ABSTRACT

ASSESSMENT OF FOOTBALL ACTIVITIES ASSOCIATED WITH SPORTS-RELATED CONCUSSIONS

by Katherine Elizabeth Bennington

The growing number of injuries and fatalities in athletes due to traumatic brain injuries has led to an increase in the need for additional research. The purpose of the study was to determine the football activities that yield the greatest number of concussions in order to gain knowledge about additional risk factors for sustaining a concussion. The study included 40 football players from Miami University who sustained a concussion from 1999 to 2008. The results revealed football players performing a running play have a greater risk for sustaining a concussion, and 75% of concussions occurred in the offensive position for running, passing, kick-off, and blocking plays. In addition, running plays consistently caused the highest number of concussions sustained over a ten-year period.
ASSESSMENT OF FOOTBALL ACTIVITIES ASSOCIATED
WITH SPORTS-RELATED CONCUSSIONS

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TABLE OF CONTENTS

Chapter I: Introduction and Review of the Literature 1

Concussions 1
Prevalence of Concussions in Football 2
History of Concussions in Football 3
Definition of Concussion 5
Second-Impact Syndrome 7
The Impact of Concussions on the Brain 8
Symptoms of a Concussion 8
Typical Symptoms 9
Cognitive Symptoms 9
Physical Symptoms 9
Psychological Symptoms 9
Assessment of Concussions in Football 10
Baseline Testing 10
Sideline Assessment 11
Neuropsychological Testing following Concussion 11
Neuroimaging 12
Risk Factors 12
Position 13
Age 13
History of Concussions 14
Height and Weight 14
Activity 14
Statement and Significance of the Problem 15
Purpose of the Study 15
Research Questions and Hypothesis 15

Chapter II: Method 16
Participants 16
Procedures 16
Statistical Analysis 18
Chapter III: Results

Research Question 1: Does a certain activity in football affect the incident rate of concussions in athletes?

Research Question 2: Does the activity that appears to cause the highest rate of concussions remain consistent over a ten-year period?

Research Question 3: Does the concussion occur more frequently in the offensive or defensive player during a certain activity in football?

Chapter IV: Discussion

Activity
Positioning
Concussions over Time
Conclusions
Clinical Implications
Limitations
Future Research

References
Appendices

Appendix A
LIST OF TABLES

Tables
1. Definitions of Concussion 6
2. The ImPACT program sections and cognitive modules 12
3. Pittsburgh Steelers Neuropsychological Battery 17
4. Immediate Postconcussion Assessment and Cognitive Testing (ImPACT) 17
5. Number of Concussions During a Specific Drill 19
6. Concussion During a Specific Activity from 1999 to 2008 21
7. Number of Concussions Occurring During Offense and Defense 22
8. Descriptive Statistics for Offense and Defense Concussions 23
LIST OF FIGURES

Figures
1. Contribution to Chi-Square Value by Category 20
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CHAPTER I

Introduction

Concussions

Approximately 300,000 U.S. athletes suffer from sports-related traumatic brain injury annually. All athletes are potentially at risk. Sport participation is one of the leading causes of traumatic brain injury, second only to motor vehicle accidents (Gesset, Fields, Collins, Dick, & Comstock, 2007).

The majority of the injuries sustained in football are of mild severity and are classified as concussions (Echemendia & Cantu, 2003). A concussion is synonymous with mild traumatic brain injury because they describe the same condition. A concussion is defined as a closed head injury induced by biomechanical forces that cause an alteration in normal consciousness and brain processes. Usually the symptoms of a concussion, such as loss of consciousness or confusion, diminish quickly. However, some symptoms can last for a significant period of time (Covassin, Swanik, & Sachs, 2003).

The growing number of injuries and fatalities due to concussions has increased the importance of research studies on the topic (Mihalik, Bell, Marshall, & Guskiewicz, 2007). Investigators have performed studies regarding how the brain is impacted during a concussion, the effectiveness of football helmets for protecting the brain during impact, and the risk factors associated with concussions. Although studies have been conducted to determine the incident rates and risk factors in football, few authors have studied the specific activities that are most likely to result in a concussion in a given collegiate sport (Shankar, Fields, Collins, Dick, Comstock, 2007).
Review of the Literature

Prevalence of Concussions in Football

Any athlete is potentially at risk for sustaining a concussion. In 2005, approximately 135,901 U.S. collegiate athletes suffered a concussion according to data collected by the National Collegiate Athletic Association Injury Surveillance System. Of those injuries, 55,007 came from football alone (Gesset, Fields, Collins, Dick, & Comstock, 2007). Echemendia (1997) estimated 29.8% of all football players had sustained a concussion before beginning collegiate football.

The incident rate of concussions in football has decreased significantly over the years due to changes in rules, techniques, and better head protection (Solomon, Johnson, & Lovell, 2006). However, there are still inconsistencies in the literature regarding estimates of the actual incident rates of concussions in U.S. football. For instance, estimates of the annual frequency rates of concussions sustained in collegiate football players have ranged from 4% to 7.7% (Zillmer, 2003).

In 1977, researchers surveyed 103 football teams in Minnesota to determine the incident rate and severity of concussions. According to the study, concussions accounted for 24% of all the football injuries. In other words, approximately 200,000 concussions occurred during the season in this sample population (Gerberich, Priest, Boen, Straub, & Maxwell, 1983). However, in 1999, Powell and Barber-Foss reported a significantly lower incident rate. According to the researchers’ published study, approximately 40,000 concussions occurred during the 1997 collegiate football season. Another study in 1999 reported a significantly higher incident rate of concussions in football. According to Collins, Grindel, Lovell, Dede, Moser, et al (1999), approximately 250,000 concussions were sustained annually in football in the U.S.

