p= .696$]. There were also no significant differences in matched players NVL across six weeks [$F (5, 110) < 1.00$, .909].

4.2. Tables

Table 4.2.1. Individual and mean subject position, date of injury (DOI), body height (height) in meters, and body mass (mass) in kilograms. Concussed participants (1-12) and non-concussed participants (1C-12C) Position abbreviations are WR- wide receiver, DT- defensive tackle, DE- defensive end, DB-defensive backs, LS- long snapper, OL- offensive line, LB- linebacker.

	Position	DOI	Height	Mass		Position	Height	Mass
# 1	WR	09-20-05	1.905	95.5	#1C	WR	1.905	100.9
# 2	DB	09-10-05	1.905	97.3	#2C	DB	1.854	93.6
# 3	LS	11-12-05	1.956	112.7	#3C	K	1.905	110.9
# 4	DB	10-28-06	1.829	99.1	#4C	DB	1.854	90.0
# 5	OL	10-26-04	1.930	151.4	#5C	OL	1.805	138.2
# 6	DB	10-05-04	1.829	92.7	#6C	DB	1.803	81.8
# 7	LB	08-19-03	1.829	99.1	#7C	LB	1.854	94.1
# 8	LB	10-01-06	1.778	105.0	#8C	LB	1.829	103.2
# 9	DE	09-11-06	1.956	119.1	#9C	DE	2.032	113.2
# 10	OL	04-12-06	1.930	131.0	#11C	OL	1.905	125.9
# 11	DB	03-29-06	1.854	95.5	#12C	DB	1.829	99.1
# 12	DT	04-08-06	1.956	119.5	#13C	DE	2.032	113.2
		Mean	1.888	109.8		Mean	1.884	105.3
		SD	0.062	17.8		SD	0.078	15.9

Table 4.2.2. Football player age (years), playing status, eligibility (SR- senior, JR- junior, SO- sophomore, FR- freshmen) and month of concussion occurrence.

	Age	Status	Eligibility	Month		Age	Status	Eligibility
# 1	21	Starter	JR	Sept	#1C	21	Starter	JR
# 2	22	Starter	SR	Sept	#2C	20	Starter	SO
# 3	22	Starter	SR	Nov	#3C	21	Starter	JR
# 4	21	2nd team	JR	Oct	#4C	20	Starter	SO
# 5	20	Starter	SO	Oct	#5C	22	Starter	SR
# 6	21	starter	JR	Oct	#6C	20	Starter	SO
# 7	19	3rd team	FR	Aug	#7C	19	3rd team	FR
# 8	22	Starter	SR	Oct	#8C	20	2nd team	SO
# 9	20	2nd team	SO	Sept	#9C	20	Starter	SO
# 10	20	3rd team	SO	April	#10C	19	3rd team	FR
# 11	21	Starter	JR	March	#11C	21	2nd team	JR
# 12	22	Starter	SR	April	#12C	20	Starter	SO

Table 4.2.3. Normalized volume load statistics for concussed (1-12) and non-concussed (1C-12C) participants from weeks 1-6. Week 6 indicates week concussion.

	WK 6	WK 5	WK 4	WK3	WK2	WK1		WK 6	WK 5	WK 4	WK3	WK 2	WK 1
#1	10.1	11.5	20.6	0.0	33.0	29.3	#1C	10.9	21.5	14.9	9.5	10.9	19.5
#2	20.3	7.0	32.4	28.8	21.4	0.0	#2C	16.0	10.3	11.8	21.0	14.4	0.0
#3	18.0	13.3	8.5	9.8	9.8	17.9	#3C	9.9	18.5	13.5	8.7	9.9	17.8
#4	10.1	10.1	10.1	10.1	10.1	10.1	#4C	11.1	11.1	11.1	11.1	11.1	11.1
#5	9.3	16.7	8.6	15.9	11.9	9.3	#5C	10.9	6.9	8.0	14.3	9.8	8.0
#6	21.8	14.6	11.9	21.8	16.2	10.4	#6C	24.1	16.5	13.4	24.7	18.3	11.7
#7	28.8	19.0	0.0	10.1	10.1	10.1	#7C	29.8	20.0	0.0	10.6	10.6	10.6
#8	9.6	9.5	9.5	9.5	17.1	10.7	#8C	9.7	9.7	9.7	9.7	14.5	9.3
#9	10.1	8.4	8.4	8.4	16.5	11.3	#9C	8.8	13.3	8.5	9.7	17.4	12
#10	14.4	23.6	25.4	23.5	15.7	21.5	#11C	24.5	26.4	24.4	16.4	18.9	26.5
#11	34.8	32.2	21.6	29.5	33.5	24.6	#12C	33.5	31.0	20.8	24	33.6	0.0
#12	30.4	35.2	22.6	14.8	30.4	26.6	#13C	27.3	29.3	27.1	18.2	21.0	29.4

Table 4.2.4. Descriptive statistics of the normalized volume loads for concussed and non-concussed participants (noncus) groups weeks 1-6.

	group	Mean	Std. Deviation	N
Week 1	concussed	15.1500	8.74097	12
	noncus	12.9917	9.07168	12
	Total	14.0708	8.78153	24
Week 2	concussed	18.8083	8.86048	12
	noncus	15.8667	6.80806	12
	Total	17.3375	7.87223	24
Week 3	concussed	15.1833	9.01260	12
	noncus	14.8250	5.90918	12
	Total	15.0042	7.45529	24
Week 4	concussed	14.9667	9.33822	12
	noncus	13.6000	7.50454	12
	Total	14.2833	8.31430	24
Week 5	concussed	16.7583	9.22816	12
	noncus	17.8750	8.01647	12
	Total	17.3167	8.47280	24
Week 6	concussed	18.1417	9.13818	12
	noncus	18.0417	9.13031	12
	Total	18.0917	8.93362	24