A large scale, 4-year study was conducted among football players at the collegiate level to further document the risk of concussion. After sampling 2,300 players, the authors concluded that the annual concussion rate was approximately 7.9% with a slightly higher multiple concussion rate of 8.4% (Macciocchi, Barth, Alves, Rimel, & Jane, 1996). However, a subsequent study, which sampled 2,385 high school and college football players, arrived at an annual frequency rate of 3.8% (McCrea, Kelly, Randolph, Cisler, & Berger, 2002).
Research indicates the incident rates for concussions may differ in various studies because of the use of different definitions for a concussion. In addition, various diagnostic practices exist among sports medicine professionals when diagnosing a concussion. Research also indicates that athletes do not consistently report their concussions. According to Solomon, Johnson, and Lovell (2006), approximately 47.3% of football players failed to report sustaining a concussion. In addition, the lack of athlete’s awareness or reluctance to report the symptoms of a concussion may be yet other factors contributing to an underestimation of concussion rates.

*History of Concussions in Football*

The history of competitive sports and concussions has been observed for over 2,000 years. Ancient medical reports and mythological literature contained numerous references to head injuries (Zillmer, Schneider, Tinker, & Kaminaris, 2006). For example, Homer’s *Iliad* and *Odyssey* often described deaths following head injuries. Furthermore, in ancient Greece, concussions sustained during organized sports have often been reported in medical documents (Zillmer, Schneider, Tinker, & Kaminaris, 2006).

In the Middle Ages, the term *concussion* became more widely used by physicians when describing injuries. As familiarity with the term increased, physicians began to document and describe the clinical symptoms they observed. With an increased understanding of the clinical presentation of a concussion, physicians began to notice a significant number of concussions resulting from sports (McCrory & Berkovic, 2001). Therefore, during this period, physicians began to focus on protecting individuals from head injuries. Protective helmets were created for athletes to wear during ballgames in 1486. The original helmets consisted of small plates of bronze and later iron. However, these helmets were heavy and ineffective at protecting athletes from concussions (Blackburn, Edge, Williams, & Adams, 2000).

During the early part of the 20th century, the number of concussions sustained during football called into question the safety of the sport. Although football helmets were available starting in 1896, the helmets were ineffective in protecting players from sustaining head injuries (Cantu & Mueller, 2003). In 1905, President Theodore Roosevelt held a meeting with representatives from Harvard, Yale, and Princeton to discuss the safety of the sport. After the *Chicago Tribune* published a report stating that 18 deaths and 159 injuries occurred during the 1905 football season, the public denounced football for its brutality. To save the sport, President
Roosevelt established the Intercollegiate Athletic Association to oversee all collegiate sports (Stewart, 1995). In addition, rule changes were instituted in football to further protect the players. For instance, the “flying wedge” formation was outlawed in the sport. The formation had been considered one of football’s most dangerous strategies because a group of offensive blockers provided protection for the ball carrier by tackling a defensive player (Zillmer, Schneider, Tinker, & Kaminaris, 2006).

The growing number of football fatalities eventually led to a need for better protection of the head and, indirectly, the brain. In the late 1940s, the plastic helmet was introduced, which was later improved to include a single-bar facemask (Cantu & Mueller, 2003). In 1964, the single-bar facemask was replaced by the double-bar facemask. In 1969, the National Operating Committee on Standards for Athletic Equipment (NOCSAE) published the first standard for helmets, which established minimum requirements for football helmets. This standard was intended to make helmets more effective in preventing injuries (Newman, Beusenberg, Shewchenko, Withnall, & Fournier, 2005).

Prior to the 1980s, little research had been conducted on concussions in football players. In 1977, researchers surveyed 103 football teams in Minnesota to determine the severity and incident rate of concussions sustained by high school football players. Based on the results of the survey, the study determined that 24% of football injuries resulted in concussions (Gerberich, Priest, Boen, Straub, & Maxwell, 1983). However, the study was conducted before NOCSAE required that all football players wear helmets (Covassin, Swanik, & Sachs, 2003).

The first sports-related concussion study on recovery rates was conducted at the University of Virginia in 1987 (Barth, Alves, Ryan, Macciocchi, Rimel, & Jane, 1989). Jeffery Barth and his colleagues at the University wanted to determine the extent to which football players recovered after experiencing a mild acceleration-deceleration head injury. The investigators determined that intelligent, young, and well-motivated student athletes, who experienced a mild traumatic injury without loss of consciousness, still showed evidence of neuropsychological decline. The decline was prominent in the areas of problem-solving and attention span. However, the athletes rapidly recovered and did not experience lasting negative effects on their problem solving abilities or attention span (Barth et al., 1989).

During the 1990s, concussions in football became a major focus for neuropsychologists, physicians, and athletic trainers. Their major concerns focused on assessing the severity of
concussions, evaluating the immediate and long term effects of multiple concussions, and developing return-to-play criteria (Covassin, Swanik, & Sachs, 2003). In 1996, Cantu developed a severity classification scale that focused on level of unconsciousness and amnesia to determine if a concussion was mild, moderate, or severe. In addition, the American Academy of Neurology introduced guidelines for treatment and return-to-play (Cantu, 1996).

Research in the late 1990s also focused on the long term effects of concussions. The term *postconcussion syndrome* was introduced to describe the combination of somatic complaints, cognitive impairments, and behavioral changes experienced after a concussion (Wrightson, 2000). In addition, neurometabolic research was conducted that focused on specific changes in the brain occurring after a concussion. For instance, concussions may cause a depolarization of the sodium-potassium pump, which triggers a decrease in cerebral blood flow (Giza & Hovda, 2001).

Recently, research has focused on developing assessment tools for sports-related concussions. Computer programs have been developed, which can speed the assessment of concussions as well as improve baseline testing. Along with the assistance of a neuropsychologist, the use of these computer-based tools may soon be the most common method for assessing concussions (Schatz & Zillmer, 2003).

**Definition of Concussion**

As noted previously, a concussion is a closed head injury induced by biomechanical forces that cause an alteration in normal consciousness and brain processes. Approximately 90% of sports-related concussions are mild in nature and are referred to as mild traumatic brain injuries (Solomon, Johnson, & Lovell, 2006).

Many definitions of concussion have been created throughout the years. Professionals have frequently debated how the definition of a concussion should be stated. The precise definition can be critical to the identification, diagnosis, and treatment of the patient (Webbe, 2006). Table 1 describes the definitions of concussions that have been utilized in the past.
Table 1
Definitions of Concussion

<table>
<thead>
<tr>
<th>Group Proposing Definition</th>
<th>Definition</th>
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<tr>
<td>Ad Hoc Committee to Study Head Injury Nomenclature of the Congress of Neurological Surgeons (1966)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>A clinical syndrome characterized by immediate and transient post-traumatic impairment in neural function, such as alteration of consciousness, disturbance of vision, equilibrium, etc. due to brain stem involvement resulting from mechanical forces</td>
</tr>
<tr>
<td>The American Academy of Neurology (1997)&lt;sup&gt;2&lt;/sup&gt;</td>
<td>A trauma-induced alteration in mental status that may or may not involve loss of consciousness. Confusion and amnesia are the hallmarks of concussion. The confusional episode and amnesia may occur immediately after the blow to the head or several minutes later</td>
</tr>
<tr>
<td>Concussion in Sport Group (2002)&lt;sup&gt;3&lt;/sup&gt;</td>
<td>A concussion is a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical, pathological, and biomechanical injury constructs that may be used in defining the nature of concussive head injury include:</td>
</tr>
<tr>
<td></td>
<td>1. Concussion may be caused either by a direct blow to the head, face, neck, or elsewhere on the body with an impulsive force transmitted to the head.</td>
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<td>2. Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously.</td>
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<tr>
<td></td>
<td>3. Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury.</td>
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<tr>
<td></td>
<td>4. Concussion results in a graded set of clinical syndromes that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course.</td>
</tr>
</tbody>
</table>
5. Concussion is typically associated with grossly normal neuroimaging studies

Although all the definitions listed above are similar, some researchers believe that a consensus regarding a precise definition is essential for effective treatment (McKeever & Schatz, 2003).

*Second-Impact Syndrome*

Second-impact syndrome is a condition that occurs when an athlete sustains a second head injury before the symptoms of a prior concussion is resolved. During a typical case, a concussed player returns to play before their symptoms have resolved. The player then sustains a second blow to the head while playing. The second impact leads to loss of regulation of the brain’s blood supply which causes increased intracranial pressure and bleeding in the brain (Solomon, Johnson, & Lovell, 2006). The athlete may initially appear dazed, but then may fall into a comatose state a few seconds later, lose eye movement, or suffer respiratory failure. Brain stem failure frequently occurs two to five minutes after impact (Newman, Beusenberg, Shewchenko, Withnall, & Fournier, 2005). According to Maroon (2000), the mortality rate for second-impact event was 50% with the morbidity rate reaching almost 100%. Even though second-impact syndrome is rare with an average of two deaths per year, because of these disturbingly high mortality and morbidity rates, an athlete should not be allowed to return to play until the symptoms of the initial concussion have completely cleared (Maroon, 2000).

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1 Maroon, 2000, pg. 61
3 Concussion in Sport Group, 2002, pg. 6-7
The Impact of Concussions on the Brain

When a concussion occurs, the brain can be impacted by two types of forces: acceleration-deceleration or rotational (Solomon, Johnson, & Lovell, 2006). An example of an acceleration-deceleration force would be a player hitting another player, thus causing the brain in the injured player’s head to move forward in the skull. When the injured player’s head eventually stops, the brain decelerates and the frontal lobe strikes the inside of skull causing a contusion. Once the front of the brain comes in contact with the skull, the rebound movement causes the occipital lobe to hit the skull resulting in a contre-coup injury. Depending on the threshold of force with which the brain is injured, the brain may be permanently or temporarily injured. However, further studies need to be conducted to determine how much force causes a temporary versus a permanent injury.

When a player experiences a rotational impact, the head rotates from side to side causing the axons in the cortex to stretch and tear (Solomon, Johnson, & Lovell, 2006). The rotational movement can also potentially cause the blood vessels in the cortex to tear resulting in a hematoma. In addition to the stretching and tearing, the brain may also impact the skull causing a contusion.

Most sports-related concussions do not involve major structural injury to the brain. However, after a concussion, disruption of the brain’s chemical and electrical activities can potentially cause a person to experience a number of side-effects. When the brain is functioning normally, neurotransmitters send signals to the cells to release potassium and take in sodium. This process allows nerves to send electric signals throughout the body to keep the system functioning normally. When the brain is impacted, potassium is released from brain cells at 4 times the normal rate. The change in potassium concentration disrupts the electrical activity of the brain causing the individual to lose consciousness (Powell, 2004).

Symptoms of a Concussion

Athletes who have sustained a concussion often experience common symptoms. According to McCrory and Johnston (2002), only certain symptoms have been scientifically linked to concussions, including: loss of consciousness; headache; dizziness; nausea; blurred vision; memory loss; and attention difficulties. Four general symptom categories are utilized to
identify concussions in athletes. The categories include: typical symptoms, cognitive symptoms, physical symptoms, and medical symptoms.

*Typical Symptoms*

After an impact is sustained, a player might experience headache, nausea, loss of balance, loss of consciousness, sleep disturbance, and fatigue. The symptoms are considered typical of a concussion and, therefore, if any of the aforementioned symptoms are present following the impact, a concussion is suspected (Solomon, Johnson, & Lovell, 2006).