4.3. Figures

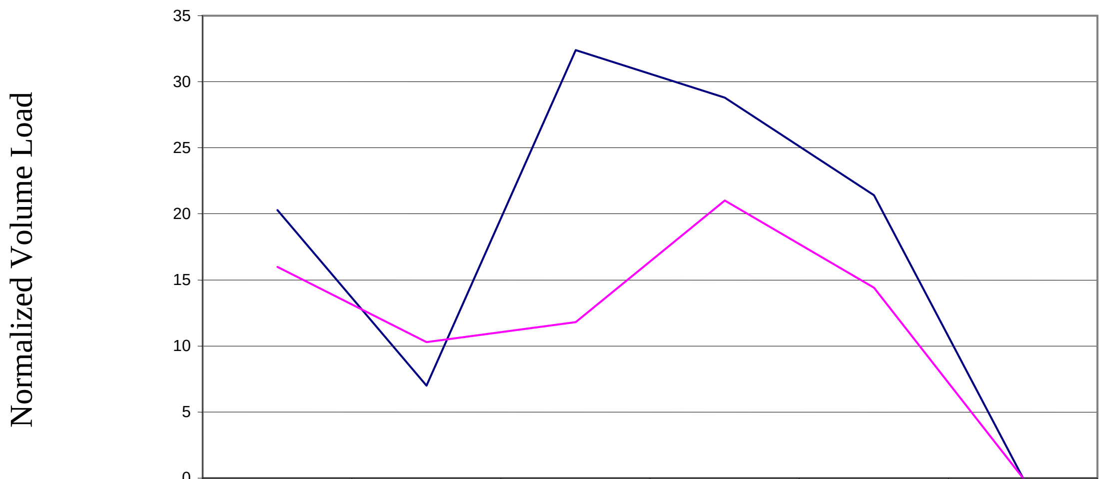
Participants 1 and 1C

	1	2	3	4	5	6
Concussed	10.1	11.5	20.6	0	33	29.3
Non Concussed	10.9	21.5	14.9	9.5	10.9	19.5

Week

Figure 4.3.1. Normalized volume load comparisons for concussed subject (1) and non-concussed (1C) subject over weeks 1-6. Week 6 was concussion occurrence.

Participants 2 and 2C

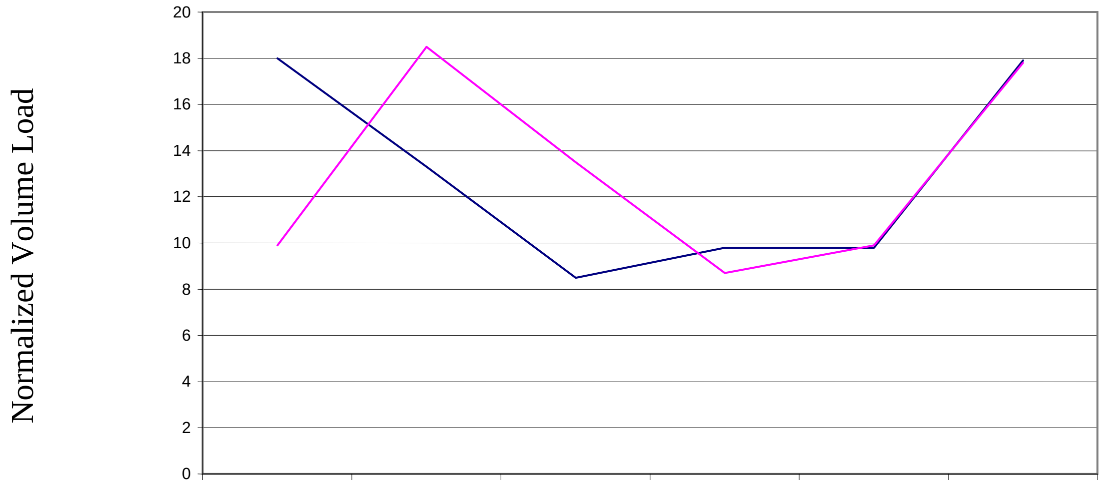


	1	2	3	4	5	6
Concussed	20.3	7	32.4	28.8	21.4	0
Non Concussed	16	10.3	11.8	21	14.4	0

Week

Figure 4.3.2. Normalized volume load comparisons for concussed subject (2) and non-concussed (2C) subject over weeks 1-6. Week 6 was concussion occurrence.

Participants 3 and 3C



	1	2	3	4	5	6
Concussed	18	13.3	8.5	9.8	9.8	17.9
Non Concussed	9.9	18.5	13.5	8.7	9.9	17.8

Week

Figure 4.3.3. Normalized volume load comparisons for concussed subject (3) and non-concussed (3C) subject over weeks 1-6. Week 6 was concussion occurrence.

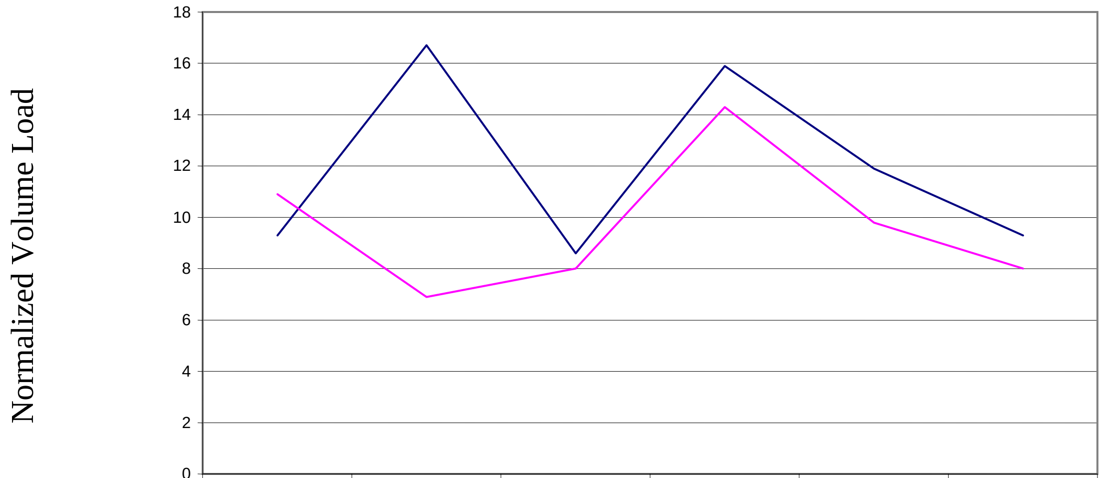
Participants 4 and 4C

	1	2	3	4	5	6
Concussed	10.1	10.1	10.1	10.1	10.1	10.1
Non Concussed	11.1	11.1	11.1	11.1	11.1	11.1

Week

Figure 4.3.4. Normalized volume load comparisons for concussed subject (4) and non-concussed (4C) subject over weeks 1-6. Week 6 was concussion occurrence.