*Cognitive Symptoms*

When concussed players experience memory loss, they may suffer from retrograde or anterograde amnesia. If the athlete experiences retrograde amnesia, the athlete may lose memory of the events that occurred prior to the impact. If the athlete experiences anterograde amnesia, events that occurred after the impact are lost (Solomon, Johnson, & Lovell, 2006). A common misconception about memory loss after concussions is that memory loss only occurs if the player experiences a loss of consciousness. However, memory loss can also occur in the absence of a loss of consciousness (Clarke, 1998).

In addition to memory loss, an athlete could experience attention difficulties and disorientation. According to a study by Iverson, Gaetz, and Lovell (2004), experiencing disorientation after a concussion is an important indicator of how an athlete will perform during subsequent neuropsychological testing. The researchers tested 19 athletes who experienced disorientation and 91 athletes who did not. The researchers discovered that the 19 athletes with persistent fogginess experienced more symptoms such as dizziness and headaches. They also performed worse on tests for reaction time, memory, and speed of information processing.

*Physical Symptoms*

The physical symptoms of a concussion can range from being mild to severe in nature. Motor deficits, such as poor coordination and slurred speech, are often considered to be physical signs of a concussion. In addition to motor deficits, an athlete might experience difficulty following directions and inappropriate game playing behavior, such as carrying the football the wrong direction on the field (Covassin, Swanik, & Sachs, 2003).

*Psychological Symptoms*

Psychological changes are important indicators of a concussion. If an athlete experiences sudden personality changes or inappropriate expression of emotions, a concussion is suspected.
For example, a previously outgoing, well-mannered individual might become more agitated and short-tempered (Covassin, Swanik, & Sachs, 2003).

Symptoms of a concussion usually diminish within a few days. However, some symptoms can last for a significant period of time (Covassin, Swanik, & Sachs, 2003). Complete recovery from all post-concussion symptoms is necessary if an athlete is going to have a safe and successful return to the playing field.

Assessment of Concussions in Football

Over the past decade, the use of neuropsychological testing has been a recent development in concussion management. The University of Virginia conducted the first large scale study on concussion assessment in the mid 1980s. Although the data gathered from that study was not used to assist in return-to-play decisions, the study helped to establish a model of neuropsychological assessment (Barth, Alves, Ryan, Macciocchi, Rimel, & Jane, 1989). The Pittsburgh Steelers established one of the first neuropsychological evaluation programs in 1993. Their assessment approach involved the use of baseline testing prior to the start of the season. After a player was concussed, the assessment was repeated and the results were used to determine when a player was allowed to return (Lovell, 1999).

Currently, when a football player sustains a concussion, a neuropsychological test battery is usually performed, especially at the collegiate level. This battery includes: baseline testing, sideline assessment, neuropsychological testing, and neuroimaging (Solomon, Johnson, & Lovell, 2006).

Baseline Testing

Prior to the beginning of football season, baseline testing is often performed on each player. The evaluation includes: tests of memory, attention span, concentration, mental processing speed, and motor speed (Echemendia, 2006). Establishing a baseline for each player is essential since different people exhibit different performance levels. Athletes may perform poorly on certain sections of the testing due to various factors, such as learning disabilities, anxiety, attention deficit disorder, or the effects of prior concussions. Recording each player’s pre-concussion level of performance will be used to help determine when or if an athlete can return-to-play after experiencing a concussion (Lovell & Barr, 2004).
Sideline Assessment

When a player sustains an impact to the head during play, the athletic trainer or physician performs an on-field evaluation. The standard protocol for the evaluation is based on the Vienna Concussion in Sports group (Solomon, Johnson, & Lovell, 2006). The sideline assessment involves a brief test for the signs and symptoms of a concussion. The athletic trainer will test the player’s orientation, recall of events prior to collision, ability to repeat words, ability to retain information, and attention span. In addition, the player is observed for physical symptoms of a concussion, including: headache, nausea, inability to balance, and confusion. The player is not allowed to return to play during the current game and must complete a neuropsychological test in order to determine if they can begin to train again or if further evaluation is needed (Kelly & Rosenberg, 1997).

Neuropsychological Testing following Concussion

Postconcussion testing should occur within two days after a suspected concussion has occurred in order to determine the severity of the injury. Potentially injured athletes should be evaluated based on their current symptoms and their cognitive functioning skills. The aforementioned skills tested include: attention span, reaction time, verbal memory, working memory, visual memory, response variability, selective attention, sustained attention, and non-verbal problem solving. The player’s post-concussion scores should then be compared to the results of their baseline tests to determine if the player is still currently suffering from the effects of a concussion. If the player falls below one standard deviation of their baseline scores and, therefore, are judged to be unable to return-to-play at the time, it is recommended that the player wait 2 to 3 days before being retested (Lovell & Barr, 2004).

Traditionally, paper and pencil tests have been used for baseline and post-concussion testing by the neuropsychologist. The one-on-one interaction allows the neuropsychologist to maintain a certain test environment, closely observe the patient, and encourage the patient to perform at an optimal level. However, the traditional test is neither cost nor time effective (Zillmer, 2003). Currently, computer-based assessments have become more popular because a specialist is not required to administer the test. Computer-assisted tests also take less time to conduct. One example of a computer-based program is the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) (Zillmer, 2003). Table 2 lists the sections of the ImPACT program and cognitive modules.
Table 2
The ImPACT program sections and cognitive modules

<table>
<thead>
<tr>
<th>Sections</th>
<th>Cognitive Modules</th>
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<tbody>
<tr>
<td>Patient’s History</td>
<td>Word Memory</td>
</tr>
<tr>
<td>Concussion Symptom Inventory</td>
<td>Design Memory</td>
</tr>
<tr>
<td>Neuropsychological Testing Modules</td>
<td>Symbol Matching</td>
</tr>
<tr>
<td>Current Concussion Details</td>
<td>Xs and Os</td>
</tr>
<tr>
<td>Comments Section</td>
<td>Color Matching</td>
</tr>
<tr>
<td></td>
<td>Three Letter Memory</td>
</tr>
</tbody>
</table>

Once the athlete has completed the test, ImPACT yields a series of composite scores. These scores are displayed together with applicable baseline scores for easy comparison. If the current scores are not considered to be within a normal range compared to the baseline scores, the athlete is not allowed to return-to-play until the scores are back to baseline (Lovell, 2006).