Participants 5 and 5C



	1	2	3	4	5	6
Concussed	9.3	16.7	8.6	15.9	11.9	9.3
Non Concussed	10.9	6.9	8	14.3	9.8	8

Week

Figure 4.3.5. Normalized volume load comparisons for concussed subject (5) and non-concussed (5C) subject over weeks 1-6. Week 6 was concussion occurrence.

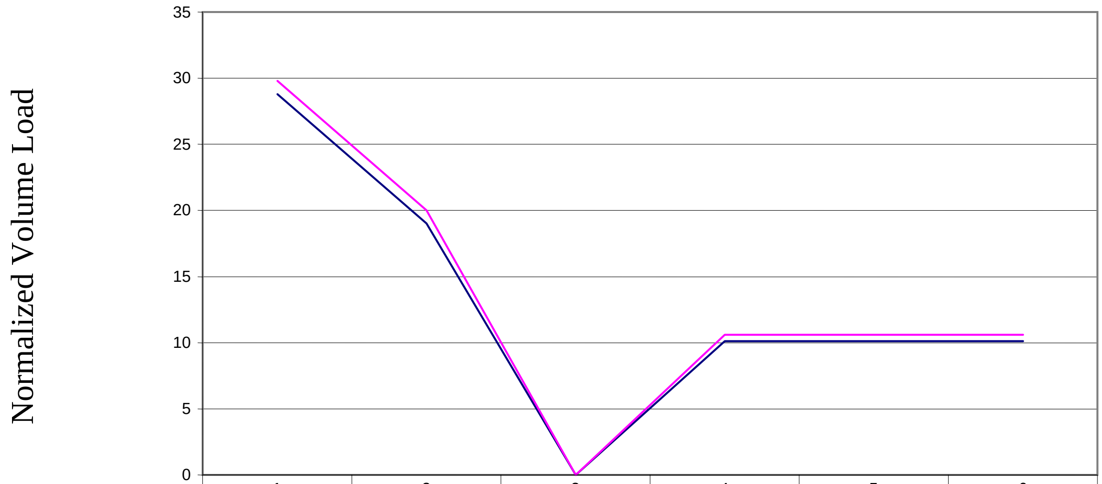
Participants 6 and 6C

	1	2	3	4	5	6
Concussed	21.8	14.6	11.9	21.8	16.2	10.4
Non Concussed	24.1	16.5	13.4	24.7	18.3	11.7

Week

Figure 4.3.6. Normalized volume load comparisons for concussed subject (6) and non-concussed (6C) subject over weeks 1-6. Week 6 was concussion occurrence.

Participants 7 and 7C

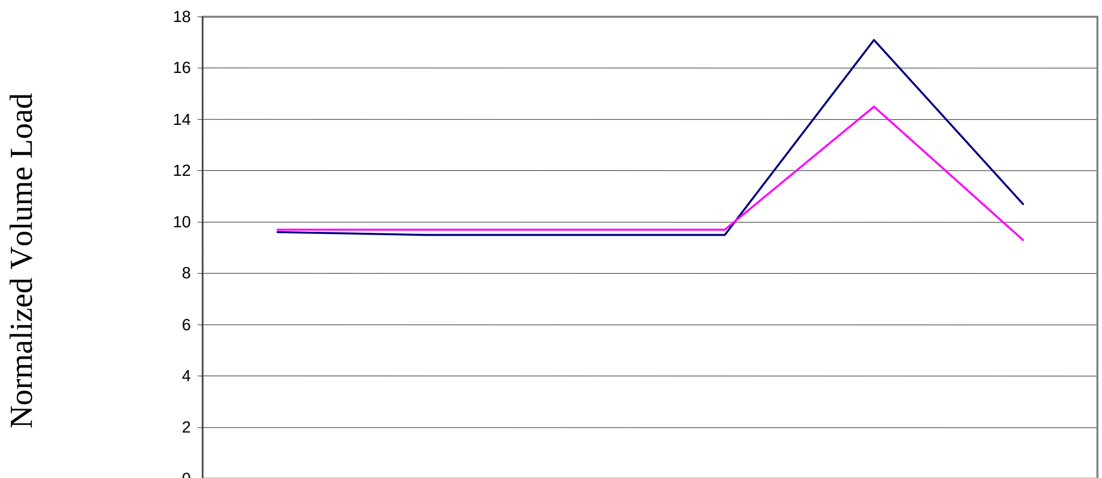


	1	2	3	4	5	6
Concussed	28.8	19	0	10.1	10.1	10.1
Non Concussed	29.8	20	0	10.6	10.6	10.6

Week

Figure 4.3.7. Normalized volume load comparisons for concussed subject (7) and non-concussed (7C) subject over weeks 1-6. Week 6 was concussion occurrence.