**Neuroimaging**

Neuroimaging scans, such as computed axial tomography (CT) or magnetic resonance imaging (MRI), are not always required for athletes with concussions. However, a scan might be considered if the post-concussion symptoms do not improve after a month (Solomon, Johnson, & Lovell, 2006). Persistent symptoms occur in approximately 10% of athletes who sustain concussions. The physician, while performing the scan, will look for any abnormalities in the individual’s brain scan. However, more research needs to be conducted to determine the types of abnormalities present after a concussion is sustained (McKeever & Schatz, 2003).

**Risk Factors**

Sports medicine researchers have conducted several studies in recent years to identify risk factors for concussions. Identifying potential risk factors for athletes is important for preventing injuries and improving the design of the protective equipment. In addition,
determining potential risk factors can be beneficial in the recovery process. A discussion of each specific risk factor follows.

**Position**

In recent years, researchers have analyzed data concerning the number of concussions experienced in certain football positions. Gessel, Fields, Collins, Dick, and Comstock (2007) documented that linebackers suffered 40.9% of all concussions among defensive players. Furthermore, running backs sustained approximately 29.4% of all concussions incurred by offensive players.

Solomon, Johnson, and Lovell (2006) reported the relative risk for concussions were highest among linebackers, running backs, quarterbacks, wide receivers, and tight ends. The majority of the concussions sustained (approximately 67.7%) occurred during an impact with another player’s helmet. In addition, 20.9% of the concussions resulted from impacting other body areas of another player, while 11.4% were due to ground contact.

**Age**

Younger grade school athletes appear to be at greater risk for concussion. Giza and Hovda (2001) stated concussions in younger athletes can impair the plasticity of the brain. Plasticity is the brain’s ability to form new neural connections in response to injury, disease, or changes in the environment (Giza & Hovda, 2001). Impaired plasticity occurs when a person sustains a concussion during a critical time in brain development. Compared to grade school athletes without concussions, injured individuals fail to develop enhanced cognitive performance and increased cortical thickness. However, the authors stated additional testing is needed to determine if the impairment is permanent or temporary.

According to Tepas, DiScala, Ramenofsky, and Barlow (1990), the pediatric population has a better overall survival rate than adults from severe traumatic brain injury. However, injuries to the brain lead to more persistent cognitive dysfunction among children, as compared to adults. Physicians and researchers have attributed the increased susceptibility of young persons to sustain a sports related concussion to decreased myelination, thinner cranial bones, and a larger head-to-body ratio (Giza & Hovda, 2001). Further research, however, is still needed to determine the relationship between concussions and age in various sports related impacts.
History of Concussions

According to Iverson, Gaetz, and Lovell (2004), football players with a history of two or more concussions are more likely to sustain another concussion than players with one or no concussions. Furthermore, Pellman, Viano, and Casson (2004) stated 8% of football players surveyed between 1996 and 2001 sustained three or more concussions during the study period. In addition to having an increased risk for another concussion, players with a history of concussions are also more likely to experience long term effects. Iverson, et al. found athletes with multiple concussions had lower memory test scores on the Immediate Postconcussion Assessment and Cognitive Testing (ImPACT). In addition, players with concussion histories were six times more likely to experience post-traumatic amnesia and eight times more likely to experience mental status changes. Guskiewicz, McCrea, and Marshall (2003) performed a similar study with 25 college football teams between 1999 and 2001. The authors determined players with a history of three or more concussions have slower recovery periods than players with two or fewer concussions. These research studies suggest that assessing an athlete’s history of concussion is extremely important before a return-to-play decision is determined.

Height and Weight

According to a recent study, football players have become taller and heavier throughout the years. For example, in 1968, offensive lineman averaged around 6 feet 3 inches compared to 6 feet 5 inches in 2006. However, the biggest differences can be found in the increase in weight of the players from 1968 to 2006. For instance, the average weight of a quarterback in 2006 was 220 pounds, which was a 13 pound increase from their average weight of 207 pounds in 1968. The study also revealed the heavier players were determined to be faster than their lighter counterparts (Brett Massie, personal communication, April 30, 2008). The increase in height, weight, and speed in a player could potentially cause an increase in the number of concussions sustained in a football season compared to earlier years. In addition, the thickness of the skull can also have an impact on the number of concussions sustained. However, further research needs to be conducted to investigate the aforementioned claim.

Activity

Few research studies exist that examine the effects of certain activities in football relative to the number of concussions sustained. One study performed with high school football players determined running plays and passing plays produced the highest number of concussions.
(approximately 72%) than blocking plays and tackling plays (Gesset, Fields, Collins, Dick, and Comstock, 2007). However, further research still needs to be conducted with regards to the frequency of concussions during specific high risk passing and running plays, especially at the collegiate level.

**Statement and Significance of the Problem**

Evidence has shown that several risk factors exist for sustaining concussions in football. However, little information exists on what specific types of offensive and defensive strategies, tactics and plays result in a higher probability for concussions at the collegiate level. If an athlete is more at risk during certain types of strategies, tactics and plays, athletic trainers, coaches, and players may need to factor that into their decision process regarding when an athlete should be allowed to return to play.

**Purpose of the Study**

The purpose of the study is to determine the football activities that yield the greatest number of concussions in order to gain knowledge about additional risk factors for sustaining a concussion.

**Research Questions and Hypothesis**

This study will be testing:

1) Does a certain activity in football affect the incident rate of concussions in athletes? It is hypothesized that more concussions will be sustained during a running play.

2) Does the activity that appears to cause the highest rate of concussions remain consistent over a ten-year period? It is hypothesized that running plays will consistently cause the highest number of concussions over a ten-year period.

3) Does the concussion occur more frequently in the offensive or defensive player during a certain activity in football? It is hypothesized that an offensive player will sustain more concussions during a football activity.
CHAPTER II

Method

Participants

The Miami University Concussion Management Program is a collaboration between the Speech Pathology and Audiology Department and the Intercollegiate Athletics program at Miami University. Prior to the beginning of pre-season training, all freshmen and transfer Miami University athletes on the varsity football, hockey, basketball, women’s softball, women’s field hockey, and women’s soccer teams received baseline neuropsychological testing using the ImPACT program.

The data used in the study was collected from Miami University concussed athletes, who participated in any Miami football season from 1999 to 2008.

Procedures

The study implemented procedures outlined in the Miami University Concussion Management Program. When an athlete sustained a concussion, they were referred to the Miami University Speech and Hearing Clinic. The athletes are referred within 48 hours of injury. Injured athletes were administered the same neuropsychological test battery that they initially completed to obtain baseline scores. If an athlete displayed a decline of greater than one standard deviation in any area tested from their baseline on the follow-up assessment or still presented with symptoms of a concussion, an additional assessment was to be scheduled 4 to 8 days later.

The assessment used for athletes in 1999 to 2005 was the Pittsburgh Steelers Neuropsychological Battery (PSNB). The Immediate Postconcussion Assessment and Cognitive Testing (ImPACT) program was used for athletes in 2006 to 2008. In addition to the assessment, each player completed an informed consent form, a concussion questionnaire, and a Postconcussion Rating Scale. The concussion questionnaire, developed by the Miami University Concussion program, obtained information regarding the athletes’ concussion history. The Postconcussion Rating Scale allowed the athlete to rate their present physical, emotional, and cognitive symptoms using a 7 point scale ranging from 0 (symptoms not present) to 6 (symptoms
are severe). The assessment was administered in a private therapy room by a trained speech pathology graduate student. Tables 3 and 4 list the tests administered and the ability evaluated.

Table 3
Pittsburgh Steelers Neuropsychological Battery

<table>
<thead>
<tr>
<th>Test</th>
<th>Ability Evaluated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hopkins Verbal Learning Test</td>
<td>Verbal Memory</td>
</tr>
<tr>
<td>Delayed Recall</td>
<td>Delay Memory</td>
</tr>
<tr>
<td>Grooved Pegboard</td>
<td>Motor speed</td>
</tr>
<tr>
<td>Trail Making Test</td>
<td>Visual Scanning</td>
</tr>
<tr>
<td>Controlled Oral Word Association Test</td>
<td>Word Retrieval</td>
</tr>
<tr>
<td>Digit Span</td>
<td>Attention Span</td>
</tr>
<tr>
<td>Symbol Digits Modalities</td>
<td>Visual Motor Speed</td>
</tr>
</tbody>
</table>

Table 4
Immediate Postconcussion Assessment and Cognitive Testing (ImPACT)

<table>
<thead>
<tr>
<th>Test</th>
<th>Ability Evaluated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word Memory</td>
<td>Attention/Verbal Recognition Memory</td>
</tr>
<tr>
<td>Design Memory</td>
<td>Recognition Memory</td>
</tr>
<tr>
<td>X’s and O’s</td>
<td>Spatial Working Memory</td>
</tr>
<tr>
<td>Symbol Match</td>
<td>Visual Processing Speed</td>
</tr>
<tr>
<td>Color Match</td>
<td>Reaction Time</td>
</tr>
<tr>
<td>Three Letter Memory</td>
<td>Verbal Working Memory/Processing</td>
</tr>
<tr>
<td>Grooved Pegboard</td>
<td>Motor Speed</td>
</tr>
</tbody>
</table>
**Statistical Analysis**

Data analysis was performed using Minitab data analysis software. A variety of descriptive statistical analyses were utilized in the study. In addition, a Chi-Square analysis was used to determine if there was significant difference between the number of concussions sustained and the football activity. A Kruskal-Wallis test was used to determine significance with regards to if the greatest number of concussions sustained during an activity remained consistent over a ten year period.
CHAPTER III

Results

The purpose of the study was to determine the football activities that yield the greatest number of concussions to gain knowledge about additional risk factors for sustaining a concussion. By examining the prevalence rates of concussions in Miami University football players during a certain activity, the results can be used to help determine the incidence rates of concussions that might emerge over a period of time. A variety of statistical analyses were utilized to examine concussions rates during a certain football activity. A total of 40 concussed athletes participated in the study. The football activities included in the study were running, blocking, tackling, passing, and kick-off plays.

Research Question 1: Does a certain activity in football affect the incident rate of concussions in athletes?

Table 5 displays the number of concussions that occurred from 1999 to 2008 in Miami University football players during a specific activity. The data showed concussions occurred the most during a running play with blocking plays being the second most frequent cause of concussions. Therefore, the incident rate of concussions was the highest with running plays.