Participants 8 and 8C

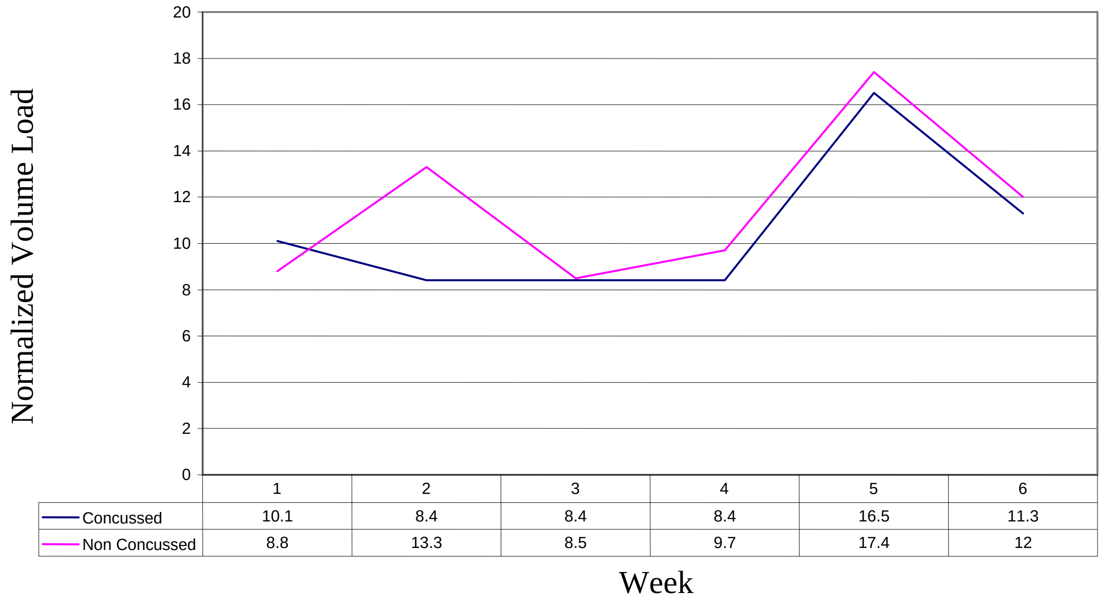


	1	2	3	4	5	6
Concussed	9.6	9.5	9.5	9.5	17.1	10.7
Non Concussed	9.7	9.7	9.7	9.7	14.5	9.3

Week

Figure 4.3.8. Normalized volume load comparisons for concussed subject (8) and non-concussed (8C) subject over weeks 1-6. Week 6 was concussion occurrence.

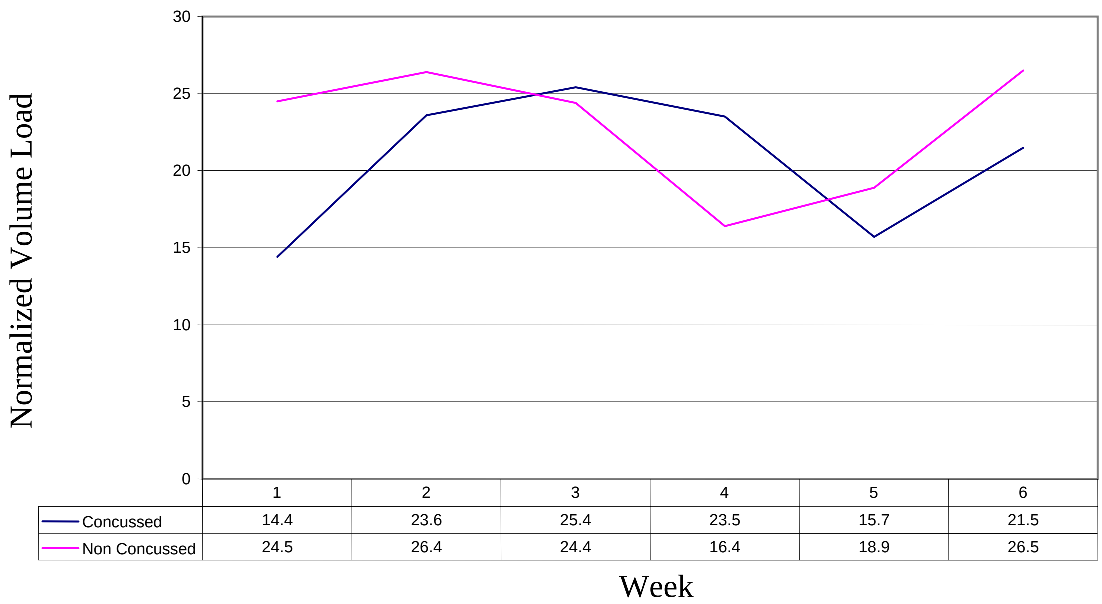
Participants 9 and 9C



	1	2	3	4	5	6
Concussed	10.1	8.4	8.4	8.4	16.5	11.3
Non Concussed	8.8	13.3	8.5	9.7	17.4	12

Figure 4.3.9. Normalized volume load comparisons for concussed subject (9) and non-concussed (9C) subject over weeks 1-6. Week 6 was concussion occurrence.

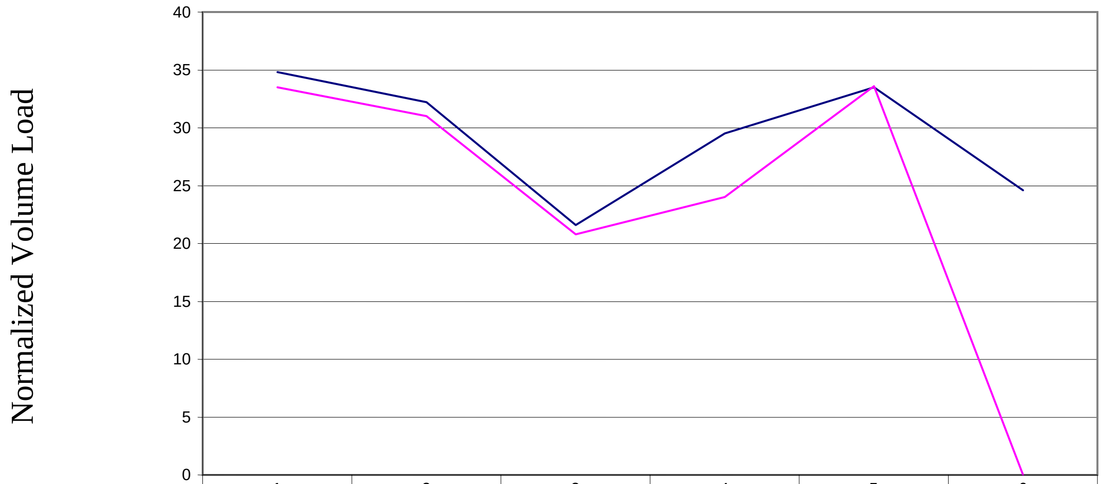
Participants 10 and 10C



	1	2	3	4	5	6
Concussed	14.4	23.6	25.4	23.5	15.7	21.5
Non Concussed	24.5	26.4	24.4	16.4	18.9	26.5

Figure 4.3.10. Normalized volume load comparisons for concussed subject (10) and non-concussed (10C) subject over weeks 1-6. Week 6 was concussion occurrence.

Participants 11 and 11C

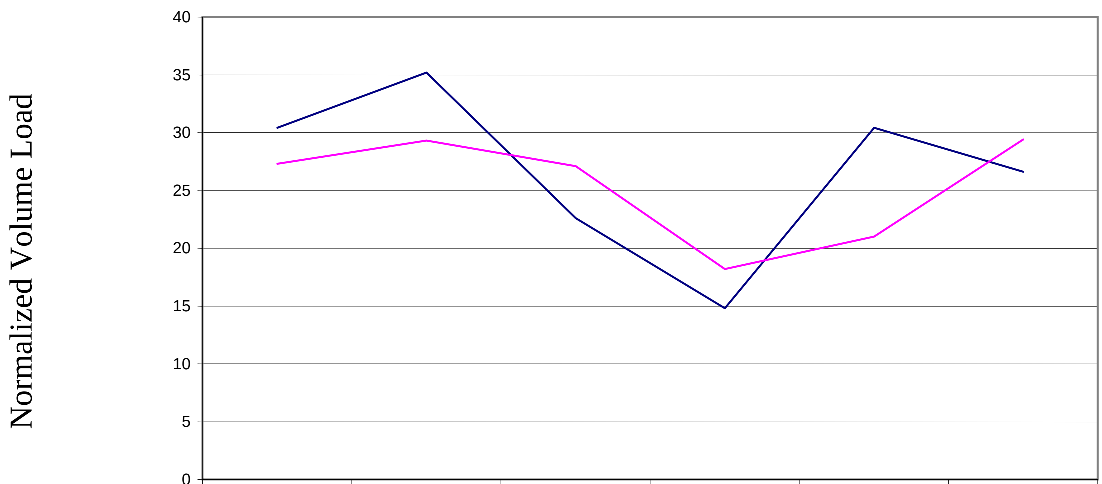


	1	2	3	4	5	6
Concussed	34.8	32.2	21.6	29.5	33.5	24.6
Non Concussed	33.5	31	20.8	24	33.6	0

Week

Figure 4.3.11. Normalized volume load comparisons for concussed subject (11) and non-concussed (11C) subject over weeks 1-6. Week 6 was concussion occurrence.

Participants 12 and 12C



	1	2	3	4	5	6
Concussed	30.4	35.2	22.6	14.8	30.4	26.6
Non Concussed	27.3	29.3	27.1	18.2	21	29.4

Week

Figure 4.3.12. Normalized volume load comparisons for concussed subject (12) and non-concussed (12C) subject over weeks 1-6. Week 6 was concussion occurrence.

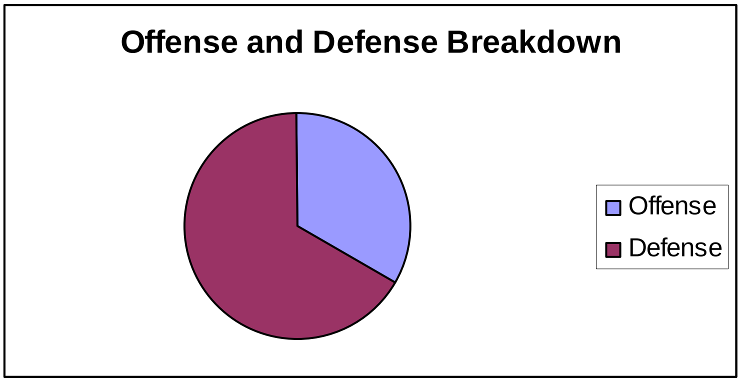


Figure 4.3.13. Offense and defense breakdown of concussed participants.

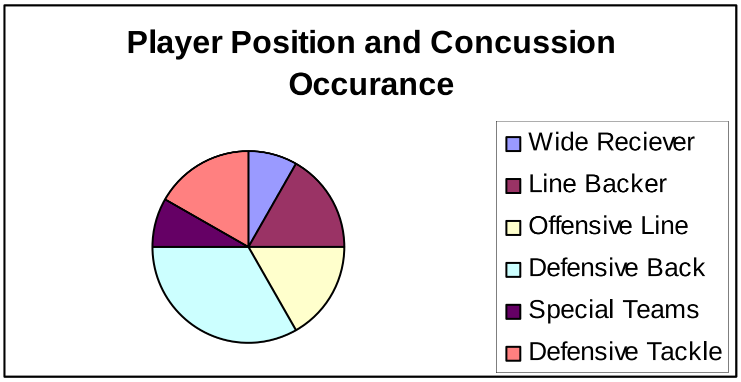


Figure 4.3.14. Player position and concussion rate in participants.

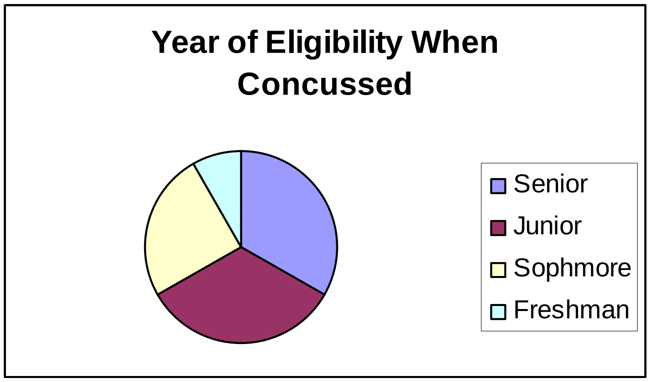


Figure 4.3.15. Concussed football athlete’s eligibility at time of concussion.