Table 5

Number of Concussions During a Specific Drill

<table>
<thead>
<tr>
<th>Play</th>
<th>Number of Concussions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running (ball carrier)</td>
<td>17</td>
</tr>
<tr>
<td>Blocking</td>
<td>10</td>
</tr>
<tr>
<td>Passing</td>
<td>1</td>
</tr>
<tr>
<td>Tackling</td>
<td>9</td>
</tr>
<tr>
<td>Kick-off</td>
<td>3</td>
</tr>
</tbody>
</table>
A Chi-Square analysis was performed to determine if there was a significant difference in the overall number of concussions between specific activities in football. This type of analysis evaluates the relationship between two independent variables. A total of 40 football players and five specific activities were included. The Chi-Square analysis showed a significant difference, $x^2=20, p=0.000$, between the number of concussions occurring during a specific activity. Running and passing plays contributed most to the difference. In addition, the analysis showed the results were due to the event that happened and not random occurrences, which implies similar results could be produced again.

Figure 1
Contribution to Chi-Square Value by Category

![Chart of Contribution to the Chi-Square Value by Category](image)

**Research Question 2: Does the activity that appears to cause the highest rate of concussions remain consistent over a ten-year period?**

Table 6 summarizes the number of concussions that occurred in Miami University football players during a certain activity from 1999 to 2008. The data shows concussions resulting from running plays remained the highest across a ten-year period. Running play concussions occurred almost every year, ranging from 1 to 4 concussions per year, with the highest of 4 concussions in 2002.
Table 6

Concussion During a Specific Activity from 1999 to 2008

<table>
<thead>
<tr>
<th>Year</th>
<th>Running</th>
<th>Blocking</th>
<th>Passing</th>
<th>Tackling</th>
<th>Kick-off</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>1</td>
<td>2</td>
<td></td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>2007</td>
<td>2</td>
<td>2</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

A Kruskal-Wallis test was performed to determine if running, blocking, and tackling plays in football produced statistically different distributions of concussion occurrences over the ten-year period. This test is useful for deciding whether the distribution of scores are identical in populations. The distribution of concussions for a running drill was not statistically different from 1999 to 2008 with $p=0.429$. One year did not produce a statistically higher number of concussions for a running play compared to another year. For a blocking play, the distribution of concussions also remained even and, therefore, was not significantly different ($p=0.416$). Tackling plays also produced an even distribution with $p=0.406$. 
Research Question 3: Does the concussion occur more frequently in the offensive or defensive player during a certain activity in football?

A descriptive statistical analysis was performed to determine if there was a difference between the number of concussions sustained during a certain activity in the offensive or defensive position. A total of 40 injured football players were included in the analysis. Table 7 displays the number of concussions in the offensive and defensive position during a certain activity.

Table 7
Number of Concussions Occurring During Offense and Defense

<table>
<thead>
<tr>
<th>Drill</th>
<th>Offense</th>
<th>Defense</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Blocking</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Passing</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Tackling</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Kickoff</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

The results showed 75% of the concussions sustained occurred in the offensive position, while 25% occurred in the defensive position. In the offensive position, 57% of the concussions occurred during a running play with the second highest of 30% during a blocking play. In the defensive position, 80% of the concussions occurred during a tackling play. Table 8 lists the findings of the descriptive statistical analysis.
Table 8

Descriptive Statistics for Offense and Defense Concussions

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offense</td>
<td>6</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>Defense</td>
<td>2</td>
<td>3.39</td>
<td>7</td>
</tr>
</tbody>
</table>
CHAPTER IV

Discussion

The objective of the study was to determine the football activities that yield the greatest number of concussions to gain knowledge about additional risk factors for sustaining a concussion. Because football injuries account for half of the total sports-related concussions sustained annually in the United States, identifying risk factors can help reduce the number of concussions sustained among college football athletes (McKeever & Schatz, 2003).

Activity

This study was designed to investigate which activity in football contributed to the highest number of concussions among football players. The results obtained from the study concluded the majority of concussions were sustained during a running play. Blocking and tackling plays had the second and third highest number of concussions with kick-offs and passing plays contributing least to the overall concussions rates. This result was similar to the findings of Gesset, Fields, Collins, Dick, and Comstock (2007) who also found running plays in high school football players produced the highest number of concussions. However, passing plays in the Gesset et al. study also contributed more to the concussion totals than blocking or tackling plays. This finding is contradictory to the results of this study, where passing plays produced only one concussion.

One explanation for running plays producing the highest number of concussions is a greater amount of force is associated with a running play. Each player is running with great speed down the field which increases the amount of force of the impact (Solomon, Johnson, & Lovell, 2006). The greater the amount of force on the brain, the more likely a significant injury will be sustained, such as a concussion.

An unexpected finding occurred with the kick-off play because all three concussions occurred during the same year. These results do not fit with the even distribution of concussions for running, blocking, and tackling plays over the ten-year period. A possible explanation could be the results are only a coincidence and chance occurrence because kick-off concussions only
appeared during one year during a ten-year period. This unanticipated finding provides a reason for further analysis of concussions during specific activities in the future years.

**Positioning**

In the present study, the majority of concussions that occurred during a certain activity happened more frequently in the offensive position. The results showed 75% of concussions were sustained in the offensive position, while only 25% were sustained in the defensive position. Furthermore, running plays were responsible for the highest number of concussions on offense, while tackling plays had the most frequently occurring concussions on defense. The findings were similar to the results of Solomon, Johnson, and Lovell (2006) who found the majority of concussions in football players resulted after being in an offensive position, such as a running back or quarterback.

The findings indicate for all activities, except for tackling plays, the concussions were sustained mostly in the offensive position. A possible explanation is running and blocking plays are performed by the team on offense, which accounts for the high number of concussions in the offensive position during the aforementioned activities. Tackling drills are primarily performed by players on defense, which explains why the activity had the highest frequency of concussions in the defensive position. In addition, players on defense know when they are going to strike someone and can prepare themselves for the hit. Offensive players, on the other hand, don’t always see or expect a hit and, therefore, cannot always prepare themselves in time to sustain strike from another player.