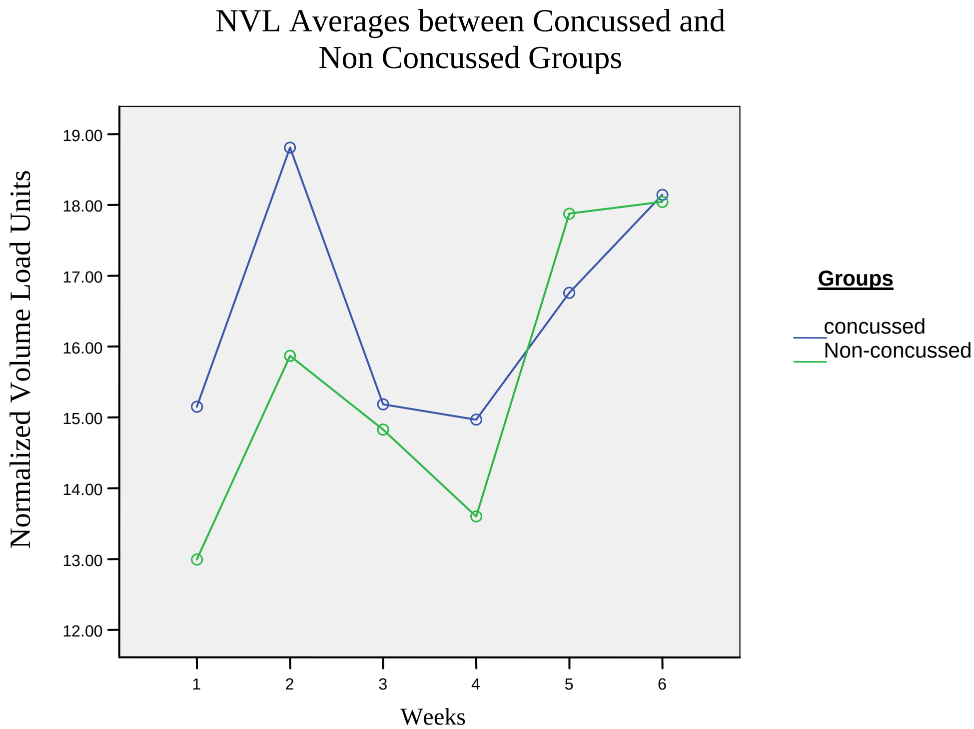


Figure 4.3.16. Normalized volume load (NVL) averages between concussed and non-concussed groups weeks 1-6. Week 1 represents week of concussion.

CHAPTER V
DISCUSSION

5.1. Importance of Cervical Neck Strength

Understanding biomechanical conditions for concussion has intrigued researchers for the last five years and has provided a new foundation in biomechanical research on concussions in athletics (Newman et al., 2005). However, mild traumatic brain injury research is still very limited because no one is willing to expose a live human being to a potentially injurious blow to the head in order to collect ‘real time data’ (Newman et al., 2005). Biomechanical research on concussion in football is essential to determine a safer playing environment for all competitors of the sport.

One significant biomechanical concept that has recently gained attention is the role that cervical neck strength plays in possibly decreasing a football athlete’s risk of concussion. This relationship suggests that if cervical neck strength in a football athlete is increased, the cross sectional area of the neck will increase, therefore complimenting it’s resistance to force (Conley et al., 1997; Kawamori & Haff, 2004). Strong relationships exist between muscle cross sectional area and strength, or in other words, hypertrophy (Kawamori & Haff, 2004). By maximizing force absorption upon a concussive impact, less force will be translated to the brain (Viano & Pellman, 2005). Because a Division IA football player will tackle or make a tackle repeatedly throughout a season it is necessary to prepare neck musculature for repeated blows to the head. It should be the responsibility of all sports medicine and strength and conditioning personnel to recognize the importance of maintaining a strong neck throughout an entire football season.

Often the neck is neglected or overlooked when planning weight training regimens because of the coaching staff’s fear of player injury. Although fear is normal and intuitive, it can hinder the coaches’ ability to decrease an athlete’s potential risk of concussion. Hypertrophy and periodization training research has shown substantial improvements in the recruitment of motor units within musculature (Conley et al., 1997;

Kawamori & Haff, 2004; Peterson, Rhea, & Alvar, 2004; Tsuyama et al., 2001). A higher rate of recruitment improves cervical musculature for protection, because motor units are trained to receive large force absorption rates in short periods of time (Conley et al., 1997; Tsuyama et al., 2001). Therefore, it is important to consistently challenge the musculature of the neck in the same manner someone would challenge other muscles used as critical protectors of joints within the body.

5.1.1. Strength Training Protocols

The use of periodization in training programs has gained more popularity in recent years due to experimental evidence of its lasting effects. Periodization is an important factor for the optimum enhancement of muscular development (Kawamori & Haff, 2004). Past research findings for a periodization program where the training emphasis was initially on the general strength verses muscular power, showed little variation in muscle ability (Kawamori & Haff, 2004). These results suggest that optimal strength and power gains within musculature come from a proper balance of hypertrophic training and periodization levels (Kawamori & Haff, 2004).

Some exercise physiologists have suggested in order to gain maximum strength within musculature one must train at a mean intensity 85% of their 1RM (repetition maximum) two days a week, with a mean training volume of eight sets per muscle group (Peterson, Rhea, & Alvar, 2004). However, according to Kawamori & Haff (2004) many investigators have supported resistance training in the range of 10-80% 1RM when maximizing mechanical power output. The mechanical power a muscle can produce obviously depends on the nature of the exercise, the training intensity of the athlete, and his/her training status. Although the author’s suggestions do not target the musculature within the neck and shoulders, the suggestions come from current research in order to improve power in striking activities within athletics (Kawamori & Haff, 2004). The discrepancy between both authors’ recommended percentage range, points out the importance of knowledge in strength and conditioning with regard to maximizing cervical neck strength. To date, there is no standard set for the optimal power and hypertrophy performance of cervical neck muscle fibers. Strength and conditioning staff must use their judgment with regards to preparing the neck for severe forces and blows.

Due to the vast amount of critical structures within the small cavity of the neck, caution must be taken with strengthing cervical spinal muscles. If the cervical spine or neck is injured in any way, the athlete must be held out of contact until the injury heals. This risk addresses a large liability issue in strength and conditioning, because the thought of a player being injured due to weight room activity, instinctively discourages strength and conditioning professionals from assigning hypertrophic lifts and moderate to high periodization levels for the neck musculature.

Concussion research presents two distinct mechanisms of injury: Coup (site of impact) and Contra Coup (opposite site of impact). Hypothetically the biomechanics of a contra coup injury suggests that increased neck strength may decrease internal forces to the brain upon a concussive impact (Guskiewicz et al., 2004). With an increase in neck strength, proper axial alignment, and a larger rigid mass (head-neck-torso) the neck will help to counteract concussive blows that are translated to the brain, assuming that the player sees and anticipates the collision. By improving neck strength, the excess translation to the brain will be prevented because the neck muscles will decrease the moment (torque) that the head experiences during a concussive impact (Guskiewicz et al., 2004).

5.2. Study Limitations

The present study has several limitations, including no current measures of strength were collected. Only the weight lifted on the cervical neck musculature prior to concussion was obtained from the weight charts of all the participants, from which NVL statistics were calculated. It was assumed that the NVL would directly relate to neck strength, which may have been an inaccurate assumption.

Statistical comparison between concussed and non-concussed groups would reveal discrepancies between group or individual training protocols leading up to the concussion. None, however were observed. Although the findings were not statistically significant it is interesting to compare the matched participant NVL across the same six week training periods (see figures 4.1-4.12) in the results section. There is no clear evidence within these results that indicate training progression overload was used, raising the question: Is just maintaining neck musculature enough to prevent concussion? Hypothetically, the answer would be no. If an athlete only maintains cervical neck strength and does not challenge the musculature to hypertrophic levels, the end result would be a decrease in motor unit recruitment, which would decrease the power capability in the muscle (Kawamori & Haff, 2004). This lack of power production in the cross sectional area of a muscle belly decreases the muscles effectiveness as a force absorber when concussive blows are presented.

The differences observed between concussed and non-concussed groups of athletes, with regard to weight training regimens, established ideas for improving concussion protection by increasing cross sectional area of the cervical neck musculature. There were no significant differences between groups with regard to training regimes, thus suggesting the examination of training records alone may not be sufficient to identify differences in muscle cross sectional area or strength. The present study was limited to weight chart data for the six weeks preceding the concussion. The data collection did not take into account any voluntary lifting exercises performed on the upper trapezius or other shoulder girdle or neck-assistor muscles. Nor did the study account for any isotonic thera-band work or manual therapy exercises the athletes may have completed in addition to their weekly workouts, as required by the athletic training staff. Honesty on all weight training reports was assumed on the parts of both the athlete and the strength and conditioning staff.

The concentric and eccentric four- way neck machine used by Texas Tech football athletes demonstrated little variation in progressing neck strength over weekly workouts. No periodization or hypertrophy training was observed during the six weeks prior to concussion, regardless of position or season. The results of this study determined that the four- way neck strengthing routines used by the training staff were not sufficient to prepare cervical neck musculature for axial compression and/or translational acceleration that are related to MTBI's, as in excess of 13 concussions were logged during the study's time frame (Viano & Pellman, 2005).

One finding from this research that was consistent with previous work was related to the position distribution of the athlete experiencing concussion. Present results demonstrated that defensive backs incurred the most concussions followed by linebackers and offensive linemen. Guskiewicz et al. (2003) and Hill (2006) reported that position could possibly predict an athlete's risk of concussion, where defensive backs, line backers, and offensive linemen were the most commonly concussed football players. The consistency of these modern reports, coupled with the present results, suggest that these three positions collectively show unique conditions in open field tackles and are worthy of closer examination. Defensive backs and line backers are more exposed to open field tackle concussions whereas linemen receive repeated blows to the frontal part of the helmet (Guskiewicz et al., 2003). Research specifically focusing on these three positions has not to any extent determined consistencies between position-related impacts and concussion incidence (Guskiewicz et al., 2003; Hill, 2006).

Football players regularly making open field tackles likely generate more force through the torso, neck, and head in order to successfully make the tackle, therefore exposing themselves to very high acceleration and potentially concussive impacts more often then other player. Football athletes can tackle and get tackled with accelerations up to 150 times the force of gravity (Hill, 2006). In order to maximize the effect of a football collision, an athlete (the tackler) must align the body through his center of mass (Viano et al., 2005). With this aligned position the transfer of momentum to the opposing player will be maximized upon impact (Viano et al., 2005). Due to the increased responsibility of a defensive back to make an open field tackle and stop their opponent in their tracks, cervical neck strength in these players is critical. In theory, since open field tackles likely transfer the most energy from head to head or head to body collisions, stronger neck musculature in athletes with high exposures to these types of impacts (open field) is likely beneficial to counterbalance the risk of concussion.

5.3. Future Research Regarding Cervical Neck Strength and Concussion

Focused and progressive strength training regimens are needed to improve strength in the cervical muscles. These strength training regimens should enhance the body's ability to resist concussive forces encountered during impact. Future studies measuring cervical neck strength and muscle power are recommended to adequately determine the relation between strength and concussion. Another suggestion includes measuring physiological cross sectional area (i.e. hypertrophy, neck girth) of neck musculature as a possibly better, compared with training logs, estimate of strength.

Previous studies of neck strength have used different equipment to assess true cervical neck strength; however, many have been hindered due to lack of appropriate technology (Deones, Steven & Worrell, 1994; Garces, Medina, Milutinovic, Garavote & Guerado, 2002; Kumar, Narayan, & Amell, 2001; Silverman, Rodriquez & Agre, 1991; Suryanarayana & Kumar, 2005). Deones et al. (2002) reported poor reliability with the use of the hand held dynamometers, while the use of the isokinetic dynamometer has high equipment costs, large space requirements, is time consuming sessions, and often requires trained personnel (Suryanarayana & Kumar, 2005).

It is recommended that future studies assume a longitudinal time line with multiple subjects across varying training regimens. Neck strength measurements should be obtained throughout the season, as well as post concussion. With this approach, the relation between grade of a concussion and neck strength at the time of the brain injury can be assessed. With research specifically measuring neck strength, different weight training protocols should be compared as well to determine the optimal power to hypertrophy ratio for cervical neck fibers. To this end, multiple periodization levels should be tested under very conservative standards in order to gain an optimal strength routine for athletes within collision sports. From these data, national standards for cervical neck strength can be established for football players as well as other contact sports athletes.