**Concussions over Time**

The results in this study show more concussions occurred during the last five years of the ten-year analysis period than the first five years. These findings are contradictory from one perspective because more padding has been added to helmets to help lessen the force exerted on the head during an impact. This, in turn, decreases the force on the brain to reduce the number of head injuries experienced by football players (Newman, Beusenberg, Shewchenko, Withnall, & Fournier, 2005). However, the findings for this study show an increase in the number of concussions experienced by players. On the other hand, clinicians and physicians are better able to diagnose concussions now then they have in the past. Improvements in neuropsychological
test batteries and symptom identification have led to more concussions being identified in players that would have been previously gone undiagnosed (Echemendia, 2006). In addition, the increase in height, weight, and speed in a player could have potentially caused the increase in the number of concussions sustained in a football season compared to earlier years (Brett Massie, personal communication, April 30, 2008). Further research needs to be conducted in the future to determine if the number of concussions sustained in players continues to rise or decline over time depending on the improvements of testing and protective equipment.

Conclusions

The study has led to the following conclusions:

1. Ball carriers performing a running play have a greater risk for sustaining a concussion.
2. Concussions resulting from running plays remained the highest over a ten-year period.
3. The distribution of concussions over a ten-year period remained even for blocking, running, and tackling plays.
4. Overall, concussions occur more frequently in the offensive position. In the offensive position, more concussions occurred during a running play. In the defensive position, more concussions occurred during a tackling play.

Clinical Implications

The growing number of injuries and fatalities in athletes due to concussions has increased the importance of research studies on the topic. If specific risk factors can be identified to determine what increases the player’s risk for sustaining a concussion, athletic associations can use the information to improve their concussion prevention and management programs. This study supports the idea that more research and education needs to be done in the area of concussions in athletes. Researchers need to continue to develop better management programs and pre-concussion education in order to ensure the safety of the athletes. In addition, if specific risk factors for concussions can be identified, players might be less likely to suffer from reoccurring concussions because coaches and athletic trainers would know what activities or positions contribute to the highest number of concussions.
This study also shows the importance of conducting further research studies to determine the effectiveness of the Miami University Concussion program. Miami University has the ability through the program to monitor the cognitive performance of their players through baseline and post-concussion testing. This allows for each athlete to be observed in order to ensure they are back to baseline before they return to play.

**Limitations**

One limitation experienced in this study was the number of subjects. Although 40 participants were included in the study, a larger number of subjects would be beneficial to analyze with any statistical power. In addition, all football players included in the study attended Miami University. In order to generalize the results to a larger population, subjects from different universities around the country would need to be included.

Another limitation was the inability to include every concussed football player in the study due to insufficient data. Because the study spanned a ten-year period, some of the data had to be collected from previous reports. If the report did not state the needed information, such as the activity being performed before sustaining the concussion, the player could not be included in the study.

**Future Research**

Concussions in athletes continue to be an important area in research due to the high incidence rates. Future research needs to focus on identifying risk factors in order to prevent concussions from occurring. If researchers can determine the aforementioned risk factors, players might be less likely to be placed in a position or activity with a high concussion rate immediately after sustaining a head injury.

Research also needs to be conducted in the area of protective equipment. Improvements need to be made in helmets in order to ensure the safety of the players. For example, if researchers can determine the areas on the helmet that sustain the greatest impacts, helmets can be remodeled in order to provide more protection in the aforementioned areas.

Some results in the study also contradicted the findings of previous studies. This shows additional research needs to be performed in areas where there is still disagreement. For instance, there are still contradictory findings with what activities produce the highest number of
concussions. By pooling data from other schools performing the same concussion testing, more support would be provided for one finding over another.
References


Appendix A

Informed Consent for College Athletes:

I. Introductory paragraph

“Before agreeing to participate in this study, it is important that the following procedures be read and understood. The following form describes the purpose, procedures, time commitment, risks or discomforts, benefits, and confidentiality of records involved in this study.”

1. Description of the Research:

“I, ______________________ agree to participate in a research study, the purpose of which is to obtain data on memory, attention, and processing abilities in college athletes.”

2. Research Procedures:

“I understand that I will be asked to perform several paper and pencil tasks which assess various cognitive functions such as memory, attention, cognitive processing speed, motor speed and dexterity, and mental fluency. As a part of this assessment I will have to remember words and numbers as well as recall visual information.”

3. Time Required for Participation:

“I understand that participation in this study consists of one meeting with the researcher, the duration of which is approximately 60 minutes.”

4. Risks:

“No invasive procedures will be used in this project. There are no foreseeable side effects, risks, or discomforts associated with this testing protocol.”

5. Benefits:

“I understand that the results of this study will provide baseline neuropsychological information. In the event that I sustain a concussion, I could choose to access the data as a reference point. My results will be filed in the Miami University Speech and Hearing Clinic under the first initial of my last name and the last four digits of my Social Security Number. I am the only person who will have access to my confidential file.”

6. Alternative Treatments:

None
7. **Confidentiality:**

"The information in this study will be confidential. A name will not be associated with any of the results of this study."

8. **Voluntary Participation:**

"Participation in this study is voluntary. Refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled. I am free to discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled."

9. **Questions About the Study:**

"Any questions that I may have concerning any aspect of this investigation will be answered by the researcher, Mrs. Knollman-Porter at (513) 529-2500, or Dr. Steven Dailey at (513) 529-6218."

10. **Questions About Rights of Subjects:**

"I also understand that I may call the Office for the Advancement of Research and Scholarship [(513) 529-3734)] regarding any questions I may have about my rights as a subject."

11. **Compensation for Injury:**

Not applicable

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Subject’s or legal guardian's Signature indicating consent  
[Signature]  
Date

Investigator's Signature  
[Signature]  
Date