5.4. A Need for Standards

There is a great deal of theoretical evidence supporting the hypothesis that increased neck musculature can possibly decrease the risk of concussion. Experimental evidence however is lacking. The present study has taken the first steps to assess this experimental link. Although statistical significance was lacking in the presented results, several correctible design limitations have been identified, which when revised will likely result in the successful experimental evidence relating greater neck strength with decreased concussion occurrence.

Head impact sports such as ice hockey, rugby, and soccer can also benefit once strength standards are established. Coaches, parents, athletes and athletic support staff worldwide have the ability to implement neck strengthening protocols designed to decrease the risk of concussion within their athletic departments. It is through prescription of the proper training programs that one will see benefits in strength gains (Rhea, Alvar, Burkett & Ball, 2003).

Specific weight lifting equipment is not required to conduct strengthing exercises for the neck, making it very economical. There should be no excuse when implementing strength standards for neck musculature in low budget programs (e.g. high school and junior high) where funds are limited and time is valuable. Exercises that do not require equipment include isometric and isotonic muscle contractions. Specifically, through eccentric and isometric exercise, strength gains will generate a greater force production, therefore potentially decreasing concussion impacts experienced by the brain (Kraemer et al., 2002). All athletes in any setting can perform isometric exercise and eccentric neck flexion against gravity. These activities will be the initial step to help coaches get closer to preventing concussion. As athletic personnel implement strength standards into football programs there could possibly be an associated decline in concussion incidence.

All the research to prevent concussion will ultimately be for naught if sports medicine personnel don’t establish universal standards for return to play protocol especially in collision sports. Concussive impacts are inevitable in American football and have even become a highlight of the sport. There are few evidence-based guidelines regarding how long it takes for an athlete to recover from a concussion, forcing sports medicine personnel to play a guessing game. Expert consensus and limited scientific data from forthcoming studies have recently made return to play decisions an issue (Collins et al., 1999; McCrea et al., 2005). The best and most adopted advice from professional physicians mandates a seven day no contact period to minimize the risk of recurrent injury (McCrea et al., 2005). Without a doubt, a player should never return to play while symptomatic. However, more often than not, a physician who has a player with borderline data will be more inclined to allow the elite athlete with professional objectives to return to the sport earlier than a similarly impaired athlete who may not have career demands or aspirations (Echemendia & Cantu, 2003). Because return to play guidelines are so vague, a vast majority of medical professionals agree that an evaluation of a player is much more valid when the physician knows the player personally (Echemendia & Cantu, 2003). Besides the personality of the player, other variables that have an effect on the return to play decision include medical factors, specific concussion factors, player factors, team factors, and extraneous factors (Guskiewicz et al., 2003). The responsibility a sports medicine professional is to keep an athlete out of harms way, so the advice given by Johnston, Lassonde and Ptito (2001) is straight forward… "When in doubt, sit them out!" (p. 521).

It is recommended that every sports medicine professional read the literature on presented grading and return to play guidelines and chose one they will follow consistently. If an athlete presents signs and symptoms outside of the recommended guideline the physician chose, the athlete should be treated according to the symptoms they report regardless of their talent or future aspirations. All evaluations, treatments, and decisions must be recorded. Collection and assessment of these records across different levels of play will establish uniformity between physicians and eventually programs and conferences. It is only by the uniformity and smart decision making that an athlete will have the best chance for a full recovery and a productive career in the sport of football.

CHAPTER VI
CONCLUSION

The number of concussive occurrences, forces causing the impact, and direction of a hit cannot be predicted prior to a football team taking the field. This is the main reason why it is essential for football athletes to be prepared for a concussive impact. This research examined the role cervical neck strength plays in the prevention of concussion in NCAA Division I football players.

The weight charts of twenty four Texas Tech football players' (grouped as concussed and non-concussed) were compared as to cervical neck strength NVL over the six weeks preceding concussion. Concussed and non-concussed NVL ratios were used to consider an athlete's predisposition to greater tolerability of concussion. Inconsistent results revealed no positive correlations when comparing NVL's between the two groups. Lack of consistency in NVL across players demonstrated a probable lack of correlation between NVL and actual neck strength. Although the results of the study were not significant, the theory and concept of the study itself is highly credible. Just the idea of decreasing the risk of concussion through improved weight training in neck musculature deserves attention.

The results of this study indicate a need for future studies to measure neck strength rather then estimate it from training logs. This neck strength should be compared to concussion occurrence over a longitudinal time line using multiple football players across different positions and training regimens. More ways to improve results include researching relationships of body composition, level of training, and specificity of the training itself with regard to neck musculature. Other contributing factors to concussion occurrence may be related to the position an athlete plays, the number and type of impacts, as well as body position during impact. Each aspect plays a critical role in the amount of force which is translated to the brain.

Higher levels of strength training can influence the body's ability to translate force at a higher rate. Neck strength training has been theorized to differ between the professional, college, and high school levels. With each level, progressive exercise becomes enhanced and a higher weight training and injury protection standard is imposed. An elevated standard is often present in professional and college level football because there is a greater concern and precaution over career ending injuries like concussion. Future research should include strength measurements taken in all levels (professional, college, and high school) of play in order to determine if elite training prevents concussion better then collegiate training.

There is a great deal of theoretical evidence that improved neck strength will help prevent concussion; only experimental evidence is lacking. With some tightly controlled studies, specifically measuring neck strength and concussion incidence, the experimental evidence for this relation will be obtained. As more knowledge is gained regarding the relationship of cervical neck strength and concussion, we will likely see improved measures for concussion prevention. There is an incredible need for proper and effective weight training strength protocols across the nation. Neck strength training regimens that decrease the risk of concussion are a valuable asset to any football team. The intuitive benefits behind neck strengthing should be introduced to football coaching staffs nation wide. If even one future concussion can be prevented due to improvements in cervical neck strength, concussion research will continue to have limitless possibilities in saving lives.

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